Chickpea in the Nineties

International Crops Research Institute for the Semi-Arid Tropics
International Center for Agricultural Research in the Dry Areas

Abstract

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

This workshop brought together leading chickpea scientists from around the world to: summarize the present status of chickpea production and utilization; review progress since the first international chickpea workshop in 1979; project future goals for production and use of chickpea; identify constraints impeding progress, and research needed to reach these goals; prioritize research required to overcome the constraints; recommend and develop collaborative research proposals based on these priorities; and suggest the resources and training required to effect these proposals.

These proceedings update information on work on chickpea since 1979. They contain 31 full papers covering; chickpea status and potential, utilization, genetic resources and enhancement of germplasm, physiology and agronomy, pathology, insect pests, breeding strategies and approaches to crop improvement, and transfer and exchange of technology. In addition there are 20 abstracts on recent advances in chickpea improvement that cover all the main chickpea-growing areas worldwide, reports of discussions and recommendations. All abstracts, discussion reports, and recommendations are published in French and English.

Résumé

Référence : ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Le pois chiche dans les anneés 90 : comptes rendus du Deuxième colloque international sur l'amélioration du pois chiche, 4-8 Déc 1989, Centre ICRISAT, Inde. Patancheru, A.P. 502 324, Inde : ICRISAT.

Ce colloque a réuni des chercheurs de pois chiche les plus importants du monde entier dans le but de faire le point sur les travaux sur le pois chiche. Les principaux objectifs en ont été : de récapituler l'état actuel de la production et l'utilisation du pois chiche; de revoir les progrès réalisés depuis le premier colloque international sur le pois chiche tenu à l'ICRISAT en 1979; d'envisager les objectifs futurs pour la production et l'utilisation du pois chiche; d'identifier les contraintes au progrès et la recherche nécessaire à la réalisation des objectifs; de déterminer les travaux de recherche les plus importants permettant de surmonter ces contraintes; de recommander et mettre au point des propositions de recherche collaborative en fonction de ces priorités; et de proposer les ressources et la formation requises pour mettre en oeuvre ces propositions.

Ces comptes rendus de 31 communications constituent une mise à jour des informations sur les travaux réalisés sur le pois chiche depuis 1979. Ils portent sur : l'état actuel et le potentiel du pois chiche, l'utilisation, les ressources génétiques et l'amélioration du matériel génétique, la physiologie et l'agronomie, la pathologie, les insectes ravageurs, les stratégies de sélection et les méthodes d'amélioration des cultures, le transfert et l'échange de technologie. En outre, ces comptes rendus comportent 20 résumés sur les progrès récents en matière d'amélioration du pois chiche réalisés dans toutes les zones principales de culture de pois chiche dans le monde, ainsi que les rapports de discussions et des recommandations. Tous les résumés, les rapports de discussions, et les recommandations sont publiés en français et en anglais.

ISBN 92-9066-181-X

Chickpea in the Nineties:

Proceedings of the Second International Workshop on Chickpea Improvement

4–8 Dec 1989, ICRISAT Center, India

ICRISAT
International Crops Research Institute for the Semi-Arid Tropics
Patancheru, A.P. 502 324, India

ICARDA
International Center for Agricultural Research in the Dry Areas
P.O. Box 5466, Aleppo, Syria

1990

Scientific Editors

H.A. van Rheenen
M.C. Saxena

Proceedings Editors

B.J. Walby
S.D. Hall

Cover design: **A.A. Majid**

Editorial assistance: D.C. Venkaiah

Contents

Session 6 Breeding Strategies and Techniques - New Approaches to Crop Improvement

Poster Presentations Recent Advances in Chickpea Improvement and Prospects for the Nineties

Session 7 Transfer and Exchange of Technology

Inaugural Session

Opening Address

L.D. Swindale[1]

Mr Chairman, distinguished speakers at the head table, distinguished delegates, colleagues, and friends

Let me add my welcome to the one extended to you by Dr Nene on behalf of International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). It is a wonderful time of the year to be present at our Center, and we hope that you will enjoy being here, and will enjoy participating in the Second International Workshop on Chickpea Improvement. The world is well represented at this meeting, with delegates from 28 different countries here, or due to arrive during the course of the meeting.

A conference such as this, should benefit all participants. It is not a conference solely to advise and benefit ICRISAT and International Center for Agricultural Research in the Dry Areas (ICARDA). You should be able to share your problems as researchers on this interesting and important crop, and you should be able to discuss possible solutions, even common solutions, to those problems. Hopefully you will learn about new advances in the science and new techniques for dealing with the crop. And most of all, I hope that you will obtain some new perspectives about this ancient crop and thereby improve your understanding of its future role in the agriculture of your countries and of the world.

The international agricultural research centers are your servants. They are here to serve the scientists of the national agricultural research systems, and we can serve you best if you will tell us what you most need. So take every opportunity in the discussions and in private conversation to inform the ICARDA and ICRISAT scientists what they should, or could, do for you to make your job easier, to make your research more productive, and to allow you to utilize the sparse resources that are available for research on chickpea as efficiently as possible. Particularly do I appeal to you to provide ICRISAT Center with advice and suggestions as to what it should do for you. For a long time ICRISAT Center has seemed to be but one of several Indian agricultural research institutions working on chickpea and producing cultivars for this country. We are keen to enlarge upon this role. Not, let me clarify, to move away from serving India. Not at all! This is our host country, it helps us in many ways and we are anxious to serve it well. But we think that we will serve it best if we implement the work of Indian scientists rather than compete with them.

Now most of you have faces familiar to me; you have been to ICRISAT before and participated in various meetings and conferences. For those who have come to ICRISAT for the first time, I would like to just say a few words about our Center. The Institute was created in 1972. It was the first center created by the Consultative Group for International Agricultural Research (CGIAR) after the group itself was formed in 1970. And it was set up very specifically to work in a difficult agricultural area to service the needs of the rainfed, semi-arid tropics. ICRISAT does not work to any significant extent on irrigated agriculture. We work in an area that occupies 11% of the globe and houses 15% of the world's population. It is an area of great agricultural promise and great agricultural problems, largely because of the uncertainty of the rainfall and the ever-present possibility of drought.

Concentrating upon the semi-arid tropics, and the food crops of that region, we work to improve five mandate crops, two cereals, sorghum and pearl millet, two pulse crops, chickpea and pigeonpea, and groundnut which is a major source of cooking oil for many people of the region as well as an important cash crop. We try, in addition, to determine the constraints to agricultural development and to find ways of alleviating them—ways which involve improvements in science as well as improvements in policy. Our five crops and our geographic region fit pretty well together. But some of our crops, and particularly chickpea, are important in many other parts of the world. We recognize

1. Director General, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

and accept a responsibility to provide assistance and support to all those who work with this crop wherever they may be located.

Chickpea was originally a crop of the subtropics, but it is also very widely grown within the tropics. Because of its broad spread, we share an international responsibility for the crop with our sister center, ICARDA, based at Aleppo, Syria. That relationship has been strong, close and very productive. Dr Mohan Saxena, representing ICARDA, will be the keynote speaker of this Workshop.

Chickpea is the world's most important pulse crop, way ahead of any other. Although more than 80% of the chickpea in the world is produced on the South Asian subcontinent, it is an important crop in many other countries, particularly in the regions of Central and West Asia, around the Mediterranean, in some northeastern African countries, and in Mexico and other countries in Latin America. More recently it has been produced in Australia and New Zealand and in the United States. I first encountered chickpea as part of a salad dish commonly used in the United States. When I came to ICRISAT, of course, I encountered it as *dhal* and as flour. And in West Asia, as a paste mixed up with vegetable oils in a preparation known as *homos*. I have heard about its use for animal feed, and there are supposedly numerous other uses of the crop. I hope that you will think about the utilization of the crop, in deciding what research is needed for the Nineties.

Although chickpea is an important crop in many parts of the world, the results of research over the last decade are not particularly promising. Dr Saxena will tell you that global production and yield of chickpea has not changed very much in recent years, although in some countries there have been significant increases, particularly in Turkey, in Australia, in my own country of New Zealand, in Myanmar, in the U.S., and more recently in the Sudan. On the other hand, according to the abstracts of your papers, the crop has declined in Ethiopia, Spain, and Iraq.

India has made substantial increases in pulse production in recent years. This has come about largely because India has embarked upon a concentrated effort to increase food crop production, not particularly because of any inherent increase in the productivity of this crop. Iraq imports 90% or more of its chickpea and India also imports a large amount. New Zealand sells its chickpeas to India. Dr von Oppen, who will speak on economic issues, points out the indicators suggest that the prospects for increase in demand are good. And yet many authors complain or comment upon the relatively poor yields, and they speak about lack of adequate moisture, poor weed control, low or no inputs, and a near absence of research. Furthermore, the crop has been called "recalcitrant", meaning that it does not respond particularly well to efforts to bring about significant improvement in genetic potential. Two ICRISAT scientists have concluded that there has been no significant change in yield potential in chickpea in India in 20 years or more. Two others say that the crop is unlikely to progress in the northern part of this subcontinent because of the existence of several serious diseases. All these do not speak well for increased production of chickpea in its traditional locations. Perhaps these will not be the places where chickpea will be grown in the future. The production and the research effort may shift to where chickpea seems to have greater comparative advantage.

The world is changing fast all around us. It would not be unwise to assume that international trade in agriculture will know few barriers by the year 2000. Crops will be grown wherever they have the greatest comparative advantage. Farmers who have a real interest in growing the crop and doing it well will benefit from their efforts. And countries that are willing to invest adequately in research on the crop will find that they will have an export market as a result. If you will think in those terms, you will prepare for chickpea to play an important role as a commercial commodity in the future, and perhaps embark upon some interesting and new types of research for yourselves.

The most significant advance in chickpea productivity in recent years has been through winter sowing in the Mediterranean area. Significant increases in yield are possible, and the change will enable chickpea to substitute for or add to lentils in rotation with wheat and barley. That is extremely important in these days of concern for the sustainability of agriculture, and it is a very good reason for ensuring that a great deal more research is done on chickpea in those particular regions.

Short-duration kabuli chickpeas seem to be proving attractive in the south of India, around ICRISAT, and I am pleased to say that we have helped in bringing about that change. The short-season crop escapes terminal drought stress and the kabuli type is proving popular in the market. How well these new trends will continue only a few more years will tell! But they seem to be quite promising.

The abstracts of the papers to be presented at the Workshop give examples of several other potentially important scientific advances. You will be able to judge those much better than I can. Perhaps they will lead to breakthroughs in various parts of the world and adjustments in chickpea production. I was particularly pleased to note that several of the papers had been authored jointly by scientists from different countries. That to me, suggests, that there is already good cooperation among chickpea scientists. It sounds like the basis for an extremely good outcome to this meeting, and for effective cooperation in research on chickpea in the future.

Drs N. Smith and D.G. Faris will describe the usefulness of networks in helping countries, particularly those that are short of funds, to get more advantage from cooperative trials and research projects. Most networks, in my view, are more form than substance. I hope that your networks will be different, and I am encouraged by the fact that already you cooperate well together.

So I wish you all a successful conference. I hope that you will enjoy your stay at ICRISAT, that you will be rested as well as exhilarated and ready at the end of the week to once again tackle Indian Airlines and that you all return home quickly and safely to your home countries. My best wishes for a successful year, and fruitful research on Chickpeas in the Nineties.

Thank you very much!

ICRISAT's Legumes Program

D. McDonald[1]

On behalf of ICRISAT's Legumes Program I welcome you to this important chickpea workshop. I would like to provide you with a brief overview of the Legumes Program, its responsibilities, organization, and some of its activities. This may help you if you wish to meet some of our staff working on other legume crops during your visit.

ICRISAT's mandate covers three legume crops—chickpea, pigeonpea, and groundnut. Chickpea and pigeonpea are the principal pulses of the Indian subcontinent, and are very important in the nutrition of the people of this region.

As many of you are already aware, chickpea is grown in South and West Asia, in several countries of Africa and the Americas, in Australia, and in Mediterranean countries. The bulk of the crop, around 80% of world production, is grown on the Indian subcontinent. The mandate to improve chickpea production is split between International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and International Center for Agricultural Research in the Dry Areas (ICARDA). ICARDA with its base in Syria concentrates research on the large-seeded kabuli type of chickpea that is commonly grown around the Mediterranean and in West Asia, while ICRISAT Center gives greater emphasis to work on the smaller-seeded desi types more commonly grown in India.

Pigeonpea is very widely grown in tropical and subtropical regions of the world, but it is difficult to calculate production in many regions as it is rarely grown as a field crop outside of South Asia, and eastern and southern Africa. It is estimated that around 90% of world pigeonpea production is from the Indian subcontinent. Research on pigeonpea is coordinated from ICRISAT Center and most of the research is done in India, but a small program has recently been established in Kenya to serve those areas of eastern Africa where the crop is grown.

Our third legume, groundnut, is widely grown in tropical and subtropical regions of the world and is important as a source of protein to humans and livestock, and very important as a cooking oil. The haulms left after removal of the pods provide a nutritious hay that is in high demand in arid regions where there is a scarcity of forage for livestock. The People's Republic of China and India are the largest producers together contributing over 50% of the world's production.

Groundnut research on global and Asian problems is organized from ICRISAT Center, while a research team based in the ICRISAT Sahelian Center in Niger looks after West African problems, and another team in Malawi is responsible for research on the crop in member countries of the Southern African Development Coordination Conference (SADCC).

The need to improve production of chickpea, pigeonpea, and groundnut is apparent when one compares their low average yields in the semi-arid tropics (SAT) of from 0.65 to 0.85 t ha^{-1} with individual SAT-farmers' yields of over 3 t ha^{-1}, and research farm yields of well over 5 t ha^{-1}.

Our research emphasis is directed at alleviating production constraints of chickpea, pigeonpea, and groundnut grown under rainfed conditions and, for the most part, in low-input farming systems. We are concerned with both abiotic and biotic constraints and for all three crops we are working on drought, nutritional problems, photoperiod, temperature, and humidity effects, diseases, and pests. Our major approach to these problems is through the use of genetic resistance or tolerance to individual stress factors, and we work closely with the ICRISAT Genetic Resources Unit which provides us with varieties and landraces of our crops and genotypes of their wild relatives for use in germplasm enhancement and breeding programs. In our Legumes Program here at ICRISAT Center we have seven disciplinary units: three Breeding Units, one for each crop; and Units of Crop Physiology, Pathology, Entomology, and Cell Biology where scientists work on all three crops. We also have the coordinating Unit of the Asian Grain Legumes Network, and a special Legumes On-farm Testing and Nursery Unit (LEGOFTEN) set up in response to a request from our host government to cooperate

1. Program Director, Legumes Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

with Indian national programs to promote increased production of the three ICRISAT mandate legumes by on-farm testing and demonstrations.

Legume scientists work in close cooperation with scientists of the Resource Management Program who incorporate ICRISAT legumes and cereals crops into improved and sustainable farming systems.

As we have developed germplasm collections, pursued crop improvement research, and built up strong technological and information bases, we have simultaneously been setting up cooperative linkages with national agricultural research systems (NARSs) so that the benefits of ICRISAT work can be effectively transferred to them. Our strategic plans envisage significantly increased cooperative research and training activities. As some developing countries in Asia are making rapid advances in developing their agricultural research infrastructures, and as many other countries are doing their best to follow suit, we have to re-think our strategies for cooperative research and training. We have to arrange for training of national systems scientists in advanced technologies to assist them in their home institutions. This has influenced our plans to further develop the capabilities of the Program in respect of advanced biotechnological methods. Hopefully, some NARSs will later be able to offer training and assistance in these research fields to scientists in other countries where facilities and expertise have yet to be developed. Emphasis will also have to be given at the other end of the research scale to development of production technologies suited to specific agroecological and socioecological conditions, and capable of giving stable and sustainable yields of our legumes.

In trying to meet the research and training needs of NARS we have received excellent cooperation from organizations such as Food and Agricultural Organisation of the United Nations (FAO), Australian Centre for International Agricultural Research (ACIAR), Peanut Collaborative Research Support Program (Peanut CRSP), International Development Research Centre (IDRC), and Centre de coopération internationale en recherche agronomique pour le développement (CIRAD).

Objectives of the Workshop

The Chickpea in the Nineties (Second International Workshop on Chickpea Improvement) will bring together leading chickpea scientists from around the world to:

- summarize the present status of chickpea production and utilization;
- review progress since the first international chickpea workshop in 1979;
- project future goals for production and use of chickpea;
- identify constraints impeding progress, and research needed to reach these goals;
- prioritize research needed to overcome the constraints;
- recommend and develop collaborative research proposals based on these priorities; and
- suggest the resources and training required to effect these proposals.

An interesting field visit will form a part of the program.

Purpose

Scientists from many different countries are participating, and we expect to have useful and lively brainstorming sessions that will have an impact on chickpea research and development in the Nineties and beyond.

Objectifs du Colloque

Le Pois chiche dans les anneés 90 (Deuxième colloque international sur l'amélioration du pois chiche) réunira les chercheurs les plus importants travaillant sur le pois chiche dans le monde entier, afin de :

- faire le point du statut actuel de la production et de l'utilisation du pois chiche;
- revoir les progrès effectués depuis le premier colloque international sur le pois chiche tenu en 1979;
- projeter les objectifs futurs pour la production et l'utilisation du pois chiche;
- identifier les contraintes entravant le progrès, et la recherche nécessaire pour atteindre les buts envisagés;
- établir les priorités pour la recherche nécessaire à la maîtrise de ces contraintes;
- recommander et élaborer des propositions de recherche collaborative basées sur ces priorités; et de
- suggérer les ressources et la formation requises pour réaliser ces propositions.

Le programme comportera également une visite intéressante aux champs. Des chercheurs de nombre de pays différents participeront à ce Colloque, et l'on espère avoir des séances d'échanges d'idées utiles et animées qui auront un impact sur la recherche et le développement du pois chiche dans les années 90 et au-delà.

Problems and Potential of Chickpea Production in the Nineties

M.C. Saxena[1]

Abstract

*Though global production and yield of chickpea (*Cicer arietinum *L.) has not increased markedly in the past few decades, the world's population has been rising. Consequently, the net availability of chickpea per caput has declined. There is a large gap between the potential yield and the farm yield. Major factors responsible for this are inappropriate production practices including weed control, inadequate biological nitrogen fixation, damage of crop by several pathogens and pests, and susceptibility of cultivars to abiotic stresses. Recent research has addressed these constraints by: (i) characterizing the photothermal regulation of flowering to facilitate identification of genotypes best adapted to specific areas; (ii) studying genotype* x *environment interaction to adapt the crop and the associated microsymbiont in the niches available in different cropping cycles in traditional and non-traditional chickpea areas; (iii) identifying sources and mechanisms of resistance to major biotic and abiotic stresses in both cultivated and wild* Cicer *spp; (iv) developing techniques, by application of appropriate biotechnological tools, to transfer desirable traits in high-yielding and adapted backgrounds; (v) developing integrated pest and disease control; and (vi) testing improved genotypes and production techniques in different cropping systems through on-farm research with socio-economic appraisal. These researches have started producing results of considerable practical importance and their application through appropriate transfer of technology should lead to increased productivity and production of chickpea in the future.*

Résumé

Problèmes et le potentiel de la production du pois chiche dans les années 90 : *Si les dernières décennies n'ont pas témoigné d'une amélioration sensible de la production mondiale et du rendement du pois chiche (*Cicer arietinum *L.), la population mondiale, par contre, ne cesse d'accroître. Par conséquent, la disponibilité nette de pois chiche par habitant est en baisse. Il existe un écart important entre le rendement potentiel et le rendement au champ. Les facteurs importants responsables de cet état des choses sont : les pratiques culturales peu adaptées y compris la lutte contre les adventices, l'insuffisance de la fixation biologique de l'azote, les dégâts aux cultures par divers agents pathogènes et ravageurs, ainsi que la sensibilité des cultivars aux contraintes abiotiques. Afin de faire face à ces contraintes, les travaux de recherche récents ont porté sur : (i) la caractérisation de la régulation photothermique de la floraison pour faciliter l'identification des génotypes le mieux adaptés à des sites spécifiques; (ii) l'étude des interactions génotype × environnement afin de pouvoir intégrer la culture et son microsymbiont associé dans les niches disponibles dans le cadre des cycles de culture différents dans des zones de pois chiche traditionnelles et non-traditionnelles; (iii) l'identification des*

1. Program Leader/Agronomist-Physiologist, Food Legume Improvement Program, International Center for Agricultural Research in the Dry Areas (ICARDA), P.O. Box 5466, Aleppo, Syria.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of theSecond International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

sources et des mécanismes de résistance aux contraintes majeures biotiques et abiotiques dans Cicer *spp. cultivé et sauvage; (iv) la mise au point de techniques, par l'application des outils biotechnologiques appropriés, permettant le transfert des caractères désirables dans des variétés adaptées et à haut rendement; (v) la mise au point d'une lutte intégrée contre les maladies et les ravageurs; et (vi) la mise à l'essai des génotypes et des techniques de production améliorés dans des systèmes de culture différents, et ceci par l'intermédiaire de recherches en milieu réel accompagnées de bilans socio-économiques.*

Ces travaux de recherche fournissent déjà des résultats d'une grande importance pratique. Leur application, grâce à un transfert de technologie approprié, devrait conduire à l'amélioration de la productivité et de la production de pois chiche à l'avenir.

On a global basis, chickpea (*Cicer arietinum* L.) is the third most important pulse crop after dry beans (*Phaseolus vulgaris* L.) and dry peas (*Pisum sativum* L.). Although predominantly consumed as a pulse, dry chickpea is also used in preparing a variety of snack foods, sweets and condiments (Saxena 1987c). Green fresh chickpeas are commonly consumed as a vegetable for a short period before the crop is mature. Nutritionally, chickpea is relatively free from various antinutritional factors, has a high protein digestibility, and is richer in phosphorus and calcium than other pulses (Ramalho Ribero and Portugal Melo in press). Because of its higher fat content and better fiber digestibility, chickpea holds great promise as a protein and calorie source for animal feed for both ruminants and non-ruminants (Cordesse in press; Ramalho Ribero and Portugal Melo in press). Chickpea straw has a forage value comparable to other straws commonly used for livestock feed (Ramalho Ribero and Portugal Melo in press). Because of these diversified uses of the crop and its ability to grow better with low inputs under harsh edaphic and arid environments than many other crops, it is an important component of the cropping systems of subsistence farmers in the Indian subcontinent, West Asia, and North Africa. Some of these attributes together with its ability to derive more than 70% of its nitrogen from symbiotic dinitrogen fixation (Saxena 1988) make chickpea a promising crop for the 'alternative agriculture' that is now attracting considerable attention in the industrialized world (National Research Council 1989).

Changes in Chickpea Production in Relation to Population Growth

The changes in area, production, and yield of chickpea on a global basis and in Asia in the last five decades are shown in Table 1. A comparison of the data for 1934-38 with those for 1961-65 shows a 50% increase in production both in Asia and worldwide. However, since 1965 there has been a slight reduction in production following a reduction in the area sown, in spite of some increase in the productivity of the crop. In contrast, the population has grown continuously (Table 2) in this period, showing a 163% increase in Asia and

Table 1. Change in area, production, and yield of chickpea in Asia and in the world in the last five decades.

	Asia			World		
Period	Area (10^3 ha)	Production (10^3 t)	Yield (t ha^{-1})	Area (10^3 ha)	Production (10^3 t)	Yield (t ha^{-1})
1934-38	7790	4280	0.55	8760	4700	0.54
1948-52	9060	4800	0.53	10300	5400	0.52
1961-65	10843	6443	0.59	11865	7039	0.59
1971-75	9020	5519	0.61	9968	6349	0.64
1979-81	8747	5377	0.61	9530	5971	0.63
1986-88	8948	6249	0.70	9747	6846	0.70

Source: FAO Production Yearbooks, FAO, Rome.

Table 2. Change in population in Asia and in the world in the last five decades.

	Population (millions)	
Year	Asia	World
1937	1137	2136
1954	1454	2658
1967	1987	3502
1981	2624	4513
1987	2939	5026
1988	2994	5114

Source: FAO Production Yearbooks, FAO, Rome.

139% worldwide from 1937 to 1988. The negative effects of these changes on per capita availability of chickpea are obvious. And the sector most affected by this reduced availability is the rural poor, in whose diet chickpeas, like other pulses, play a dominant nutritional role (Oram and Belaid 1989). Efforts will have to be made in the 1990s to increase the production of chickpea at a faster rate than in past decades, and that is the challenge to researchers and the extension and production agencies concerned with the crop.

The status of area, production, and yield of chickpea in major geographical regions in the world during the 1980s is shown in Table 3. The major regions are the Indian subcontinent including Myanmar; West Asia, North Africa, and Southern Europe; Ethiopian and the East African Highlands; the Americas (mainly Mexico); and Australia (Smithson et al. 1985). The major share in area and production is that of Asia followed by Africa, the Americas, and Europe. Yields on a regional basis are higher in Europe, and in the Americas than in Asia and Africa. Average yields are higher in the countries where the crop is raised under more assured moisture supply conditions because of either higher rainfall (e.g., in Greece and Italy), or partial or complete irrigation (e.g., in Mexico and the Nile Valley). The global yield averaged over 1985-87 is, however, low at 0.7 t ha^{-1} and is close to that of Asia, where the crop is generally grown in harsh production environments. Raising the productivity in Asia is the key to global improvement in the production of the crop.

Prospects for Increased Production in the Nineties through Area Expansion

Because of the increasing demand for other food crops, and the decreasing possibility for bringing newer areas under crop production, scope for increasing chickpea production through area expansion on a long-term basis is rather limited. However, if the economics of production of chickpea could be improved, it could gain areas in several countries in West Asia, North Africa, and Mediterranean Europe, which over the past few decades have experienced a reduction (Pluvinage in press). Compared to other crops, the economics of chickpea production in these areas was poor because of low yields, and high labor costs due to a lack of mechanization of operations and lack of chemical weed control. Fortunately, these problems are being addressed by recent research, and practical solutions are becoming available for adoption. Scope also exists to increase the area under chickpea through replacement of fallow. This program is receiving high priority in several countries in the West Asia and North Africa (WANA) region where nearly 20% of agricultural land is left fallow (Oram and Belaid 1989). Turkey has taken a lead in this regard by initiating a program of more efficient use of fallow land through a pilot project with the assistance of the World Bank. The first phase of the project started in the late 1970s, and the second phase is currently underway. Rotational studies conducted in southeastern Anatolia on a long-term basis, showed that although wheat yields in 'fallow-wheat' rotation were the highest (3.4 t ha^{-1}) amongst various two-course rotations, the yields in 'chickpea-wheat' rotation were only marginally lower (3.2 t ha^{-1}), whereas those in 'wheat-wheat' rotation were nearly half of that level (1.89 t ha^{-1}) over the period 1983-88. There was an additional yield of nearly 1 t ha^{-1} of chickpea and 1.76 t of wheat in 'chickpea-wheat' and 'wheat-wheat' rotations in the year when 'fallow-wheat' rotation was in the fallow phase (Oram and Belaid 1989).

These results have been used as a base for an educational campaign, accompanied by the provision of inputs, machinery, and credit, to replace fallow by legumes such as chickpea, lentil, and vetch. There was an overall reduction of 33% in the fallow area in Turkey between 1979 and 1986. The impact of this has been that the area under chickpea grew at an annual rate of 15.9% between 1980-1986, and production has nearly doubled although the yields have slightly decreased (Table 3). Cold, drought, and ascochyta blight are major yield constraints for chickpea in those areas of the Anatolian plateau where fallows are being replaced by the introduction of this crop. Development of cold, drought, and ascochyta blight resistant genotypes adapted to these environments and appropriate agronomic practices could lead to further improvement in production in these areas through increased yields.

If the main reason for the striking success in reducing

Table 3. Changes in area, production, and yield of chickpea over periods 1979-81 and 1985-87 in different countries (FAO, 1988).

	Area (10^3 ha)		Production (10^3 t)		Yield (t ha^{-1})	
	1979-81	1985-87	1979-81	1985-87	1979-81	1985-87
North Africa	169	194	94	118	0.56	0.61
Algeria	42	63	16	17	0.39	0.27
Egypt	7	9	11	15	1.54	1.57
Morocco	53	81	38	55	0.62	0.68
Tunisia	67	41	29	31	0.44	0.75
Eastern Africa	181	240	135	155	0.75	0.65
Ethiopia	154	180	128	135	0.83	0.75
Tanzania	27	60	7	20	0.28	0.33
South Asia	8341	8431	4989	5690	0.60	0.68
Bangladesh	57	48	40	37	0.70	0.78
India	7092	7163	4474	4935	0.63	0.69
Myanmar	127	177	79	154	0.61	0.87
Pakistan	1065	1043	396	564	0.37	0.54
West Asia	354	724	366	720	1.03	0.99
Iran	48	101	52	73	1.09	0.72
Iraq	20	16	12	12	0.63	0.77
Palestine	4	4	4	6	1.30	1.64
Jordan	2	2	1	1	0.60	0.53
Lebanon	2	2	3	3	1.15	1.28
Syria	65	67	49	40	0.72	0.60
Turkey	213	532	245	585	1.15	1.10
South Europe	158	131	98	90	0.61	0.69
Greece	15	5	15	5	1.04	1.16
Italy	14	9	16	10	1.18	1.15
Portugal	35	25	12	12	0.33	0.49
Spain	92	90	53	60	0.56	0.70
Central and South America	243	192	244	205	1.00	1.00
Mexico	195	150	218	177	1.10	1.18
Argentina	5	3	4	3	0.81	1.00
Chile	18	15	9	11	0.51	0.85
Peru	3	3	2	2	0.78	0.83
Oceania	0	34	0	36		1.06
Others	84	84	45	47	0.54	0.56
Total	9530	10030	5971	7061		

Source: FAO Production Yearbooks, FAO, Rome.

fallow and diversifying the cropping system through the introduction of chickpeas to the rainfed areas of southeastern Anatolia was the special ecological situation of the upland areas, this approach should be applicable in Afghanistan, Iran, northern Iraq, northern Pakistan, Nepal, Mexico, Ethiopia, and parts of Algeria and Morocco (Oram and Belaid 1989). If however, the Turkish success was mainly due to technical achievements, economic incentives, good extension efforts, and appropriate market development, it should be more widely applicable throughout the WANA region. According to a very conservative estimate, there is currently a potential for the replacement of nearly six million hectares of fallow land in this region by legumes such as chickpea.

On the Indian subcontinent, where the high pressure of population on agricultural land necessitates intensification of cropping, the development of extra-short duration cultivars could permit the introduction of chickpea into those cropping systems that have traditionally been of low intensity because the available moisture supply is insufficient for double cropping with crops of normal duration. In a country such as Egypt, where intensity of cropping on the presently cultivated land is already high, newer areas are being reclaimed from the desert by irrigation. Chickpeas have shown great potential for introduction into these areas.

There is also scope for further expansion of chickpea in such countries as Australia and those in North America, where the crop has only recently been introduced, because of its potential role in economical and environmentally safe crop diversification, and in the development of a sustainable 'alternative agriculture'.

Prospects for Increased Production through Improved Yields

Yield Gap

As indicated earlier, the global productivity of chickpea has shown a trend towards some increase in the last few decades, but at 0.7 t ha^{-1} it continues to be rather low, and far below the potential levels of productivity actually realized at research stations, demonstration plots, and farmer managed on-farm trials. A chickpea yield analysis by Bahl and Baldev (1981) in the Indian states of Haryana, Uttar Pradesh, Madhya Pradesh, and Rajasthan, using the data of the coordinated varietal trials, the 'minikit' trials, and the state average, has shown a gap of more than 70% between the research station yield and the state average, and nearly 50% gap between the improved cultivar minikit yields on farmers, fields and the state average. Similar data are available from the G.B. Pant University of Agriculture and Technology (GBPUAT 1986) in India, and International Center for Agricultural Research in the Dry Areas (ICARDA) in Syria as shown in Figure 1. In fact, the yield gap is more than 80% in Syria, where the productivity of chickpeas in research station trials and large demonstration plots has exceeded 4 t ha^{-1}. The large gap between yields in on-farm demonstrations and average yields obtained by farmers points to the opportunities that exist for some major productivity gains by alleviating the production constraints at farm level. Recent national, regional, and international research efforts have helped in the identification of some of these production constraints and in developing appropriate solutions.

Factors Affecting Productivity at Farm Level

Several environmental, agronomic, and biotic factors constrain productivity of chickpea. The relative importance of these factors, however, varies from region to region because of the diversity of agroecological conditions. Since the yield in chickpea under normal cropping conditions is dependent on the symbiotic association between the host plant and the specific *Rhizobium*, the crop is constrained in its performance when conditions for either of these become sub-optimal.

Environmental Constraints

Drought is the major environmental constraint to chickpea productivity in many areas of the Indian subcontinent and the WANA region because the crop is grown mainly on the receding soil moisture conserved from the rain received prior to the chickpea growing season. Development of genotypes that either escape drought because of short duration or have intrinsic properties to withstand drought would help to enhance and stabilize productivity in these areas. Work at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (Saxena 1987; ICRISAT 1989) and lately also at ICARDA (ICARDA 1989), has shown promising results. Traits such as high early vigor and fast development of canopy cover have shown high positive correlation with yield (ICARDA 1989).

In the WANA region, where the crop is traditionally spring-sown, another major environmental constraint is the supra-optimal temperature regime during the reproductive phase of the crop (Fig. 2). ICARDA's strategy to deal with this constraint, and also to reduce the effect of drought, has been to shift the sowing date from spring (March/April) to early winter (early December) in the low-altitude areas of WANA. This permits matching various phenological stages of crop development to the environmental conditions that are optimum for them (Saxena 1987b). The results of this change have been striking — yields have shown phenomenal increases, although the magnitude of increase has varied depending upon the severity of cold spells during winter (Fig. 3). The prerequisite for winter

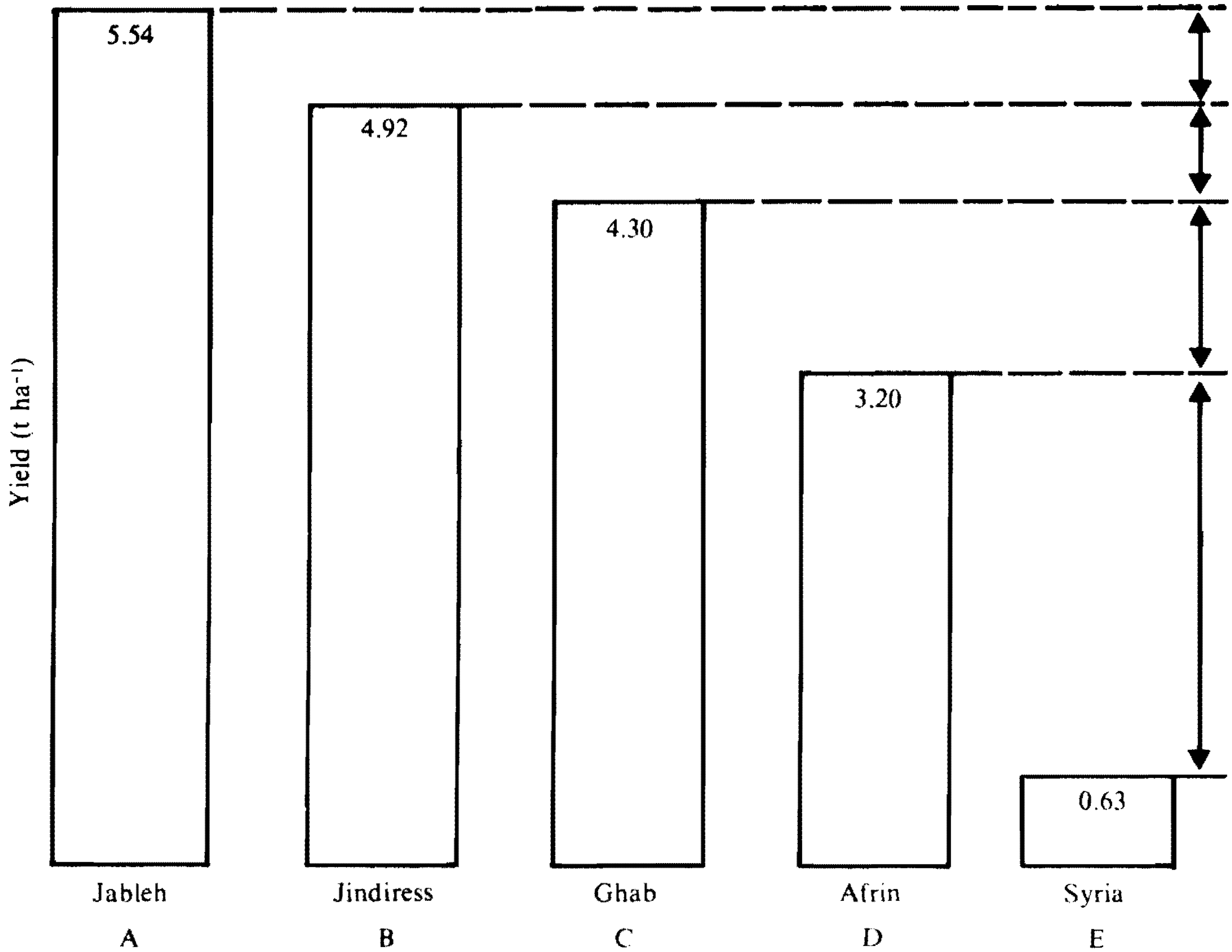


Figure 1. Yield gap analysis for chickpea in Syria: A and B are the mean seed yields (t ha^{-1}) of 24 genotypes in the CIYT- W-Mr-87 yield trial at research stations of Jableh and Jindiress; C is the yield (t ha^{-1}) of ILC 482 chickpea in yield maximization plot (2 ha); D is the yield (t ha^{-1}) in farmers' field (1.24 ha) of ILC 482 in 1985/86; and E is the average yield (t ha^{-1}) of chickpea in Syria in 1985-87.

sowing of chickpea in WANA is a high level of cold tolerance and resistance to ascochyta blight, and therefore ICARDA in collaboration with the National Agricultural Research Systems (NARSs) in WANA has given major attention to this aspect of crop improvement research (Singh in press). On-farm evaluation of winter sowing has shown large economic gains (ICARDA 1988) and several NARSs have released cultivars adapted to winter sowing (Singh in press). Collaborative studies with scientists in southeastern France have shown that the advantage of winter sowing can be achieved even in cooler environments than those found in the low-altitude sites around the Mediterranean Sea. Using ICARDA-developed chickpea breeding lines in sites with minimum temperatures ranging from -10°C to -18.5°C, Wery (in press) showed that it was possible to group them into three categories based on their 'frost resistant ratio' (i.e., number of plants at harvest:number of plants emerged): (1) Fall type (resistant to frost; e.g., FLIP 81-293C, FLIP 82-128C, FLIP 83-7C), (2) Winter type (tolerant to frost; e.g., ILC 3279, ILC 482, INRA 199), and (3) Spring type (susceptible to frost; e.g., ILC 1929). The first group included cultivars that withstood as low a temperature as -12.5°C with no snow cover on the crop. The second and the third group had decreasing levels of cold tolerance. Wery (1988) showed that chickpea cultivars in category 1 (e.g., FLIP 81-293C) could be used for autumn sowing in plateau areas with a yield potential of nearly 5 t ha^{-1}. Research on enhancing cold tolerance in chickpea has made excellent progress at ICARDA (Singh et al. 1989a) and it is being complemented by collaborative basic research with scientists in Italy and France.

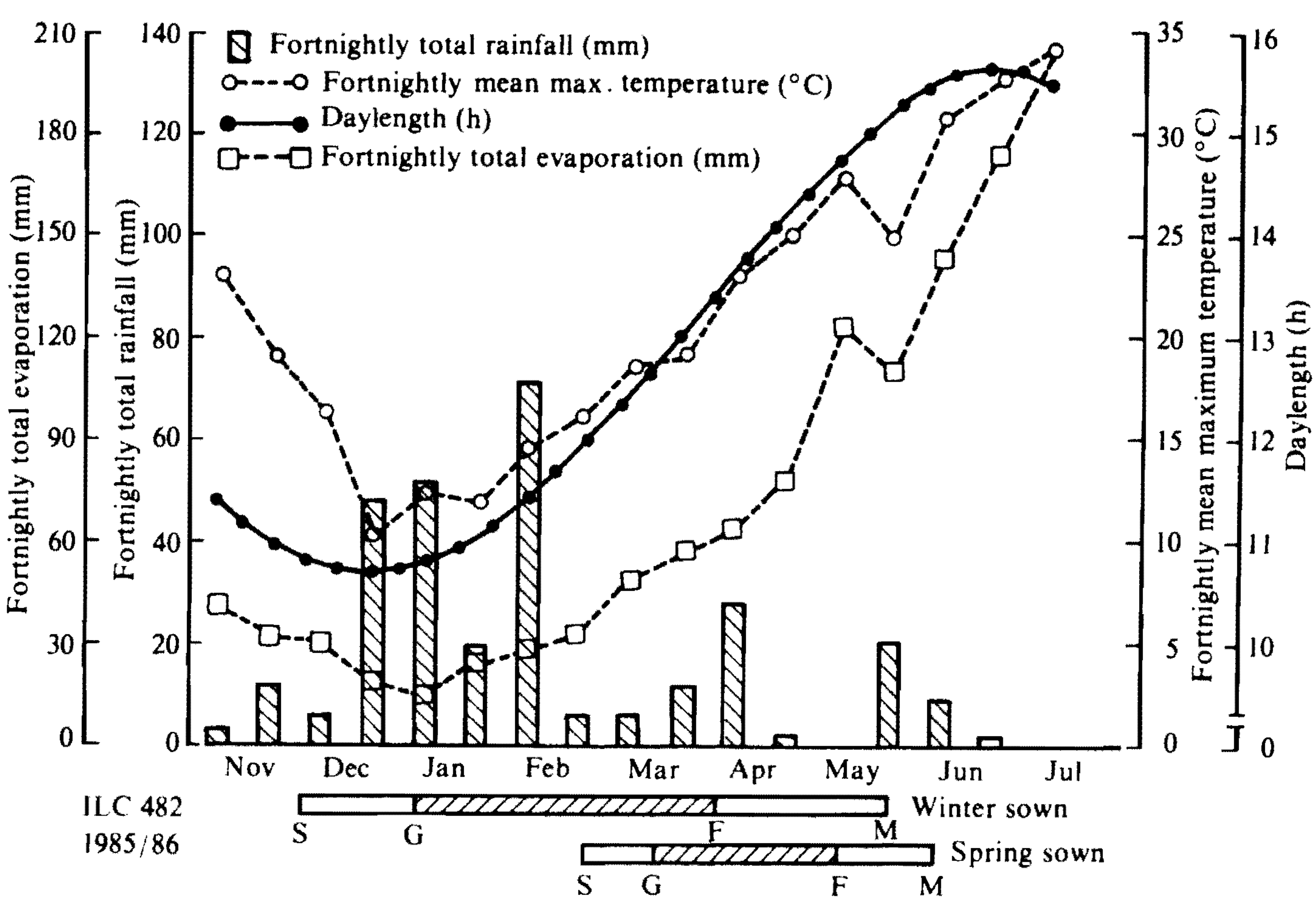


Figure 2. Crop phenology of winter- and spring-sown chickpea ILC 482 in relation to the weather conditions during the period of crop growth at Tel Hadya, Syria, 1985/86.

Another promising line of work with respect to adaptation to environment is being pursued at ICRISAT (Saxena et al. 1988). It aims at improving flowering and pod setting at low temperatures in the crop grown under northern Indian conditions so that the reproductive period of growth, and thus build-up of economic yield could be increased. Recent studies (ICRISAT 1989) have shown that there are lines setting pods when night temperatures ranged from 7°C to -1°C and several of these indeed have a high harvest index; but their yields are still not higher than those of the conventional types. Obviously more work on varietal improvement and development of optimum agronomy is needed.

Matching the crop phenology with environmental conditions to ensure that exploitation of the available environmental resources is maximized, is the key to reducing the environmental constraints to crop productivity in stressful environments (Buddenhagen and Richards 1988). Chickpea breeders have, therefore, developed systems to evaluate genotypes specifically targetted to the environments available in different cropping systems. National programs such as the All India Coordinated Pulses Improvement Program (AICPIP) and international centers such as ICRISAT and ICARDA have diversified their screening nurseries and yield trials keeping the target environments and niches in the cropping systems in view, and this has facilitated identification of cultivars well adapted for the purpose (ICARDA 1989; ICRISAT 1989). This direction will have to be increasingly followed. Fortunately, the recent research work on photothermal modulation of flowering in chickpea has permitted the development of predictive models (Roberts et al. 1985) and simple and efficient protocols for characterizing the germplasm for this phenological trait (Roberts and Summerfield 1987). These will further help breeders to develop genotypes well adapted to different environmental conditions.

Agronomic Constraints

Whereas use of landraces and unimproved cultivars with low inherent yield potential and susceptibility to

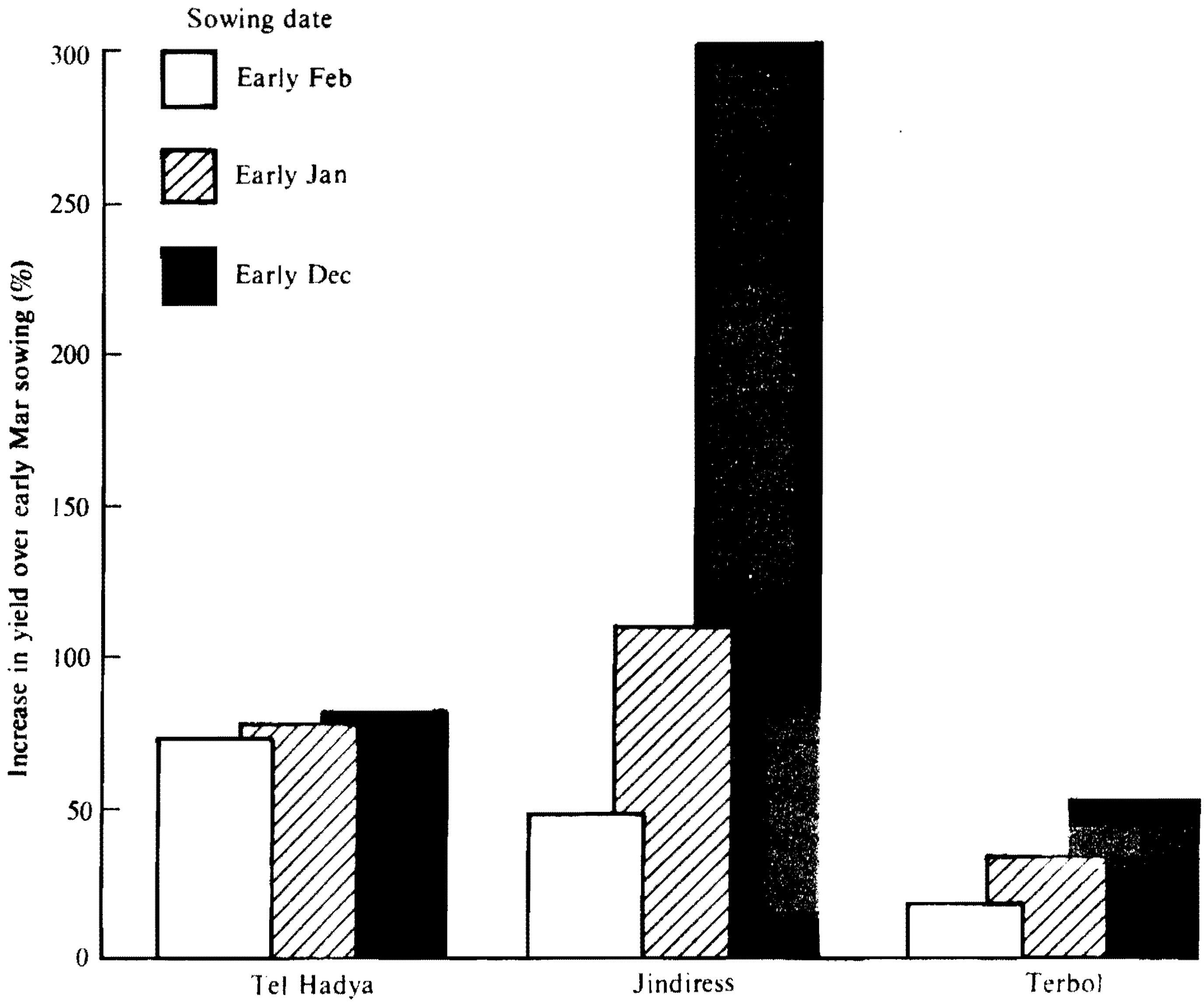


Figure 3. Effect of sowing date on yield of chickpea ILC 482, Tel Hadya, Jindiress, and Ter bol stations of ICARDA, 1986/87.

abiotic and biotic stresses continues to be a major yield retardant (Bahl and Baldev 1981), there are many other agronomic factors that prevent full realization of the yield potential at farm level (Saxena 1987a). Since chickpea is grown in diverse environmental conditions and cropping systems, not only the cultivars but also the agronomic practices suitable for each of these conditions have to be identified and recommended to the farmers. On-farm trials to validate research station results for different agroecological conditions and cropping systems become important in this regard.

Inadequate plant stand is the most common yield retardant in many production areas in the world (Sheldrake and Saxena 1979; Saxena 1987a). The effect of inadequate plant stand becomes particularly conspicuous in those cropping situations where the adverse environmental conditions do not permit yield compensation by increased per plant productivity. Poor quality seed, conventional sowing methods, inadequate seedbed preparation, lack of seed treatment against seedling diseases, and damage by rodents and birds are some of the common causes of inadequate plant stand. Good information on methods to improve plant stand is available and should be transferred to farmers for adoption. The use of grain drills in WANA has permitted establishment of more uniform and optimum plant stands with lower seed rate, in contrast to the traditional broadcast sowing using ducks-foot cultivators. Since suboptimal soil moisture content at the seeding depth is often responsible for inadequate emergence, studies on genotypes able to germinate at low soil moisture content have been undertaken, and if this trait could be combined with other economic traits it would help to increase and stabilize chickpea production. Differences among genotypes have also been found in the ability of seeds to withstand long periods of wet and cold seedbed conditions common in the plateau region (Wery 1988), and these can also be exploited while adapting chickpea for autumn or winter sowing at high altitudes in WANA.

Weeds cause considerable loss in yield of chickpea (Bhan and Kukula 1987). Although weeding by hand to prevent weed competition during the period before the development of a full canopy cover has invariably been most effective, limitations of labor and high labor costs often prevent the adoption of this method particularly in WANA. Through the International Chickpea Weed Control Trial coordinated by ICARDA, several national programs in WANA have identified effective herbicides to control weeds. The best treatments have involved the preemergence application of such herbicides as terbutryne (2.5 to 4 kg a.i. ha^{-1}), chlorbromuron (1.5 to 2.5 kg a.i.ha^{-1}), methabenzthiazuron (3.0 kg a.i. ha^{-1}) or cyanazine (0.5 to 1.0 kg a.i. ha^{-1}) either alone or in combination with pronamide (0.5 kg a.i. ha^{-1}) for wide-spectrum weed control (Saxena 1987a). There is a need to evaluate these treatments on farmers' fields and demonstrate their value. On-farm evaluation of effective weed control treatments in northern Syria gave yield increase of 17-105%, the effect being particularly conspicuous in the winter-sown crop (ICARDA 1986).

Since the productivity of chickpea in many areas is constrained by the lack of moisture, particularly during the reproductive growth phase, supplementary irrigation (if available) can improve and stabilize yields. Studies at ICARDA have shown that yields of both the spring- and winter-sown chickpea crop can be improved by a supplemental irrigation with 50 to 100 mm of water, the relative improvement in yield being more in the spring-sown crop (ICARDA 1988). There are large genotypic differences in response to supplemental irrigation, and work is in progress at ICARDA to make use of this variation in improving the productivity of chickpea (ICARDA 1988) since many farmers in WANA have access to water for supplementary irrigation.

Inadequate symbiotic nitrogen fixation, either because of lack of an adequate soil population of *Rhizobium*, or inefficacy of the strains present, or unfavorable environmental conditions for symbiosis, can cause reduction in chickpea yield. As the adaptation of chickpea is being extended to newer areas, this aspect becomes increasingly important. Work at ICARDA has shown high genotype x strain interactions for symbiotic nitrogen fixation and yield (ICARDA 1989). A simple technique involving intact soil cores to assess the efficacy of symbiotic nitrogen fixation of a strain has been developed. Polyclonal antibodies have proved valuable in distinguishing the effective strains from the native population using ELISA techniques (Makkouk et al. 1989). A technique for assessing the need for inoculation is being disseminated to the national programs so that scope for introduction of improved biological nitrogen fixation (BNF) on farmers' fields can be determined. One of the reasons for growing chickpea in rotation with cereals is to conserve soil nitrogen. Hence nitrogen balance studies on the whole system are important, and these are being conducted in collaboration with the national programs in WANA. Results obtained so far suggest that there is scope for improvement in the BNF of chickpea in WANA, and similar studies are needed in other areas.

Biotic Constraints

A major biotic constraint to the productivity of chickpea is the damage to the crop by diseases, insect pests, nematodes, and parasitic weeds. These organisms are also responsible, to a large extent, for the instability in the yield of the crop in the major production areas in the world.

Although a large number of pathogens affects the crop, the most serious diseases on a global basis are those caused by *Ascochyta rabiei* (ascochyta blight), *Fusarium oxysporum* f.s. *ciceri* (fusarium wilt), *Rhizoctonia bataticola* (dry root rot), *Botrytis cinerea* (botrytis gray mold) and bean leaf roll virus (stunt). The major insect pests include pod borers (*Helicoverpa armigera* and *Heliothis* spp.), and leaf miners (*Liriomyza cicerina* and *Phytomyza cicerina*). Seed beetle (*Callosobruchus* spp) damages stored produce and causes considerable physical and economic losses. Root-knot (*Meloidogyne artiellia*), cyst (*Heterodera ciceri*), and root-lesion *(Pratylenchus thornei)* nematodes commonly affect the crop, but their incidence is generally restricted to certain areas and cropping systems. *Orobanche* spp (broomrapes) can adversely affect the productivity of winter-sown chickpea in the Mediterranean region in the fields infested with this parasite.

Researchers have addressed these problems and information on yield losses, chemical control, and host-plant resistance that have been developed has been recently reviewed for diseases (Nene and Reddy 1987; Singh 1987) and insect pests (Reed et al. 1987; Weigand in press). Host-plant resistance has been given higher priority because of its simplicity and the economics of its use by farmers. The development of integrated control measures based on host-plant resistance, cultural methods, and selective use of safe chemicals has also been emphasized. The transfer of this information and technology is a major challenge that will have to be effectively met by national research and extension systems. As host-parasite interactions are dynamic, there is a need for continued efforts to identify newer sources of resistance in the cultigen and use them in breeding programs to develop durable multiple-stress resistance in genotypes adapted to specific environments.

Wild relatives of crop plants contain a wealth of desirable characters including resistance to stress factors (Frey 1983) and wild relatives of chickpea are no exception. Work at ICARDA showed that higher levels of resistance to ascochyta blight, leaf miner, cold, and the only sources of resistance to cyst nematode and seed beetle could be found in wild annual *Cicer* spp. accessions rather than in cultivated species (Singh et al. 1989b). Techniques have to be developed to use the useful traits from the wild *Cicer* spp. by overcoming barriers to inter-specific hybridization. In vitro culture techniques will have to be developed and used, and work is already underway at several institutes including ICARDA and ICRISAT. In vitro techniques could also be applied to recover mutants tolerant to particular antimetabolites such as host-specific pathotoxins using somaclonal variation (Scowcroft 1989). Fortunately progress is being made in identification of pathotoxins for such host-parasite interactions as chickpea – *Ascochyta rabiei* and chickpea - *Fusarium oxysporum* (pers. commun. R.N. Strange, University College London), and this should facilitate work on breeding for resistance to the diseases caused by these pathogens. Also, better understanding of the mechanisms involved in host-plant resistance to parasites can help in developing more efficient and rapid screening techniques for diseases and insect resistance.

Breeding for host resistance could be further facilitated by application of restriction fragment length polymorphism (RFLP) since it permits DNA fingerprinting, trait mapping, and marker-based breeding, and makes the reservoir of genetic material available in landraces, wild relatives and germplasm accessions more accessible (West et al. 1989). In collaboration with the Institute of Botany of the University of Frankfurt, FRG, some progress has been made by ICARDA in DNA fingerprinting using ^{32}P-labeled $(GATA)_4$ probe in the chickpea genome (pers. commun. K. Weising, University of Frankfurt and F. Weigand, ICARDA) and work at several other centers has also started. Development of non-radioactive probes for oligonucleotide fingerprinting is also showing promise. Chickpea breeders should thus be able to routinely use this powerful tool in the nineties. Application of other developments in biotechnology to improve host resistance in chickpea also seems promising. Utilization of gene coding for the production of insect toxin by the spores of *Bacillus thuringiensis* (B.t.) can be an important application of genetic engineering in chickpea, as it has been for several other crops (Delannay et al. 1989; Meeusen 1989), not only for controlling lepidopteran larvae (Dulmage 1981), but also for dipteran (Goldberg and Margalit 1977) and coleopteran (Krieg et al. 1983; Herrnstadt et al. 1986) larvae. The technique uses the *Agrobacterium tumefaciens* transformation system, where transgenic *A. tumefaciens* serves as a vector for the desired gene (Meeusen 1989). Our tests on wild strains of *A. tumefaciens* have identified highly virulent strains (Weigand and Saxena 1989) that could eventually be used as vectors for transferring B.t. genes through a non-tissue culture technique. Of course, the possibility of using transgenic cultivars would depend upon the assurance of their safety, and the regulations in the country concerned in this regard.

Use of an endophyte that produces some antibiotic or antifungal substances and thus protects the crop against pathogens is a new system for biological crop protection against diseases that is being commercially sold for some important crops by 'Crop Genetics International, USA' (Carlson 1989). Scope for use of such a system in chickpea needs to be investigated. Some preliminary work at ICARDA showed that in the phyllosphere of ILC 482 chickpea there was a bacterium that showed an antifungal property for *Ascochyta rabiei*.

Future Outlook

The outlook for improving the production of chickpea and its yield in the nineties looks bright. The research gains made so far in terms of improved production systems and locationally specific cultivars need to be consolidated and effectively transferred to farmers through national agricultural research and extension agencies. Better targetting of extension efforts, increased emphasis on enhancing the production capacity, and distribution of improved seeds, and appropriate governmental policy for price support, crop use and marketing would ensure that the potential for improved production and productivity as promised by the current research is actually realized on farmers' fields. National programs will have to work more closely with their farmers in verification and validation of their applied research, and evaluating the socioeconomic consequences in different agroecological conditions and production systems. International centers, working closely with NARSs on one hand, and with institutions in industrialized countries on the other, should backstop NARSs by developing better understanding of the physiological basis for yield and the mechanisms underlying resistance to stresses, devising more efficient breeding and screening techniques, and ensuring that modern developments in biotechnology are applied in chickpea improvement.

References

Bahl, P.N., and **Baldev, B.** 1981. Production technology for chickpea. Indian Farming 31(5):67-71.

Bhan, V.M., and **Kukula, S.** 1987. Weeds and their control in chickpea. Pages 319-328 *in* The chickpea (Saxena, M.C., and Singh, K.B., eds.). Wallingford, Oxon, UK: CAB International.

Buddenhagen, I.W., and **Richards, R.A.** 1988. Breeding cool season food legumes for improved performance in stress environments. Pages 81-96 *in* World crops: cool season food legumes: proceedings of the International Food Legume Research Conference on Pea, Lentil, Faba Bean and Chickpea, 6-11 Jul 1986, Spokane, Washington, USA (Summerfield, R.J., ed.). Dordrecht, Netherlands: Kluwer Academic Publishers.

Carlson, P.S. 1989. One company's attempt to commercialize an agricultural biotechnology technology. Pages 413-422 *in* Strengthening collaboration in biotechnology: international agricultural research and the private sector: proceedings of a conference, 17-21 Apr 1988, Rosslyn, Virginia, USA (Cohen, J.I., ed.). Washington, D.C., USA: Agency for International Development.

Cordesse, R. (In press). Value of chickpea as animal feed. *In* proceedings of the CIHEAM, ECC (AGRIMED), and ICARDA Conference on Present Status and Future Prospects of Chickpea Crop Production and Improvement in the Mediterranean Countries, 11-13 Jul 1988, Zaragoza, Spain (Cubero, J.I., Saxena, M.C., and Wery, J., eds.). Zaragoza, Spain: Centre International de Hautes Etudes Agronomiques Méditerranéennes.

Delannay, X., Fraley, R.T., Rogers, S.G., Horsch, R.B., Kishore, G.M., Beachy, R.N., Tumer, N.N., Fischhoff, D.A., Klee, H.J., and **Shah, D.M.** 1989. Development and field testing of crops improved through genetic engineering. Pages 185-195 *in* Strengthening collaboration in biotechnology: international agricultural research and the private sector: proceedings of a Conference, 17-21 Apr 1988, Rosslyn, Virginia, USA (Cohen J.I., ed.). Washington, D.C., USA: Agency for International Development.

Dulmage, H.T. 1981. Insecticidal activity of isolates of *Bacillus thuringiensis* and their potential for pest control. Pages 193-222 *in* Microbial control of pests and plant diseases 1970-1980 (Burges, H.D., ed.). New York, USA: Academic Press.

FAO. 1988. 1987 FAO Production Yearbook, vol. 41. Rome, Italy: FAO.

Frey, K.J. 1983. Genes from wild relatives for improving plants. Pages 1-20 *in* Crop improvement research: proceedings of the Fourth International SABRAO Congress, 4-8 May 1981, Kuala Lumpur, Malaysia (Yap, T.C., Graham, K.M., and Sukaimi, J., eds.). Bangi, Selangor, Malaysia: Society for the Advancement of Breeding Researches in Asia and Oceania.

GBPUAT (Govind Ballabh Pant University of Agriculture and Technology). 1986. Pulses research at Pantnagar. Experimental Station Bulletin no. 113. Pantnagar, Nainital. India: GBPUAT. 124 pp.

Goldberg, L.J., and **Margalit, J.** 1977. A bacterial spore demonstrating rapid larvicidal activity against *Anopheles sergentii, Urantenia unguiculata, Culex univittatus, Aedes aegypti* and *Culex pipens*. Mosquito News 37:353-358.

Herrnstadt, C., Soares, C.G., Wilcox, E.R., and **Edwards, D.L.** 1986. A new strain of *Bacillus thuringiensis* with activity against Coleopetran insects. Biotechnology 4:305-308.

ICARDA (International Center for Agricultural Research in the Dry Areas). 1986. Farming Systems Program: annual report 1985. Aleppo, Syria: ICARDA.

ICARDA (International Center for Agricultural Research in the Dry Areas). 1988. Annual report 1987. Aleppo, Syria: ICARDA.

ICARDA (International Center for Agricultural Research in the Dry Areas). 1989. Food Legume Improvement Program: annual report 1988. Aleppo, Syria: ICARDA.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1989. Annual report 1988. Patancheru, A.P. 502 324, India: ICRISAT.

Krieg, A., Huger, A.M., Langenbruch, G.A., and **Schnetter, W.** 1983. *Bacillus thuringiensis* var. *tenebrionis*, ein neuer, gegenuber Larven von Coleopteran wirksamer Pathotyp. (In De.) Zeitschrift fuer Angewandete Entomologie 96:500-508.

Makkouk, K., Beck, D., and **Diekmann, M.** 1989. Applications ofimmuno and DNA hybridization diagnostics in research at ICARDA. Pages 399-411 *in* Strengthening collaboration in biotechnology: international agricultural research and the private sector: proceedings of a Conference, 17-21 Apr 1988, Rosslyn, Virginia, USA (Cohen, J.I., ed.). Washington, D.C., USA: Agency for International Development.

Meeusen, R. 1989. Genetically engineered insect resistance in crops. Pages 165-173 *in* Strengthening collaboration in biotechnology: international agricultural research and the private sector: proceedings of a Conference, 17-21 Apr 1988, Rosslyn, Virginia, USA (Cohen, J.I., ed.). Washington, D.C., USA: Agency for International Development.

Nene, Y.L., and **Reddy, M.V.** 1987. Chickpea diseases and their control. Pages 233-270 *in* The chickpea (Saxena, M.C., and Singh, K.B., eds.). Wallingford, Oxon, UK: CAB International.

NRC (National Research Council). 1989. Alternative agriculture. Washington, D.C., USA: National Academy Press.

Oram, P., and **Belaid, A.** 1989. ICARDA/IFPRI legume study. Aleppo, Syria: International Center for Agricultural Research in the Dry Areas.

Pluvinage, J. (In press). Chickpea in the Mediterranean production systems: two contrasting examples of possible developments in Algeria and France. *In* proceedings of the CIHEAM, ECC (AGRIMED), and ICARDA Conference on Present Status and Future Prospects of Chickpea Crop Production and Improvement in the Mediterranean Countries, 11-13 Jul 1988, Zaragoza, Spain (Cubero, J.I., Saxena, M.C., and Wery, J., eds.). Zaragoza, Spain: Centre International de Hautes Etudes Agronomiques Mediterraneennes.

Ramalho Ribero, J.M.C., and **Portugal Melo, I.M.** (In press). Composition and nutritive value of chickpea. *In* proceedings of the CIHEAM, ECC (AGRIMED), and ICARDA Conference on Present Status and Future Prospects of Chickpea Crop Production and Improvement in the Mediterranean Countries, 11-13 Jul 1988, Zaragoza, Spain (Cubero, J.I., Saxena, M.C., and Wery, J., eds.). Zaragoza, Spain: Centre International de Hautes Etudes Agronomiques Mediterraneennes.

Reed, W., Cardona, C., Sithanantham, S., and **Lateef, S.S.** 1987. Chickpea insect pests and their control. Pages 283-318 *in* The chickpea (Saxena, M.C., and Singh, K.B., eds.). Wallingford, Oxon, UK:CAB International.

Roberts, E.H., Hadley, P., and **Summerfield, R.J.** 1985. Effects of temperature and photoperiod on flowering in chickpeas (*Cicer arietinum* L.). Annals of Botany 55:881-892.

Roberts, E.H., and **Summerfield, R.J.** 1987. Measurement and prediction of flowering in annual crops. Pages 17-50 *in* Manipulation of flowering (Atherton, J.G., ed.). London, UK: Butterworths.

Saxena, M.C. 1987a. Agronomy of chickpea. Pages 207-232 *in* The chickpea (Saxena, M.C., and Singh, K.B., eds.). Wallingford, Oxon, UK: CAB International.

Saxena, M.C. 1987b. Effects of climatic stress and soil chemical toxicities on productivity of chickpea in West Asia and North Africa. Pages 135-143 *in* Adaptation of chickpea and pigeonpea to abiotic stresses: proceedings of the Consultants' Workshop, 19-21 Dec 1984, ICRISAT Center, India, Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Saxena, M.C. 1987c. Utilization of food legumes for human consumption. Pages 406-419 *in* Jornadas Portuguesas de Protenaginosas Comunicacoes, 19 a 21 de Fevereirode 1986, Oeiras, Portugal: Estacao Agronomica Nacional.

Saxena, M.C. 1988. Food legumes in the Mediterranean type of environment. Pages 11-23 *in* Nitrogen fixation by legumes in Mediterranean agriculture: proceedings of a Workshop, 14-17 Apr 1986, Aleppo, Syria (Beck, D.P., and Materon, L.A., eds.). Dordrecht, Netherlands: Martinus Nijhoff.

Saxena, N.P. 1987. Screening for adaptation to drought: case studies with chickpea and pigeonpea. Pages 63-76 *In* Adaptation of chickpea and pigeonpea to abiotic stresses: proceedings of the Consultants' Workshop, 19-21 Dec 1984, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Saxena, N.P., Johansen, C., Sethi, S.C., Talwar, H.S., and **Krishnamurthy, L.** 1988. Improving harvest index in chickpea through incorporation of cold tolerance. International Chickpea Newsletter 19:17-19.

Scowcroft, W.R. 1989. Impact of somaclonal variation on plant improvement and IARC/private sector collaborative research. Pages 129-139 *in* Strengthening collaboration in biotechnology: international agricultural research and the private sector: proceedings of a Conference, 17-21 Apr 1988, Rosslyn, Virginia (Cohen, J.I., ed.). Washington, D.C., USA: Agency for International Development.

Sheldrake, A.R., and **Saxena, N.P.** 1979. Growth and development of chickpeas under progressive moisture stress. Pages 465-483 *in* Stress physiology in crop plants (Mussell, H., and Staples, R.C., eds.). New York, USA: John Wiley.

Singh, K.B. 1987. Chickpea breeding. Pages 127-162 *in* The chickpea (Saxena, M.C., and Singh, K.B., eds.). Wallingford, Oxon, UK: CAB International.

Singh, K.B. (In press). Winter chickpea: problems and potentials in the Mediterranean region. *In* proceedings of the CIHEAM, ECC (AGRIMED), and ICARDA Conference on Present Status and Future Prospects of Chickpea Crop Production and Improvement in the Mediterranean Countries, 11-13 Jul 1988, Zaragoza, Spain (Cubero, J.I., Saxena, M.C., and Wery, J., eds.). Zaragoza, Spain: Centre Internationalde Hautes Etudes Agronomiques Mediterraneennes.

Singh, K.B., Malhotra, R.S. and **Saxena, M.C.** 1989a. Chickpea evaluation for cold tolerance under field conditions. Crop Science 29:282-285.

Singh, K.B., Weigand, S., Haware, M.P., Di Vito, M., Malhotra, R.S., Tahhan, O., Saxena, M.C., and **Holly, L.** 1989b. Evaluation of wild species to biotic and abiotic stresses in chickpea. Poster abstract 14-13 presented at the XII Eucarpia Congress, 27 Feb-4 Mar 1989, Gottingen, Federal Republic of Germany. Vortrage fur Pflanzenzuchtung 15-1.

Smithson, J.B., Thompson, J.A., and **Summerfield, R.J.** 1985. Chickpea (*Cicer arietinum* L.). Pages 312-390 *in* Grain legume crops (Summerfield, R.J., and Roberts, E.H., eds.). London, UK: Collins.

Weigand, F., and **Saxena, M.C.** 1989. Crown gall tumour formation on chickpea (*Cicer arietinum* L.) induced by wild strains of *Agrobacterium*. Poster abstract 14-14 presented at XII Eucarpia Congress, 27 Feb-4 Mar 1989, Gottingen, Federal Republic of Germany. Vortrage fur Pflanzenzuchtung 15-1.

Weigand, S. (In press). Insect pests of chickpea in the Mediterranean areas and possibilities for their control. *In* proceedings of the CIHEAM, ECC (AGRIMED), and ICARDA Conference on Present Status and Future Prospects of Chickpea Crop Production and Improvement in the Mediterranean Countries, 11-13 Jul 1988, Zaragoza, Spain (Cubero, J.I., Saxena, M.C., and Wery, J., eds.). Zaragoza, Spain: Centre International de Hautes Etudes Agronomiques Mediterraneennes.

Wery, J. (In press). Adaptation to frost and drought stress in chickpea and implications in plant breeding. *In* proceedings of the CIHEAM, ECC (AGRIMED), and ICARDA Conference on Present Status and Future Prospects of Chickpea Crop Production and Improvement in the Mediterranean Countries, 11-13 Jul 1988, Zaragoza, Spain (Cubero, J.I., Saxena, M.C., and Wery, J., eds.). Zaragoza, Spain: Centre International de Hautes Etudes Agronomiques Mediterraneennes.

West, D.P., Cramer, J.H., Romero-Severson, J., Ma, Y., and **Murray, M.** 1989. Application of restriction fragment length polymorphism to plant breeding. Pages 175-184 *in* Strengthening collaboration in biotechnology: international agricultural research and the private sector: proceedings of a Conference, 17-21 Apr 1988, Rosslyn, Virginia, USA (Cohen, J.I., ed.). Washington, D.C., USA: Agency for International Development.

Inaugural Session

Main Items of Presentation and Discussion

- When a farmer decides to grow chickpea for the first time he needs to know which crops it could replace, and what yield is needed for it to compete economically with those crops. For example in Australia, the need to break continuous cereal cropping because of nematode infestations led to chickpea replacing wheat in some areas.
- In the rainfed areas of the West Asia and North Africa (WANA) region, yield levels of about 1 t ha^{-1} make the crop competitive with cereals.
- One of the constraints responsible for the yield gap between farmers' fields and experimental plots is the non-availability of effective, easy-to-use herbicides. There is, therefore, a need for research to find such herbicides, and this work should include on-farm trials with economic evaluation.
- In the 1990s more emphasis needs to be given to finding new ways of using chickpea. The high protein content of chickpea makes it ideal for such uses as textured protein products, noodles, baby foods, and as a component of loaf and flat bread. It could also be used in mixed feeds for ruminant and non-ruminant animals.
- In the 1990s consideration needs to be given to biological nitrogen fixation (BNF) by chickpea. In WANA, BNF is poorer in chickpea than in the other two common food legumes and the crop often suffers from nitrogen deficiency. Introduction of more effective strains of *Rhizobium* has shown good promise. 'Need-to-inoculate' trials in farmers' fields have confirmed the advantage of using efficient strains, even in traditional chickpea-growing areas.
- Effective use of molecular biology requires basic genetic information. Presently such information is lacking for chickpea. Thus ICARDA intends to allocate about 10-15% of its resources for chickpea improvement to such basic research in the coming years. In collaboration with mentor institutions in industrialized countries ICARDA scientists intend to develop information on the basic genetics and cytogenetics of chickpea. ICARDA already has one such collaborative project in progress with institutions in Italy.

Session inaugurale

Principaux thèmes de présentation et de discussion

- Lorsqu'un paysan décide, pour la première fois, de cultiver le pois chiche, il a besoin de savoir quelles cultures celui-ci peut remplacer, et quel rendement permettra au pois chiche de concurrencer économiquement ces cultures. Par exemple, en Australie, le besoin d'interrompre la culture continue des céréales à cause des infestations par les nématodes a provoqué le remplacement du blé par le pois chiche dans certaines régions.

- Dans les zones pluviales de la région de l'Asie de l'Ouest et de l'Afrique du Nord (région 'WANA'), des niveaux de rendement d'environ 1 t ha^{-1} rendent la culture concurrentielle à l'égard des céréales.

- Une des contraintes responsables pour l'écart de rendement entre le milieu paysan et les parcelles d'essai est la non disponibilité d'herbicides efficaces et d'usage facile. Il existe donc le besoin des travaux de recherche pour identifier de telles herbicides; ces travaux doivent comporter des essais en milieu réel avec l'évaluation économique.

- L'identification de nouvelles méthodes d'utilisation du pois chiche doit recevoir plus d'importance dans les années 90. La teneur très élevée du pois chiche en protéines le rend idéal pour les utilisations telles les produits à protéine texturé, les pâtes, les aliments pour enfants, et comme composant du pain rond et du pain plat. Il peut également être utilisé dans les aliments mélangés pour les animaux ruminants et non-ruminants.

- Dans les années 90, il serait utile de considérer la fixation biologique de l'azote par le pois chiche. Dans la région WANA, la fixation est plus faible chez le pois chiche que chez les deux autres légumineuses alimentaires communes. La culture subit généralement une carence d'azote. L'introduction des souches plus efficaces de *Rhizobium* s'est révélée prometteur. Les essais 'Besoin d'inoculer' (*Need-to-inoculate trials*) effectués en milieu réel ont confirmé l'avantage de l'utilisation des souches efficaces, mêmes dans les zones traditionnelles de culture du pois chiche.

- L'exploitation efficace de la biologie moléculaire exige des informations génétiques de base. Actuellement, une telle information n'est pas disponible pour le pois chiche. Ainsi l'ICARDA envisage-t-il affecter environ 10 à 15% de ses ressources de l'amélioration du pois chiche à de tels travaux de recherche fondamentale dans les années à venir. En collaboration avec les institutions guides dans les pays industrialisés, les chercheurs de l'ICARDA envisagent le développement de l'information sur la génétique et la cytogénétique fondamentales du pois chiche. L'ICARDA a déjà mis en place un tel projet collaboratif avec des institutions en Italie.

Session 1

Status and Potential

World Market for Pulses and Implications for Chickpea Research

M. von Oppen[1]

Abstract

World trade in pulses has been consistently increasing over the past ten years. From a stagnant 3% of total production over many years, it began to increase to about 6% around 1980 and 8% around 1985; because their unit value is more than twice that of cereals, pulses are more transportable and can be expected to further advance in world trade to at least the level of cereals, which have long remained constant at around 12% of total production. At present more than 50% of the pulses exported originate from developing countries, and most of these are being imported by industrialized countries.

The reasons for such a rapidly growing world market in pulses include the following:

- *in industrialized countries there is a growing demand for vegetarian diets and consequently for pulses and food products derived from pulses;*
- *in several developing countries rising incomes lead to a growth in demand for pulses, e.g., in India; and*
- *intensified agricultural research and exchange of information enables potential suppliers to take up production wherever a comparative advantage exists, e.g., in Australia.*

It is likely that chickpeas will follow these general statistical trends for pulses as a whole. Hence chickpea researchers would need to test the following hypotheses:

Areas of comparative advantage for chickpea production can be identified on the basis of agroclimatic data in combination with yield trials and field research on the costs of production.

There are potential regions for chickpea production in other parts of the semi-arid tropics and subtropics, where presently chickpeas are grown only to a limited extent.

Demand for chickpeas will increase in industrialized as well as developing countries.

Assuming that chickpeas are produced in areas of comparative advantage and that supplies of chickpeas increase in line with projected demand (so that prices remain remunerative and stable), new trade flows will develop; world chickpea trade will grow beyond 12% or even 20% of the total production.

If the above hypotheses are correct, ICRISAT and ICARDA researchers may have to review their research priorities to decide whether chickpea research should remain focused on the traditional target group of small producers and local consumers.

Résumé

Marché mondial des légumineuses, et les conséquences pour la recherche sur le pois chiche : *Depuis les dix dernières années, on constate une croissance régulière du commerce mondial des légumineuses. Après une stagnation, pendant plusieurs années, à 3% de la production globale, le commerce s'est élevé à environ 6% vers 1980, et à 8% vers 1985. Etant donné leur valeur unitaire plus de deux fois supérieure à celle des céréales, les légumineuses sont plus facilement transportées, et peuvent avancer davantage sur le plan du commerce mondial pour atteindre au moins le niveau des céréales. Celui-ci est longtemps resté constant à environ 12%*

1. Professor, Institute of Agricultural Economics and Social Sciences in the Tropics, Universitat Hohenheim, Institut 490, Postfach 700 562, 7000 Stuttgart 70, Federal Republic of Germany.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

de la production globale. A l'heure actuelle, plus de 50% des légumineuses exportées proviennent des pays en développement, la plupart étant importées par les pays développés.

Les raisons d'une telle expansion du marché mondial des légumineuses sont, entre autres :

- *dans les pays industrialisés, la demande pour des régimes végétariens ne cesse d'accroître; il y a, par conséquent, une forte demande pour ces cultures et des produits alimentaires dérivés;*
- *dans plusieurs pays en développement, notamment en Inde, l'augmentation des salaires engendre une augmentation de la demande pour les légumineuses;*
- *la recherche agricole intensifiée, et l'échange des informations, permet aux fournisseurs potentiels de reprendre la production partout où il y a un avantage comparatif, par exemple, en Australie.*

Il est fort probable que le pois chiche suivra ces mêmes tendances générales statistiques de l'ensemble des légumineuses. Ainsi les chercheurs auront-ils à tester les hypothèses suivantes :

Des zones d'avantage comparatif pour la production de pois chiche peuvent être identifiées en fonction des données agroclimatiques, accompagnées d'essais de rendement et recherches en milieu réel sur les coûts de production. Il existent des zones potentielles de production de pois chiche dans d'autres parties des régions tropicales et subtropicales semi-arides où la culture des pois chiche est actuellement limitée.

La demande pour les pois chiches s'élèvra progressivement tant dans les pays industrialisés que dans les pays en développement.

Si les pois chiches sont produits dans des zones d'avantage comparatif, et si la fourniture des pois chiches augmente en fonction de la demande projetée (de façon à ce que les prix demeurent rémunératifs et stables), il en résulterait une mise en place de nouveaux flux commerciaux. Le commerce mondial du pois chiche pourrait dépasser, par conséquent, 12%, voire 20% de la production globale.

Si ces hypothèses s'avèrent valables, les chercheurs de l'ICRISAT et de l'ICARDA auront peut-être à revoir les priorités de leurs travaux de recherche afin de décider si la recherche sur le pois chiche doit rester axée sur le but traditionnel de petits paysans et de consommateurs régionaux.

The earlier state of stagnant or declining world pulse production in relation to steadily increasing cereal production has been reversed. Since the early 1980s pulse production has increased at a rate faster than cereals; the gap between the index of world pulse production and world cereal production is narrowing (Fig. 1a). The proportion of pulses traded in the world rose from a long-time 3% to over 8% of world production in 1987.

In 1986 we argued, "there are several reasons to believe that the past trend of stagnating pulse area and production of 1970s is giving way to a moderately improving trend ..." (Rao and von Oppen 1987). The expectations expressed then for Asia have been confirmed by the actual development in recent years (Fig. 1b).

Even though African data (Fig. 1c) show a decline in the index of pulse production and those for Africa and Asia (without China) both indicate a high variability at the regional level, the continuous upward trend of pulse production at the world level is clearly visible (Fig. 1). For chickpeas, however, such a trend reversal has not yet begun; and one asks whether the reasons that have led to an increase in pulse production in the world during the 1980s are also valid for chickpeas in the 1990s.

The increase in pulse production was expected for the following three reasons: breeders were optimistic about producing higher-yielding varieties; national and international demand and trade of pulses were on the increase; and a growing awareness by policy makers about the importance of pulses for producer and consumer welfare in developing countries had led to a more active support of pulse improvement programs. These points have proved to be valid for pulses as a whole; however, chickpeas seem to follow a pattern and pace of their own.

The development of chickpea production and trade

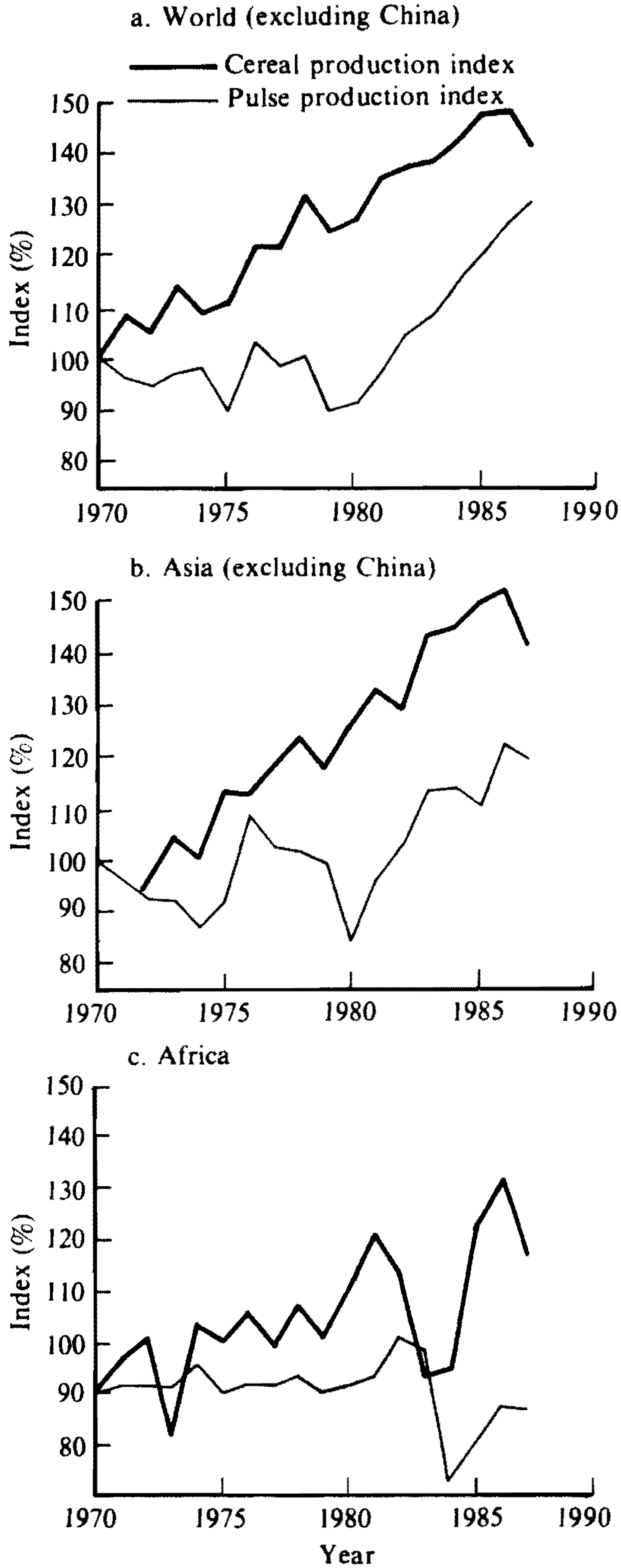


Figure 1. Indices of cereal and pulse production a. World (excluding People's Republic of China), b. Asia (excluding China), and c. Africa (Base year 1970 = 100).

in the world is documented in the following section. It leads to questions in the subsequent section on chickpea-specific research prospects, comparative advantage and trade, and policy decisions. Finally the implications for future research are drawn.

Chickpea Production and Trade

Data on production and trade of chickpea have been compiled by Rees (1988). In Table 1, the annual growth rates of chickpea production in developing and developed countries are given for the period from 1981 to 1986.

The data show that in India, by far the largest chickpea producer in the world, chickpea production since 1981 has only grown very slowly at less than 6% per annum; however, the next three most productive countries, each producing between 200 000 to more than 600 000 t of chickpea, show remarkable annual growth rates. They are Pakistan 11%, Myanmar 18%, and Turkey 21%. Two other countries where chickpea production seems to be expanding rapidly are Uganda (32%) and Sudan (8%). All developing countries together have an annual growth of chickpea production from 1981 to 1986 of about 7%.

Three out of the six chickpea-producing countries in Europe have a declining production, while the other three show increasing trends, so that the overall growth for the developed countries is <5%.

Table 2 shows the average annual consumption of chickpeas countrywise per caput for the period 1981-1985. The highest consumption rates of 5 to 6 kg per caput are found in the major producing countries India and Pakistan; Tunisia, Myanmar, Turkey, Ethiopia, Syria, and Malawi follow with 3 to 4 kg per caput.

In the developed countries chickpea consumption per caput is comparatively low; it amounts to around 1 to 2 kg in Spain, Portugal, and Greece, and to less than 1 kg in the others.

The distribution of world chickpea production and consumption, as shown in Tables 1 and 2, indicates that countries primarily produce to satisfy their own needs. Accordingly, international trade in chickpeas exported (Table 3) and imported (Table 4) is limited: world trade comprises only about 2 to 4% of world production. Turkey, Mexico, and Syria are major exporters; Spain and Algeria are major importers; and over recent years India has increasingly been importing chickpeas (30 000 t in 1986).

The general picture of production, consumption, and trade as reflected in the available FAO data up to 1986 shows that some countries such as Turkey and

Table 1. World production of chickpea 1981–86 ('000 t).

	1981	1982	1983	1984	1985	1986	Average	Annual rate of growth %
Developing countries								
India	4328.0	4642.1	5289.9	4750.0	4561.4	5683.1	4875.8	5.6
Pakistan	336.9	293.7	491.0	527.3	523.7	577.6	458.4	11.4
Turkey	235.0	280.0	290.0	335.0	400.0	600.0	356.7	20.6
Mexico	145.3	160.5	169.0	172.7	170.0	180.0	166.3	4.4
Myanmar	102.3	155.6	125.7	173.3	137.6	234.0	154.8	18.0
Ethiopia	118.3	101.5	118.5	108.5	135.0	135.0	119.5	2.7
Iran	61.0	60.0	60.0	50.0	53.0	55.0	56.5	-2.0
Syrian Arab Republic	63.8	37.0	74.8	35.8	50.4	53.2	52.5	-3.6
Bangladesh	37.6	36.8	40.9	41.4	38.2	38.2	38.8	0.3
Morocco	6.0	50.9	55.9	28.7	45.4	45.0	38.6	49.6
Tunisia	32.0	33.0	37.0	22.0	30.0	35.0	31.5	1.8
Nepal	22.0	23.0	22.0	20.0	19.0	18.0	20.7	-3.9
Malawi	18.0	19.0	20.0	21.0	22.0	21.7	20.3	3.8
Egypt	12.8	16.2	10.1	11.4	16.5	17.0	14.0	5.9
Algeria	16.8	9.3	9.9	12.6	16.0	18.0	13.8	1.4
Iraq	12.0	11.6	12.5	9.4	12.0	12.5	11.7	0.8
Colombia	11.0	11.0	11.0	11.0	11.0	11.0	11.0	0.0
Tanzania	7.5	8.0	8.0	9.0	9.0	10.0	8.6	5.9
Chile	6.4	4.1	3.2	6.9	9.2	8.9	6.5	6.7
Uganda	2.0	3.0	4.0	4.0	8.0	8.0	4.8	32.0
Argentina	3.9	1.3	1.7	3.8	3.0	3.0	2.8	-5.1
Peru	2.1	2.2	2.2	2.3	2.4	2.4	2.3	2.7
Lebanon	2.5	2.6	2.0	1.6	1.2	1.4	1.9	-10.9
Jordan	1.5	1.5	1.5	0.6	1.6	1.6	1.4	1.5
Sudan	1.0	0.7	0.8	0.6	1.1	1.5	0.9	8.4
Cyprus	0.6	0.5	0.5	0.5	0.5	0.5	0.5	-1.3
Libya	0.3	0.3	0.3	0.3	0.4	0.4	0.3	3.0
Dominican Rep.	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.0
Bolivia	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.8
Palestine (Gaza Strip)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Total developing	5587.2	5966.0	6862.9	6360.4	6278.2	7772.7	6471.2	6.8
Developed countries								
Spain	33.2	47.1	49.4	61.9	57.0	57.0	50.9	11.4
Italy	15.6	14.5	13.4	14.2	12.7	11.1	13.6	-6.6
Portugal	7.6	9.7	8.2	14.0	13.4	12.0	10.8	9.5
Greece	12.7	10.5	8.0	6.0	6.0	7.0	8.4	-11.2
Israel	3.0	2.4	3.6	2.3	3.5	2.4	2.9	-4.4
Yugoslavia	1.3	2.0	1.9	1.9	2.1	2.7	2.0	15.7
Total developed	73.4	86.1	84.6	100.3	94.7	92.2	88.6	4.7
World total	5660.6	6052.1	6947.4	6460.7	6372.9	7864.9	6559.8	6.8

Source: FAO Production and Trade Yearbooks, 1983–86 (taken from Rees 1988).

probably Mexico are expanding production and exports of chickpeas while others are compensating a decreasing or stagnant production by increasing imports (e.g., Greece and India). These may be the first signs of a reallocation of chickpea production to areas of comparative advantage.

Another chickpea producing and exporting country not listed as yet in the FAO data is Australia. Table 5 shows how the development of chickpea production began in 1983 with 4 000 t and that it has reached

Table 2. World consumption of chickpea 1981-85.

	Total consumption ('000 t)[1]						Average consumption (kg caput⁻¹)
	1981	1982	1983	1984	1985	Average	
Developing countries							
India	4330.3	4643.4	5302.2	4764.5	4586.5	4725.4	6.51
Pakistan	338.2	303.3	497.0	531.6	528.0	439.6	4.89
Turkey	62.9	123.7	126.2	175.7	288.4	155.4	3.22
Myanmar	102.3	155.6	125.7	173.3	137.6	138.9	3.73
Ethiopia	118.1	101.3	117.6	108.3	134.3	115.9	3.41
Mexico	80.8	126.4	96.4	127.5	125.8	111.4	1.48
Iran	61.0	60.0	70.1	58.0	60.0	61.8	1.48
Algeria	46.8	31.4	50.6	53.9	56.0	47.8	2.32
Bangladesh	37.6	36.8	40.9	41.4	38.2	38.9	0.41
Morocco	-4.2	50.8	55.0	28.7	45.4	35.1	1.57
Tunisia	30.1	32.6	37.0	22.0	37.5	31.8	4.60
Syrian Arab Republic	62.2	-1.9	55.3	-5.6	40.4	30.1	3.13
Iraq	22.0	23.6	24.5	34.4	25.0	25.9	1.77
Nepal	22.0	23.0	22.0	20.0	19.0	21.2	1.35
Malawi	18.0	19.0	20.0	21.0	22.0	20.0	3.09
Colombia	14.4	15.0	15.4	13.0	13.0	14.2	0.51
Total developing	5417.3	5818.4	6727.6	6243.9	6237.0	6088.9	
Developed countries							
Spain	76.0	90.1	81.0	84.9	80.0	82.4	2.16
Italy	15.6	14.5	13.4	14.2	12.7	14.1	0.25
Portugal	7.9	13.2	12.3	14.4	12.5	12.1	1.20
USA	13.0	9.2	13.8	12.1	9.6	11.5	0.05
Greece	12.6	11.7	9.3	7.8	10.0	10.3	1.05
Israel	3.0	2.4	3.6	2.3	3.5	3.0	0.72
Total developed	129.4	143.2	135.4	137.7	130.5	135.3	
World total	5546.7	5961.6	6863.1	6381.7	6367.5	6224.1	

1. Consumption = Production + imports − exports, therefore some negative entries appear in the table for some exporting countries.
Source: FAO Production and Trade Yearbooks, 1983-85 (taken from Rees 1988).

83 000 t in 1989/90, nearly all of which is exported. 'Australia is well placed to become the only developed country to be a consistent supplier of relatively low priced desi chickpeas' (Rees 1988).

Thus, with unrestricted international trade allowing for free exchange, chickpeas are finding new locations for production and export. In contrast to the limited international trade in chickpeas, movements within India are substantial owing to the widely distributed demand for chickpea there (von Oppen and Rao 1987). For India it has also been shown that chickpea production is becoming increasingly concentrated in the rainfed areas of Madhya Pradesh and Rajasthan (von Oppen 1982). Similarly, Italy is concentrating production in the southern regions; this is leading to an increase in overall yield despite an overall decrease in production (Orsi and Casini 1985).

However, an unrestricted trade is not always assured. India decided in 1987 to impose a 25% ad valorem tax on all grain legume imports and it is not known how long this tax will remain in force (Connell 1987). The tax has since been raised to 35% in October 1988 and then reduced to 10% in November 1989. This causes a disincentive for Australian production and export of desi chickpeas. On the other hand, if this tax remains in force for several years then the higher demand will provide incentives for increasing production in India (Table 6).

Implications for Research

To summarize, there is an overall trend of growing production and national and international trade in

Table 3. World exports of chickpea 1981-85 ('000 t).

	1981	1982	1983	1984	1985	Average 1981-85
Developing countries						
Turkey	172.1	156.3	163.8	159.3	111.6	152.6
Mexico	64.5	34.1	72.6	45.2	44.2	52.1
Syrian Arab Republic	1.6	38.9	19.5	41.4	10.0	22.3
Singapore	1.5	1.4	5.4	2.3	0.9	2.3
Morocco	10.2	0.1	0.8	0.0	0.0	2.2
Chile	3.8	1.4	0.8	0.7	4.0	2.1
India	1.0	0.6	1.0	1.5	1.5	1.1
Cyprus	0.1	0.0	0.0	5.0	0.0	1.0
Tunisia	1.9	0.4	0.0	0.0	0.0	0.5
Ethiopia	0.2	0.2	0.9	0.2	0.7	0.4
Argentina	0.0	0.6	0.0	0.0	0.0	0.1
Jordan	0.1	0.1	0.1	0.4	0.1	0.1
Malaysia	0.0	0.2	0.1	0.1	0.0	0.1
Pakistan	0.1	0.0	0.0	0.0	0.3	0.1
Saudi Arabia	0.0	0.0	0.0	0.1	0.0	0.0
Peru	0.0	0.0	0.1	0.0	0.0	0.0
Kuwait	0.0	0.1	0.0	0.0	0.0	0.0
Philippines	0.0	0.0	0.0	0.0	0.0	0.0
Total developing	257.2	234.4	265.1	256.2	173.2	237.2
Developed countries						
Greece	1.4	0.6	1.2	0.2	0.1	0.7
Spain	0.4	0.7	1.4	0.0	0.0	0.5
Portugal	0.2	0.1	0.1	0.5	0.9	0.4
Total developed	2.0	1.4	2.7	0.8	1.0	1.6
World total	259.2	235.8	267.8	257.0	174.2	238.8

1. NA = not available.
Source: FAO Production and Trade Yearbooks, 1983-86 (taken from Rees 1988).

grain legumes. In comparison, world production of chickpeas is still only increasing slowly. However, there are indications of the beginning of a reallocation of the production of this crop to areas of comparative advantage, and of an increase in trade.

Research on chickpea improvement requires verification and quantification of these trends and an exploration of where exactly the development will lead. If chickpeas behave as other pulses and break out of their former primarily self-sufficiency oriented production and consumption patterns and enter international trade, then overall production may rapidly increase. However, the new locations of production and consumption will have to be identified, technologies and farming systems developed, suitable seed material provided, etc. Also the welfare effects of these changes on consumers and producers will need to be assessed. Several research problems need to be addressed. These areas are described below by postulating a hypothesis and proposing an approach for its verification.

Chickpea Breeders' Supply Projections

Hypothesis: Chickpea breeders can assess the potential for chickpea production in the major future producing areas.

To test this hypothesis an opinion survey should be carried out among the breeders as a group to identify:

- the future producing areas in India;
- other countries offering promising prospects;
- expected yields in those countries and regions at different levels in
- farmers' fields, demonstration plots and research stations.

Table 4. World imports of chickpea 1981-86 ('000 t).

	1981	1982	1983	1984	1985	1986	Average 1981-85
Developing countries							
Algeria	30.0	22.2	40.8	41.3	40.0	28.0	34.8
Iraq	10.0	12.0	12.0	25.0	13.0	15.0	14.4
India	3.3	1.9	13.3	16.0	26.6	30.0	12.2
Lebanon	11.0	11.0	11.0	10.0	9.0		10.4
Jordan	6.6	7.0	9.8	8.4	10.1	10.0	8.4
Saudi Arabia	4.7	6.1	7.0	7.4	7.0	8.2	6.4
Pakistan	1.4	9.6	6.0	4.3	4.5	7.0	5.2
Iran	0.0	0.0	10.1	8.0	7.0		5.0
Colombia	3.4	4.0	4.4	2.0	2.0	2.0	3.2
Malaysia	3.0	2.5	2.6	2.9	3.0		2.8
Singapore	2.2	2.4	4.3	2.1	1.1	3.0	2.4
Venezuela	2.2	2.0	2.3	4.4	0.0	1.1	2.2
Tunisia	0.0	0.0	0.0	0.0	7.5	NA[1]	1.5
Libya	4.9	1.4	0.0	0.0	0.0	NA	1.3
Cyprus	0.0	0.3	0.3	5.4	0.3	0.2	1.2
Brazil	2.5	1.3	2.4	0.0	0.0	NA	1.2
Kuwait	1.0	2.5	2.4	0.0	0.0	2.2	1.2
Philippines	0.6	0.4	0.5	0.4	0.2	0.3	0.4
Panama	0.3	0.2	0.2	0.2	0.2	NA	0.2
Qatar	0.0	0.0	0.0	0.5	0.6	NA	0.2
Uruguay	0.2	0.2	0.2	0.3	0.1	0.2	0.2
Bahrain	0.0	0.0	0.0	1.0	0.0	NA	0.2
Dominican Rep.	0.0	0.0	0.2	0.0	0.0	NA	0.0
Brunei	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Egypt	0.0	0.0	0.0	0.0	0.0	NA	0.0
Total developing	87.3	86.8	129.9	139.8	132.0	NA	115.2
Developed countries							
Spain	43.2	43.7	33.0	23.0	23.0	40.0	33.2
USA	13.0	9.2	13.8	12.1	9.6	11.6	11.5
Greece	1.4	1.9	2.5	2.1	4.1	8.3	2.4
Portugal	0.5	3.6	4.2	0.9	0.0	3.9	1.8
Malta	0.0	0.0	0.0	0.1	0.1	0.1	0.0
Bulgaria	0.0	0.0	0.0	0.0	0.0	NA	0.0
Total developed	58.0	58.5	53.5	38.1	36.8	NA	49.0
World total	145.3	145.3	183.4	177.9	168.8	173.1	164.2

1. NA = not available.
Source: FAO Production and Trade Yearbooks, 1983-86 (taken from Rees 1988).

Regional Comparative Advantages for Chickpea Production

Hypothesis: Areas of comparative advantage for chickpea production can be identified on the basis of agroclimatic data in combination with yield trials and field research on costs of production.

Apart from the traditional producing areas, there are regions with a potential for expanding chickpea production in other parts of the semi-arid tropics and subtropics, where chickpeas are not grown at present to a large extent, e.g., Ethiopia, Uganda, Sudan, Malawi, etc., but current developments indicate the possibility of a comparative advantage. A projection of future demand and prices required in all of these regions should be attempted.

Table 5. Production of peas ('000 t) in Australia.

Year	Field peas	Chickpeas	Cowpeas	Total
1980/81				
1981/82				
1982/83	29.5	0.0	3.6	33.1
1983/84	133.4	3.6	3.8	140.8
1984/85	164.1	5.9	3.1	173.1
1985/86	240.7	36.4	3.4	280.5
1986/87	518.0	63.0	9.0	590.0
1987/88	485.0	42.3	4.0	531.3
1988/89	533.0	63.8	3.5	600.3
1989/90	530.5	83.1	3.7	617.3

Source: Australian Bureau of Agricultural and Resource Economics, mainly: Commodity and Statistical Bulletins, 1986, 1987, 1988.

Chickpea Demand Projections

Hypothesis: Demand for chickpeas increases in industrialized as well as in developing countries.

High income and price elasticities of demand for pulses are found among low-income groups in developing countries (Table 6). Consequently economic growth and population increases cause a rapid growth in demand in certain developing countries. In industrialized countries consumption of chickpeas is introduced by immigrants belonging to, and travellers coming from, chickpea-eating societies; moreover, the number of vegetarian consumers is increasing in industrialized countries and, for these, chickpeas provide an attractive option. A projection of quantities demanded and prices paid in developing and industrialized countries is necessary.

Trade Patterns of World Trade in Chickpeas

Hypothesis: Assuming that chickpeas are produced in areas of comparative advantage as projected and that supplies of chickpeas increase in line with projected demand, then new trade patterns will emerge.

The existing and projected trade flows could be derived from information created under the previous two hypotheses. An interregional trade model could be applied to quantify trade flows and price levels which will emerge. Price/quality relationships will need to be taken into consideration in such an analysis, as well as the utilization of chickpeas as an industrially processed food product.

Conclusion

Unlike pulses as a whole, chickpeas are yet to respond to changes in the world market. However, there are reasons to believe that such a response can be hypothesized. If the hypotheses are found to be acceptable, then international chickpea research in the 1990s may need to be reviewed; it will be necessary to: (1) redefine mandate areas and priorities; (2) identify target populations and the roles of producers and consumers; and (3) determine strategies for attaining satisfactory progress in regional and overall chickpea production.

References

Connell, P. 1987. Markets for Australian grain legumes. Quarterly Review of the Rural Economy 9(2):170-176.

Table 6. Income and price elasticity of pulses in India, by expenditure group.

	Expenditure group[1]				
	1	2	3	4	5
Income elasticity					
Rural areas	1.82	1.02	1.03	0.53	0.46
Urban areas	1.47	0.96	0.72	0.44	0.14
Price elasticity					
Rural areas	-1.43	-0.91	-0.63	-0.36	-0.05
Urban areas	-1.07	-0.67	-0.59	-0.38	-0.29

1. 1 = lowest, 5 = highest.
Source: Murthy (1983).

Orsi, S., and **Casini, P.** 1985. Coltivazione del cece. Una leguminosa da granella da vilanciare. Informatore Agrario, Verona 41:46.

Rao, P.P., and **von Oppen, M.,** 1987. Food legume production in Asia: past trends and future prospects. Pages 54-63 *in* Food legume improvement for Asian farming systems: proceedings of an International Workshop, 1-5 Sep 1986, Khon Kaen, Thailand (Wallis, E.S., and Byth, D.E., eds.). ACIAR Proceedings no. 18. Canberra, Australia: Australian Centre for International Agricultural Research.

Rees, R.O. 1988. Supply and demand trends, price relationships and the market potential for selected grain legumes grown in Australia. Grain Legumes Research Council, Canberra, Australia: Department of Primary Industries. (Limited distribution.)

von Oppen, M. 1982. Prospects for grain legumes in Asia. Pages 191-211 *in* Grain legumes production in Asia. Tokyo, Japan: Asian Productivity Organization.

von Oppen, M., and **Rao, P.P.** 1987. Chickpea marketing, trade and prices. Pages 383-397 *in* The chickpea (Saxena, M.C., and Singh, K.B., eds.). Wallingford, Oxon, UK: CAB International.

Present Status and Prospects for Utilization of Chickpea

R. Jambunathan and Umaid Singh[1]

Abstract

Although desi and kabuli types of chickpea are used in a variety of ways around the world for different end products, detailed information on their similarities and differences is lacking. Additional knowledge on physical, chemical, and functional properties of desi and kabuli types will provide valuable clues about their end-use quality. This will also lead to better evaluation of newly developed chickpea cultivars and could provide avenues for better utilization. Thc influence of adverse growing, harvesting, or storage conditions on end-product quality also needs to be monitored. The present status of knowledge in these areas and future research needs are discussed.

Résumé

Bilan actuel et prévisions d'utilisation du pois chiche : *Bien que les types 'desi' et 'kabuli' de pois chiche sont utilisés de plusieurs manières dans le monde pour fournir des produits finis différents, nous ne disposons guère de renseignements détaillés sur leurs similarités et leurs différences. Des connaissances additionnelles sur les propriétés physiques, chimiques et fonctionnelles de ces types desi et kabuli fourniront des données utiles sur la qualité de leur usage final. Elles permettront également une meilleure évaluation de nouveaux cultivars de pois chiche et pourraient ainsi fournir des indices sur l'amélioration de l'utilisation. L'influence de conditions défavorables de culture, de récolte ou de stockage sur la qualité du produit fini mériterait aussi d'être suivie. Le bilan actuel des connaissances dans ces domaines et les besoins à venir en matière de recherche sont examinés.*

Amongst grain legumes, chickpea is unique because of the variety of food products that are prepared from it in different parts of the world. Chickpea forms an important dietary component in those countries in which it is a major crop. Although most of the world's chickpea production and consumption is in India (>70%), the crop is also important in other countries of Asia, Africa, Europe, and the Americas (ICRISAT 1986).

There are two main types of chickpea: desi, which constitutes about 85% of the total production, and kabuli which accounts for the remaining 15% of grain produced. Some of the differences between these two types of chickpea have been documented (Jambunathan and Singh 1980; Singh et al. 1982). The nutritional quality, biochemistry, and technology of chickpea have been thoroughly investigated (Singh 1985; Williams and Singh 1987; Chavan et al. 1988). Chickpea is a good source of carbohydrates, protein, minerals, and trace elements, and its protein quality is similar to, or better than other legumes, such as pigeonpea,

1. Principal Biochemist and Biochemist, Biochemistry Unit, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

ICRISAT Conference Paper no. CP 554.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

black gram, and green gram (Williams and Singh 1987). In this paper, the present status and prospects for utilization of chickpea are discussed.

Consumption of Whole Seed and *Dhal*

Chickpea is mostly consumed in the form of whole seed, *dhal* (decorticated split cotyledons) or as *dhal* flour *(besan)*. From a questionnaire on chickpea utilization sent to 386 scientists in 47 countries in 1986, we received responses from 102 scientists from 23 countries on the mode of consumption of chickpea (Table 1). The information provided in Table 1 may be considered as intelligent guesses by chickpea scientists around the world. In India, about 75% of chickpea is consumed in the form of *dhal* or *besan*, and the remaining 25% as whole seed. This finding appears to be similar to that in other Asian countries, except in Afghanistan and Nepal, where *besan* preparations are not common. Most of the chickpea consumed in other countries including Australia, Ethiopia, Mexico, Sudan, Tanzania, Turkey, UK, and USA is in the form of whole seed

Methods of Utilization

Several traditional processing practices are still used to convert chickpea into a consumable form. These processes include soaking, sprouting, fermenting, boiling, steaming, roasting, parching, and frying. Some important food products based on these methods of preparation are listed in Table 2. Among the common pulses in India, chickpea is prepared as food in a very wide variety of ways.

Developing green (immature) chickpeas harvested 10–15 days before maturity are consumed as snacks or vegetables with the major meal of the day. Sometimes, green seeds are boiled and fried with potatoes; otherwise they are roasted in the pod, shelled, and then consumed. Green chickpeas have less starch and protein, and more sugars than mature chickpeas and they are easily digested, even when eaten raw (Pushpamma and Geervani 1987).

Soaking and boiling whole seed before frying is a common practice. The seed is usually soaked to reduce the cooking time. Soaked seeds become soft after boiling for 20-25 min, whereas dry seeds take much longer. After boiling, excess water is discarded, and the boiled seeds are fried after the addition of spices, when the dishes are prepared according to local food habits. Germinated chickpea is also processed and consumed in different ways.

Roasted *dhal* and puffed whole seeds are also commonly used. For puffing, the seed is sprinkled with fresh or salt water, allowed to remain in a wet condition for 5-10 min and then roasted with hot sand at 240°–250°C for 1-2 min. The husk is thus loosened and removed by winnowing. The puffed chickpea seeds are eaten in this form. Roasted *dhal* is popular on the Indian subcontinent. Chickpea flour made out of whole seed or *dhal* is mixed with wheat flour in the ratio of 3:7 for making *roti* i.e., unleavened bread. Other uses of chickpea flour include *dhokla*, a fermented breakfast food, and several extruded and fried products.

Most of the chickpea produced in the Mediterranean region is consumed in the form of *homos-biteheneh*, *falafel*, and *tisqieh* (soaked and boiled seeds are used in these preparations). Roasted and sugar-coated chickpeas are also commonly eaten in this region. *Lablebi* which is prepared by boiling kabuli chickpea in water with salt and pepper is a common food in Tunisia and Turkey.

Table 1. Relative proportion (%) of chickpea consumption in the world[1].

Component	India	Asia (excluding India)	Other countries
Whole seed	25	23	88
Dhal (decorticated)	33	58	6
Besan (*dhal* flour)	42	19	6

1. Based on the responses received to a questionnaire. Number of respondents, India 76, Asia 8, and other countries 18.

Cooking Quality of Whole Seed and *Dhal*

The cooking quality of whole seed and *dhal* of chickpea is important in gaining consumer acceptance. Recently, we determined the cooking quality of whole seed and *dhal* samples of 125 genotypes having a large variation in 100-seed mass (range 10.4-36.7 g). The cooking time of whole seed of these genotypes varied from 52 to 98 min and for *dhal* from 26 to 46 min. This shows that decortication i.e., removal of the seed coat from whole seed reduces the cooking time considerably. Desi types are normally decorticated before consumption whereas kabuli are eaten in the form of whole seed. There was a positive and significant correlation ($P<0.01$) between cooking time of whole seed and 100-seed mass (Table 3). Protein content was positively and

Table 2. Some important food preparations of chickpea around the world.

Food[1]	Component	Method (in brief)	Country
Dhal	Decorticated dry split cotyledons	Boiled in water to a soft consistency and fried with spices and consumed with cereals	Bangladesh, India, Nepal, and Pakistan
Chhole	Whole seed	Prepared and consumed similar to above	Afghanistan, Bangladesh India, Iran, and Pakistan
Pakoda	*Besan* (*dhal* flour)	Batter is fried in oil and consumed as a snack	Egypt, India, Iran, Pakistan, and Sudan
Kadi	*Besan*	*Besan* is boiled with butter milk and used as curry	Indian subcontinent
Unleavened bread	Whole seed/ *Besan*	Chickpea flour is mixed with wheat flour and *roti* is prepared.	Ethiopia, India, Pakistan, and Syria
Kiyit injera	Whole seed	Fermented	Ethiopia
Roasted	Whole seed at	Grains-heated 245-250°C for 2 min.	Afghanistan, Ethiopia, India, Iraq, Iran, and Nepal
Homos-biteheneh	Whole seed	Soaked, boiled and mixed with other ingredients.	Egypt, Jordon, Lebanon, Syria, Tunisia, and Turkey
Tempeh	Decorticated split seed	Fermented product.	Canada, and USA
Lablebi	Whole seed	Boiled in water with salt and pepper	Jordon, Tunisia, and Turkey
Dhokla	*Besan*	Fermented with green gram flour	India
Salad	Whole seed	Boiled in water and served with other vegetables.	Australia, Canada, Mexico, Spain, and USA
Green immature seeds	Whole green seed	Raw, salted or roasted and consumed	Ethiopia, India, Iran, Nepal, Pakistan, and Sudan

1. Local names are given where applicable.

significantly correlated with the cooking time of whole seed and *dhal* (Table 3). Interestingly, there was a positive and significant correlation ($P<0.01$) between the cooking time of *dhal* and whole seed.

Cooking time is a heritable characteristic that differs widely among genotypes. Williams and Singh (1987) reported a range of 50 to 237 min for the cooking time of kabuli types and suggested that genotypes with shorter cooking time be selected in the breeding program. However, it should also be kept in mind that cooking time of whole seed is significantly reduced by simple household practices such as soaking overnight, so that most of the differences between cultivars are reduced or eliminated (Williams and Singh 1987).

Organoleptic Properties and Consumer Acceptance

The important criteria for acceptance of chickpea foods by consumers are appearance (color), taste, texture (mouth feel) and flavor. These terms are collectively referred to as general acceptability. The nutritive value of chickpea in addition to the general acceptability and

Table 3. Correlation matrix for 100-seed mass, protein content, and cooking quality of 125 chickpea genotypes, ICRISAT Center, 1987/88[1].

	Whole seed					*Dhal*	
	100-seed mass (g)	Seed coat (%)	Protein (%)	Cooking time (min)	Water absorption ($g\ g^{-1}$)	Protein (%)	Cooking time (min)
Whole seed							
Seed coat (%)	-0.64						
Protein (%)	0.26	-0.28					
Cooking time (min)	0.71	0.54	0.36				
Water absorption ($g\ g^{-1}$)	-0.68	-0.51	-0.37	-0.93			
Dhal							
Protein (%)	0.01	-0.03	0.83	0.19	-0.20		
Cooking time (min)	0.59	-0.26	0.33	0.53	-0.52	0.53	
Water absorption ($g\ g^{-1}$)	-0.57	0.25	-0.30	-0.52	0.55	-0.05	-0.98

1. For 123 degrees of freedom, the correlation values at 5% level of significance are ±0.17 and those at 1% level of significance are ±0.23.

eating quality should also be considered while developing new genotypes. They must also meet stipulated industrial and commercial requirements for processing into acceptable foods. A new cultivar must satisfy these requirements for better utilization by consumers. Growing seasons play an important role in influencing the quality and consumer acceptance of chickpea. Cooking quality and organoleptic properties of whole seed of some kabuli cultivars grown in different seasons at one location showed considerable differences (Table 4). L 550 and ICCC 33 when grown in 1985/86 produced lower scores for color, texture, flavor, and

Table 4. Cooking quality and organoleptic properties of whole seed of kabuli chickpea cultivars grown in 1984/85 and 1985/86 seasons at Hisar[1].

		Cooking quality		Organoleptic properties[2]				
Cultivar	100-seed mass (g)	Cooking time (min)	Water absorption (ratio)	Color	Texture	Flavor	Taste	General acceptability
L 144	28.9	80	1.07	3.9	3.1	3.6	3.8	3.9
	(24.9)	(78)	(1.20)	(3.6)	(3.0)	(3.2)	(3.2)	(3.3)
ICC 25	(17.1)	(64)	(1.02)	(3.3)	(3.0)	(3.4)	(3.0)	(3.2)
L 550	18.2	74	1.04	3.7	3.1	3.4	3.1	3.4
	(18.5)	(72)	(1.04)	(2.5)	(1.8)	(2.1)	(2.3)	(1.7)
ICCC 32	16.2	66	1.07	2.7	3.1	2.9	2.9	2.7
	(17.9)	(66)	(1.12)	(2.2)	(2.2)	(2.1)	(2.1)	(2.2)
ICCC 33	16.4	62	1.15	3.0	3.1	2.8	2.7	3.0
	(16.8)	(64)	(1.15)	(1.6)	(1.8)	(1.7)	(1.5)	(1.7)
ICCC 34	18.4	60	1.20	3.7	3.4	3.6	3.5	3.8
	(20.9)	(66)	(1.15)	(3.0)	(2.8)	(3.2)	(3.4)	(3.5)
SE	±0.21	±1.12	±0.03	±0.16	±0.20	±0.21	±0.16	±0.24
	(0.18)	(0.75)	(0.02)	(0.14)	(0.18)	(0.22)	(0.21)	(0.17)

1. Figures in parentheses show the data obtained in 1985/86.
2. Rating scale : Excellent, 4; good, 3; fair, 2; poor, 1, based on evaluation of 10 panelists.

taste than when grown in 1984/85. Differences were also observed in the cooking quality parameters of these cultivars due to seasonal effects. This suggests that both growing season and cultivar influence the acceptability and eating quality of chickpea and that these should be carefully monitored.

Processing and Nutritive Value of Chickpea-based Products

The effect of the processing method on the nutritive value of chickpea products has been investigated. During the course of processing, chickpea receives either one or a combination of the three major treatments i.e., germination, fermentation, and heat-treatment. Heat-treatment generally includes, steaming, boiling, roasting, or frying. When cooked after soaking for 20 h and sprouting for 24 h, the protein efficiency ratio (PER) of chickpea increased significantly over that of nontreated seeds (Deep et al. 1978). Germination had no advantage over moist heat treatment in improving the biological value of the protein, but the PER of chickpea germinated for up to 48 h was higher than that of the non-germinated control (Venkataraman et al. 1976). Germination of chickpea did not alter the concentration of amino acids (Finney et al. 1982) but it improved the carbohydrate digestibility (Jaya and Venkataraman 1981). *Tempeh* and *dhokla*, both fermented products had better protein quality than the nonfermented control (Williams and Singh 1987). Fermentation also increased the levels of the vitamins, thiamine and riboflavin and improved the concentration of limiting amino acids (Williams and Singh 1987). Although the protein quality of chickpea depends on the method of cooking, moist heat treatment is better than dry heat treatment (Geervani and Theophilus 1980).

Conclusions

There is little available information with supportive evidence on the consumption pattern of whole seed, *dhal* and *besan* of chickpea. It would be desirable to document the various forms of foods that are prepared from desi and kabuli chickpea around the world along with detailed recipes and photographs. It may then be possible to classify these products into a few major groups for conducting further research. The effect of environment on chickpea quality factors and consumers acceptance has to be evaluated before releasing any advanced genotypes for cultivation.

Future Research Needs

A Consultants' Meeting on Uses of Grain Legumes was held at ICRISAT Center in March 1989. Scientists from several countries involved in chickpea production and utilization participated in this meeting and made recommendations for future research. Important recommendations were:

1. Develop and standardize reliable evaluation methods.
2. Carry out research to understand the inherent properties of desi and kabuli chickpea. Use the knowledge gained to improve the quality of traditional chickpea foods and explore alternative avenues for utilization at consumers level and industrial manufacture of human foods and animal feeds.
3. Develop new genotypes with improved dehulling properties.
4. Investigate the effects of storage on various quality parameters and take appropriate follow-up action.
5. Establish a network of scientists to better understand consumer needs in different parts of the world and to identify areas for collaborative research and training needs.

References

Chavan, J.K., Kadam, S.S., and **Salunkhe, D.K.** 1988. Biochemistry, and technology of chickpea (*Cicer arietinum* L.) seeds. CRC Critical Reviews in Food Science and Nutrition 25:107-158.

Deep, D., Bajaj, S., and **Bhat, C.M.** 1978. The effects of soaking, sprouting, and cooking on the protein quality of two pulses. Journal of Research, Punjab Agricultural University 15:375-378.

Finney, P.L., Beguin, D., and **Bubbard, J.D.** 1982. Effects of germination on bread-making properties of mung bean (*Phaseolus aureus*) and garbanzo bean (*Cicer arietinum* L.). Cereal Chemistry 59:520-524.

Geervani, P., and **Theophilus, F.** 1980. Effect of home processing on nutrient composition of certain high yielding legume varieties. Indian Journal of Nutrition and Dietetics 17:443-446.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1986. Pages 141 *in* Annual report 1985. Patancheru, A.P. 502 324, India: ICRISAT.

Jambunathan, R., and **Singh, U.** 1980. Studies on desi and kabuli chickpea (*Cicer arietinum* L.) cultivars. I. Chemical composition. Pages 61-66 *in* Proceedings of the International Workshop on Chickpea Improvement, 28 Feb - 2 Mar 1979, ICRISAT, Hyderabad, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Jaya, T.V., and **Venkataraman, L.B.** 1981. Influence of germination on the carbohydrate digestibility (*in vitro*) of chickpea flour (*Cicer arietinum*) and green gram (*Phaseolus aureus* L.). Indian Journal of Nutrition and Dietetics 18:62-68.

Pushpamma, P., and **Geervani, P.** 1987. Utilization of chickpea. Pages 357-368 *in* The chickpea (Saxena, M.C., and Singh, K.B., eds.). Wallingford, Oxon, UK: CAB International.

Singh, U. 1985. Nutritional quality of chickpea (*Cicer arietinum* L.): current status and future research needs. Qualitas Plantarum: Plant Foods for Human Nutrition 35:339-351.

Singh, U., **Kherdekar, M.S.**, and **Jambunathan, R.** 1982. Studies on desi and kabuli chickpea (*Cicer arietinum* L.) cultivars. The levels of amylase inhibitors, levels of oligosaccharides and *in vitro* starch digestibility. Journal of Food Science 47(2):510-512.

Venkataraman, L.V., **Jaya, T.V.**, and **Krishnamurthy K.S.** 1976. Effect of germination on the biological value, digestibility coefficient and net protein utilization of some legume proteins. Nutrition Reports International 13:197-205.

Williams, P.C., and **Singh, U.** 1987. The chickpea—nutritional quality and the evaluation of quality in breeding programmes. Pages 329-356 *in* The chickpea (Saxena, M.C., and Singh K.B., eds.). Wallingford, Oxon, UK: CAB International.

Session 1

Main Items of Presentation and Discussion

- There is a worldwide trend towards increased demand for chickpea both in developing and in industrialized countries.
- To meet this demand in the 1990s, new production areas with comparative advantages for chickpea production need to be identified and developed.
- Factors such as irrigation and changes in sowing date can substantially increase chickpea yield, but this knowledge has so far found little practical application. There is need for further investigation of these factors, and for their implementation.
- As starch is a major component of chickpea seed (65%), improvement of starch quality should receive more attention.

Recommendations for Economic Research on Chickpea

There are indications that the rapidly increasing demand for chickpea in developing and industrialized countries cannot be met solely by chickpea production from traditional locations. Therefore, chickpea production will move into areas of comparative advantage. If these assumptions are correct, the following research on the economics of production, demand and trade is urgently required:

- To determine the potential supply of chickpeas at two levels: in collaboration with mentor institutions, and with national agricultural research systems (NARSs); by assessing experts' opinions on future yields in potential production areas in the world; and by determining production areas based on agroclimatic data and crop modeling in combination with yield trials and field research on cost of production.
- To assess future demand for chickpea, by quantifying the demand in developing countries, through work on elasticities of demand and on consumer preferences for quality characteristics, and by assessing the potential demand in industrialized countries through research on emerging trade patterns, and by conducting consumer and trader opinion surveys.
- To project trade patterns; by analyzing the existing world trade of this crop using an interregional trade model to generate information on future trade flows and price levels of chickpea; and by incorporating the expected changes in supply and demand into the model so that future production and trade patterns can be projected.

Session 1

Principaux thèmes de présentation et de discussion

- Il existe une tendance mondiale à une demande accrue pour le pois chiche tant dans les pays industrialisés que dans les pays en développement.

- Pour satisfaire à cette demande dans les années 90 il serait nécessaire d'identifier et d'aménager de nouvelles régions de production ayant des avantages comparatifs pour la production du pois chiche.

- Les facteurs tels l'irrigation ou les changements de date de semis peuvent considérablement augmenter le rendement du pois chiche, mais ces connaissances ont trouvé peu d'application pratique jusqu'à maintenant. La poursuite de l'étude de ces facteurs ainsi que leur mise en oeuvre sont donc nécessaires.

- Etant donné que l'amidon est une composante majeure de la graine de pois chiche (65%), il faut accorder plus d'attention à l'amélioration de la qualité de l'amidon.

Recommandations pour la recherche économique sur le pois chiche

Les indices laissent à croire que la demande rapidement croissante pour le pois chiche dans les pays en développement et dans les pays industrialisés ne peut pas être satisfaite uniquement par la production du pois chiche dans les régions traditionnelles. La production du pois chiche sera donc adoptée dans des régions d'avantage comparatif. Si ces hypothèses s'avèrent valables, les travaux de recherche suivants sur l'économie de la production, la demande et le commerce seront nécessaires d'urgence :

- La détermination de l'offre potentielle des pois chiches à deux niveaux : en collaboration avec des institutions guides et avec les systèmes nationaux de recherche agricole, i) par l'étude des opinions de spécialistes sur les rendements futurs dans les zones de production potentielles dans le monde, ii) par la détermination des zones de production à l'aide de données agroclimatiques et de la modélisation des cultures en combinaison avec des essais de rendement et la recherche en milieu réel sur le coût de production.

- L'évaluation de la demande future pour le pois chiche, i) par la quantification de la demande dans les pays en développement, à l'aide des travaux sur les élasticités de demande et sur la préférence des consommateurs pour les caractéristiques de qualité, ii) par l'évaluation de la demande potentielle dans les pays industrialisés à travers la recherche sur les nouvelles orientations commerciales, et iii) par la réalisation des enquêtes des opinions des commerçants.

- La projection des structures des échanges commerciaux, i) par l'analyse du commerce global actuel de cette culture à l'aide d'un modèle de commerce interrégional pour engendrer des informations sur les flux commerciaux et les niveaux de prix futurs du pois chiche, ii) par l'incorporation, dans le modèle, des changements escomptés dans la fourniture et la demande afin de pouvoir projeter les structures futures de commerce et de production.

Session 2

Genetic Resources and Enhancement of Germplasm

Chickpea Genetic Resources - Present and Future

M.H. Mengesha[1], L. Holly[2], R.P.S. Pundir[1], and T.A. Thomas[3]

Abstract

Chickpea, Cicer arietinum *L., is an ancient crop cultivated in over 40 countries. However, the important diversity areas are India, Pakistan, Ethiopia, Turkey, and Mexico. The* Cicer *taxon forms a vast gene pool encompassing 42 wild* Cicer *species besides the cultivated,* Cicer arietinum *L. In the early sixties, systematic assembly of chickpea germplasm was started by the Regional Pulse Improvement Program (RPIP), India. The work was further pursued by ICRISAT and ICARDA. The last two organizations are entrusted respectively, with the global and regional responsibilities of the chickpea germplasm. Besides, there is considerable germplasm holding of this species at the National Bureau of Plant Genetic Resources (NBPGR, India), Instituto Nacional de Investigaciones Agricolas (INIA, Mexico), National Seeds Storage Laboratory (NSSL, Fort Collins, USA), United States Department of Agriculture (USDA, Washington D.C., USA), and the Vavilov Institute of Plant Industry, USSR. The gene bank at ICRISAT now holds 15 939 chickpea accessions representing 42 countries. ICARDA collection consists of 6804 accessions from 34 countries. About 3/4 of the accessions were assembled from other institutes and the remaining are landraces recently collected from priority areas.*

The passport data for the entire collection have been published. The accessions have also been evaluated for 25 morphoagronomic traits at ICRISAT and 29 traits at ICARDA and the results have been published in catalogs. Regional and multilocational evaluation also has been started to identify useful germplasm lines with wide/specific adaptation. From the ICRISAT collection, a total of 172 450 seed samples have been distributed to research workers in 74 countries.

In the future, local chickpea material is to be collected from Algeria, Iraq, Libya, Jordan, Myanmar, Tanzania, and in parts of India and Ethiopia. Wild Cicer *species can be collected from Afghanistan, Iran, Turkey, and USSR. With emerging needs for new traits and plant types, the germplasm would be further evaluated and screened for new characteristics such as response to fertilizer, resistance to lodging, early seedling vigor, low light interception, etc. Future emphasis will be given to collaborative research on germplasm enhancement, basic research on the use of wild species, and long-term conservation of the germplasm.*

Résumé

Ressources génétiques du pois chiche—aujourd'hui et demain : *Le pois chiche,* Cicer arietinum *L., est une culture ancienne, exploitée actuellement dans plus de quarante pays. Toutefois, les régions de diversité importantes sont l'Inde, le Pakistan, l'Ethiopie, la Turquie et le Mexique. Le taxon* Cicer *constitute un vaste pool génique comprenant 42 espèces de* Cicer

1. Leader and Botanist, Genetic Resources Unit, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

2. Germplasm Scientist, International Center for Agricultural Research in the Dry Areas (ICARDA), P.O. Box 5466, Aleppo, Syria.

3. Head, Germplasm Evaluation Division, National Bureau of Plant Genetic Resources (NBPGR), New Delhi 110 012, India.

ICRISAT Conference Paper no. CP 555.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

sauvage, outre l'espèce cultivée, Cicer arietinum *L. Au début des années 60, le Regional Pulse Improvement Program (RPIP) de l'Inde entreprit de rassembler systématiquement le matériel génétique de pois chiche. Ce travail a été poursuivi par l'ICRISAT et l'ICARDA. Ces deux dernières organisations ont respectivement un mandat global et un mandat régional sur le matériel génétique de pois chiche. En outre, une collection importante de ressources génétiques de cette espèce est conservée dans les organismes suivants : au National Bureau of Plant Genetic Resources (NBPGR, Inde), à l'Instituto Nacional de Investigaciones Agricolas (INIA, Mexique), au National Seeds Storage Laboratory (NSSL, Fort Collins, Etats-Unis), au United States Department of Agriculture (USDA, Washington D.C., Etats-Unis) et au Vavilov Institute of Plant Industry, URSS. La banque de gènes de l'ICRISAT conserve aujourd'hui 15 939 entrées de pois chiche représentant 42 pays. La collection de l'ICARDA regroupe 6804 entrées provenant de 34 pays. Environ les trois-quarts de ces entrées ont été rassemblées à partir des collections des autres instituts et le reste est composé de variétés locales récemment collectées dans des zones prioritaires.*

Les données d'identification pour l'ensemble de la collection ont été publiées. Les entrées ont également été évaluées pour 25 caractères morphoagronomiques à l'ICRISAT et pour 29 caractères à l'ICARDA; les résultats ont été publiés dans des catalogues. L'évaluation régionale et multilocale a également été entreprise pour identifier des lignées utiles à adaptation large/spécifique. De la collection de l'ICRISAT, un total de 172 450 échantillons de semences ont été distribués à des chercheurs de 74 pays.

A l'avenir, on envisage la collection du matériel local de pois chiche dans les régions de : Algérie, Irak, Libye, Jordanie, Myanmar, Tanzanie et de certaines parties de l'Inde et de l'Ethiopie. Des espèces spontanées de Cicer *peuvent être collectées dans les pays d'Afghanistan, d'Iran, de Turquie et d'URSS. Des besoins de nouveaux caractères et de nouveaux types de plantes nécessiteraient la poursuite de l'évaluation du matériel génétique ainsi que le criblage pour de nouvelles caractéristiques comme la réponse aux engrais, la résistance à la verse, la vigueur précoce des plantules, une faible interception de lumière, etc. Les travaux futurs seront axés essentiellement sur des recherches collaboratives sur l'amélioration du matériel génétique, la recherche de base sur l'utilisation d'espèces sauvages et la conservation à long terme du matériel génétique.*

Chickpea (*Cicer arietinum* L.) is an ancient crop whose earliest record from the Middle East dates back to 6250 BC. Subsequently, this crop spread to other countries with arid/semi-arid and subtropical environments. Chickpea is now cultivated in over 40 countries. Its major cultivation and diversity are in Ethiopia, India, Iran, Mexico, Myanmar, Pakistan, and Turkey. In addition to the cultivated *Cicer arietinum*, 42 wild species are known to exist. Natural distribution of these wild species is restricted to countries around the Mediterranean Sea, Soviet Union, Ethiopia, Sudan, and in the Himalayan mountains of India where perennial *Cicer microphyllum* is endemic in cold and arid areas. Several centers hold considerable numbers of chickpea germplasm lines (Hanson et al. 1984; Pundir et al. 1988b). National programs such as the National Bureau of Plant Genetic Resources (NBPGR), India and Plant Genetic Resources Center (PGRC), Ethiopia hold several germplasm accessions of their area.

Germplasm Assembly at ICRISAT and ICARDA Centers

After the establishment of ICRISAT in 1972, several national centers contributed their germplasm to ICRISAT. Possible duplicates were rejected and finally, in 1974, a total of 5958 germplasm lines originating from 31 countries were entered in the chickpea collection (ICRISAT 1975). Germplasm assembly by correspondence and exchange continued. New germplasm was collected from priority areas (Table 1). By April 1989, a total of 15 939 accessions had been registered in the ICRISAT gene bank. With its inception in 1977, ICARDA assumed regional responsibility to work on kabuli chickpea and hence all the kabuli chickpea accessions in ICRISAT gene bank and at other centers were shared with ICARDA. New collections in the ICARDA region were made (Table 1) and this Center now holds 6804 accessions from 34 countries. We

Table 1. Recent collection expeditions for chickpea and wild *Cicer* species, 1975-1989, conducted by ICRISAT, ICARDA, and NBPGR.

Year	Country/State
1975	Afghanistan (22)[1], Pakistan (30), Turkey (25), India: West Bengal (115)
1976	Afghanistan (13), India: Rajasthan (131)
1977	Afghanistan (13), Turkey (4), India: northern Karnataka (84), Gujarat (111), Uttar Pradesh (15)
1978	Pakistan (10), India: Maharashtra, Gujarat and Karnataka (40), Gujarat and Rajasthan (21)
1979	Bangladesh (32), Nepal: central and eastern region (45), India: Uttar Pradesh (53), Himachal Pradesh (104)
1980	Myanmar (4), Nepal: western region (35), India: Punjab (146), central Uttar Pradesh (15)
1981	India (27)
1982	Ethiopia: Central region (210), India (160)
1983	India (144)
1984	Ethiopia: eastern and southern regions (104), Cyprus (28), Pakistan (259), India (114)
1985	Bangladesh (133), India (157), Turkey (109)
1986	Syria (11), India (366)
1987	Morocco (122), India (225)
1988	Syria (92), India (83)
1989	Algeria (13), India (139)

1. Figures in parentheses refer to numbers of germplasm accessions collected.

continue to collect seeds of wild *Cicer* species from various countries. ICRISAT now holds and maintains 48 accessions of wild annual *Cicer* species these include: *C. yamashitae* (3); *C. pinnatifidum* (8); *C. chorassanicum* (3); *C. judaicum* (16); *C. reticulatum* (6); *C. echinospermum* (4), *C. bijugum* (7); and *C. cuneatum* (1).

A set of these wild *Cicer* species is also maintained at ICARDA. The total number of wild *Cicer* accessions held at ICARDA is 73 (Table 2), including the new additions from Syria and Turkey (van Slageren et al. in press).

Characterization and Evaluation

Chickpea descriptors were developed (IBPGR, ICARDA, and ICRISAT 1985) in order to facilitate effective characterization, documentation, and the easy exchange of seed and information. The entire set of germplasm accessions at ICARDA was evaluated in spring-sown trials for 29 characters, and the results have been published in catalog form (Singh et al. 1983). At ICRISAT Center, chickpea evaluation work is carried out in the postrainy season. Data were recorded for 25 morphoagronomic characters. Data obtained from 1974 to 1983 were summarized and published in the ICRISAT Chickpea Germplasm Catalog (Pundir et al. 1988b). The summary of the results showed diverse and useful genetic characteristics (Table 3). Results of interdisciplinary screening tests of chickpea germplasm are also given in Table 3.

The analysis of variance by country of origin revealed interesting results. Accessions from Bangladesh produced more pods, had higher resistance to fusarium wilt (*Fusarium oxysporum*), and were conspicuous with their shorter plant height. Sudanese

Table 2. Evaluation of *Cicer* species for some biotic and abiotic stresses[1] at ICARDA, Tel Hadya, Syria, 1987/88.

Cicer species	No. of accessions	No. of pure lines tested	Ascochyta blight		Leaf miner		Cyst nematode		Seed beetle		Cold	
			R[2]	S[2]	R	S	R	S	R	S	R	S
C. bijugum	14	24	16	6	0	16	22	1	18	3	23	0
C. chorassanicum	4	4	0	1	1	0	0	4	0	4	0	4
C. cuneatum	4	2	2	1	1	0	0	2	2	1	0	2
C. echinospermum	7	3	0	2	1	0	0	3	3	0	3	0
C. judaicum	18	46	32	11	40	5	0	46	11	36	19	28
C. pinnatifidum	13	30	26	4	30	0	0	30	2	28	30	0
C. reticulatum	10	43	0	12	0	2	0	23	5	15	22	1
C. yamashitae	3	2	0	2	0	0	0	2	0	2	0	2
Total	73	154	76	39	73	23	22	111	41	89	97	37

1. Due to shortage of seed not all the 154 lines were tested for each stress.
2. R = Resistant, S = Susceptible.

accessions offer the best source for early maturity, a high number of apical secondary branches, and high seed protein content. Accessions from Chile are a source of long growth duration, tall plant canopy, and great seed mass. Accessions originating in India, produced the highest average seed yield at ICRISAT Center. Accessions from Greece and USSR commonly had an erect growth habit whereas germplasm from Jordan had, in general, a spreading habit.

Much variation was observed when 6224 kabuli chickpea accessions were evaluated in 1987/88 by ICARDA for 25 descriptors in a winter-sown trial at Tel Hadya, Syria. Days to flowering ranged from 115 to 155. Among the tested germplasm, 34 accessions were classified as very early (ICARDA 1988). The results of screening for biotic and abiotic stresses are given in Table 3.

Evaluation of Wild *Cicer* Species

Wild species of chickpea possessing resistance to several diseases, increased vigor, and the multiseeded characteristic have been identified (Malhotra et al. 1987). *Cicer cuneatum* and *C. judaicum* are of special significance for introgression work.

In addition to maintaining wild *Cicer* accessions as population samples at ICARDA, work has started to separate distinct genotypes from the bulk samples to obtain well defined lines for further studies and utilization in interspecific crosses. A total of 154 pure lines were identified, these were separated and described on the basis of morphological characters, and esterase and protein banding patterns (ICARDA 1988). Evaluation of these lines helped in identifying genotypes resistant to ascochyta blight, leafminer, cyst nematode, seed beetle, and cold (Table 2). *Cicer judaicum* and *C. bijugum* possess resistance to four stresses each, while the latter has relatively large seeds.

Regional and Multilocational Evaluation

In general, crop species perform better near their area of origin, and their performance may be unpredictable elsewhere. Therefore, there is a need for multilocational evaluations to identify germplasm lines that can perform well at diverse locations. Testing of ICRISAT chickpea germplasm material in different locations has already been started. In Ethiopia, ICRISAT and the Debre Zeit Agricultural Research Center jointly evaluated 1000 chickpea accessions during 1986/87 and 1987/88. Since 1986, long-duration chickpea has been evaluated at Gwalior and New Delhi, in collaboration with the National Bureau of Plant Genetic Resources (NBPGR). Short-duration accessions are annually evaluated at ICRISAT Center and Akola, India. These experiments have already provided some useful results (Thomas et al. 1988).

ICARDA, in collaboration with national programs, has started to systematically evaluate chickpea landraces in their original habitat. In 1987/88, 122 landraces collected in Morocco were sown both at Settat, Morocco and Tel Hadya, Syria for preliminary screening, with the main emphasis on comparing their performance with promising breeding lines developed for winter sowing (Holly et al. 1988).

Table 3. Chickpea germplasm accessions having special trait(s)/resistance, based on evaluations at ICRISAT and ICARDA.

Trait(s)	No. of accessions identified
ICRISAT	
Short growth duration (<39 days) to flowering	43
Erect growth habit	86
Twin pods per leaf axil	100
Multiseed (>2.1 seeds per pod)	43
Heavy seed mass (>44 g per 100 seeds)	35
Tall accessions plant canopy >65 cm	43
Short accessions (plant canopy <19 cm)	55
High seed protein (>27%)	25
Polycarpy	1
Prostrate growth habit	2
Glabrous stem	1
Fusarium wilt	166
Dry root rot	47
Stunt disease	11
Fusarium wilt and dry root	18
Fusarium wilt and black root rot	18
Fusarium wilt and botrytis gray mold	1
Fusarium wilt and ascochyta blight	1
Fusarium wilt and sclerotinia stem blight	8
Botrytis gray mold and ascochyta blight	2
Botrytis gray mold and colletotrichum blight	2
Ascochyta blight and stunt	3
Fusarium wilt, dry root rot, and black root rot	2
Pod borer	22
ICARDA (ICARDA 1988)	
Ascochyta blight	12
Fusarium wilt	12
Leafminer	1
Cold	15
Cyst nematode	0
Seed beetle	0

Germplasm Diversification

New germplasm is the main source of diversity for crop improvement. There are also occasional genetic changes (mutations) in the population, and if these natural mutations are selected and tested, they may prove to be very useful for future utilization. There are many reports of such mutations. Some recent ones, namely, lobed vexillum (Rao and Pundir 1983), polycarpy and twin-podded (Pundir et al. 1988a), and thick stem, open flower, and short bushy mutants (Dahiya et al. 1984) are important. The recent reports on wilt resistance in twin-podded chickpea (Pundir and Mengesha 1988) and glabrousness in chickpea (Pundir and Reddy 1989) which were generated by artificial mutagenesis, show further enhanced variability in the genus.

Documentation

The ultimate value of any germplasm line will be fully realized with the availability and clarity of the documented information about each accession. The passport and the evaluation data of the germplasm held at both ICRISAT and ICARDA have been computerized and published as catalogs (Singh et al. 1983 and Pundir et al. 1988b).

Future Outlook

The status of chickpea germplasm is periodically reviewed. Some of the chickpea-growing regions e.g., Algeria, Myanmar, parts of Ethiopia and India, Afghanistan, Iraq, Libya, Jordan, Turkey, Tanzania, and USSR are not well represented in the world collection. Germplasm from these countries will be collected in the future with more emphasis on wild species. We should also identify a center where a duplicate set of the world collection of chickpea germplasm can be conserved. Germplasm enhancement should be given emphasis in existing and future research programs mainly to transfer desirable genes to elite backgrounds and in developing new and efficient plant types. New biotechnological innovations will have to be adopted when necessary to transfer desirable genes from wild *Cicer* species to cultivated chickpeas.

References

Dahiya, B.S., Lather, V.S., Solanki, I.S., and **Kumar, R.** 1984. Useful spontaneous mutants in chickpea. International Chickpea Newsletter 11:408.

Hanson, J., Williams, J.T., and **Freund, R.** 1984. Institutes conserving crop germplasm: the IBPGR global network of gene banks. Rome, Italy: International Board for Plant Genetic Resources.

Holly, L., Solh, M., and Kamel, M. 1988. Food legume germplasm evaluation and utilization with special reference to Moroccan chickpea landraces. Presented at the IBPGR/UNEP/IITA Workshop on Plant Genetic Resources in Africa, 26-30 Sep 1988, Nairobi, Kenya.

IBPGR/ICARDA/ICRISAT. 1985. Chickpea descriptors. Rome, Italy, International Board for Plant Genetic Resources.

ICARDA (International Center for Agricultural Research in the Dry Areas). 1988. Genetic Resources Program: annual report 1987. Aleppo, Syria: ICARDA.

ICARDA (International Center for Agricultural Research in the Dry Areas). 1989. Food Legume Improvement Program: annual report 1988. Aleppo, Syria: ICARDA.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1975. Annual report 1974/75. Patancheru, A.P. 502 324, India: ICRISAT.

Malhotra, R.S., Pundir, R.P.S., and Slinkard, A.E. 1987. Genetic resources of chickpea. Pages 67-81 *in* The chickpea (Saxena, M.C., and Singh, K.B., eds.). Wallingford, Oxon, UK: CAB International.

Pundir, R.P.S., and Mengesha, M.H. 1988. An induced twin-podded mutant from a wilt resistant Annigeri chickpea cultivar. International Chickpea Newsletter 18:3-4.

Pundir, R.P.S., Mengesha, M.H., and Reddy, K.N. 1988a. Occurrence and genetics of a natural mutant of chickpea having twin flower peduncles and polycarpy. Journal of Heredity 79:479-481.

Pundir, R.P.S., and Reddy, K.N. 1989. Induction, genetics, and possible use of glabrousness in chickpea. Euphytica 42:141-144.

Pundir, R.P.S., Reddy, K.N., and Mengesha, M.H. 1988b. ICRISAT chickpea germplasm catalog: evaluation and analysis. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics. 94 pp.

Rao, N.K., and Pundir, R.P.S. 1983. Inheritance and linkage relationships of a new lobed vexillum mutant in chickpea. Journal of Heredity 74:300.

Singh, K.B., Malhotra, R.S., and Witcombe, J.R. 1983. Kabuli chickpea germplasm catalog. Aleppo, Syria: International Center for Agricultural Research in the Dry Areas. 284 pp.

Thomas, T.A., Prasada Rao, K.E., and Pundir, R.P.S. 1988. ICRISAT/NBPGR joint evaluation of germplasm in India. Pages 59-64 *in* Collaboration on genetic resources: summary proceedings of a Joint ICRISAT/ NBPGR (ICAR) Workshop on Germplasm Exploration and Evaluation in India, 14-15 Nov 1988, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

van Slageren, M.W., Elings, A., Holly, L., Humeid, B., Jaradat, A.A., and Obari, K. (In press.) Recent collections of cereals, food legumes and their wild relatives in Syria and Jordan. Genetic Resources Newsletter.

Session 2

Main Items of Presentation and Discussion

- The gene bank of ICRISAT holds 15 939 chickpea accessions from 42 different countries. These have been evaluated for 25 morphoagronomic traits, and passport data have been published.
- Basic studies on interspecific differences in *Cicer* are of great importance.
- Partial male sterility is already known in chickpea, but the search should continue for other useful and novel traits, such as determinate growth habit and complete and stable male sterility, which are not presently available in the germplasm collection.

Session 2

Principaux thèmes de présentation et de discussion

- La banque de gènes de l'ICRISAT possède 15939 introductions de pois chiche provenant de 42 pays différents. Celles-ci ont été évaluées pour 25 caractères morphoagronomiques et les données d'identification sont publiées.

- Des études fondamentales sur les différences interspécifiques chez le *Cicer* sont d'une grande importance.

- La stérilité mâle partielle est déjà connue chez le pois chiche, mais il faut poursuivre la recherche des autres caractères utiles et nouveaux, tels le port défini et la stérilité mâle complète et stable, qui ne sont pas disponibles actuellement dans la collection de ressources génétiques.

Session 3

Physiology/Agronomy

Adaptation of Chickpea to Agroclimatic Constraints

R.J. Summerfield[1], S.M. Virmani[2], E.H. Roberts[1], and R.H. Ellis[1]

Abstract

The experience of farmers, research scientists and plant breeders (notably those working in the Indian subcontinent and Mediterranean basin) suggests that increasing emphasis should be placed on improving adaptation to climate if chickpea crops are to yield well. An appropriate phenology relative to the growing season available is especially important for improved productivity in environments where drought stress and temperature extremes are to be expected.

Empirical approaches to the screening of germplasm for various adaptive traits have predominated in most breeding programs. Such methods have generated many data, but these evaluation descriptors of the timing of phenological events are largely specific to location and season and so are of limited use.

By considering not the time taken but the rate of progress towards phenological events (i.e., the reciprocal of time), we describe the quantitative responsiveness of germination and flowering to photothermal conditions, question previous conclusions which concern the effects of vernalization, and suggest protocols for screening and the genetic characterization of phenological responses in the chickpea germplasm which are independent of environment and yet predict the responses of accessions in any location or season.

Résumé

Adaptation du pois chiche à des contraintes agroclimatiques : *L'expérience des exploitants, des chercheurs et des sélectionneurs (notamment ceux qui travaillent dans la région du sous-continent indien et du bassin de la Méditerranée) laisse entendre que l'on devrait insister davantage sur l'amélioration de l'adaptation au climat, pour que les cultures de pois chiche puissent donner de bons rendements. Une phénologie appropriée en fonction de la saison de culture disponible est surtout importante pour améliorer la productivité dans des environnements où il faut s'attendre à la contrainte hydrique et à des extrêmes de température.*

Des méthodes empiriques sur le criblage du matériel génétique pour différents caractères d'adaptation ont prédominé dans la plupart des programmes de sélection. De telles méthodes ont fourni d'innombrables données mais les descripteurs d'évaluation du calendrier des événements phénologiques sont surtout spécifiques au lieu et à la saison et donc d'intérêt restreint.

En examinant non pas le temps nécessaire mais le taux de progrès vers les événements phénologiques (c'est-à-dire la réciproque du temps), nous décrivons les réponses quantitatives de la germination et de la floraison aux conditions photothermiques, nous examinons de façon critique les conclusions précédentes sur les effets de la vernalisation et, finalement, nous

1. Reader in Crop Physiology and Deputy Director, Professor of Crop Production and Director, and Lecturer in Agriculture and Scientific Associate, Plant Environment Laboratory, University of Reading, Department of Agriculture, Cutbush Lane, Shinfield, Reading RG2 9AD, Berkshire, UK.

2. Principal Agroclimatologist, Resource Management Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

suggérons des protocoles pour le criblage et la caractérisation génétique des réponses phénologiques du pois chiche qui sont indépendantes de l'environnement et qui pourtant permettent la prévision des réponses du matériel génétique dans tout emplacement ou toute saison.

Four seminal publications devoted wholly or in substantial part to chickpea (*Cicer arietinum* L.) have formally updated knowledge of the crop during the decade which has now elapsed since the International Workshop on Chickpea Improvement held at Hyderabad in March 1979 (ICRISAT 1980). In 1985, Smithson et al. scrutinized and synthesized more than 250 references for their review of world production, constraints to productivity, and prospects for crop improvement. Then followed the first (many authored) standard reference book to be devoted to the crop, providing "a sound basis and direction for future research" (Saxena and Singh 1987). The severe constraints imposed by abiotic stresses in general, and by droughts in particular, were debated in 1984 (ICRISAT 1987). And finally, it is sobering to compare many "Country Reports" from the regions of North Africa, West and Southeast Asia with those genetic and biotechnologies now being applied in attempts to overcome traditional constraints in the warmer regions and elsewhere—as they are outlined in World Crops: Cool Season Food Legumes (Summerfield 1988).

In contemplating the 1990s and seeking to complement published information, we shall describe briefly the major chickpea cropping environments, and then go on to discuss recent advances which attempt to quantify selected adaptive traits. Departing from tradition, we shall focus not on empirical evaluation descriptors (which are largely specific to location and season), but on the genetic characterization of those traits and associated protocols for screening germplasm. This novel approach, we believe, can be the basis for a better exploitation of characters which are independent of environment yet predict the responses of accessions in any location or season.

Climates of the Major Chickpea-growing Regions

Detailed reviews of the agroclimatic environments and abiotic stresses which prevail in the major chickpea cropping regions of South and Southeast Asia and the Mediterranean are given by Chandra (1980), Huda and Virmani (1987), and Saxena (1987a).

South and Southeast Asia

This region includes the major producing countries for desi chickpea: India (which accounts for about 60% of world production, and more than two-thirds of the area cropped worldwide), Pakistan, Nepal, Bangladesh, and Myanmar. Figure 1 shows that the distribution of rain fall is strongly seasonal throughout the region. In general, more than 80% of the annual total falls during a rainy season which extends from May/June until October, with peaks during the summer monsoons in August and September. The variability (unreliability) of annual rainfall within the region is reflected by coefficients of variation which commonly exceed 20%.

The wettest months are also hot (Fig. 1): average diurnal air temperatures vary between 25° and 30°C, daily maximum values are typically close to 35°C, and nights are warm (20°-25°C). These temperatures are supra-optimal for seed production (Sinha 1977) and so chickpea is traditionally cropped during the postrainy season when temperatures average around 20°C, with warm days (20°-25°C) and cool (5°-10°C) or even cold, frosty nights (-1° - 0°C). Rainfall is low and unreliable; the crop essentially survives on moisture stored in the soil profile.

The alluvial soils (Entisols) in northwest India and Nepal may retain up to 200 mm of available water in a profile 120-cm deep. Over similar depths, the black cotton soils (Vertisols) of peninsular India have the potential to store 250 mm of available water.

Potential evapotranspiration demand during the 5-6-month period extending from October/November to March is typically within the range 200-300 mm for most chickpea growing areas in the region. If the soil profile is fully charged with available moisture, and if some rain falls during the reproductive period, then chickpea crops can give excellent yields of biomass and seeds. In reality, however, seed yields seldom exceed 0.7 t ha^{-1} (Jodha and Subba Rao 1987).

Winter Rainfall Areas of South Asia and the Mediterranean Region

Throughout an extensive region from northern Pakistan, through Afghanistan, Iran and the Middle East,

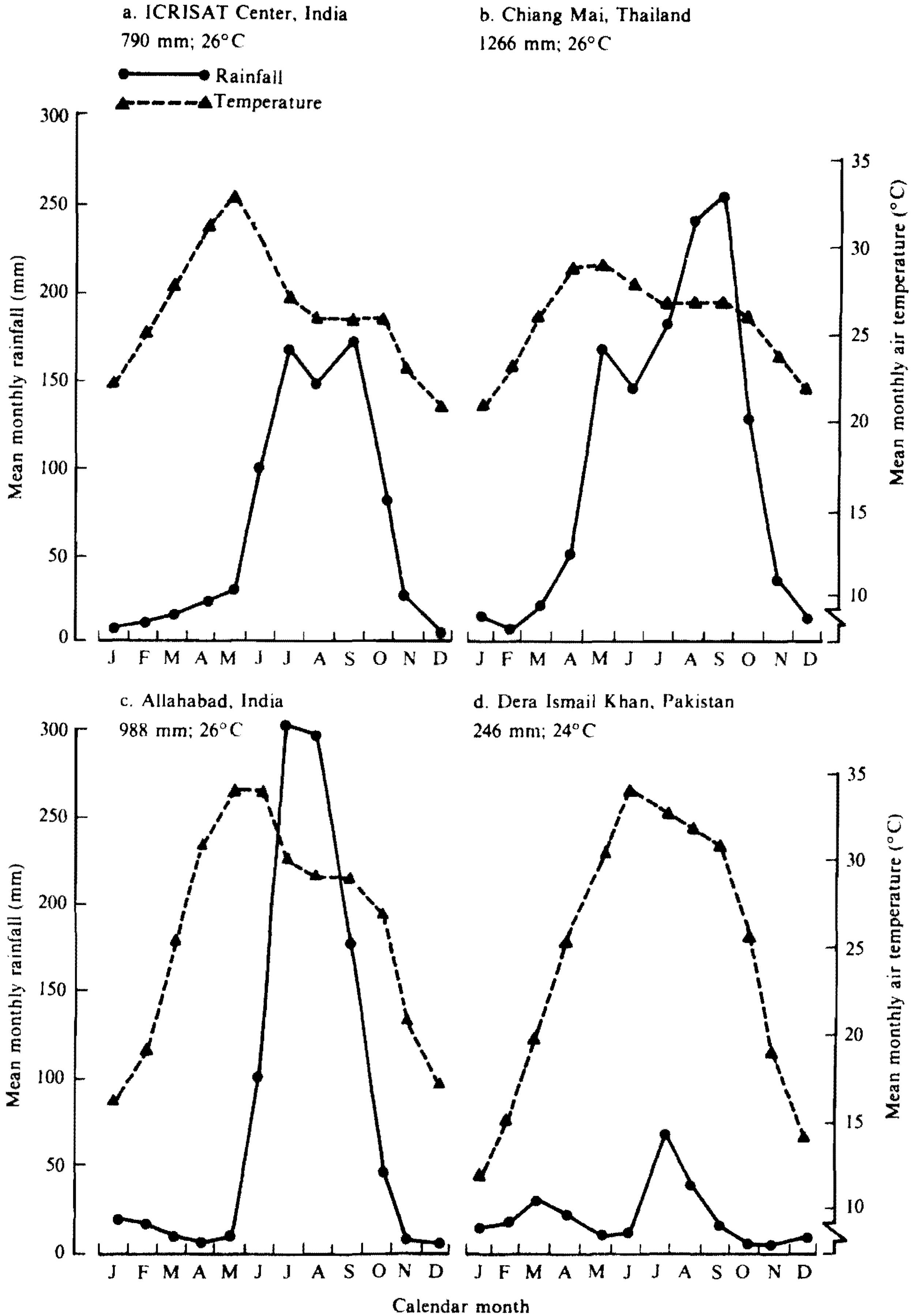


Figure 1. Mean monthly values of rainfall (mm) and air temperature (° C) at four locations representative of chickpea cropping regions in South and Southeast Asia (Source: data in Hargreaves and Samani 1986). a. ICRISAT Center, India - 17° N,78° E, 545m; b. Chiang Mai, Thailand - 18° N,99° E, 313m; c. Allahabad, India - 25° N,81° E, 98m; and d. Dera Ismail Khan, Pakistan - 31° N,70° E, 174m. (Numbers above each figure are the mean annual total rainfall receipts and mean yearly air temperatures).

and into Mediterranean Europe chickpeas are extensively cultivated during the wetter winter months or, where snow occurs, during the cool dry springtime period. Most (> 70%) of the annual precipitation (i.e., snow plus rain) falls during the 5-6 months between November/December and the following April; summers are typically dry and warm (Khan 1980).

Although mean total annual precipitation throughout the region rarely exceeds 500 mm (Fig. 2) it is conserved and used rather effectively during the cool winter season by a crop that has a relatively small evapotranspiration requirement (200-250 mm). Mean annual air temperatures are often cooler than 20°C except in some areas where rainfall distribution is bimodal (e.g., Fig. 2b). Where frosts and snowfall are rare, chickpea crops are sown at the onset of the winter rains. In colder regions, sowing coincides approximately with the time the seasonal values of mean daily temperature rise to about 10°C. Providing crops can be protected from, or are resistant to the ravages of ascochyta blight *(Ascochyta rabiei)*, can tolerate cold and waterlogging, are able to nodulate well, and can compete effectively with weeds, then dramatic increases in productivity can be achieved by sowing earlier, i.e., during the late winter months (Saxena and Singh 1984).

Agroclimatic Constraints

The principal agroclimatic constraints to chickpea productivity and production are summarized in Table 1. In many parts of South and Southeast Asia, plant stands in farmers' fields are poor; the seed yields harvested are often < 25% of those commonly achieved without irrigation on experiment stations within the same region, and from similar cultivars (Sheldrake and Saxena 1979). Recent work on chickpea seed germination (as a prelude to rapid seedling emergence and the achievement of target plant population densities) as it is affected by the water-storage environment and subsequent conditions in the seedbed is discussed by Ellis 1988; Ellis et al. 1986, 1987.

Once the crop is established, a large body of experience confirms that if chickpea is to have the potential to yield well then an appropriate crop duration in relation to the available growing season is essential; not surprisingly, sowing date is one of the most important agronomic factors affecting productivity (Saxena 1987b). Much has been learned during the 1980s about the modulation of phenology in annual crops by the photothermal environments experienced by imbibed seeds and vegetative plants (Roberts and Summerfield 1987). These advances, which we shall illustrate with chickpea, have exciting implications not only for predictive purposes in fluctuating field environments, but also for the genetic analysis of those responses and the screening of germplasm.

Photothermal Modulation of Flowering

One of the objectives of CGIAR Centers and of others

Table 1. Principal agroclimatic constraints to productivity and production of chickpea[1].

	Crop growth stage		
Soil group	Seedling establishment	Vegetative period	Flowering and seed formation
South and Southeast Asia			
Vertisols	Hot and/or dry seedbeds	Supra-optimal temperatures (>30°C) and/or drought	Supra-optimal temperatures; drought (exacerbated by soil cracking)
Entisols	Hot and/or dry and/or saline seedbeds	Drought (if winter rains fail); soil salinity	Drought; soil salinity; frost damage
Winter rainfall areas of Asia and the Mediterranean			
Mollisols and Vertisols	Cold and/or wet seedbeds; poor radiation receipts	Cold temperatures with or without frost damage	Drought; poor radiation receipts; frost damage

1. Compiled from numerous sources.

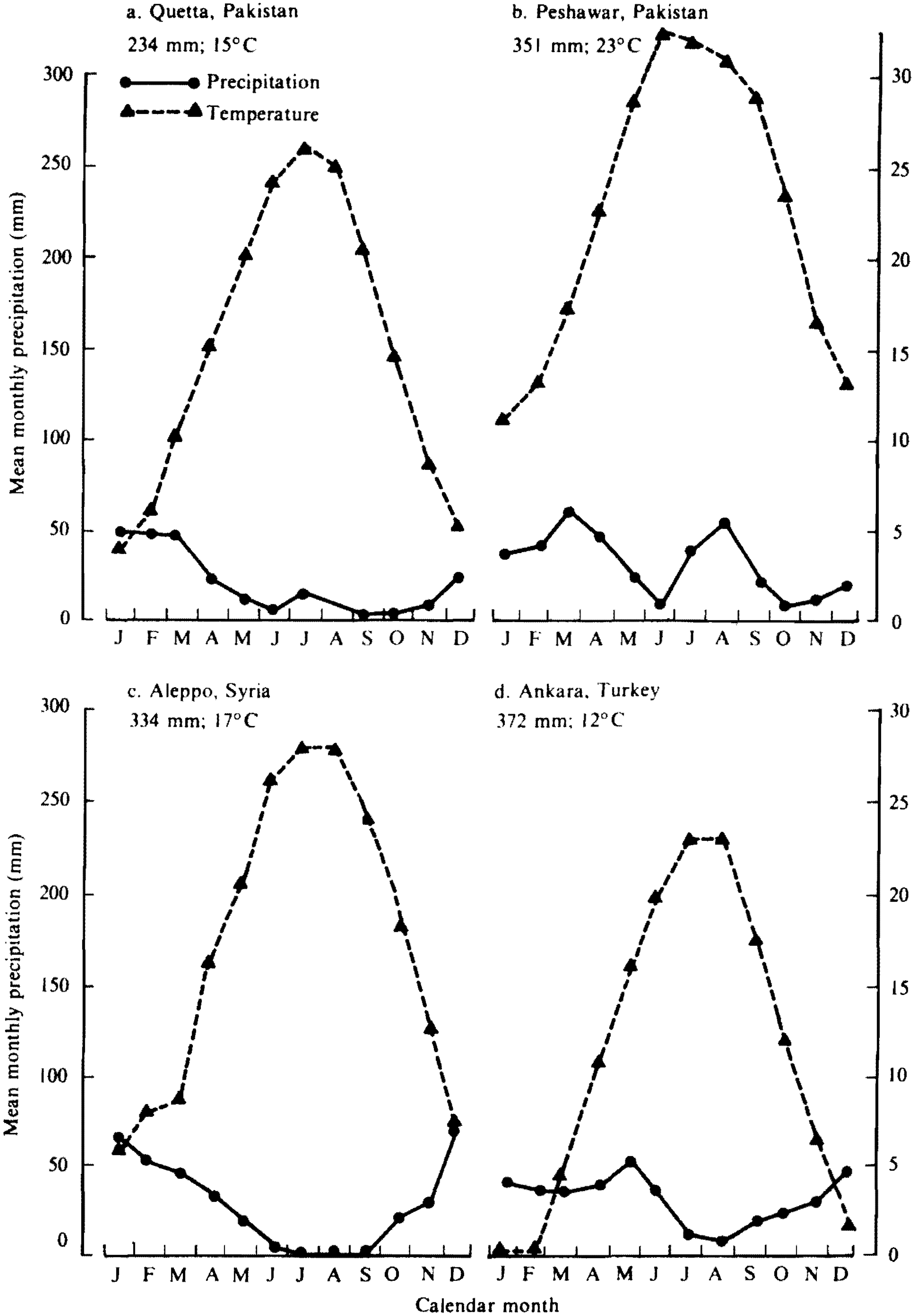


Figure 2. Mean monthly precipitation values [snow plus rainfall (mm)] and air temperatures (°C) at four locations representative of chickpea cropping areas in the winter rainfall zones of South Asia and the Mediterranean region; a. Quetta, Pakistan - 30° N, 67° E, 1673m; b. Peshawar, Pakistan - 34° N, 71° E, 359m; c. Aleppo, Syria - 36° N, 37° E, 393m; and d. Ankara, Turkey - 40° N, 32° E, 894m. (Numbers above each figure are the mean annual total precipitation receipts and mean yearly air temperatures). (Source: Hargreaves and Samani 1986).

seeking to improve output and yields in rainfed agriculture is to help to design, for individual crops, cultivars and production practices that are adapted to make the best use of the features of a target environment (Mulitze et al. 1987). To achieve this objective, data are needed that describe variations in soils and climate, and especially in rainfall, together with ecophysiological models of the ways in which crop plants are adapted to their environments (Bunting 1975). Studies on phenology are important in this context, not only in relation to the genetic improvement of crops but also for the agronomic improvement of production systems (Lawn 1988; Monteith 1987).

In chickpea, crop durations (i.e., sowing to reproductive maturity) are strongly correlated with relative earliness to flowering (e.g., Pundir et al. 1988). Not surprisingly, it is the time to flowering of different genotypes sown on various dates at different locations which researchers and breeders have been keen to predict.

A decade ago, we (Summerfield et al. 1980) argued that studies concerned solely with flowering responses to photoperiod in chickpea were of limited use; as in all annual crops for which data are sufficiently extensive, responsiveness to photoperiod is strongly modified by temperature (Summerfield and Roberts 1985). And so, for example, whilst it is known that most of the chickpea genotypes that are resistant to ascochyta blight are also very sensitive to photoperiod (Singh and Malhotra 1984), their reactions to temperature remain to be determined. Thus, until recently, resistant genotypes, phenologically well-adapted to particular photothermal environments, could only be identified by empirical and time-consuming trials at many locations.

It is now clear that the plastic trait of time from sowing to flowering, f, in chickpea is modulated by both the mean photoperiod (P) and the mean temperature (T) experienced during vegetative growth (Roberts et al. 1985). However, as we describe in detail elsewhere (Roberts and Summerfield 1987), photothermal effects on flowering in annual crops, are best exposed and quantified (between unambiguous limits) by models that relate not times of flowering, but rates of progress towards flowering (i.e., $1/f$, the reciprocals of the times taken) to photoperiod and temperature. These models are based largely on work done in controlled environments but, as we shall illustrate here for chickpea, the relations and the recommendations based on them should prove applicable to fluctuating field environments. Furthermore, our experience with a wide range of crops of both temperate and tropical origin, including chickpea, is that between wide respective limits the effects of photoperiod and temperature seldom interact when rates of progress towards flowering are considered.

Briefly, between a base, T_b, and an optimum temperature, T_o, and between a critical, P_c, and a ceiling photoperiod, P_{ce}, variation in rate may be described as a response plane given by:

$$1/f = a + bT + cP \qquad (1)$$

in which a, b, and c are genotype-specific constants. The value of T_b, at and below which there is no progress made towards flowering (i.e., the time taken to flower is infinite), is given by:

$$T_b = -(a + cP)/b \qquad (2)$$

This is because when $T = T_b$ then $1/f = 0$, and so $a + bT_b + cP = 0$; the value of the base temperature, then varies with photoperiod. Nevertheless, it is feasible to use equation (1) to devise a photothermal time concept for predicting time to flower. This is analogous to the thermal-time concept (e.g., Robertson 1973) which, while valuable, is only appropriate to photoperiod-insensitive plants (or in the unlikely case of field crops which experience a constant photoperiod throughout the preflowering period).

The photothermal time necessary for flowering, $\theta\Phi$, is measured in similar units to thermal time, i.e., day-degrees (°C d) above the base temperature, T_b, and is given by:

$$\theta_\Phi = 1/b \qquad (3)$$

Finally, for long-day species (LDP) such as chickpea, the critical photoperiod, P_c, we define as that daylength below which there is a delay in flowering and the ceiling photoperiod, P_{ce}, as the longest photoperiod in which maximum delay is achieved. If this delay is infinite the photoperiodic response is obligate, whereas if it is finite the response is quantitative. Despite some misleading statements to the contrary, LDP can eventually flower in relatively short days–and short-day species (SDP) can often flower in relatively long days. The fact that a genotype is categorized as either a LDP or a SDP tells us nothing about the duration of the critical or ceiling photoperiods (Roberts and Summerfield 1987; Summerfield et al. in press).

When pre-flowering daylengths are longer than P_c in LDP (i.e., under conditions where daylength is most inductive but variations in it have no effect) then $1/f$ is modulated exclusively by temperature, as described by:

$$1/f = a' + b'T \qquad (4)$$

In these agronomically rare circumstances, it can be shown that the value of T_b is given by:

$$T_b = -a'/b' \quad (5)$$

and that providing $T_o > T > T_b$ then the thermal time, θ, necessary for flowering may be calculated from the expression:

$$\theta = 1/b' \quad (6)$$

Conditions in many field environments where chickpeas are or may come to be grown are likely, we believe, to be always or mostly within the range $P_{ce} < P < P_c$ and so equations (1), (2), and (3) will apply. We recognize, however, that simple, linear equations may give absurd values for the dependent variable and for derived entities if the clearly stated and valid limits are transgressed (e.g., Landsberg 1977). Certainly, more information is needed on the effects of transitory excursions into regimes where $T > T_o$ and $T < T_b$. In the interim, however, an increasing body of evidence points to the utility of equation (1) as a sound basis for the prediction of field responses over wide ranges of each of P and T — as we now illustrate.

More than 20 years ago, Eshel (1967) sowed two genotypes of chickpea (one from the USA, cv. California), the other from Bulgaria, cv. Bulgaria) at successive 3-week intervals between October and August at Rehovot, Israel. Times from emergence to flowering varied between 24-30 and 131-145 days; average daily temperatures during the pre-flowering period differed by almost a factor of two (from 12.0° to 22.7°C); and average daylength (sunrise to sunset) varied between 10.5 and 14.1h [and, in passing, times to flowering of both genotypes, we calculate, were strongly correlated (r = 0.989 and 0.994, n = 10) with those to reproductive maturity].

When discussing his results, Eshel was unable to "draw firm conclusions concerning the (flowering) response of chickpea to daylength and temperature" but suggested "that the effect of day elongation on shortening the vegetative growth period was stronger than the effect of temperature increase". However, when Eshel's field data on times to flowering, f, are transformed into $1/f$ and equation (1) is applied, the photothermal model gives r^2 values of 0.84 (cv. Bulgaria) and 0.99 (cv. California). Unfortunately, as is a common problem with serial sowing date studies in the field, the seasonal march in temperature and daylength at Rehovot were almost perfectly correlated (i.e., as days lengthened so average temperatures increased). For that reason, we are hesitant to rely, in these circumstances, on the estimated values of the constants a, b, and c. Nevertheless, application of equation (1) leaves us in no doubt that cv. California was far more sensitive to P than cv. Bulgaria which, in turn, was far more sensitive to T. The similar phenological plasticity of these two genotypes was, in fact, a consequence of markedly different responsiveness to photoperiod and temperature.

Once again, the inclusion of an interaction term in the photothermal model, i.e.,

$$1/f = a + bT + cP + d(P \times T) \quad (7)$$

had no significant effect ($P > 0.05$); it increased r^2 compared with those given by equation (1) by only 0.006 or 0.009. We suggest, then, that responsiveness to daylength and responsiveness to temperature in chickpea are under separate genetic control.

We have discussed in detail elsewhere (Roberts et al. 1985; Roberts and Summerfield 1987) how reliable estimates of the genetic parameters a, b, and c can be obtained from just four field environments. Our tentative recommendations for chickpea are daylengths of 11-12h and 14-15h combined with day and night temperatures which give mean values close to 15° or 23°C.

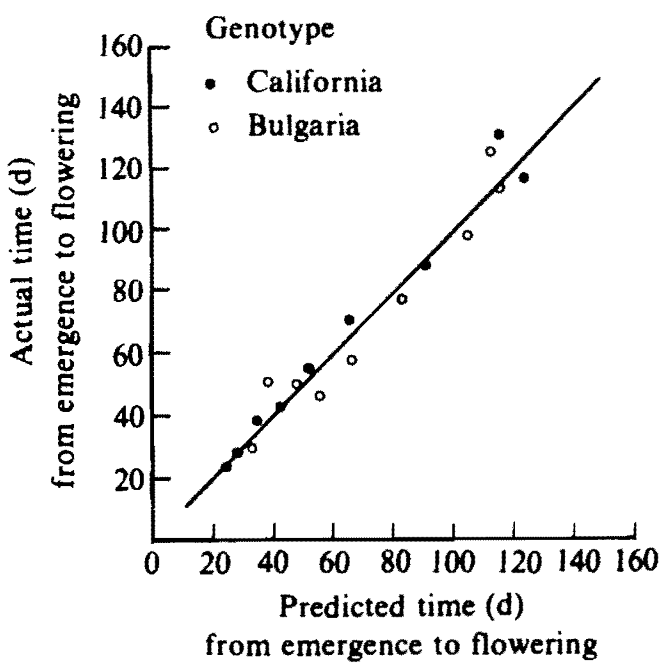


Figure 3. Relationship between actual times from emergence to first flowering (d) and those times predicted based on equation 3 for two genotypes of chickpea grown in the field at Rehovot, Israel.The solid diagonal line ($y = x$) represents perfect agreement between observed and predicted times to first flower. Source: original raw data of Eshel 1967 .

Day temperatures > 25°C, we suspect, may be supra-optimal for some (and possibly many) genotypes (Roberts et al. 1985). Only after establishing linear relations between $1/f$ and each of P and T, and over wide ranges of each factor, are we now able to suggest a protocol for screening and the genetic characterization of flowering responses in the chickpea germplasm. Figure 3 shows the utility of equation (1) over the photothermal range recommended using, as an example, the original data of Eshel (1967).

Vernalization in Chickpea (Fact or Artefact?)

The timing of flowering in various genotypes of chickpea has long been said to be significantly influenced by quantitative responses to vernalization (e.g., Pal and Murty 1941; Saxena and Siddique 1980). Vernalization (i.e., the hastening of flowering by temperatures much cooler than the optimum for growth) has been thought to be especially important in later-flowering, more photoperiodically sensitive genotypes; indeed, in some cases, it has been thought to be capable of substituting for longer photoperiods in this quantitative long-day species (Angus and Moncur 1980). However, problems arise in the design of experiments which seek to demonstrate vernalization effects.

If a cool pre-treatment is given to imbibed seeds or seedlings before transfer to a subsequent, warmer environment, and pre-treatment effects on f are then compared with a control treatment in which plants have not been exposed to cold, it follows that if the cool pre-treatment had been a regime where T_b (equation (2)) was exceeded, then some progress towards flowering during pre-treatment would be expected as photothermal time would have accumulated. The essential question is: "Does any reduction in the subsequent time to flowering following a putative vernalization treatment exceed that which is expected due solely to the accumulation of photothermal time during the pre-treatment period?"

This question has been recently addressed for two genotypes of chickpea known to differ appreciably in their flowering responses to photothermal conditions: kabuli cv. Rabat, from Morocco, is far more sensitive to P than the desi accession ICC 5810, from northern India, which is far for more sensitive to T (Roberts et al. 1985). Imbibed seeds of both genotypes were pre-treated in various combinations of cold or cool temperatures (1°-10°C) and durations (5-42 days) before transfer of seeds or seedlings to each of six growing-on regimes (photoperiods of 11 or 15h day^{-1} combined with various mean temperatures between 15.6° and 22.7°C). Compared to the non-pretreated controls, these potentially vernalizing treatments hastened subsequent times to flowering by 6% for ICC 5810 and by 12-20% for cv. Rabat (Summerfield et al. 1989). One interpretation, then, is that cv. Rabat responds to vernalization whereas ICC 5810 probably does not.

However, knowledge of the values of the constants a, b, and c in equation (1) (Roberts et al. 1985) reveals that, at a given value of P, the value of T_b is considerably smaller in cv. Rabat than in ICC 5810. Consequently, it is not surprising based only on considerations of photothermal time accumulated during pre-treatment that exposure to cool temperatures hastened flowering relatively more in cv. Rabat than in ICC 5810. Indeed, Figure 4 shows when photothermal time was accumulated during both the pre-treatment periods and subsequently, flowering occurred when predicted (for cv. Rabat, $r^2 = 0.910$, $n = 162$, $P > 0.10$; for ICC 5810, $r^2 = 0.976$, $n = 162$, $P > 0.25$). There is therefore no evidence of a specific vernalization response in either genotype. Accordingly, a thorough re-evaluation of "responsiveness to vernalization" in the chickpea germplasm might well be prudent.

Prospect

The main opportunities to increase yields in drought-prone environments seem likely to be based on approaches that increase total water use and harvest index of crops protected in one way or another from local biotic constraints. In general, phenological traits are important in that they offer to breeders the potential to match crop growth to water supply (e.g., Buddenhagen and Richards 1988; Lawn 1988). The rate of establishment and stand density achieved affect the loss of water from soil evaporation relative to the amount transpired by the crop (Cooper et al. 1988). Later, timely flowering must not only match crop durations with the growing season available, but must also favor satisfactory partitioning of dry matter and nitrogen into harvested organs. An ability to predict phenology in different environmental circumstances (e.g., at different locations and for different dates of sowing) would, then, enable well-adapted genotypes to be grown so that environmental resources are fully exploited (e.g., periods during which water supply, radiation, and temperatures are favorable) whereas the adverse consequences of seasonal constraints (e.g., extremes of temperature and aridity) are minimized. An ability to predict phenological events in crop germplasm would assist in the breeding process too: it would facilitate the more efficient

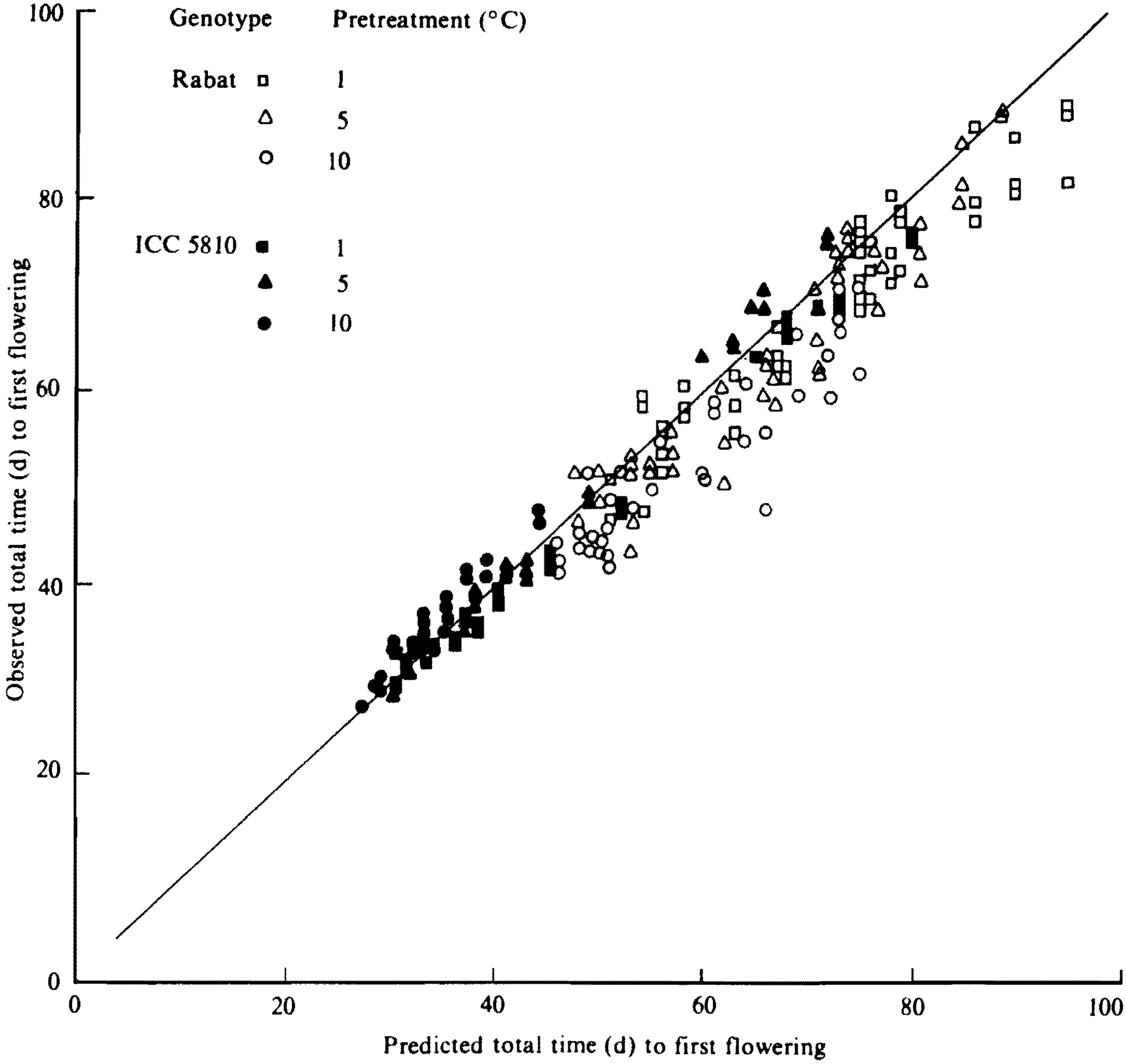


Figure 4. Relationship between actual predicted and total times to first flower chickpea plants of cv Rabat and accession ICC 5810. The times shown (d) include pretreatment periods in cool environments of 1° C, 5° C, or 10° C before transfer to each of six warmer environments in which flowering occurred. Results for 162 plants of each genotype are presented but many points are obscured by coincidence of position. The solid diagonal line ($y = x$) represents perfect agreement between observed and predicted total times to first flower (for full details see Summerfield et al. 1989).

screening of genotypes to select those best adapted to specific target environments, and would enable the range of environments over which genotypes need to be tested to be rationalized (Lawn 1981). In other words, breeders would "more fully exploit the genetic resources that are available to them as they have never done before" (Frankel 1989).

The principal chickpea-cropping environments and their regional variations have been well described; key phenology parameters (for which useful heritable variations are already known to exist) can now be genetically characterized; and protocols for screening the chickpea germplasm have been recommended. Progress during the last decade, then, leads us into the 1990s confident that chickpea genotypes well adapted to traditional and novel systems of production can become increasingly available.

Acknowledgments

Our (RJS, EHR, RHE) research in collaboration with ICRISAT and with the International Center for Agricultural Research in the Dry Areas (ICARDA) was funded by the Overseas Development Administration of the UK Foreign and Commonwealth Office. We thank Drs J. B. Smithson, C. Johansen, and M. C. Saxena for their comments and guidance. The engineering assistance of Messrs D. Dickinson, the late A. C. Richardson, K. Chivers, and S. Gill, and the technical assistance of Mr M. Craig, Mrs C. Hadley, and Mrs J. Allison is also gratefully acknowledged. Generous financial support from ODA, ICRISAT, and the Research Board, University of Reading allowed the senior author to participate in the Workshop.

References

Angus, J.F., and **Moncur, M.W.** 1980. Photoperiod and vernalization effects on phasic development in chickpea. International Chickpea Newsletter 2:8-9.

Buddenhagen, I.W., and **Richards, R.A.** 1988. Breeding cool season food legumes for improved performance in stress environments. Pages 81-96 *in* World crops: cool season food legumes: proceedings of the International Food Legume Research Conference on Pea, Lentil, Faba Bean and Chickpea, 6-11 Jul 1986, Spokane, Washington, USA (Summerfield, R.J., ed.). Dordrecht, Netherlands: Kluwer Academic Publishers.

Bunting, A.H. 1975. Time, phenology, and the yields of crops. Weather 30:312-325.

Chandra, S. 1980. Effect of edaphic factors on chickpea. Pages 97-105 *in* proceedings of the International Workshop on Chickpea Improvement, 28 Feb-2 Mar 1979, Hyderabad, India: Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Cooper, P.J.M., **Campbell, G.S.**, **Heath, M.C.**, and **Hebblethwaite, P.D.** 1988. Factors which affect water use efficiency in rainfed production of food legumes, and their measurement. Pages 813-829 *in* World crops: cool season food legumes: proceedings of the International Food Legume Research Conference on Pea, Lentil, Faba Bean and Chickpea, 6-11 Jul 1986, Spokane, Washington, USA (Summerfield, R.J., ed.). Dordrecht, Netherlands: Kluwer Academic Publishers.

Ellis, R.H. 1988. The viability equation, seed viability nomographs, and practical advice on seed storage. Seed Science and Technology 16:29-50.

Ellis, R.H., **Covell, S.**, **Roberts, E.H.**, and **Summerfield, R.J.** 1986. The influence of temperature on seed germination rate in grain legumes. II. Intraspecific variation in chickpea (*Cicer arietinum* L.) at constant temperatures. Journal of Experimental Botany 37:1503-1515.

Ellis, R.H., **Hong, T.D.**, and **Roberts, E.H.** 1987. The development of desiccation-tolerance and maximum seed quality during seed maturation in six grain legumes. Annals of Botany 59:23-29.

Eshel, Y. 1967. Effect of sowing date on growth and seed yield components of chickpea (*Cicer arietinum* L.). Israel Journal of Agricultural Research 17:193-197.

Frankel, O. H. 1989. Principles and strategies of evaluation. Pages 245-260 *in* The use of plant genetic resources (Brown, A.H.D., Frankel, O.H., Marshall, D.R., and Williams, J.T., eds.). Cambridge, UK: Cambridge University Press.

Hargreaves, G., and **Samani, Z.A.** 1986. World water for agriculture precipitation management. Logan, Utah, USA: Utah State University, International Irrigation Center. 617 pp.

Huda, A. K. S., and **Virmani, S. M.** 1987. Agroclimatic environment of chickpea and pigeonpea. Pages 15-31 *in* Adaptation of chickpea and pigeonpea to abiotic stresses: proceedings of the Consultants' Workshop, 19-21 Dec 1984, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1980. Proceedings of the International Workshop on Chickpea Improvement, 28 Feb-2 Mar 1979, ICRISAT, Hyderabad, India. Patancheru, A. P. 502 324, India: ICRISAT. 306 pp.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1987. Adaptation of chickpea and pigeonpea to abiotic stresses: proceedings of the Consultants' Workshop, 19-21 Dec 1984, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT. 184 pp.

Jodha, N.S., and **Subba Rao, K.V.** 1987. Chickpea: world importance and distribution . Pages 1-10 *in* The chickpea. (Saxena, M.C., and Singh, K.B., eds.). Wallingford, Oxon, UK: CAB International.

Khan, M.A. 1980. Chickpea report from Pakistan. Pages 258-263 *in* Proceedings of the International Workshop on Chickpea Improvement, 28 Feb-2 Mar 1979, ICRISAT, Hyderabad, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Landsberg, J.J. 1977. Some useful equations for biological studies. Experimental Agriculture 13:273-286.

Lawn, R.J. 1981. The potential contribution of physiological research to pigeonpea improvement. Pages 151-164 *in* proceedings of the International Workshop on Pigeonpeas, 15-19 Dec 1980, ICRISAT Center, India. Vol. 1. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Lawn, R.J. 1988. Breeding for improved plant performance in drought-prone environments. Pages 213-219 *in* Drought research priorities for the dryland tropics (Bidinger, F.R., and Johansen, C., eds.). Patancheru, A. P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Monteith, J. L. 1987. Climate and productivity in dryland agriculture. Indian Journal of Dryland Agriculture Research and Development 2:1-16.

Mulitze, D., Malhotra, R.S., and **Goldsworthy, P.** 1987. Relating production and environment: the international nursery networks. Pages 85-96. *In* Agricultural environments: characterization, classification and mapping: proceedings of the Rome Workshop on Agro-ecological characterization, classification, and mapping, 14-18 Apr 1986, Rome, Italy (Bunting, A.H., ed.). Wallingford, Oxon, UK: CAB International.

Pal, B.P., and **Murty, G.A.** 1941. Vernalization of Indian crops. Indian Journal of Genetics and Plant Breeding 1:61-85.

Pundir, R.P.S., Reddy, K.N., and **Mengesha, M.H.** 1988. ICRISAT chickpea germplasm catalog: evaluation and analysis. Patancheru, A. P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics. 94 pp.

Roberts, E. H., Hadley, P., and **Summerfield, R.J .** 1985. Effects of temperature and photoperiod on flowering in chickpeas (*Cicer arietinum* L.). Annals of Botany 55:881-892.

Roberts, E.H., and **Summerfield, R.J.** 1987. Measurement and prediction of flowering in annual crops. Pages 17-50 *in* Manipulation of flowering (Atherton, J. G., ed.). London, UK: Butterworths.

Robertson, G. W. 1973. Development of simplified agroclimatic procedures for assessing temperature effects on crop development. Pages 327-343 *in* Plant response to climatic factors (Slatyer, R.O., ed.). Paris, France: UNESCO.

Saxena, M.C. 1987a. Effects of climatic stress and soil chemical toxicities on productivity of chickpea in West Asia and North Africa. Pages 135-143 *in* Adaptation of chickpea and pigeonpea to abiotic stresses: proceedings of the Consultants' Workshop, 19-21 Dec 1984, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Saxena, M.C. 1987b. Agronomy of chickpea. Pages 207-232 *in* The chickpea (Saxena, M. C., and Singh, K. B., eds.). Wallingford, Oxon, UK: CAB International.

Saxena, M.C., and **Siddique, M.H.** 1980. Response of some diverse kabuli chickpea genotypes to vernalization. International Chickpea Newsletter 2:7-8.

Saxena, M.C., and **Singh, K.B.** (eds.). 1984. Ascochyta blight and winter sowing of chickpeas: proceedings of the Workshop, 4-7 May 1981, Aleppo, Syria. World Crops: Production, Utilization, Description vol. 9. The Hague, Netherlands: Martinus Nijhoff/W. Junk. 288 pp.

Saxena, M.C., and **Singh, K.B.** (eds.). 1987. The chickpea. Wallingford, Oxon, UK: CAB International. 409 pp.

Sheldrake, A.R., and **Saxena, N.P.** 1979. Growth and development of chickpeas under progressive moisture stress. Pages 465-483 *in* Stress physiology in crop plants (Mussell, H., and Staples, R. C., eds.). New York, USA: John Wiley.

Singh, K.B., and Malhotra, R. S. 1984. Collection and evaluation of chickpea genetic resources. Pages 105-122 *in* Genetic resources and their exploitation - chickpeas, faba beans and lentils (Witcombe, J.R., and Erskine, W., eds.). The Hague, Netherlands: Martinus Nijhoff/W. Junk.

Sinha, S.K. 1977. Food legumes: distribution, adaptability and biology of yield. FAO Plant Production and Protection Paper no. 3. Rome, Italy: FAO. 124 pp.

Smithson, J.B., Thompson, J.A., and **Summerfield, R.J.** 1985. Chickpea (*Cicer arietinum* L.). Pages 312-390 *in* Grain legume crops (Summerfield, R.J., and Roberts, E.H., eds.). London, UK: Collins.

Summerfield, R.J. (ed.). 1988. World crops: cool season food legumes: proceedings of the International Food Legume Research Conference on Pea, Lentil, Faba Bean and Chickpea, 6-11 Jul 1986, Spokane, Washington, USA: Dordrecht, Netherlands: Kluwer Academic Publishers.

Summerfield, R.J., Ellis, R.H., and **Roberts, E.H.** 1989. Vernalization in chickpea (*Cicer arietinum* L.): fact or artefact? Annals of Botany 64:599-603.

Summerfield, R.J., Lawn, R.J., Roberts, E.H., and **Ellis, R.H.** (In press.) Towards the reliable prediction of time to flowering in six annual crops. 1. The development of simple models for fluctuating field environments. Experimental Agriculture.

Summerfield, R.J., Minchin, F.R., Roberts, E.H., and **Hadley, P.** 1980. The effects of photoperiod and air temperature on growth and yield of chickpea (*Cicer arietinum* L.). Pages 121-149 *in* Proceedings of the International Workshop on Chickpea Improvement, 28 Feb-2 Mar 1979, ICRISAT, Hyderabad, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Summerfield, R.J. and **Roberts, E.H.** 1985. *Cicer arietinum*. Pages 92-99 *in* CRC handbook of flowering, vol. 1 (Halevy, A.H., ed.). Boca Raton, Florida, USA: CRC Press.

Defining, Modeling, and Managing Water Requirement of Chickpea

Piara Singh[1], N.P. Saxena[2], J.L. Monteith[1], and A.K.S. Huda[1]

Abstract

A chickpea model based on the capture of water and light is presented. The model simulates canopy and root growth, transpiration, total dry matter, and seed yield. The model is sensitive to the amount of soil water made available either through rainfall or irrigation, and can thus be used to assess the water requirements of chickpea for a given level of production. Simulations for peninsular India show that maximum chickpea yields should be obtained if the crop is given 5 cm irrigation at flowering and at pod-filling. This preliminary version of the model needs further testing and validation for a wide range of cultivars and environments.

Résumé

Définition, modélisation et gestion des besoins en eau du pois chiche : *Un modèle de pois chiche basé sur la prise de l'eau et de la lumière est présenté. Le modèle simule la croissance de la canopie et des racines, la transpiration, la matière sèche totale et le rendement en semences. Le modèle est sensible à la quantité d'eau du sol mise à disposition, soit par suite de la pluie ou de l'irrigation, et il peut donc servir pour évaluer les besoins en eau du pois chiche pour un niveau de production déterminé. Les simulations pour l'Inde péninsulaire montrent que des rendements maximum de pois chiche peuvent être obtenus si la culture reçoit 5 cm d'irrigation au moment de la floraison et au stade de remplissage des gousses. Cette version préliminaire du modèle doit subir des essais plus détaillés avant d'être validée pour une gamme large de cultivars et d'environnements.*

The amount of water needed by a crop throughout its growth is the sum of evaporation from the soil surface and transpiration needed to achieve potential growth and yield. This sum depends on the climate and the cultivar grown. Crops need more water when potential evaporation is rapid and the duration of growth is long. Under rainfed conditions such potential water needs of the crop are very rarely met because of infrequent rainfall and decreasing soil water supply. It has been shown in several studies that, depending on yield, chickpea uses 100 to 450 mm of water and has water use efficiencies ranging from 5.2 to 35.2 kg ha^{-1} mm^{-1} for biomass yield, and from 1.1 to 15.7 kg ha^{-1} mm^{-1} for seed yield (Sandhu et al. 1978; Sivakumar and Singh 1987; Siddique and Sedgley 1986; Singh and Bhushan 1980; Keatinge and Cooper 1984). Huda and Virmani (1987) made an initial attempt to utilize the information on water use by chickpea to simulate seed yield of the past years for ICRISAT Center, Patancheru and Hisar. It was evident from these figures that water use by

1. Soil Scientist, Program Director, and Agroclimatologist, Resource Management Program, and 2. Senior Crop Physiologist, Legumes Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

ICRISAT Conference Paper no. CP 557.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

chickpea is location and cultivar-specific, and therefore cannot be generalized.

Doorenbos and Pruitt (1977) suggested a methodology for assessing the water requirements of a crop using potential evapotranspiration and crop coefficients. With the recent advances made in the modeling of evapotranspiration, the soil evaporation and transpiration could be separately estimated from the crop, climate, and soils data. Thus the water requirements of a crop (or cultivars) could be estimated more accurately across environments than by using the fixed crop coefficient approach. Hence to assess water requirements of chickpea and to assess its yield responses to variability in climate and management, we developed a growth and yield model of chickpea using the framework of the Resource Capture Model (RESCAP) initially developed for cereals by Monteith et al. (1989). The model estimates soil evaporation and transpiration by simulating the growth of a crop canopy (treated as a light capture system) and of roots (treated as a water and nutrient capture system). Crop growth and water balance are simulated on a daily basis, and yield is estimated at maturity. The model is briefly described in the following sections.

Model Structure

Phenology

Chickpea development is determined by temperature, photoperiod, drought stress, and cultivar. Chickpea is a quantitative long-day plant. Considering changes in dry-matter allocation with development, growth can be divided into three phases: emergence to flowering (GS1), flowering to pod-initiation (GS2), and pod-initiation to physiological maturity (GS3). Duration of emergence to flowering was computed according to relations established by Summerfield et al. (1987) which account for the influence of photoperiod and temperature on flowering. The durations of GS2 and GS3 were specified in terms of thermal time computed (°Cd) above a base temperature of 8°C and with a ceiling temperature of 30°C. The duration of all growth phases was further adjusted allowing for the amount of water deficit experienced by the crop. Studies at ICRISAT have shown that the durations GS1, GS2, and GS3 decreased by 1.9, 1.6, and 1.5°Cd mm^{-1} of evapotranspiration (ET) deficit, defined as the difference between actual evaporation and potential taken as 0.9 x open-pan evaporation (unpublished data, ICRISAT).

Dry Matter Production

When water does not limit plant growth the rate of dry matter production C ($kg\ m^{-2}\ d^{-1}$) per unit of intercepted solar radiation S ($MJ\ m^{-2}\ d^{-1}$) is assumed to have a constant value of 0.67 g MJ^{-1} of solar radiation (ICRISAT 1988). When water is limiting, dry matter production is calculated from the amount of water transpired and the saturation vapor pressure deficit of the air. If q is the mass of dry matter per unit mass of water transpired, and SD is the mean saturation deficit of the atmosphere (kPa), the quantity qd = q * SD is conservative for a crop and has a value of 4.8 g kg^{-1} kPa for chickpea (ICRISAT 1988). On a day when dry matter production is C, the demand for water to transpire is C * SD/(qd).

Allocation of Dry Matter to Shoots

The fraction of above-ground dry matter (FAG) was divided between leaves (FL), stems (FS), pods (FP), and seeds (FG) in proportions which changed with plant age. From emergence to pod-initiation (GS1 + GS2), 50% of above-ground dry matter was allocated to leaves, and the remaining 50% to stems including branches. After pod-initiation, the fraction allocated to pods (pod wall + seed) was increased at a constant rate from 0 to 1.1 to allow up to 10% translocation to pods of the assimilates produced before pod-initiation (unpublished data of ICRISAT). All translocation was assumed to occur from leaves. If a plant experiences drought stress, vegetative growth is suppressed and proportionately more assimilates are allocated to reproductive organs. To allow for this, the fraction allocated to pods was increased by an amount TCP per mm of ET deficit. Similarly when pod-filling started the fraction allocated to seeds increased with time from 0 to 1.1, and if water was short the fractional allocation was increased by an amount TCS per mm of ET deficit. Both TCP and TCS are cultivar-specific and were obtained by cultivar calibration. Allocation to stems was decreased exponentially from 0.5 to a minimum value determined by the time after initiation of pods. After assimilates were allocated to pods and stems, the remaining fraction was allocated to leaves.

Root Growth and Water Uptake

The volume of available water per unit volume of soil (AW) was assumed to be a function of soil depth Z. The size and distribution of the root system was specified by two parameters: the downward velocity of a root "front" (THCK) which is the thickness of the soil layer traversed by the root front in one day; and RLV, the root length per unit volume of soil (m m^{-3}) which is a function of Z and therefore of time.

Analysis of sequential root harvests on a Vertisol showed that chickpea reaches a maximum velocity of root extension (RRMAX) of about 1.5 cm d^{-1} about 20 days after emergence. Field measurements on Vertisols have shown that RLV usually has a maximum value of about 1×10^4 m m^{-3} at minimum rooting depth (RDMIN) and decreases with depth to about 1/10th of this value at a maximum rooting depth (RDMAX) at approximately 1.5 m. RLV was considered to be inversely proportional to the square root of rooting depth RD. Then RLV at depth RD is

$$RLV (RD) = RLV(1) (RDMIN/RD)^{0.5} \quad \text{............. (1)}$$

If the allocation of dry matter to the root system is a fraction Xr of C then

$$Xr.C(TIME) = RHO . RLV . THCK(TIME) \quad \text{.................. (2)}$$

where RHO is root mass per unit length (5×10^{-6} kg m^{-1}). During early growth we used equation 2 to calculate THCK. Xr was set at an arbitrary value of 0.4, so that THCK reached a maximum value of root extension (RRMAX) within 20-25 days after emergence as often observed in the field. When THCK reached its maximum value of RRMAX, we set THCK at RRMAX and allowed Xr to decrease with increasing depth.
Provided there is no input of water from rain or irrigation and evaporation is limited by water extraction and not by water demand, the available water at depth z and time t' is assumed to decrease exponentially with time, and can be calculated from the expression

$$AW(z,t') = AW(z,0) \exp (-t'/TAU) \quad \text{.................. (3)}$$

where t' is the time when the root front arrives at depth z and TAU is a time constant for the extraction process. This quantity is likely to depend upon the physical properties of the soil and on plant water relations, but cannot yet be estimated with confidence from a submodel. We assumed TAU to be inversely proportional to the root length density as suggested by Passioura (1983) so that TAU is proportional to the square root of depth. The rate of extraction at any depth was then given by

$$-d \{AW(z,t')\} / dt = (AW(z,o) /TAU) \exp (-t'/TAU) \quad \text{...................... (4)}$$

The depth of layer traversed by the root zone on the day defined by time t after emergence is u(t) so that the amount of water extracted from the layer is

$$THCK.d (AW(z,t'))/dt' \quad \text{...................... (5)}$$

To find the total potential extraction XT for the whole profile on day t this quantity was summed for values of t' from 1 to t. If XT is less than the water equivalent of dry matter production as estimated from light interception, XT was adopted as the transpiration rate and the rate of dry matter production became

$$C = (qD/SD)XT.$$

When XT was more than the water equivalent of dry matter production, or when the layer of soil above the drying front but below seed depth was wetted by rain or irrigation we assumed that growth and transpiration were light limited until this water had been removed. The rate of transpiration then reverted to XT.

Soil Evaporation

The rate of potential soil evaporation EP from newly wet soil with no ground cover was assumed to be 0.9 times the rate of evaporation from a class A pan, PANE. Ground cover reduced the evaporation by the factor (1-Fi), where Fi is intercepted radiation. Drying reduced the rate by a factor proportional to the amount of water in the surface layer expressed as a fraction of water held at field capacity. If AE is the actual water content of the layer, AD is the air-dry value, and FC is the water content at field capacity, then the actual soil evaporation ES is

$$ES = 0.9 PANE (1-Fi) (AE-AD) / (FC-AD) \quad \text{........... (6)}$$

the air-dry water content was assumed to be 1/3 of the value at the conventional wilting point -1.5 MPa.

Soil Water Status

To a first approximation, water content at field capacity is constant with depth in the root zone whereas the total plant extractable water content decreases with depth. At the maximum depth of rooting taken to be 1.5 m, the maximum available water content (MAW) was assumed to be half the value at 0.1 m. To initiate the distribution of water, the ratio of actual to maximum available water ISW was assumed to be the same at all depths. The decrease of available water with depth was therefore given by

AW = MAW*(1 - 0.5*RD/RDMAX) * ISW .... (7)

The corresponding initial soil water deficit (mm) was

SMDO = 0.75 * MAW * (1-ISW)*(RDMAX-RDMIN)*1000 .... (8)

Soil Water Balance

Changes in the soil water deficit of the surface layer (0-10 cm depth) were assumed to occur as a result of the direct input of water from precipitation (P) or irrigation (IRR) and losses as a consequence of evaporation (E) or percolation (PRC). If SM10D is the soil water deficit in the top 10 cm on day (t-1), then the water balance for day t is as follows:

if (P + IRR) > SM10D,

then PRC = P + IRR - SM10D and SM10D = 0 .... (9)

But if (P + IRR) $\leq$ SM10D then PRC = 0

and SM10D = SM10D - (P + IRR) .... (10)

Similar algorithms are used if the soil water deficit in the root zone (SMD) increases as a result of drainage from above (PRC) and decreases as a result of transpiration and drainage.

Model Performance

The inputs required to run the model are given in Table 1. The model was calibrated against the 1985 and 1987 measurements on cultivars Annigeri and JG 74, and then used to predict biomass, seed yield, and evapotranspiration (ET) for other seasons. A total of 27 independent data sets for seasons from 1978 to 1986 were available for testing the performance of the model. Simulated total dry matter was strongly correlated (r^2 = 0.87, $P < 0.01$) with observed yields (Fig. 1). Similarly simulated seed yields and ET were well correlated with observations (r^2 = 0.72 for seed yield and r^2 = 0.91 for ET) (Figs 2 and 3). These correlations suggest that the model could be used more widely to assess water requirements and the associated biomass and seed

Table 1. Input requirements for the chickpea model.

Location data	
1.	Latitude (°′)
Climatic data (daily)	
1.	Solar radiation (MJ d^{-1})
2.	Maximum and minimum temperature (°C)
3.	Rainfall (mm)
4.	Open-pan evaporation (mm)
5.	Relative humidity at 0700 and 1400 h (%)
Soil data	
1.	Maximum available water capacity of soil (mm)
2.	Actual available water at emergence (mm)
Management data	
1.	Plant population (plants m^{-2})
2.	Date of sowing (Julian)
3.	Date (Julian) and amount of irrigation (mm)
Crop coefficients	
1.	Specific leaf area (cm^2 g^{-1})
2.	Extinction coefficient for radiation (unitless)
3.	Dry matter transpiration ratio (g kPa kg^{-1})
4.	Radiation-use efficiency (g MJ^{-1})
5.	Root mass per unit length (kg m^{-1})
6.	Root length density (mm^{-3})
7.	Maximum velocity of root extension (m d^{-1})
8.	Photoperiod and thermal time relationships for duration of growth stages (°Cd)

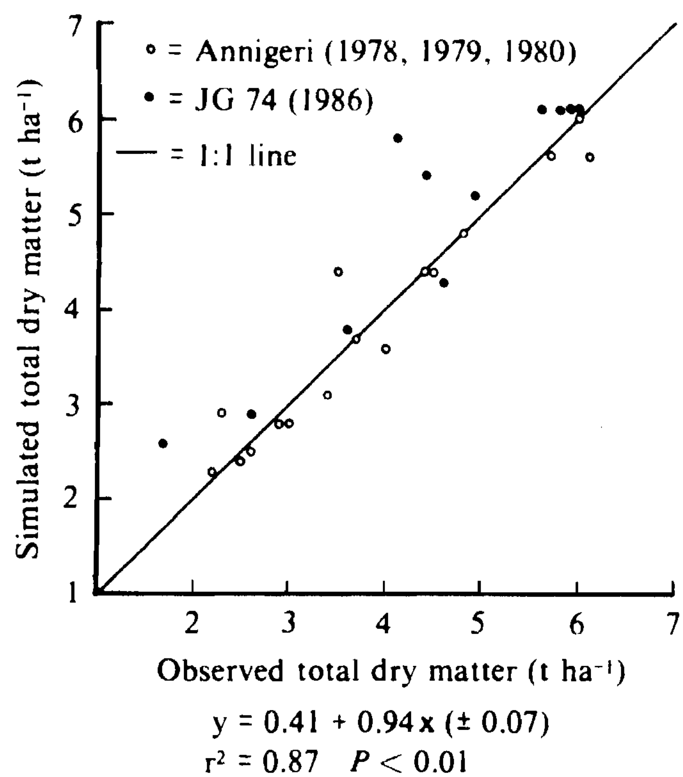


Figure 1. Relationship between observed and simulated total dry matter (t ha^{-1}) of chickpea.

yields of chickpea in response to soil water availability and supplemental irrigation.

The model was further used to assess yield responses of chickpea (cv Annigeri) to irrigation schedules, and

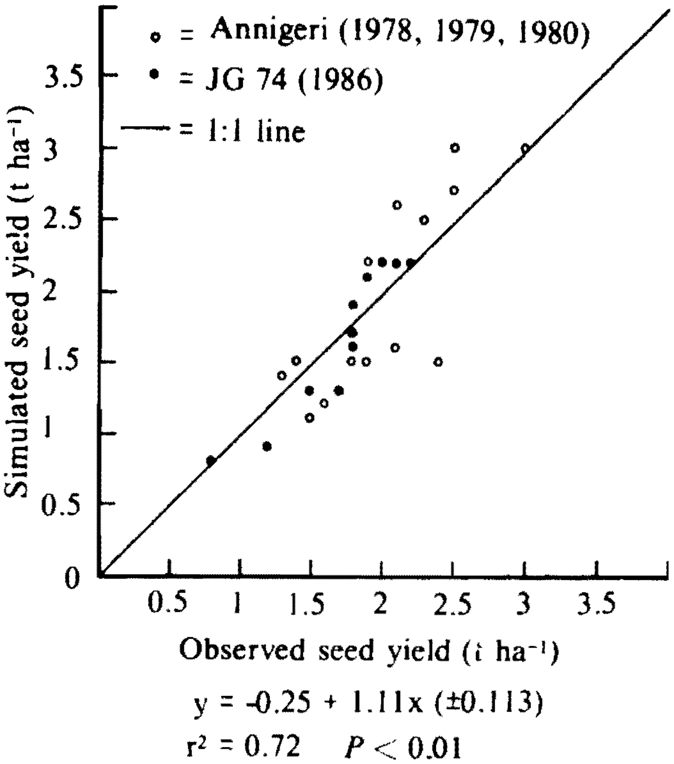


Figure 2. Relationship between observed and simulated seed yield (t ha^{-1}) of chickpea.

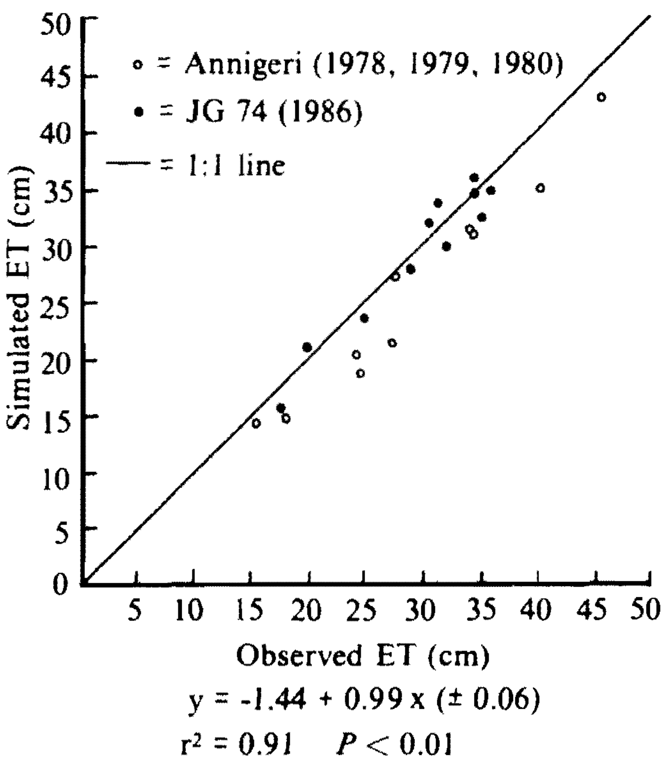


Figure 3. Relationship between observed and simulated evapotranspiration (ET) of chickpea.

to soil water availability on a Vertisol for 11 postrainy seasons using the 1978 to 1989 climatic data. In response to irrigation a maximum seed yield of 2.2 t ha^{-1} with a coefficient of variation (CV) of 21.4% was obtained when the (modeled) crop was given 5 cm of irrigation at vegetative, flowering, and pod-filling stages (Table 2). Total biomass production with three irrigations was 5.0 t ha^{-1} with a CV of 9.2%. On average, the crop used 30.5 cm of water to produce 5.0 tons of biomass per hectare. With two irrigations each of 5 cm, the best strategy was to irrigate the crop during flowering and pod-filling to obtain higher and stable yields over the years. The mean seed yield was 2.2 t ha^{-1} with a CV of 13.3%. With one irrigation, the crop could be irrigated either during flowering or pod-filling to increase yields, but the yields were more stable when the crop was irrigated during pod-filling. Non-irrigated yield was 1.4 t ha^{-1} with a CV of 13.3%. These predictions on scheduling of and response to irrigation are similar to those reported elsewhere (ICRISAT 1983). The response of chickpeas to available soil water at emergence (ASW) was also examined. On average 2.9 t ha^{-1} of dry matter and 1.4 t ha^{-1} of seed were produced when the soil profile was full (20 cm ASW) at emergence (Table 3). As expected, the yields declined and yield stability decreased with the decrease in soil water availability and when ASW was only 50% of its maximum value, only 0.6 t ha^{-1} of dry matter and 0.3 t ha^{-1} of seed yield could be produced. The crop was unable to extract water deeper in the profile because of restricted root growth.

It is clear from the above results that the model is sensitive to water availability and could be used to assess yield responses to soil water availability, rainfall, and supplemental irrigation. The model needs cultivar-specific coefficients before it can be used for new cultivars and needs testing for environments other than peninsular India.

Future Work

More work is needed in the following areas to further improve the model.

Phenology

More information needs to be generated on base temperature, ceiling temperature, and photoperiod sensitivity of developmental processes of individual cultivars of chickpea, so that phenological events can be

Table 2. Simulated response of total dry matter, seed yield, and ET of chickpea (cv Annigeri) to various irrigation schedules on a Vertisol at ICRISAT Center, using climatic records from 1978 to 1988[1].

Irrigation schedule	Irrigation amount (cm)	Total dry matter Mean (t ha^{-1})	Total dry matter CV (%)	Seed yield Mean (t ha^{-1})	Seed yield CV (%)	ET Mean (cm)	ET CV (%)
Nonirrigated	Nil	2.9	13.4	1.4	13.3	16.4	10.9
Vegetative (20 DAE)[2]	5	3.3	11.8	1.4	15.7	20.7	8.6
Flowering (40 ± 2 DAE)	5	3.6	14.3	1.6	25.1	21.7	8.5
Pod-filling (60 ± 2 DAE)	5	3.5	14.8	1.6	13.7	21.1	15.2
Vegetative + flowering	10	4.1	14.4	1.5	29.0	25.5	8.1
Vegetative + pod-filling	10	4.0	12.2	1.7	20.0	25.6	4.8
Flowering + pod-filling	10	4.5	11.0	2.2	13.3	26.3	3.8
Vegetative + flowering + pod-filling	15	5.0	9.2	2.2	21.4	30.5	4.2

1. Amount of soil water available at emergence was assumed to be 20 cm, and 5 cm irrigation was given at each growth stage considered in an irrigation schedule.
2. DAE = days after emergence.

Table 3. Simulated response of total dry matter, seed yield, and ET of chickpea (cv Annigeri) to available soil water (ASW) at emergence on a Vertisol at ICRISAT Center, using climatic records from 1978 to 1988.

Amount of ASW at emergence (cm)	Total dry matter Mean (t ha^{-1})	Total dry matter CV (%)	Seed yield Mean (t ha^{-1})	Seed yield CV (%)	ET Mean (cm)	ET CV (%)
20	2.9	13.4	1.4	13.3	16.4	10.9
15	1.6	24.9	0.9	19.7	11.0	16.6
10	0.6	70.2	0.3	74.4	6.3	34.0

predicted more accurately and the model applied to a larger number of genotypes and environments.

Roots

Careful studies are needed on growth and extension of the root system of chickpea as influenced by management, environment, and soil characteristics.

Assimilate Allocation

Little is known about how the allocation of assimilates to different plant parts, translocation, and senescence are modulated by physical stresses and management.

Calibration and Testing

The model needs to be calibrated and tested for different genotypes and environments so that its use can be extended to different chickpea-growing areas.

References

Doorenbos, J., and **Pruitt, W.O.** 1977. Guidelines for predicting crop water requirements. FAO Irrigation and Drinage paper no. 24. Rome: Food and Agriculture Organization of the United Nations. 129 pp.

Huda, A.K.S., and **Virmani, S.M.** 1987. Agroclimatic environment of chickpea and pigeonpea. Pages 15-21 *in* Adaptation of chickpea and pigeonpea to abiotic stresses. Proceedings of the Consultants' Workshop. 19-21 Dec 1984, ICRISAT, Patancheru, A.P. 502 324, India. ICRISAT: International Crops Research Institute for the Semi-Arid Tropics.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1983. Pages 100-128 *in* Annual report 1982. Patancheru, A.P. 502 324, India: ICRISAT.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1988. Pages 327-330 *in* Annual report 1987. Patancheru, A.P. 502 324, India: ICRISAT.

Keatinge, J.D.H., and **Cooper, P.J.M.** 1984. Physiological and moisture-use studies on growth and development of winter-sown chickpeas. Paes 141-157 *in* proceedings of the Workshop on ascochyta blight and winter sowing of chickpea. ICARDA, 4-7 May 1981, Aleppo, Syria (Saxena, M.C., and Singh, K.B., eds.). Aleppo, Syria: International Center for Agricultural Research in Dry Areas.

Monteith, J.L., **Huda, A.K.S.**, and **Midya, D.** 1989. RESCAP: a resource capture model for sorghum and pearl millet. Pages 30-34 *in* Modeling the growth and development of sorghum and pearl millet (Virmani, S.M., Tandon, H.L.S., and Alagarswamy, G., eds.). Research Bulletion no. 12. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Passioura, J.B. 1983. Roots and drought resistance. Agricultural Water Management 7:265-280.

Sandhu, B.S., **Prihar, S.S.**, **Khera, K.L.**, and **Sandhu, K.S.** 1978. Scheduling irrigation to chickpea. Indian Journal of Agricultural Sciences 48:486-492.

Siddique, K.H.M., and **Sedgley, R.M.** 1986. Canopy development modifies the water economy of chickpea (*Cicer arietinum* L.) in south-western Australia. Australian Journal of Agricultural Research 37:599-610.

Singh, G., and **Bhushan, L.S.** 1980. Water use, water-use efficiency and yield of dryland chickpea as influenced by P fertilization, stored soil water and crop season rainfall. Agricultural Water Management 2:299-305.

Sivakumar, M.V.K., and **Singh, P.** 1987. Response of chickpea cultivars to water stress in a semi-arid environment. Experimental Agriculture 23:53-61.

Summerfield, R.J., **Roberts, E.H.**, and **Hadley, P.** 1987. Photothermal effects on flowering in chickpea and other grain legumes. Pages 33-48 *in* Adaptation of chickpea and pigeonpea to abiotic stresses: Proceedings of the Consultants' Workshop, 19-21 Dec 1984, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Chickpea Ideotypes for Genetic Enhancement of Yield and Yield Stability in South Asia

N.P. Saxena and C. Johansen[1]

Abstract

Despite intensive breeding efforts, there has been no significant enhancement of yield potential of chickpea in India over the last two decades at least. The harsh and variable environment where chickpea is grown, predominantly as a rainfed crop, complicates conventional breeding approaches using multilocational testing, as traits useful at one site may be detrimental at another. Thus an ideotype approach is recommended to increase yields in specifically defined environments. Constraints of the physical environment are described for chickpea in the major growing areas of South Asia. Functional traits to overcome these constraints are then proposed. For example, in drought-stressed environments, characteristics such as denser and longer root systems and smaller leaf size are considered advantageous. At higher latitudes, failure of conventional genotypes to set pods at low night temperatures is considered a major constraint and progress has been made in identifying a cold tolerance trait. Further research is needed to establish causal relationships, determine negative associations, and understand the inheritance of putatively useful traits.

Résumé

Idéotypes de pois chiche pour l'amélioration génétique du rendement et de la stabilité du rendement en Asie du Sud : *En dépit d'efforts intensifs de sélection génétique, il n'y a pas eu d'amélioration significative du potentiel de rendement du pois chiche en Inde depuis deux décennies au moins. L'environnement difficile et variable où l'on cultive le pois chiche, surtout comme culture pluviale, complique les méthodes traditionnelles de sélection qui utilisent des essais multilocaux, puisque des caractères utiles à un endroit peuvent être nuisibles à un autre. C'est ainsi qu'une méthode basée sur les idéotypes est recommandée pour accroître le rendement dans des environnements spécifiquement définis. Des contraintes de l'environnement physique sont décrites pour le pois chiche dans les principales zones de culture de l'Asie du Sud. Des caractères fonctionnels pour surmonter ces contraintes sont alors proposés. Par exemple, dans des environnements où la sécheresse est une contrainte, des caractéristiques comme des systèmes racinaires plus denses et plus longs et des surfaces foliaires plus petites sont considérées comme avantageux. A plus hautes latitudes, l'impossibilité des génotypes conventionnels de former des gousses à de faibles températures nocturnes est considérée comme une contrainte importante; des progrès ont été réalisés dans l'identification d'un caractère de tolérance au froid. Des recherches plus poussées sont nécessaires pour déterminer les rapports causaux, pour déterminer des associations négatives et pour comprendre l'hérédité de caractères putativement utiles.*

---

1. Senior Crop Physiologist and Principal Agronomist, Legumes Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

ICRISAT Conference Paper no. CP 558.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

Significant genetic enhancement of yield potential (Y_p) by empirical/conventional breeding approaches are well recognized for such major crops as wheat and rice. However, in South Asia no such progress has been recorded for Y_p in chickpea despite intensive breeding efforts over the last two decades. Most improvements in yield and stability of recently released varieties can be attributed to incorporation of disease resistances. Genotype x environment interactions (G x E) are particularly large for chickpea and thus breeding programs have, understandably, given a high priority to increasing stability of yield by multilocational testing. Where environmental differences are large, as is the case for chickpea, we believe that a thorough understanding of environmental constraints is necessary for the successful progress of multilocational breeding programs, to increase Y_p in any one environment, or to identify genotypes with improved yield stability across environments. For example, a trait useful in one environment may be detrimental in another environment, and development of apparently stable genotypes may be an averaging process whereby the new genotypes may not

Table 1. Major abiotic constraints and their effects in contrasting chickpea growing environments in South Asia.

		Warm winter		Cold winter	
Constraint	Parameter affected	Rainfed	Well-watered	Rainfed	Well-watered
Drought	Plant stand	Poor	1[1]	Poor	1
	Biomass	Small	Sub-optimum	Sub-optimum	Excessive
	Harvest index	Very high	High	Low	Very low
	Crop duration	Short	Medium	Long	Very long
Temperature					
Heat (>30°-35°C)	Plant stand	Poor	1	Poor	1
	Biomass	Small	Sub-optimum	Sub-optimum	Excessive
	Seed-filling period	Short	Short	Short	Short
Cold (<5°C)	Pod set	1	1	Delayed	Delayed
	Late sowing				
	Emergence	1	1	Delayed	Delayed
	Biomass	1	1	Small	Relatively small
Light	Efficiency of interception for:				
	Ceiling biomass	Intercep-tion too low	Intercep-tion too high	Intercep-tion low to high	Intercep-tion too high
	Pod set	1	Shading	Possible shading	Large shading
Nutrition					
N (N_2 fixn)	Biomass and yield	Losses measurable in all environments			
P	Biomass and yield	Losses measurable in all environments			
Fe	Biomass and yield	1	30–40% loss to total crop failure		
Toxicities					
Salinity	Plant stand and growth	Usually not a limitation		Significant limitation	

1. 1 = not an important constraint.

Table 2. Constraints and opportunities in exploiting functional traits in chickpea germplasm for constructing ideotypes.

Constraining factor	Opportunity	Trait	Extent of useful variability in germplasm[1]	Knowledge of nature of inheritance[1]	Ease of screening[1]	Expected yield increase (%)
Drought	Improvement of plant stand	Germination and emergence from suboptimal seedbed moisture	1	-	2	50
	Maximum exploitation of available soil water	Dense and long roots	2	2	3	30->50
		Large and greater number of xylem vessels	-	-	3	-
	Greater water economy	Smaller (fewer pinnules) leaf size	1	2	3	30->50
		Stomatal regulation of transpiration	-	-	-	-
	Matching seedfilling to favorable thermal/ moisture regimes	Large seed or twin pods at basal nodes	3	3	3	50
		Osmotic adjustment	-	-	-	-
Temperature						
Heat	Enable early sowing, good plant stands and extending growth duration.	Germination and emergence at high temperatures	-	-	-	50
	Increasing biomass	Early growth vigor and greater dry matter addition in preterminal stages	1	-	3	20
Cold	Overcoming failure of pod set, increasing harvest index and possibly yield	Pod set at low night temperatures	3	-	3	30
	Increase of biomass production with late sowing	Rapid emergence and early growth vigor	1	-	3	>50
Light	Reduce mutual shading	Small leaf size	1	2	3	20-30
		Erect branched canopies	2	2	3	20-30
	Reflect excessive light and reduce heat load	Multipinnate, chrysanthemum-like leaves	1	2	3	20

Continued

Table 2. *Continued*

Constraining factor	Opportunity	Trait	Extent of useful variability in germplasm[1]	Knowledge of nature of inherit-ance[1]	Ease of screen-ing[1]	Expected yield increase (%)
Nutrients						
N	Selection of host for efficient symbiosis	Prolificity of nodulation, high nitrogenase activity and nodule longevity	1	-	2	20
P	Increase yields	Greater efficiency of P uptake and utilization	-	-	2	10–30
Fe	Avoid yield losses	Greater efficiency of uptake and utilization	2	3	3	30–40
Salinity	Extending adaptation and increasing productivity	Biomass production	0	-	2	80–>100

1. Assessed on a scale of 0–3, where 0 = negligible; 1 = limited; 2 = moderate; 3 = good; - = not known.

carry any improved traits as compared with well-adapted landraces in a particular environment.

We suggest that an ideotype approach may be of particular help to a breeding program where both E and G x E effects are large. Ideotypes have traditionally been considered only in terms of morphological characters but we prefer to define functional ideotypes, describing also particular physiological responses to the constraining factors. The major steps in this ideotype approach are:

- thorough definition of the target environment and identification and quantification of the constraints thereof;
- conceptualization, identification and testing of traits likely to overcome particular constraints; and
- genetic incorporation of these into adapted and acceptable agronomic backgrounds, and extensive validation within the defined target environment.

In this paper we summarize our experience of ideotype development in South Asia, using two specified target environments for chickpea — cold winter, as represented by Hisar (29° N) in northern India, and warm winter, as at ICRISAT Center, Patancheru (18° N) in peninsular India.

The major abiotic constraints of the target environments with which we are concerned are summarized in Table 1. This clearly indicates the need for specific ideotypes for given target environments.

Our current understanding of the opportunities for overcoming, partially or completely, some of these constraints, functional traits required, extent of variability in germplasm, knowledge of nature of inheritance of a trait, and expected yield increases due to its incorporation are listed in Table 2. Many of the functional traits listed are a description of unique features associated with an adapted genotype in a given target environment. Information on establishing a causal relationship between a functional trait and a physiological process is usually lacking, and this deserves greater attention in the future. Fruitful utilization of these traits largely depends upon a critical evaluation of the trait with regard to negative associations, such as, undesirable pleiotropic effects, allometric constraints, compensation effects the trait is likely to exert, and the non-anticipated physiological changes the introgressed gene may cause in the adapted agronomic backgrounds. For example: long, dense and thick roots; small leaf size; and cold tolerance (pod set at low night temperatures) may be associated with some suspected or unknown undesirable effects which may negate the benefit and thus limit the utilization of an otherwise useful trait.

Very often a desired variability in germplasm is found to be associated with a poor agronomic and genetic background. Proper evaluation of such traits is possible only when the desired genes are carried into an acceptable background. In such efforts crop physiologists and breeders need to closely collaborate in the transfer and evaluation of desired traits, for example, in the production of near-isogenic lines.

Ideotypes are not fixed targets and differ not only from one location to another but at a given location depending upon new cropping systems that may evolve. Late sowing of chickpea to fit in a rotation with rice, or early sowing of chickpea to follow immediately after the rainy season are examples of unconventional cropping systems where ideotype development for chickpea could be advantageous.

We believe that some of the components of ideotypes described in Table 2 may also be useful in other environments similar to the ones we describe, such as spring sowing in West Asia (warm winter, rainfed) and in Pakistan (cold winter, rainfed).

Space limitations preclude the citation of supporting references for the proposals summarized here. However, they will be given later in a full publication by the authors.

Chickpea Ideotypes for Mediterranean Environments

R.H. Sedgley[1], K.H.M. Siddique[2], and G.H. Walton[2]

Abstract

Chickpea ideotypes for Mediterranean environments must take into account the stress environment, i.e., the stresses associated with the soil factors/climatic regimes, and the competition from the environment in terms of the method of cultivation, i.e., sowing density and spacing at high- or low-density cultivation.

Mediterranean environments cover a wide range of conditions, and a number of different ideotypes may need to be defined. The major characteristic of a Mediterranean climate is a cool wet winter followed by rapid warming in spring, culminating in terminal drought.

Major differences between environments result from the intensity of the winter period, which may be severe, as in parts of Syria with prolonged periods of wet, cold conditions, and sometimes snow, and the danger of occurrence of epiphytotics, e.g., ascochyta blight, or mild conditions, as in parts of southwestern Australia, with monthly mean minimum temperatures of about 5°C and short rainy periods interspersed with clear dry conditions, which are less conducive to foliar diseases.

The generally rapid onset of spring drought dictates that early pod set be a prime strategy for avoiding drought stress. However, chickpea appears to require fairly high mean daily temperatures (above 15°C) for successful pod set of early flowers, and so in addition to early flowering, tolerance to sub-optimal spring temperatures is required.

Under high input systems, with good weed control, a communal type plant of erect habit with few branches, sown at high density, should lead to a slower rate of moisture depletion in the winter, and result in higher biological yields and harvest indices.

Résumé

Idéotypes de pois chiche pour des environnements méditerranéens : *Les idéotypes de pois chiche pour environnements méditerranéens doivent tenir compte de l'environnement de stress, c'est-à-dire des contraintes associées avec les facteurs du sol/régimes climatiques, ainsi que de la concurrence de l'environnement en termes de la méthode de culture, c'est-à-dire la densité des semis et l'espacement dans la culture à forte ou à faible densité.*

Les environnements méditerranéens couvrent une vaste gamme de conditions et la définition d'un certain nombre d'idéotypes différents pourrait être nécessaire. La principale caractéristique d'un climat méditerranéen est un hiver humide et frais, suivi par un réchauffement rapide au printemps, s'achevant d'une sécheresse terminale.

Les principales différences entre environnements résultent de l'intensité de l'hivernage, qui peut être dur, comme dans certaines parties de la Syrie, avec soit de longues périodes de temps humide et froid et parfois de neige, accompagnées du danger d'apparition d'épiphytotiques (flétrissure ascochytique) ou de conditions de temps plus doux, comme dans certaines parties de l'Australie du sud-ouest, avec des températures moyennes minimales mensuelles de près de 5°C et de brèves périodes de pluie intercalées avec des conditions claires et sèches, qui prédisposent moins aux maladies foliaires.

1. Senior Lecturer, Agronomy Department, School of Agriculture, University of Western Australia, Nedlands, WA 6009, Australia.
2. Crop Physiologist, and Research Officer, Division of Plant Industries, Department of Agriculture, Baron-Hay Court, South Perth, WA 6151, Australia.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

Le début généralement rapide de la sécheresse du printemps impose le choix d'une formation précoce de gousses comme stratégie primordiale pour éviter le stress hydrique. Toutefois, le pois chiche semble exiger des températures quotidiennes moyennes assez élevées (au-dessus de 15°C) pour réussir la formation de gousses à partir des fleurs précoces. Donc, outre la floraison précoce, il est nécessaire d'avoir une tolérance aux températures sub-optimales du printemps.

Dans les systèmes à intrants importants, soutenu par une lutte efficace contre les adventices, un type communal de plante à port érigé avec peu de branches, semé à forte densité, devrait permettre un taux moins élevé de perte d'humidité en hiver et devrait fournir des rendements biologiques et des indices de récoltes plus élevés.

Recent moves to improve the yield potential of crops such as chickpea (*Cicer arietinum* L.), have given fresh impetus to the approach of Donald (1968) involving the "breeding of model plants or ideotypes". Here, we analyse and discuss ideotype characters for Mediterranean-type environments, as exemplified at two locations: Tel Hadya (35° 55'N) (Aleppo) in Syria, and Merredin (31° 29'S) in southwestern Australia.

Chickpeas have long been adapted to the Syrian region, but have been evaluated only recently in southwestern Australia, where they are well adapted, but low-yielding, relative to other crops (Siddique and Sedgley 1986; Walton and Trent 1988).

Climate

The growing season at Merredin is 8 weeks shorter and generally milder and drier than that for winter-sown chickpeas in Aleppo. (Siddique and Sedgley 1987; Cooper et al. 1988).

Growing season temperatures average 2°C higher at Merredin than Aleppo. Winter-sown (15 November) kabuli chickpea required 1396°C days (base temperature of 0°C) to flower by the second week of April in Aleppo, when mean temperatures are relatively low at 12°C (Keatinge and Cooper 1983). For 1 June sowings at Merredin, the same thermal time would accumulate by the end of August (mean temperature of 15°C), leaving 6 weeks for maturation, but with less soil water stored than at Tel Hadya.

High humidity in early spring in Aleppo, associated with a high incidence of ascochyta blight, led farmers to adopt spring sowing to mitigate disastrous crop losses, with sacrifices of seed yield and water use efficiency (WUE) because of higher soil evaporation (E_s) and evaporative demand.

WUE is largely determined by three parameters (Sedgley 1987): E_s(mm of water), transpiration efficiency (TE: kg dry matter m^{-2}, mm^{-1} water transpired); and harvest index (HI = ratio of grain yield to biological yield). HI is the most sensitive of these to manipulation by genetic means, and should therefore be the target of ideotype breeding for higher WUE.

According to Siddique and Sedgley (1985, 1987) late sowing reduced the WUE of grain yield in 1982 at Merredin (Table 1) due mainly to the extra 25 mm E_s; HI was unaffected. For early-sown chickpea in 1983, high biological yield resulted from rapid development, due to warmer conditions (2.2°C higher than monthly mean temperature) in June; in the late sown crop, excessive E_s and lower TE reduced biological yield. However, a 38% lower HI in the early sown crop largely cancelled out the benefit of early sowing; early flowering in mid-August and subsequent flower abortion reduced HI and hence seed yield. In a test of limited branching (Table 1), some water was saved in the more erect biculm, but most of the increase in WUE was due to the higher HI.

Ideotypes

Donald (1968) defined an ideotype as "a biological model which is expected to perform or behave in a predictable manner within a defined environment. More specifically, a crop ideotype is a plant model that is expected to yield a greater quantity or quality of grain, oil, or other useful product when developed as a cultivar". Donald's general ideotype can be resolved into three components (Sedgley 1990): a market ideotype, which identifies the characteristics of the desired product, e.g., cooking quality of the seed; a stress ideotype, which identifies the characters required to fit the plant to its target environment, e.g., phenology; and the competition ideotype, which identifies the "communal" characters required to enhance seed yield by minimizing negative effects of natural selection, through plant competition on seed yield. These effects arise in the normal course of early generation selection from widely

Table 1. Effect of sowing date and debranching on water use efficiency (WUE) of chickpea at Merredin, Western Australia.

Treatment	Water use (mm)	Soil evaporation (mm)	Dry matter (t ha^{-1})	WUE of dry matter (kg ha^{-1} mm^{-1})	Grain yield (t ha^{-1})	Harvest index	WUE of grain (kg ha^{-1} mm^{-1})
Sowing date							
11 May 1982[1] (Early)	213	105	4.94	23.0	1.46	0.29	6.8
30 Jun 1982 (Late)	227	130	3.84	17.0	1.11	0.29	4.9
17 May 1983 (Early)	191	70	6.76	35.2	1.25	0.18	6.5
20 Jul 1983 (Late)	182	110	3.22	17.7	0.94	0.29	5.2
Debranching							
Control[2]	198	87	6.10	31	1.54	0.25	7.8
Debranched	198	80	6.47	33	2.22	0.34	11.2

1. Sowing date experiment, Siddique and Sedgley (1987).
2. Siddique and Sedgley (1985); plant density 70 m^{-2}; primary branches: 280 m^{-2} in control, 140 m^{-2} in biculm (two branches, i.e., main stem and branch 1). In the debranching treatment all basal branches except the main stem and first-formed basal branch were cut off when they were 3–4 cm long.

spaced sowings and mixed and segregating populations used by plant breeders.

The Competition Ideotype

Donald (1968), working with cereals, proposed a "communal" plant form which included the characters of limited tillering, erect habit and short stature, to ensure that high-yielding morphological characters were not lost inadvertently in early generations and to obtain maximum biological yields in high density pure stands. Plants are normally selected from mixed or segregating populations, under widely spaced conditions, in early generations because of the small amounts of seed available for new genotypes. Donald found that characters that conferred high competitive ability and high seed yield on individual plants, e.g., tallness or multiple tillering, in these populations, were negatively correlated with yield, when grown in pure stands, as in commercial practice. Hence plants with the optimal form for high-yielding crops, were likely to be discarded in early generations. The characters of the communal plant are not site-specific and were thought to apply generally to annual seed crops (Donald and Hamblin 1983). For chickpea they would include: limited branching and erect habit, moderate height, high photosynthetic capacity, and erect leaf posture.

Limited branching. Donald (1968) argued that plant neighbors should interfere minimally with each other, i.e., they should be weak competitors. But since all plants are genetically similar in crop stands, they should all be weak competitors. Ideally this leads to stands of uniculm or biculm plants, sown in nearly square planting patterns, and at densities high enough to utilize their low competitiveness to fully exploit the environment and so maximize biological yields.

Siddique et al. (1984) found that at low (23 plants m^{-2}) densities, plants grew as isolated units for most of their early life and interfered less with each other than at the higher (50 plants m^{-2}) density; each branch was relatively more efficient in producing grain at low rather than at high density, and HI was fairly uniform among branches:

Density	Harvest index: Main stem	Branch 1	Branch 2	Branch 3	Whole plant
Low	0.41	0.32	0.37	0.32	0.36
High	0.44	0.19	0.21	0.10	0.28

Plants at high density exploited their environment more than at the low density, as indicated by a higher biological yield, i.e., higher seed yield potential; greater interference between branches resulted in a steep decline in HI of later branches and a lower overall HI, and a lower yield.

Intra-plant competition was reduced in the debranched treatment (Table 1), even though plant density was the same as in the control. The primary branch density was 140 vs 280, but the former density was still sufficient to fully exploit the environment and so maximize biological yield. In the debranched treatment, representing the more communal type plant, yield increased by 39%.

Erect habit. In Syria, Keatinge and Cooper (1984) compared low and high density sowings of an erect line (ILC 72) with one of traditional spreading habit (ILC 482). Biological yield of the high density erect line averaged 17% more than that of the spreading line, indicating a higher yield potential at high density. WUE of grain production was 39% lower in ILC 72, but this was due to the lower HI. However, this can be attributed to later flowering (2 weeks) in the erect line, and so there seem to be good prospects for higher WUE in earlier-flowering erect lines.

The Stress Ideotype

Stress ideotypes are site-specific and should be chosen to alleviate the constraints that prevent "communal" plants, grown at high density, from reaching their potential. The limited wet season and terminal drought stress in Mediterranean climates dictate early flowering, whereas the varying intensity of low winter temperatures may require different levels of vernalization and low temperature winter hardiness (Murray et al. 1988).

Tolerance to suboptimal pre-flowering temperatures. Low-temperature stress results in abortion of early flowers and pods that develop at temperatures below 15°C. Savithri et al. (1980) identified genetic variation in the response of early flowers to sub-optimal temperatures. At Merredin in 1983, only 38% of flowers formed pods in the earliest sowing, which started flowering at temperatures of 12°C compared to 83% in the latest sowing, which started flowering at 15°C (Siddique and Sedgley 1986). The low HI of 0.18 in sowing date 17 May (Table 1) was attributed to the effect of low temperature on early flowers, and assuming a potential HI of 0.29, comparable to later treatments; the estimated yield loss was 57%.

Saxena et al. (1988) reported potentially useful low-temperature tolerant material at ICRISAT. Savithri et al. (1980) showed that pollen tube development was important in causing early flower abortion. This raises the possibility of applying pollen manipulation techniques (Zamir 1983) as a means of increasing the efficiency of breeding programs for cold tolerance.

Conclusion

An ideotype with promise for winter sowing in Mediterranean-type environments would combine early flowering and tolerance to suboptimal preflowering temperatures with an erect, limited branching habit, when sown as square as feasible at high density.

Acknowledgments

The authors appreciate the opportunity to contribute to the workshop. R.H.S. thanks the Grain Research Committee of Western Australia for the travel grant to attend the workshop.

References

Cooper, P.J.M., Campbell, G.S., Heath, M.C., and Hebblethwaite, P.D. 1988. Factors which affect water use efficiency in rainfed production of food legumes, and their measurement. Pages 813-829 *in* World crops: cool season food legumes: proceedings of the International Food Legume Research Conference on Pea, Lentil, Faba Bean and Chickpea, 6-11 Jul 1986, Spokane, Washington, USA (Summerfield, R.J., ed.). Dordrecht, Netherlands: Kluwer Academic Publishers.

Donald, C.M. 1968. The breeding of crop ideotypes. Euphytica 17:385-403.

Donald, C.M., and Hamblin, J. 1983. The convergent evolution of annual seed crops in agriculture. Advances in Agronomy 36:97-143.

Keatinge, J.D.H., and Cooper, P.J.M. 1983. Kabuli chickpea as a winter-sown crop in northern Syria: moisture relations and crop productivity. Journal of Agricultural Science (UK) 100:667-680.

Keatinge, J.D.H., and **Cooper, P.J.M.** 1984. Physiological and moisture-use studies on growth and development of winter-sown chickpeas. Pages 141-157 *in* Ascochyta blight and winter sowing of chickpeas: proceedings of the Workshop, 4-7 May 1981, Aleppo, Syria (Saxena, M.C., and Singh, K.B., eds.). The Hague, Netherlands: Martinus Nijhoff/W. Junk.

Murray, G.A., Eser, D., Gusta, L.V., and **Eteve, G.** 1988. Winter hardiness in pea, lentil, faba bean and chickpea. Pages 832-843 *in* World Crops: cool season food legumes (Summerfield, R.J., ed.). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Savithri, K.S., Ganapathy, P.S., and **Sinha, S.K.** 1980. Sensitivity to low temperature in pollen germination and fruit- set in *Cicer arietinum* L. Journal of Experimental Botany 31(121):475-481.

Saxena, N.P., Johansen, C., Sethi, S.C., Talwar, H.S., and **Krishnamurthy, L.** 1988. Improving harvest index in chickpea through incorporation of cold tolerance. International Chickpea Newsletter 19:17-19.

Sedgley, R.H. 1987. Water use efficiency in relation to chickpea production. Pages 63-67 *in* Proceedings of the Australian Chickpea Workshop, 27-29 Oct 1987, Warwick, Australia. St. Lucia, Queensland, Australia: Australian Institute of Agricultural Science.

Sedgley, R.H. 1990. An appraisal of the Donald ideotype after twenty one years. Presented at the Fifth Australian Agronomy Conference on Ideotypes and Physiology–tailoring plants for increased production, 19-24 Feb 1990, Australian Society of Agronomy, Perth, Australia.

Siddique, K.H.M., and **Sedgley, R.H.** 1985. The effect of reduced branching on yield and water use of chickpea (*Cicer arietinum* L.) in a Mediterranean type environment. Field Crops Research 12:251-269.

Siddique, K.H.M., and **Sedgley, R.H.** 1986. Chickpea (*Cicer arietinum* L.), a potential grain legume for south-western Australia: seasonal growth and yield. Australian Journal of Agricultural Research 37:245-261.

Siddique, K.H.M., and **Sedgley, R.H.** 1987. Canopy development modifies the water economy of chickpea (*Cicer arietinum* L.) in south-western Australia. Australian Journal of Agricultural Research 37:599-610.

Siddique, K.H.M., Sedgley, R.H., and **Marshall, C.** 1984. Effect of plant density on growth and harvest index of branches in chickpea (*Cicer arietinum* L.). Field Crops Research 9:193-203.

Walton, G.H., and **Trent, T.R.** 1988. Evaluation of pulses and other seed legumes for crop rotations in Western Australia. Technical Bulletin no. 79. Perth, Australia: Department of Agriculture. 31 pp.

Zamir, D. 1983. Pollen gene expression and selection: applications in plant breeding. Pages 313-330 *in* Isozymes in plant genetics and breeding (Tanksley, S.D., and Orton, T.J., eds.). Part A. Developments in Plant Genetics and Breeding, 1A. Amsterdam, Netherlands: Elsevier.

Diagnosis and alleviation of mineral nutrient constraints in chickpea

I.P.S. Ahlawat[1]

Abstract

This paper deals with various methods of diagnosis of mineral nutrient constraints and their alleviation in chickpea. Different criteria such as visible foliar symptoms, nutrient ratios, critical and toxic nutrient concentrations with associated physiological and biochemical processes have been documented. Under water stress chickpea showed differential response to nutrients like iron, zinc, manganese, etc. Some nutrient elements such as sodium and calcium caused toxic effects on growth, yield, and chemical composition of chickpea. Significant and economic responses to major nutrients and their sources and methods of application under varying agroclimatic conditions resulting in higher yields of chickpea have been presented. Besides, application of micronutrients with appropriate sources and methods has also been documented.

Résumé

Diagnostic et allègement des contraintes en éléments nutritifs minéraux chez le pois chiche : *Cet article traite de diverses méthodes de diagnostic des contraintes en éléments nutritifs minéraux chez le pois chiche ainsi que de leur allègement. Les différents critères tels les symptômes foliaires visibles, proportions de substances nutritives, les concentrations critiques et toxiques des éléments nutritifs avec les processus physiologiques et biochimiques associés sont détaillés. Sous le stress hydrique, le pois chiche montre une réponse différentielle aux éléments tels le fer, le zinc, le manganèse, etc. D'autres éléments comme le sodium et le calcium provoquent des effets toxiques sur la croissance, le rendement, et la composition chimique du pois chiche. Des réponses économiques et significatives aux principaux éléments nutritifs, ainsi que les sources et les méthodes d'application de ceux-ci dans diverses conditions agroclimatiques permettant des rendements élevés de pois chiche sont également présentées. En outre, l'application des oligo-éléments avec les sources et les méthodes appropriées sont détaillées.*

Chickpea cultivation is mainly confined to marginal lands, usually deficient in one or more nutrients. In India, chickpea is grown on a variety of soils, ranging from coarse-textured sandy soils to heavy clay soils. The crop is seldom fertilized and hence often suffers from deficiency of one or more nutrients. Until the 1960s, the emphasis was on the supply of macronutrients only, but continuous cropping has resulted in the removal of large amounts of secondary and micronutrients. The response to mineral nutrients largely depends on various soil and environmental factors. Different criteria have been proposed to diagnose the nutrient

1. Senior Scientist (Legumes), Division of Agronomy, Indian Agricultural Research Institute, New Delhi 110 012, India.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

disorders in crop plants. Here an attempt has been made to present information obtained on the diagnosis and response to various mineral nutrients in chickpea.

Diagnosis of Mineral Nutrient Constraints

Soil testing is a common tool used to judge the mineral status of the soil and to decide critical nutrient concentrations. The critical level of available zinc (Zn) for example is 0.48 mg kg^{-1} soil. In Entisols and Alfisols the critical limit of Zn for chickpea is 0.35 ppm (Katyal 1985). In Alluvial soils, this limit was found to be 0.66-0.89 ppm (Singh et al. 1987).

Foliar disorders, the first indication of nutrient deficiency, have many limitations for practical use. For example, nitrogen (N) and molybdenum (Mo) deficiencies show almost identical symptoms in chickpea. Similarly, phosphorus (P) deficiency symptoms are identical to aluminium (Al) toxicity symptoms.

The deficiency symptoms for N, P, potassium (K), and magnesium (Mg) appear initially in the older leaves, whereas those of sulfur (S), copper (Cu), Zn, and Mo occur mainly in young tissues. Toxicity symptoms generally appear in older leaves, because of their tendency to accumulate elements. The foliar disorders of chickpea are given in Table 1.

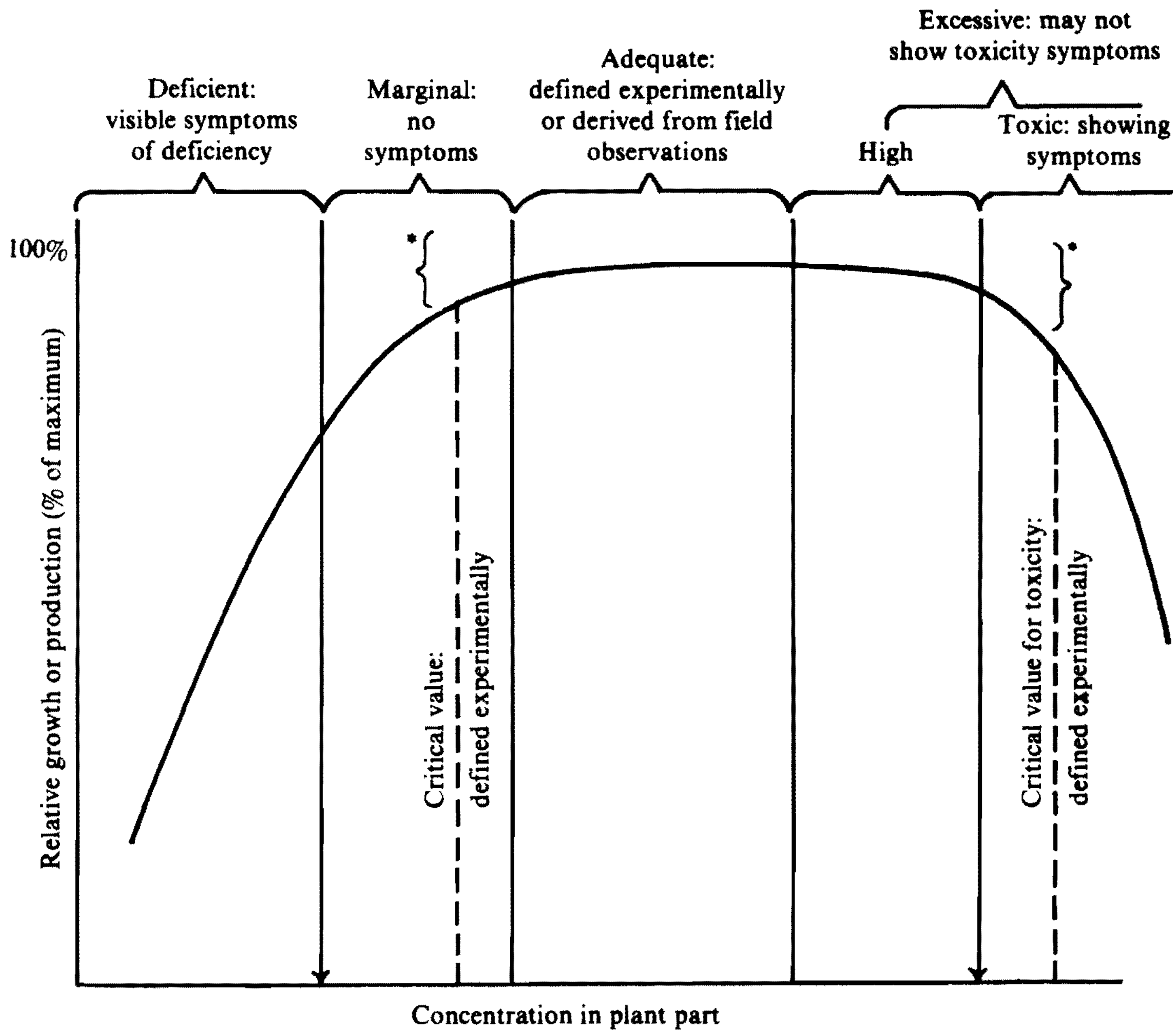
Table 1. Foliar symptoms of mineral nutrient disorders in chickpea.

Mineral nutrient	Symptoms
Nitrogen	Chlorosis first on older leaves, pink pigmentation on stems, and in a diffuse pattern on the upper surfaces of older leaves.
Phosphorus	Dark green foliage, red-purple pigmentation on stem and upper surface of leaflets of the lower leaves. Leaflets later become yellow-green or buff-green.
Potassium	Chlorosis of margins and tips of older leaves, reddish pigmentation on leaflets. Necrosis developing first on the tips of leaflets, and later covering the whole leaflet turning it light brown in color.
Calcium	Development of rachis and leaflets of young expanding leaves arrested, growing tip of rachis, and tips of unexpanded leaflets turn brown. Necrosis of leaflets. Death of growing points enhances axillary bud development. Older plant parts remain dark green.
Magnesium	Young and middle-aged leaves initially show light green chlorosis, which becomes more severe on the distal half of the leaflets of fully expanded leaves. Necrosis of the leaflet tips or margins in severe deficiency.
Sulfur	Chlorosis first appearing on younger leaves, extending over the entire plant in severely deficient plants. Red anthocyanin pigmentation on stems.
Copper	Leaflet size of top 3-4 leaves on each stem reduced, leaflets remain tightly folded inwards along the midrib. Fewer leaflets per leaf produced on the young leaves. Development of the terminal growing point retarded.
Zinc	Chlorosis of younger leaves, red-brown pigmentation on the margins of upper surfaces of leaflets, and lower portions of the stems. Stunted plant growth. Stipules of younger leaves become chlorotic.
Manganese	Chlorosis and necrosis of leaflets and stipules of young expanded leaves, top leaves turn pale-green in color, brown necrotic patches formed on leaflets except those around the leaf base and midrib. In toxicity, diffuse red-brown pigmentation develops on stem.
Iron	Chlorosis first on the terminal 3-4 leaves of each stem. White light straw-colored necrotic patches develop on the distal half of leaflets and stipules of young leaves.
Boron	Yellowing and bronzing on the tip and margins of leaflets of young fully expanded leaves. Axillary buds develop giving the plant a witches broom appearance due to the death of growing tip. Toxicity results in chlorosis of tips and serrated margins of leaflets, and tips of stipules on lower leaves. Necrosis later develops in chlorotic zones.
Molybdenum	Plants show chlorosis similar to that of nitrogen deficiency.

Plant analysis is the most reliable diagnostic method for identifying nutrient disorders. However, the age of the plant, the part analysed, and the environmental conditions need to be considered while interpreting plant analysis data. The critical nutrient concentration is not a single value but a range above which the plant is nutrient-sufficient and below which the plant is deficient (Fig. 1).

Katyal (1985) and Reuter (1986), have identified the nutrient concentrations in chickpea ranging from deficient to toxic (Table 2). These show variations due to genotype, growth stage, and environmental factors. The information on chickpea, however, is meagre. Cultivar differences to iron (Fe) deficiency are known (Singh et al. 1986). Iron-deficient cultivars (Table 3) accumulate less Fe^{++} possibly because of lower redox potential to oxidize Fe^{++} to Fe^{+++}. Fe-susceptible cultivars showed no chlorosis on soils with 65% $CaCO_3$. Potash application delayed the onset of chlorosis (Hamze et al. 1987) (Table 4).

Nutrients do interact in the plant system. For example, interactions between Cu and N, and S and N are



*Specified reduction in growth or yield (often 5%, 10%, or 20%)

Figure 1. Classification of nutrient status of plants.
Source: Reuter and Robinson 1986.

Table 2. Nutrient concentration in chickpea plant.

Nutrient	Growth stage	Plant parts	Deficient	Critical	Adequate	High	Toxic
N (%)	Veg.	Whole shoot		2.3			
P (%)	Veg.	Whole shoot		0.24			>0.75
	45 DAS	Whole shoot[1]	0.09-0.25		0.29-0.33		
	77 DAS	Whole shoot[1]	0.15-0.20		>0.26		
S (%)	Veg.	Whole shoot		0.15			
Cl (%)	Veg.	Whole shoot					>1.6
Cu (mg kg^{-1})	Veg.	Whole shoot	<4.0			4-35	>35
Zn (mg kg^{-1})	Veg.	Whole shoot				12-500	>510
	40 DAS	Whole shoot[1]		30			
Mn (mg kg^{-1})	Veg.	Whole shoot	<20				>520
	77DAS	Whole shoot				>120	
B (mg kg^{-1})	Veg.	Whole shoot	<10	40		>235	
Mo (mg kg^{-1})	Veg.	Whole shoot	<0.1				

1. Values obtained from soil culture.
Source: Katyal 1985; Reuter 1986.

Table 3. Concentration of nutrients in shoots of chickpea grown on Entisols, Rajendra Agricultural University, Bihar, postrainy season 1984/85.

Genotypes and their reactions to iron chlorosis	Nutrient concentration			
	Ca (g kg^{-1})	Na (g kg^{-1})	K (g kg^{-1})	Fe^{++} (mg kg^{-1})
Tolerant				
Dh G 82-1	1.9	0.7	2.9	155
Dh G 82-9	1.6	0.7	3.1	161
Susceptible				
Dh G 82-16	2.9	0.5	3.0	121
Highly susceptible				
Dh G 81-3	3.1	1.3	3.4	91
Correlation with shoot mass (r)	-0.887	-0.790	-0.850	0.983*

* Significant at 5% level of probability
Source: Singh et al. 1986.

Table 4. Mineral content in chickpea genotypes with and without Fe-EDDHA on calcareous soil, Beirut, Lebanon.

Treatment	Ca (%)	Mg (%)	K (%)	P (%)	Fe^{+++} (ppm)	Fe^{++} (ppm)
			Susceptible ICCL 81192			
+ Fe-EDDHA	1.42	0.28	2.4	0.58	75	28
Control	2.83	0.83	4.2	0.64	50	14
			Resistant ICL 263			
+ Fe-EDDHA	1.49	0.26	2.6	0.66	82	36
Control	1.70	0.33	2.1	0.53	101	28

Source: Hamze et al. 1987.

known. Similarly exchangeable sodium (Na) increases Na and Fe concentration and decreases Ca, N, K, Mg, Zn, and Mn concentrations (Singh and Abrol 1987). Such nutrient disorder resulted in 50% decrease in yield in chickpea.

Chickpea Response to Mineral Nutrients

Macronutrients

Chickpea responds favorably to low rates of 15-20 kg N ha^{-1} in N-deficient soils (Singh and Khangarot 1987; Thakur et al. 1989). Substantial increases in yield ranging from 20 to 40%, have been obtained with 10-20 kg N ha^{-1}.

Generally the responses to applied P in chickpea in the range of 40-60 kg P_2O_5 ha^{-1} have been positive (Table 5) (Ahlawat 1986; Thakur et al. 1989). The effects of P are usually more pronounced when applied in conjunction with starter N, *Rhizobium* (Pal 1986), or irrigation (Dev et al. 1987). Placement of P 3-5 cm below the soil surface and a foliar spray of 0.1% P_2O_5, showed better results than broadcast application. In a pulse-pulse sequence, single superphosphate as a source of P applied to rainy-season pulses gave greater response in a succeeding chickpea crop than Mussoorie rock phosphate (Daftardar et al. 1988).

The responses to K are generally small and seldom significant. Increases in grain yields of the order of 18-20% have been obtained with 20-60 kg K_2O ha^{-1} under Indian and Pakistani conditions (Thakur et al. 1989; Hamidullah et al. 1989).

Secondary Nutrients

Information in this area is scanty. Based on two studies, 80 kg S ha^{-1} gave a 38% increase in grain yield with a response of 7.6 kg grain for each kg of applied S (Tandon 1986). The superiority of single superphosphate as a source of P may also be assigned to its S (12%) and Ca (29%) contents.

Micronutrients

Zinc. Zinc deficiency in chickpea plants depresses the activity of glutamic dehydrogenase and carbonic anhydrase. Katyal (1985) reported a response to Zn application of more than 1 t ha^{-1} in one third of the experiments conducted in farmers' fields. In pot culture studies, Singh and Gupta (1986) and Singh and Badhoria (1986) obtained marked increases in yields and improved root growth and nodulation with 5 mg Zn kg^{-1} soil. Higher dry matter production and uptake of Zn, P, and Fe were recorded with Zn applied at 5 kg ha^{-1} in greenhouse studies (Dravid and Goswami 1987). Thakur et al. (1989) obtained a 16% increase in grain yield of chickpea with 25 kg $ZnSO_4$ ha^{-1} over the recommended dose of NPK. Chickpea cultivars, H 208, H 355, Pusa 43, L 144, and L 345 were zinc efficient and least susceptible to zinc deficiency when compared with other cultivars tested.

Manganese (Mn). Chickpea plants deficient in Mn may accumulate P, Cu, Mo, and NO_3^- in the tissues.

Table 5. Effect of phosphorus on chickpea yields (t ha^{-1}) at various locations.

Added P_2O_5 (kg ha^{-1})	New Delhi India 1985/86	Rahuri[1] India 1984/85	Indore India 1983/85	NWF Pakistan 1982/84
0	1.3	1.0	1.2	0.4
20	-	1.1	-	-
40	1.7	1.2	-	-
46	-	-	1.4	-
50	-	-	-	1.1

1. Mean of 24 trials.
Source: Ahlawat 1986; Joshi et al. 1988; Thakur et al. 1989; Hamidullah et al. 1989.

Kalbhor et al. (1988) observed improved nodulation and dry matter yields with increasing levels of $MnSO_4$ from 0 to 20 kg ha^{-1} on a clay loam soil with 16.3 ppm Mn. Manganese sulfate is the most common and best source of Mn. The optimum rate may range from 10-25 kg $MnSO_4$ ha^{-1} as a soil application and 1-2.5 kg ha^{-1} as a foliar spray. Foliar spray, in general, proved superior.

Iron. Chickpea genotypes differ in their susceptibility to Fe chlorosis under iron stress owing to their differential enzyme activities (Hamze et al. 1987). Mehrotra et al. (1987) observed that seeds of chickpea genotypes with higher Fe content were less susceptible to Fe chlorosis. The effect of Fe was more pronounced in the presence of Zn (Dravid and Goswami 1987). In Karnataka (India), one spray of 2% ferrous sulfate solution 30 days after sowing was effective and increased the chickpea yields on calcareous soil (Perur and Mithyantha 1985).

Boron (B). Sakal et al. (1988) obtained increased yields with increasing levels of B from 0 to 2.5 kg B ha^{-1}, but rates higher than 2.5 kg ha^{-1} caused reduction in yield. Fruiting was most adversely affected in B-deficient plants. In general, soil application of 1-2.5 kg B ha^{-1} or foliar application of 0.25 kg B ha^{-1} is adequate to mitigate B deficiency in chickpea.

Copper. In calcareous and in acid soils, as well as in saline and sodic soils, the availability of Cu is adversely affected. Coarse-textured soils are more likely to be deficient in Cu. Perur and Mithyantha (1985) recommended 5-10 kg $CuSO_4$ ha^{-1} for chickpeas in Cu-deficient areas of Karnataka (India). Copper sulfate is the most common source. The rate of $CuSO_4$ is 5-10 kg ha^{-1} as a soil application and 0.5-1.0 kg ha^{-1} as a foliar spray.

Molybdenum. The availability of Mo in soils with high clay content and in lateritic soils is generally low, whereas its availability is relatively high in saline alkaline and calcareous soils due to their higher pH. Pal (1986) obtained a marked increase in chickpea yield by applying up to 1.5 kg sodium molybdate ha^{-1}. The effect of Mo was more pronounced when applied with P and *Rhizobium*.

Conclusion

The above discussion clearly indicates that no single method of diagnosis of nutrient constraint is perfect, and other supporting and confirming data may often be needed. However, plant analysis often successfully used and will give satisfactory results. There is not much information on secondary nutrient and micronutrient requirement in chickpea in different situations. Information on relative nutrient sensitivity of chickpea cultivars would be of great help in identifying cultivars for different chickpea-growing areas.

References

Ahlawat, I.P.S. 1986. Effect of phosphorus fertilization and weed control measures in chickpea on nitrogen economy in succeeding maize. Pages 27-28 *in* Annual report 1986, Division of Agronomy. New Delhi 110 012, India: Indian Agricultural Research Institute.

Daftardar, S.Y., Kumbhar, D.D., and **Deshpande, A.N.** 1988. Phosphorus utilization of Mussoorie rock phosphates by legume sequences. Page 87 *in* The use of rock phosphate in west coast soils: proceedings of a Seminar, 29 Jan 1988, University of Agricultural Sciences, Bangalore, India. New Delhi, India: Pyrites, Phosphates, and Chemicals Ltd. (Abstract.)

Dev, S., Raj, M., and **Nath, J.** 1987. Interactive effect of phosphorus and irrigation on Kabuli gram (*Cicer arietinum* L.). Legume Research 10(1):41-43.

Dravid, M.S., and **Goswami, N.N.** 1987. Effect of salinity, fertility and variety on growth and nutrient uptake by chickpea (*Cicer arietinum* L.). Journal of Nuclear Agriculture and Biology 16(2):69-72.

Hamidullah, J., Siddiq, M., and **Dast, Z.** 1989. Response of chickpea to fertilizer and *Rhizobium* inoculation in rainfed sandy soils of the North West Frontier Province, Pakistan. International Chickpea Newsletter 20:20-21.

Hamze, M., Ryan, J., Mikdashi, R., and **Solh, M.** 1987. Evaluation of chickpea (*Cicer arietinum* L.) genotypes for resistance of lime induced chlorosis. Journal of Plant Nutrition 10(9-16):1031-1039.

Joshi, A.C., Aparadh, V.H., Rao, K.V., and **Umrani, N.K.** 1988. Response of Bengal gram to NPK fertilization under protective irrigation in Sangli district. Journal of Maharashtra Agricultural Universities 13(2):168-170.

Kalbhor, H.B., Rasal, P.H., and Patil, P.L. 1988. Effects of Zn and Mn on nodulation and yield of gram. Journal of Maharashtra Agricultural Universities 13(2):213-214.

Katyal, J.C. 1985. Research achievements of All India Coordinated Scheme of Micronutrients in Soils and Plants. Fertiliser News 30(4):67-80.

Mehrotra, S.C., Mehrotra, N.K., Sharma, C.P., and **Agrawala, S.C.** 1987. Mineral constituents in the seeds of pea and chickpea genotypes that differ in susceptibility under iron stress. Indian Journal of Plant Physiology 30(4):408-411.

Pal, A.K. 1986. Interaction of *Rhizobium* inoculation with phosphate and molybdenum application on chickpea (*Cicer arietinum*) at rainfed condition. Environmental Ecology 4(4):642-647.

Perur, N.G., and **Mithyantha, M.S.** 1985. Soils of Karnataka and their management. Pages 177-207 *in* Soils of India and their management (Alexander, T.M., ed.). 2nd edn. New Delhi, India: Fertiliser Association of India.

Reuter, D.J. 1986. Temperate and sub-tropical crops. Pages 38-99 *in* Plant analysis - an interpretation manual (Reuter, D.J., and Robinson, J.B., eds.). Melbourne, Australia: Inkata Press.

Reuter, D.J., and **Robinson, J.B.** (eds.). 1986. Plant analysis - an interpretation manual. Melbourne, Australia: Inkata Press. 36 pp.

Sakal, R., Sinha, R.B., and **Singh, A.P.** 1988. Effect of boron application on blackgram and chickpea production in calcareous soil. Fertiliser News 33(2):27-30.

Singh, B., and **Badhoria, B.S.** 1986. Potassium and zinc nutrition of chickpea. Science and Culture 52(2):62-65.

Singh, B.P., Sakal, R., Singh A.P., and **Sinha, R.B.** 1987. An appraisal of chemical extractants for zinc availability and response of chickpea to applied zinc in recent alluvial soils. Journal of Micronutrient Analysis 3(2):85-95.

Singh, G., and **Khangarot, S.S.** 1987. Effect of nitrogen and agrochemicals on chickpea. Indian Journal of Agronomy 32(1):4-6.

Singh, K., and **Gupta, V.K.** 1986. Response of chickpea (*Cicer arietinum*) to zinc fertilization and its critical level in soils of semi-arid tropics. Fertilizer Research 8:213-218.

Singh, R.A., Sinha, N.P., Singh, B.P., and **Sharma, S.G.** 1986. Reaction of chickpea genotypes to iron deficiency in a *calcareous* soil. Journal of Plant Nutrition 9(3-7):417-422.

Singh, S.B., and **Abrol, I.P.** 1987. Effect of exchangeable sodium percentage on the growth, yield and chemical composition of chickpea. Indian Journal of Agricultural Sciences 57(7):475-478.

Tandon, H.L.S. 1986. Sulphur research and agricultural production in India. 2nd edn. New Delhi, India: Fertilizer Development and Consultation Organisation.

Thakur, N.S., Raghuvanshi, R.K.S., and **Sharma, R.A.** 1989. Response of irrigated chickpea to applied nutrients. International Chickpea Newsletter 20:19-20.

Prospects for Optimizing Biological Nitrogen Fixation in Chickpea

O.P. Rupela[1] and D.P. Beck[2]

Abstract

Chickpea is largely grown in marginal lands by resource-poor farmers and has an important role in sustaining cropping system productivity. Biological nitrogen fixation (BNF) is a major component of the nitrogen economy of the system. Most of the early BNF work concentrated on improving the role of Rhizobium *in the symbiotic process, but with limited success. Genotypic variability in N_2-fixation, though established earlier, has not been used by crop improvement scientists, but is proposed as a promising area to enhance BNF in chickpea. More work using ^{15}N-based techniques to establish genotypic variability in BNF seems necessary, while experiments to determine optimum levels of BNF in chickpea would be desirable.*

During a recent successful program to identify spontaneous non-nodulating mutants we noticed considerable plant-to-plant variability within a given genotype. It is suspected that this variability is largely genetic. If so, it may be possible to select relatively high N_2-fixing lines within existing varieties and to make use of the variation in nodulation to quantify optimum BNF for chickpea.

Résumé

Prévisions d'optimisation de la fixation biologique de l'azote par le pois chiche : *Le pois chiche est surtout cultivé dans des terres marginales par des paysans disposant de peu de ressources et il joue un rôle important pour maintenir la productivité des systèmes de culture. La fixation biologique d'azote est un élément important de l'économie de l'azote du système. Au départ, la plupart des travaux s'étaient concentrés sur l'amélioration du rôle du* Rhizobium *dans le processus symbiotique, mais les résultats n'ont pas été très fructueux. La variabilité génotypique dans la fixation de N_2, bien qu'elle ait déjà été déterminée, n'a pas été utilisée par les chercheurs dans l'amélioration des cultures. Elle est cependant proposée comme un domaine comportant de bonnes possibilités de travail sur l'amélioration de la fixation de l'azote chez le pois chiche. Il semble nécessaire d'effectuer des travaux plus approfondis utilisant des techniques basées sur ^{15}N afin d'établir la variabilité génotypique de la fixation d'azote; des expériences pour déterminer les niveaux optimaux de la fixation chez le pois chiche seraient aussi souhaitables.*

Une variabilité considérable d'une plante à une autre à l'intérieur d'un génotype déterminé a été constatée au cours d'un programme récent, tenu avec succès, sur l'identification des mutants spontanés non nodulant. Il est possible que cette variabilité soit surtout génétique. Dans ce cas, il serait peut-être possible de sélectionner des lignées à fixation relativement élevée de N_2 au sein des variétés existantes et de tirer parti de cette variation de nodulation pour quantifier la fixation optimale pour le pois chiche.

1. Crop Physiologist, Legumes Program, ICRISAT Cooperative Research Station, College of Agriculture Farm, Jawaharlal Nehru Krishi Viswa Vidyalaya (JNKVV), Gwalior 474 002, Madhya Pradesh, India.
2. Food Legume Microbiologist, Food Legumes Improvement Program, International Center for Agricultural Research in the Dry Areas (ICARDA), P.O. Box 5466, Aleppo, Syria.

ICRISAT Conference Paper no. CP 559.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

Rhizobium strains that nodulate chickpea are specific, and do not show cross-inoculation affinity with any members of the known cross-inoculation groups (Rupela and Saxena 1987). With updated nomenclature they are called *Bradyrhizobium* sp. (Chickpea), but in this paper we have used *Rhizobium* sp. (Chickpea). Research on biological nitrogen fixation (BNF) in chickpea has largely concentrated on aspects of rhizobial strain selection, and assessing yield improvement through their use as inoculants. Several studies showing large increases in chickpea yields due to inoculation, often in soils containing high native rhizobial populations, lacked data on nodulation and N_2- fixation (occupancy (%) by inoculant or ^{15}N assessment) to show that the increased yield was really due to application of *Rhizobium*. The contributions of the legume host in determining different functions of this symbiotic process are certainly important, but are poorly understood (Beringer et al. 1988). In this paper we have restricted discussion to applied aspects of BNF in chickpea and given greater attention to the host plant.

Constraints in Increasing N_2- fixation

High Native Population of *Rhizobium*

Much of the early research work on BNF created the impression that yield of legumes can be significantly increased by *Rhizobium* inoculation. Subsequent work, however, suggested that successful establishment of inoculant strains in soils with high native populations of rhizobia is difficult and is only occasionally observed (Schmidt 1988). Therefore, use of identified effective *Rhizobium* strains and *Rhizobium* strain x host genotype interactions, though significant in some cases (Rai and Singh 1979), would be difficult to exploit for yield increase.

Abiotic Factors

Abiotic stresses such as drought and high temperature adversely affect nodulation and nitrogen fixation (Rupela and Kumar Rao 1987). Chickpea is largely rainfed and grown on residual and receding soil moisture, and thus may face drought conditions during crop growth. The amount of nodulation and N_2-fixation is related to the amount of soil moisture. Under rainfed conditions, sowing depth is generally determined by the depth of moisture in the soil profile. Increased sowing depth, however, tends to decrease the amount of nodulation.

Soil temperatures above 25°C during the day occurs in some chickpea-growing areas (17°N, peninsular India) and is supraoptimal for nodule functions (Rupela and Saxena 1987). Ambient maximum temperature (weekly mean) remains >30°C at the time of sowing and early growth stages of chickpea in latitudes at least up to 26°N. Soil temperature in these areas is likely to be higher than ambient. Similarly soil temperatures lower than 15 °C that occur in the West Asia and North Africa (WANA) region are likely to adversely affect N_2-fixation in the early stages of plant growth.

Nodulation and N_2-fixation are greatly reduced whenever high levels of soil nitrogen are available to a legume (Rupela and Saxena 1987). Unpublished studies at ICRISAT Center recorded a 4- to 6-fold reduction in nodule mass when soil-nitrate concentration in the top 15 cm soil profile, where most chickpea nodules occur, increased from about 6 mg kg^{-1} to about 13 mg kg^{-1}. Plant selection under such conditions may encourage dependence on soil-N instead of on fixed-N_2.

New Chickpea Areas

It is well established that areas new to a given legume nodulated by specific rhizobia generally lack appropriate *Rhizobium* strains. Evaluation of legumes without appropriate symbioses may adversely affect legume introduction efforts and may result in the selection of inappropriate genotypes. Rice-growing conditions have been observed to adversely affect the survival of chickpea inoculant (Rupela et al. 1987). Development of new cropping systems such as winter sowing of chickpea in WANA, and chickpea after rice are the areas where native chickpea rhizobia populations are likely to be low or absent, necessitating inoculation as part of the chickpea introduction package.

Promising Research Areas

Ecological Studies

Indigenous rhizobia when present in large numbers generally out-compete the inoculant strain in forming nodules on the host. Competition for nodule occupancy must be better understood in terms of microbial ecology, biochemistry, and molecular biology (Schmidt 1988). Selection of high temperature and high soil-nitrate tolerant rhizobial strains is possible but would be useful only in limited areas unless: (i) techniques to establish inoculant *Rhizobium* in soils with high populations of native rhizobia are developed; and (ii) concomitant host selection for these traits is carried out.

Effective Symbiosis with Native Rhizobia

Simultaneous selection or manipulation of genotypes of both symbiotic partners has been supported by many reviewers. Genes from the *Rhizobium* and legume host that are involved in the symbiosis are being identified, and in some cases isolated and cloned, to facilitate further studies and to provide sources of genes which might be used in the future to manipulate either partner (Beringer et al. 1988). This seems a desirable but difficult approach. Until these methodologies have shown promise,and techniques to establish inoculant rhizobia in fields are perfected, exploitation of host genotypic variability in N_2-fixation in the presence of native rhizobia appears the most applicable strategy to improve BNF. It can be assumed that native rhizobia are reasonably efficient. Prolifically nodulating genotypes have been identified (Rupela and Saxena 1987) that are stable across locations. The search for genotypes with prolonged N_2-fixation into the pod-filling stage seems to be worth while. The transfer of such traits into adapted genotypes is desirable.

Development of Specific Compatibles

With availability of nonnodulating chickpea lines (Rupela and Saxena 1987) it seems possible to develop or identify compatible *Rhizobium* strain(s) that could only nodulate the given nonnodulating line. This could by-pass the problem of competition that an inoculant strain has to face from native rhizobia. Comparative advantage(s) of host-specific *Rhizobium* combinations over normal symbiotic genotypes could then be studied.

Plant-to-plant Variability in Nodulation within a Genotype

During a recent successful search for nonnodulating spontaneous mutants the authors also noticed a range of nodulation within a high nodulating line K 850. It is plausible that variability for traits such as nodulation would exist from bulking during development of a variety. Whether this kind of variability is environmental or genetic can be verified. If found to be genetic, it has implications in assessing the optimum level of nodulation/N_2-fixation and in selection of high nodulating/N_2-fixing lines from within a released variety.

Acknowledgments

We thank Drs M.C. Saxena, C. Johansen, and E.A. Kueneman for their helpful comments.

References

Beringer, J.E., Bisseling, T.A., and **LaRue, T.A.** 1988. Improving symbiotic nitrogen fixation through the genetic manipulation of *Rhizobium* and legume host plants. Pages 691-702 *in* World crops: cool season food legumes: proceedings of the International Food Legume Research Conference on Pea, Lentil, Faba Bean and Chickpea, 6-11 Jul 1986, Spokane, Washington, USA (Summerfield, R.J., ed.). Dordrecht, Netherlands: Kluwer Academic Publishers.

Rai, R., and **Singh, S.N.** 1979. Interaction between chickpeas (*Cicer arietinum* Linn.) genotypes and strains of *Rhizobium* sp. Journal of Agricultural Sciences Cambridge 92:437-441.

Rupela, O.P., and **Kumar Rao, J.V.D.K.** 1987. Effects of drought, temperature and salinity on symbiotic nitrogen fixation in legumes, with emphasis on chickpea and pigeonpea. Pages 123-131 *in* Adaptation of chickpea and pigeonpea to abiotic stresses: proceedings of the Consultants' Workshop, 19-21 Dec 1984, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Rupela, O.P., and **Saxena, M.C.** 1987. Nodulation and nitrogen fixation in chickpea. Pages 191-206 *in* The chickpea (Saxena, M.C., and Singh, K.B., eds.). Wallingford, Oxon, UK: CAB International.

Rupela, O.P., Toomsan, B., Mittal, S., Dart, P.J., and **Thompson,** J.A. 1987. Chickpea *Rhizobium* populations: survey of influence of season, soil depth and cropping pattern. Soil Biology and Biochemistry 19:247-252.

Schmidt, E.L. 1988. Competition for legume nodule occupancy: a down-to-earth limitation on nitrogen fixation. Pages 663-674 *in* World crops: cool season food legumes: proceedings of the International Food Legume Research Conference on Pea, Lentil, Faba Bean and Chickpea, 6-11 Jul 1986, Spokane, Washington, USA (Summerfield, R.J., ed.). Dordrecht, Netherlands: Kluwer Academic Publishers.

Improved Cropping Systems and Alternative Cropping Practices

C.S. Saraf[1], B. Baldev[1], M. Ali[2], and S.N. Silim[3]

Abstract

The role of grain legumes in Indian agriculture has long been appreciated in view of their ability to fix atmospheric nitrogen. Since the 1950s considerable attention has been given to various cropping systems designed to improve profitability both in time and space. In view of the improved plant types and soil-ameliorative properties, cropping systems involving chickpea are increasingly being adopted. It has been found that inclusion of chickpea in cropping systems has resulted in enhanced yield and profitability. However, alternative cropping systems are needed in the 1990s for further improvement of chickpea yields under both rainfed and irrigated conditions. An attempt has been made to highlight some research findings and ideas for future improvement in chickpea yields.

Résumé

Systèmes de culture améliorés et de nouvelles pratiques culturales : *Le rôle des légumineuses à grains dans l'agriculture en Inde a longtemps été apprécié à cause de l'aptitude de ces cultures à fixer l'azote atmosphérique. Depuis les années 50, une attention considérable a été accordée aux divers systèmes de culture destinés à l'amélioration de la rentabilité en fonction du temps et aussi de l'espace. Etant donné les types de plantes améliorées et les propriétés d'amélioration du sol, on constate l'adoption de plus en plus importante des systèmes de culture comportant le pois chiche. L'insertion du pois chiche dans les systèmes de culture a permis une augmentation du rendement et de la rentabilité. Cependant, de nouveaux systèmes de culture sont nécessaires pour les années 90 afin de pouvoir améliorer davantage les rendements du pois chiche dans les conditions tant pluviales qu'irriguées. On a essayé de souligner quelques résultats de recherche et des idées pour l'amélioration future des rendements du pois chiche.*

The world population is growing rapidly, and by the turn of the Century it is expected to be around 6.2 billion (FAO 1986). The major population increase is expected in developing countries where self sufficiency in food production is a major concern. In India, for example, population has been increasing annually by 2.58% and demand for food by 3.25 to 3.40%. However the domestic food production has been rising only by 2.60 to 3.10%.

Nutritional imbalances in the agricultural sector, such as those causing high ratios of carbohydrate to protein production, are common in developing countries. In India, over the last three decades, while the contribution of wheat and rice to the total food grain

1. Principal Scientist (Legumes), Division of Agronomy, and Principal Scientist, Division of Plant Physiology, Indian Agricultural Research Institute (IARI), New Delhi 110 012, India.
2. Principal Investigator and Head (Agronomy), Directorate of Pulses Research, Kalyanpur, Kanpur 208 024, Uttar Pradesh, India.
3. Postdoctoral Fellow, Agronomy/Physiology, Food Legume Improvement Program, International Center for Agricultural Research in the Dry Areas (ICARDA), P.O. Box 5466, Aleppo, Syria.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

output rose from 53 to 64%, the share of coarse grains and pulses declined from 30.7 to 26.4%. Increasing pulse production, and hence protein output, is thus one of the major objectives in Indian agriculture.

Response of Chickpea to Water Management

Crop yield can be increased in three distinct ways: a) increasing the area under cultivation, b) increasing productivity in existing areas, and c) increasing cropping intensity. However, available information suggests that there is very little scope for further expansion of agricultural land. Hence, increasing cropping intensity and crop productivity per unit area are possibilities, which can be effective only if cropping systems are improved and alternative cropping practices are adopted. Since almost the entire area under pulse crops is rainfed, relatively high levels of tolerance to drought are assumed to be present in these crops. However, water management is more critical in pulses than in most other crops. Excess and deficient moisture conditions both reduce the yield of pulses. In other crops, excess soil moisture may be tolerated without significantly affecting levels of productivity.

It has been found that chickpea needs 15% soil moisture by volume in the root zone extending down as much as 50 cm in sandy loam soil (Baldev 1988) and that this amount is critical especially during seed development. Stress starts developing even with 12% available soil moisture. On the other hand, an excess of soil moisture, caused by frequent rain, and too much irrigation, leads to excessive vegetative growth, at the expense of seed yield.

From the above observations it is clear, that chickpea cultivation must differ in rainfed and irrigated conditions. In the former, techniques are needed to enhance and maintain growth and in the latter vegetative growth should be controlled at optimal levels.

Judicious use of soil moisture is a key to successful rainfed farming. For most crops soil moisture is most critical during the seed germination and seed development stages. Chickpea is largely sown where there is residual moisture at the end of a rainy season. Where there is limited surface soil moisture, pre-sowing irrigation is desirable, but not always feasible. The only practical agronomic practice that has given consistently good results and is cheap, is deep sowing of the seeds. Deep sowing (10-12 cm) not only enables better germination compared to shallow sowing (3-5 cm) (Baldev 1988), but also reduces the incidence of wilt (Saraf 1974), thus ensuring a relativevly good plant stand. The grain yield of shallow-sown chickpea in one of our experiments was only 1.1 t ha^{-1} against 1.8 t ha^{-1} from a deep-sown crop under nonirrigated conditions. One irrigation applied to shallow-sown crops 75 days after sowing increased the yield to 1.7 t ha^{-1} indicating that deep sowing was equivalent to one irrigation. It has been shown in agronomic trials under the All India Coordinated Pulses Improvement Project (AICPIP) that during normal years one irrigation applied to chickpea at 45 to 75 days after sowing significantly increases grain yields.

In deep sowing, root systems grow comparatively deep, enabling the plant to extract soil moisture from lower layers. Our studies of soil moisture profiles during the crop season have shown that the growing plant will move its root zone to draw its moisture from deeper layers (Baldev 1988). In shallow-sown crops the available soil moisture in nonirrigated plots was less than 10% by the end of February, by which time pod filling is initiated, compared to about 15% for deep-sown crops.

Although irrigation can increase phosphorus uptake efficiency, due to increased solubilization (Prabhakar et al. 1987), excess soil moisture results in increased vegetative growth in chickpea. Under normal soil moisture conditions at New Delhi, flowering is initiated by the end of December in early genotypes, and by the end of January in late genotypes if they are sown in mid-October. Excess soil moisture due to rainfall or over-irrigation at this stage promotes excessive vegetative growth at the cost of flowering and fruiting, and makes the crop prone to lodge which leads to decreased yields. Delays in flowering will transfer the seed-filling phase to an unfavorably high temperature environment during April. Excessive vegetative growth is also conducive to disease and pest attacks, poor partitioning of photosynthates, and abscission of flowers and immature fruits.

Vegetative growth can be controlled by delaying the date of sowing by a month or so, until the third week of November in Northwest India. Because of cool weather conditions, late sowing also reduces vascular diseases such as wilt.

However, a late-sown crop may sometimes need higher inputs in the form of irrigation and fertilizers so that the slow vegetative growth under the cool temperature regime can be speeded up to achieve optimum dry matter production for good yields. The harvest index increases slightly under late-sown conditions. The low dry matter production during the vegetative phase due to cool weather can also be compensated for by increasing the plant density.

Chickpea in Intercropping Systems

Improved cropping systems and alternate cropping practices can increase and stabilize food grain yields. The adoption of a cropping system in a particular region results from ecological factors, such as soil and climate, as well as non-ecological factors, such as consumer demand, market, socio-economic policies of the region, and technological capabilities. Can chickpea be a successful intercrop or a beneficial grain legume in multiple and relay cropping system and crop rotations? Generally successful intercropping of two or more species should result in efficient use of resources leading to enhanced total crop production returns when compared to sole cropping (Saraf and Ganga Saran 1986). Intercropping of chickpea and safflower is practised in India; it reduces the risk that sole crops are exposed to (Malvi et al. 1988). Both are winter crops and traditional chickpea cultivars are spreading types and their yields are reduced by pest infestations and diseases. Tall, upright, high-yielding chickpea cultivars that are disease resistant and do not interfere with the growth of safflower have been identified (Bahl and Baldev 1981).

Intercropping with traditional chickpea genotypes has had some success. Our research results show that Land Equivalent Ratios (LER) of 1.6 can be achieved by intercropping chickpea with safflower.

The study of intercropping systems in rainfed agriculture in India is important as 72 million out of a total of 142 million ha of cultivated land is rainfed (Swindale 1982). However, the benefits of intercropping are better achieved by increasing inputs including irrigation.

Our studies of water use in monocropping and intercropping have shown that more water is seasonally consumed by intercropping than by monocropping, and that sowing pattern in sole cropping and plant population in intercropping have little or no effect on seasonal water consumption.

Safflower may not be the best companion crop for chickpea in intercropping systems, possibly due to its shading effect. It is not uncommon to observe lanky chickpea in the chickpea-safflower combination. Other highly remunerative crops such as mustard could be used instead. Studies on genotypic compatability in intercropping with the chickpea genotype, Pusa 261, and the mustard genotype, Varuna, (Ali 1989) indicated that in some locations for instance at Kanpur the crops ratio 4:1 for chickpea and mustard gave the highest yield.

Results from sequential cropping studies by the All India Coordinated Research Project on Pulses show, that at Gulberga in Karnataka, India, the pearl millet–chickpea sequence significantly outyielded the traditional sesame–safflower sequence and gave the highest total monetary return (AICPIP 1989). Similarly Meena and Ali (1987) have observed that chickpea–rice sequences have outyielded all other sequences.

Continuous cropping of cereals, a practice commonly followed in several regions, for example the Mediterranean basin, can lead to a decline in yield. At ICARDA, both winter and spring sown chickpeas in a sequence with other legumes have a beneficial effect in sustaining the yield of cereals and can replace fallow without causing a decline in the yield of a succeeding cereal. Replacing fallow is now one of the strategies used to expand chickpea cultivation without competition to other crops (Silim and Saxena 1989).

Conclusion

Agronomic practices alone such as deep sowing under nonirrigated conditions, late sowing under irrigated conditions, suitable intercropping patterns, crop sequences, and crop rotations can increase chickpea yield and total crop yield per unit area. However for a quantum jump to occur in chickpea yields, genotype improvement has to be coupled with improved agronomic practices and cropping systems. Selection of genotypes based on highly heritable characters has had its value; in the future chickpea genotypes may need such traits as deep rooting ability, and tolerances to drought and to salinity for specific environments.

For irrigated chickpea, the major objective should be to control excessive vegetative growth so that the harvest index is improved and damage lodging minimized. Late sowing is not without drawbacks, as pod filling has often to occur under unfavorably high temperatures in April. It will therefore be necessary to identify genotypes that tolerate high temperature. Alternatively cold tolerance can possibly be used in early-flowering genotypes.

References

AICPIP (All India Coordinated Pulses Improvement Project). 1989. Chickpea based promising intercrops. Pulses Improvement Project Consolidated report of All India Coordinated Research Project on pulses (1986-89). Kanpur, Uttar Pradesh, India: AICPIP.

Ali, M. 1989. Chickpea-mustard intercropping: I. Genotypic compatibility and planting pattern. Consolidated report (unpublished). Kanpur, Uttar Pradesh, India: All India Coordinated Pulses Improvement Project.

Bahl, P.N., and **Baldev, B.** 1981. Production technology for chickpea. Indian Farming 31(5):67-71.

Baldev, B. 1988. Cropping patterns in pulse crops. Pages 513-557 *in* Pulse crops (grain legumes) (Baldev, B., Ramanujam, S., and Jain, H.K., eds.). New Delhi, India: Oxford and IBH Publishing Co.

FAO. 1986. FAO agricultural commodity projections to 1990. FAO Economic and Social Development Paper no. 62. Rome, Italy: Food and Agriculture Organization of the United Nations.

Malvi, G.C., Saraf, C.S., and **Pandey, S.L.** 1988. Effect of intercropping on yield attributes of chickpea and safflower under different soil moisture regimes and population densities. Journal of Agronomy and Crop Science 126:224-227.

Meena, N.L., and **Ali, M.** 1987. Effect of rabi pulses on nitrogen economy and productivity of succeeding rice. Presented at the National Symposium on Alternate Farming Systems, 21-23 Feb 1987, Indian Agricultural Research Institute, New Delhi, India.

Prabhakar, M., Saraf, C.S., and **Ghosh, G.** 1987. Influence of irrigation levels on phosphorus uptake and utilization by chickpea genotypes. Journal of Nuclear Agriculture and Biology 16:104-106.

Saraf, C.S. 1974. Agronomic management to reduce gram wilt incidence. Indian Journal of Genetics and Plant Breeding 34(2):263-266.

Saraf, C.S., and **Ganga Saran.** 1986. Crop production techniques and input management in rainfed pulses and oilseeds. Pages 1-35 *in* proceedings of the Second Seminar. World Phosphate Institute and The Fertilizer Association of India, New Delhi Jan. 22-25. Carabianca: World Phosphate Institute.

Saraf, C.S., and **Than Soe.** 1989. Research Project report on oilseed-pulse based cropping systems. FAO/IARI Joint Project, New Delhi, India: Indian Agricultural Research Institute. (Limited distribution.)

Silim, S.N., and **Saxena, M.C.** 1989. Winter sowing chickpea - case study. Presented at the International Workshop on Soil and Crop Management for Improved Water Use Efficiency, 15-19 May 1989, Ankara, Turkey. International Center for Agricultural Research in the Dry Areas.

Swindale, L.D. 1982. A time for rainfed agriculture. Fertiliser News. 27(1):48-59.

Session 3

Main Items of Presentation and Discussion

- Adaptation of chickpea to agroclimatic constraints is of fundamental importance for cultivar development. The rate of progress towards flowering, determined by photothermal conditions, is of major significance; it can be established for different genotypes by following the screening protocols presented at the workshop.
- when extrapolating temperature data from controlled environments to the field the effective field temperature ($\bar{T}$) is determined by expanding the formula

$$\bar{T} = \sum_{t=0}^{t=f}[(T_{max} + T_{min})/2]/f+1$$

  where f=days to flowering, and T_{max} and T_{min} are daily maximum and minimum temperatures as recorded in standard meteorological screens.
- Tropical grasses and some tropical legumes have base temperatures $T_b \sim 10°C$ and optimum temperatures $T_o \sim 35°C$, whereas for temperate species these values are $Tb \sim 0°C$ and $T_o \sim 25°C$. Only a few chickpea genotypes have been evaluated for these traits. In terms of crop and areas of production T_b may be cooler in kabuli than in desi types while T_o may be warmer in desi than in kabuli. Genetic differences within the two groups may well exceed those between them.
- Considerable genetic variation exists in the germplasm collection tested in California for high-temperature tolerance. Flower and pod retention was noted in some genotypes at 40°C. Other useful traits for adaptation are earliness in maturity, and the ability to produce flowers and pods at extreme temperatures and under drought stress.
- Modeling of chickpea's growth and yield, although only recently started, has already yielded interesting results. The RESCAP model developed at ICRISAT, had a good predictability of dry matter production ($r^2 = 0.86$) and could be used to calculate the optimal time and quantity of irrigation. However, further model development is needed to predict partitioning of dry matter to grain and water fluxes at the leaf surface.
- The concept of functional ideotypes for prioritizing and testing useful traits was proposed for yield improvement at locations where conventional breeding faces problems e.g., due to variability in harsh production environments. Some ideotype examples for particular environments were mentioned: plants with a long, dense root system and small leaves for environments prone to drought stress; and cold-tolerant, early-maturing plant types with a high harvest index and lodging resistance for high latitudes. For high-input systems a communal plant type, with reduced branching was proposed. Statements that 'little or no improvement in yield potential had been achieved in chickpea over the past 20 years', and 'the ideotype approach could provide a possible alternative to conventional yield breeding' were challenged. Examples of yield improvement over years were cited. The complexity and apparent limited success of previous ideotype breeding efforts were pointed out.
- Ideotypes for quality improvement can be described. A 'market' ideotype needs to incorporate the characters that the consumer wants, and breeding programs must be both market- and productivity-oriented.
- Mineral nutrient constraints need to be identified using such criteria and methodologies as plant symptoms and critical nutrient concentrations. The impact of alleviating mineral nutrient constraints was documented.
- The emphasis for nitrogen fixation should move from rhizobial strain differences to host plant variability. The nodulation of the chickpea plant is optimal when the seed is sown 10 cm deep; but usually it is sown deeper than this because of the limited soil moisture in the semi-arid tropics. For undetermined reasons, chickpea has in some cases been noted to exert a negative effect on the succeeding crop. Depletion of soil nitrogen, or water, or exacerbation of disease and pest problems were suggested as possible causes.
- Increasing the ability of chickpea to fix N by genetic means could be at the expense of yield potential, due to competition between nodules and reproductive parts for assimilates. The ideal combination of host plant/*Rhizobium* strain is achieved when most of the N-requirement of the legume plant is satisfied through N-fixation, and some of the N-requirement of the following non-leguminous crop is also provided for.
- With good nodulation, 70% of the plant's N requirement can be derived from N-fixation; without inoculation and in fertile soils the plant derives much less of its N-requirement from N-fixation. Chickpea is extremely effective in absorbing mineral N from the soil and moderate concentrations of mineral N, whether soil- or fertilizer-derived, can severely depress nodule de-

velopment and function. Therefore, to minimize exploitation of soil N by chickpea, it would be desirable to develop chickpea that can nodulate and fix N under conditions of moderate to high ambient mineral N.

- It was suggested that genetic solutions to micronutrient problems were not necessary as they could easily be solved by simple and cheap methods of fertilizer application.
- The need for a common definition and usage of harvest index for chickpea (accounting for fallen leaves) was emphasized. It was also suggested that calculation and more widespread use of harvest index for nitrogen would be desirable in comparing genotypes and environments.

Recommendations

- Yield improvement in chickpea in the 1990s will be best achieved through hybridization programs based on wide variability with selection directed toward location-specific characteristics and management strategies.
- The growth physiology of chickpea is strongly influenced by temperature, photoperiod, and water supply: specific strategies need to be developed for each of the major agro-climatic zones in which the crop is grown.
- The objectives for each zone are best formulated in terms of 'functional ideotypes' that define not only desirable above-ground morphological characteristics (the original 'ideotype' concept) but also desirable physiological responses (e.g., to temperature and photoperiod), rooting characteristics, water use, nitrogen fixation attributes, and characters useful in disease and pest resistance.
- Methods of screening for some components of functional ideotypes are available, and suggestions were made for alternative and additional techniques; these need to be more widely evaluated. Although screening needs to be based on location specific data, the applicability of screening techniques, and usefulness of traits identified as a result (e.g., drought tolerance traits), need to be evaluated across regions.
- The water-driven plant growth model presented needs to be refined, and used to specify the plant attributes and management strategies that optimize the use of water at a particular location. This model will then be useful to estimate potential yield, evaluate proposed changes in sowing time, define the optimum rooting depth, and determine the best use of irrigation water.
- The development of a carbon dioxide metabolism/light-driven model will help to refine ideotypes for plant structure, responses to temperature, and responses to change in partitioning coefficients.
- Rates of development of chickpea in response to temperature and photoperiod are well established although little practical use has been made of this information. Therefore:
- photothermal coefficients for each zone need to be determined;
- photothermal coefficients for each new line or cultivar need to be described as a cultivar attribute; and
- new cultivars need not be tested for yield in zones to which their flowering behavior is not adapted.
- The mineral nutrition of chickpea is inadequately understood: responses to phosphate application, and the requirement for trace elements in specified environments need clarification. Further work is needed on the development of diagnostic procedures appropriate to chickpea to detect nutrient imbalances and monitor nutrient status.
- Chickpea is extremely sensitive to temperature, and sources of genes for the following physiological attributes need to be located:
- capacity to germinate and grow vegetatively at low temperature;
- frost resistance;
- decreased sensitivity to both low (<10°C) and high (>30°C) temperature during flowering and early pod fill; and
- low maintenance respiration at high temperature.
- Work on nitrogen metabolism and nutrition of chickpea needs to be undertaken in the following areas:
- the ecology of *Rhizobium* in situations where inoculation is necessary, e.g., in new chickpea-growing areas, on 'problem' soils or where rhizobial populations are low;
- the basic interaction between nitrogen fixation and mineral nitrogen;
- the abilities of different strains of *Rhizobium* or particular plant genotypes to maintain nodule activity during grain filling, since nitrogen fixation in chickpea declines markedly after flowering;
- decreased sensitivity of nitrogen fixation to mineral nitrogen to increase the capacity of chickpea to contribute to increasing soil fertility of cropping systems; and
- effects of drought stress on nitrogen fixation, especially intermittent stress during vegetative growth and flowering, as an integral part of drought research.

Session 3

Principaux thèmes de présentation et de discussion

- L'adaptation du pois chiche aux contraintes agroclimatiques est d'une importance fondamentale pour la mise au point de cultivars. Le taux de progrès vers la floraison, déterminé par les conditions photothermiques, est d'une signification majeure; il peut être établi pour divers génotypes en suivant les protocoles de criblage présentés au colloque.

- Au moment de l'extrapolation, au milieu réel, des données de température à partir d'environnements contrôlés, la température réelle du milieu ($\bar{T}$) est déterminée par l'expansion de la formule :

$$\bar{T} = \sum_{t=0}^{t=f}[(T_{max} + T_{min})/2]/f+1$$

  Où f = jours à la floraison, et T_{max} et T_{min} sont les températures maximale et minimale quotidiennes telles qu'elles sont enregistrées sur les écrans météorologiques types.

- Les graminées tropicales ainsi que certaines légumineuses tropicales ont des températures de base T_b ~ 10°C et des températures optimales T_o ~ 35°C, alors que pour les espèces tempérées ces valeurs sont T_b ~ 0°C et T_o ~ 25°C. Seulement quelques génotypes ont été évalués pour ces caractères. En termes de culture et superficies de production, T_b pourrait être moins élevée chez les types kabuli que chez les desi, alors que T_o pourrait être plus élevée chez le desi que chez le kabuli. Les différences génétiques à l'intérieure des deux groupes pourraient dépasser celles entre eux.

- Une variation considérable existe dans la collection des ressources génétiques testée en Californie pour la tolérance aux températures élevées. La rétention des fleurs et des gousses a été constatée chez quelques génotypes à 40°C. D'autres caractéres utiles pour l'adaptation sont la précocité de maturation, et le pouvoir de produire des fleurs et des gousses aux températures extrèmes ainsi que sous le stress hydrique.

- La modélisation de la croissance et du rendement du pois chiche, bien que démarrée seulement récemment, a déjà donné des résultats intéressants. Le Modèle RESCAP mis au point à l'ICRISAT avait une bonne prévisibilité de la production de matière sèche (r^2 = 0,86) et pourrait être utilisé pour calculer le temps optimal et la quantité d'irrigation. Toutefois, des travaux plus approfondis sont nécessaires pour prédire la partition de matière sèche au grain et les flux d'eau à la surface foliaire.

- Le concept d'idéotypes fonctionnels pour la prioritisation et l'évaluation des caractères utiles a été proposé pour l'amélioration du rendement à des emplacements où la sélection traditionnelle fait face à des problèmes, par exemple, dû à la variabilité dans les milieux de production difficiles. Quelques exemples d'idéotypes pour environnements particuliers étaient cités : les plantes avec un système racinaire dense et long et petites feuilles pour les environnements susceptibles aux stress hydriques; et les types de plantes tolérantes au froid et à maturation précoce avec une indice de récolte élevée et la résistance à la verse pour les latitudes supérieures. Pour les systèmes à intrants élevés, un type communal de plante avec ramification réduite a été proposé. Des énonciations telles "Peu ou aucune amélioration du potentiel de rendement a été réalisée chez le pois chiche pendant les 20 dernières années" ou "l'approche par idéotype pourrait offrir une solution autre que la sélection traditionnelle pour le rendement" ont été remises en question. Des exemples de l'amélioration du rendement pendant les années ont été cités. La complexité et le succès apparemment limité des efforts précédents de sélection d'idéotypes ont été soulignés.

- Des idéotypes pour l'amélioration de la qualité peuvent être décrits. Un idéotype 'marché' devrait incorporer les caractères utiles au consommateur, et les programmes de sélection devraient s'orienter tant au marché qu'à la productivité.

- Des contraintes en éléments minéraux nutritifs devraient être identifiées en utilisant des critères et des méthodologies telles que symptômes des plantes et des concentrations critiques des éléments nutritifs. L'impact de l'allégement des contraintes en éléments minéraux nutritifs a été documenté.

- En ce qui concerne la fixation de l'azote, l'accent devrait être reporté sur la variabilité de la plante-hôte au lieu des différences entre souches rhizobiales. La nodulation de la plante de pois chiche est optimale lorsque la graine est semée à 10 cm de profondeur; mais le semis s'effectue normalement à une profondeur plus importante à cause de l'humidité du sol limitée dans les régions tropicales semi-arides. Pour des raisons non-déterminées, le pois chiche en quelques cas, a été responsable d'exercer un effet négatif sur la culture suivante. La réduction de l'azote du sol ou de l'eau, l'exacerbation des problèmes de maladies et de ravageurs ont été suggéré comme causes possibles.

- L'augmentation du pouvoir de fixation N du pois chiche par les moyens génétiques pourrait être au dépens du potentiel de rendement, dû à la concurrence entre nodules et les parties reproductives pour assimilats. La combinaison idéale de planté-hôte/souche de Rhizobium est réalisée lorsque la plupart du besoin en N de la plante légumineuse est satisfaite à travers la fixation de l'azote, et deuxièmement, une partie du besoin en N de la culture suivante non-légumineuse est également pourvue.

- Avec une bonne nodulation, 70% des besoins en N de la plante peut être dérivé de la fixation de N; sans inoculation et dans des sols fertiles la plante obtient bien moins de ses besoins en N à partir de la fixation de N. Le pois chiche est extrêmement efficace dans l'absorption du N minéral à partir du sol. Les concentrations modérées de N minéral, qu'il soit dérivé du sol ou de l'engrais, peuvent sévèrement réduire le développement et la fonction des nodules. Par conséquent, pour minimiser l'exploitation du N du sol par le pois chiche, il serait souhaitable de mettre au point un pois chiche qui peut noduler et fixer le N dans des conditions de N minéral ambiant élevé ou modéré.

- Il a été suggéré que les solutions génétiques aux problèmes d'éléments micronutritifs n'étaient pas nécessaires car ils peuvent facilement être résolus par des méthodes simples et peu onéreux d'application d'engrais.

- La nécessité d'une définition commune et l'usage de l'indice de récolte pour le pois chiche (tenant compte des feuilles tombées) a été souligné. Il a également été suggré que le calcul et l'emploi plus élargie de l'indice de récolte pour l'azote serait désirable dans la comparaison des génotypes et environnements.

Recommandations

- L'amélioration du rendement du pois chiche dans les années 90 sera réalisée le plus efficacement par l'intermédiaire des programmes d'hybridation basés sur la grande variabilité avec la sélection orientée vers les caractéristiques et les stratégies de gestion spécifiques aux emplacements.

- La physiologie de la croissance du pois chiche est fortement influencée par la température, la photopériode et l'alimentation en eau; des stratégies spécifiques doivent être élaborées pour chacune des zones agroclimatiques importantes dans laquelle la culture est exploitée.

- Les objectifs de chaque zone sont le mieux formulés en termes d' "idéotypes fonctionnels" qui définissent non seulement des caractéristiques morphologiques aériennes désirables (le concept 'idéotype' de départ) mais aussi des réponses physiologiques désirables (par exemple, à la température et à la photopériode), des caractéristiques d'enracinement, l'utilisation d'eau, attributs de fixation de l'azote, et des caractères utiles dans la résistance aux maladies et aux ravageurs.

- Méthodes de criblage pour quelques composantes des idéotypes fonctionnels sont disponibles, et des suggestions ont été faites pour des techniques différentes ou supplémentaires. Celles-ci doivent être évaluées plus largement. Bien que le criblage doit être basé sur les données spécifiques à l'emplacement, l'applicabilité des techniques de criblage, et l'utilité des caractères identifiés par conséquent (par exemple, les caractères de tolérance à la sécheresse), doivent être évalués à travers les régions.

- Le modèle de croissance végétale à base de l'eau doit être raffiné et utilisé pour la détermination des attributs des plantes et des stratégies de gestion qui optimisent l'utilisation de l'eau à un emplacement particulier. Ce modèle sera alors utile dans l'estimation du rendement potentiel, dans l'évaluation des changements proposés du temps de semis, dans la définition de la profondeur optimale d'enracinement, et dans la détermination de la meilleure utilisation de l'eau d'irrigation.

- La mise au point d'un modèle actionné par la lumière/le métabolisme du bioxide de carbone permettra de raffiner des idéotypes pour la structure de la plante, des réponses à la température, et des réponses au changement des coefficients de partition.

- Les taux de croissance du pois chiche en réponse à la température et à la photopériode sont bien établis bien que peu d'utilisation pratique est découlée de cette information. Donc :

  - des coefficients photothermiques pour chaque zone doivent être déterminés;

  - des coefficients photothermiques pour chaque nouvelle lignée ou cultivar doivent être décrits comme un attribut du cultivar;

  - il n'est pas nécessaire de tester de nouveaux cultivars pour le rendement dans des zones auxquelles leur comportement de floraison n'est pas adapté.

- La nutrition minérale du pois chiche est insuffisamment comprise. Les réponses à l'application des phosphates, et le besoin en oligo-éléments dans des milieux spécifiques doivent être explicités. Davantage de travaux sont nécessaires sur la mise au point de procédures diagnostiques appropriées au pois chiche afin de détecter les déséquilibres en éléments nutritifs et de suivre les niveaux d'éléments nutritifs.

- Le pois chiche est extrêmement sensible à la température et les sources de gènes pour les attributs physiologiques suivants doivent être identifiées :

  - pouvoir de germination et de croissance végétative à des basses températures;

  - résistance à la gêlée;

  - sensibilité réduite à la température basse ($<10°$ C) aussi bien qu'élevée ($>30°$ C) pendant la floraison et le remplissage précoce des gousses;

  - respiration de maintenance faible à haute température.

- Les travaux sur le métabolisme et la nutrition en azote du pois chiche doivent être entrepris sur les thèmes suivants :

  - l'écologie du Rhizobium dans des situations où l'inoculation est nécessaire, par exemple, dans les nouvelles régions de culture de pois chiche, sur des sols "problèmes" ou dans le cas de populations rhizobiales peu élevées;

  - l'interaction fondamentale entre la fixation de l'azote et l'azote minérale;

  - les pouvoirs des souches différentes de Rhizobium ou des génotypes de plantes particuliers de maintenir l'activité nodulaire pendant le remplissage des gousses, puisque la fixation de l'azote chez le pois chiche diminue considérablement après la floraison;

  - la sensibilité réduite de la fixation de l'azote à l'azote minérale pour accroître la capacité du pois chiche à contribuer à l'augmentation de la fertilité du sol des systèmes de culture;

  - les effets de stress hydrique sur la fixation de l'azote, en particulier le stress intermittent pendant la croissance végétative et la floraison, comme une partie intégrante de la recherche sur le stress hydrique.

Session 4

Pathology

Strategies for Management of Foliar Diseases of Chickpea

M.V. Reddy[1], Y.L. Nene[1], Gurdip Singh[2], and M. Bashir[3]

Abstract

Ascochyta blight (AB), botrytis gray mold (BGM), alternaria blight (ALB), rust, and stemphylium blight (SB) are important foliar diseases of chickpea. Foliar diseases occur in areas that have the highest potential for chickpea production due to a long growing season and lack of drought stress. Thus good growing conditions for chickpea and occurrence of foliar diseases are linked and, unless the linkage is broken, there is very little chance of increasing chickpea production in the northern latitudes.

Among the foliar diseases, serious attempts have only been made to develop control measures for AB. High and stable genetic resistance, especially in the podding stage, is lacking in the available germplasm. Integration of host-plant resistance with foliar fungicidal sprays is effective and feasible, but needs wider testing and evaluation.

Limited screening for BGM resistance and observations on disease epidemics indicate that it may be difficult to obtain a sufficient level of genetic resistance for exploitation in the management of the disease. There appears to be some scope for manipulation of plant geometry (including intercropping) and crop maturity for the management of the disease. It is essential to integrate the control measures for AB, BGM, and other foliar diseases, as the incidence of these diseases can overlap in certain areas.

The epidemiology of the diseases is not fully understood and this information is essential for developing effective management practices. Germplasm enhancement for resistance and studies on genetics of resistance and pathogenic variability also should receive better attention.

Résumé

Stratégies de gestion des maladies foliaires du pois chiche : *La flétrissure ascochytique, la pourriture grise due à botrytis, la flétrissure causée par alternaria, la rouille et la pourriture due à stemphylium sont d'importantes maladies foliaires du pois chiche. Les maladies foliaires se produisent dans des régions qui ont le meilleur potentiel de production de pois chiche, en raison d'une saison de culture longue et de l'absence de stress hydrique. Il existe donc un lien entre de bonnes conditions de culture du pois chiche et l'apparition de maladies foliaires. Par conséquent, il ne semble guère possible d'accroître la production de pois chiche dans les latitudes nord à moins de briser ce lien.*

Parmi les maladies foliaires, seule la flétrissure ascochytique a fait l'objet d'efforts sérieux de mise au point de moyens de lutte. Il n'existe pas de sources de résistance élevée et stable, particulièrement au stade de formation des gousses, dans le matériel génétique disponible

---

1. Senior Plant Pathologist, Legumes Program, and Deputy Director General, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.
2. Senior Plant Pathologist (Pulses), Department of Plant Breeding, Punjab Agricultural University, Ludhiana 141 004, Punjab, India.
3. Plant Pathologist, National Agricultural Research Centre (NARC), P.O. National Institute of Health, National Park Road, Islamabad, Pakistan.

ICRISAT Conference Paper no. CP 560.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

actuellement. L'intégration de la résistance de la plante-hôte avec la pulvérisation de fongicides sur les feuilles est efficace et faisable mais exige davantage d'essais et d'évaluations.

Un criblage restreint pour la résistance à la pourriture grise due à botrytis et des observations sur les épidémies de la maladie indiquent qu'il pourrait être difficile d'obtenir un niveau suffisant de résistance génétique pour servir à la lutte contre la maladie. Il semble possible de manipuler la géométrie des plantes (y compris la culture associée) et la maturité de la culture pour maîtriser la maladie. Il est essentiel d'intégrer des moyens de lutte contre la flétrissure ascochytique, la pourriture grise due à botrytis, et d'autres maladies foliaires, car l'incidence de ces dernières peut se chevaucher dans certaines régions.

L'épidémiologie des maladies n'est pas encore complètement comprise et cette information est essentielle pour mettre au point des pratiques de gestion efficaces. L'amélioration du matériel génétique pour la résistance ainsi que les études sur la génétique de la résistance et la variabilité pathogénique devraient également recevoir davantage d'attention.

Chickpeas suffer from some serious foliar diseases. In the order of importance worldwide, these are ascochyta blight (*Ascochyta rabiei* [Pass.] Labr.), botrytis gray mold (*Botrytis cinerea* Pers. ex Fr.), stemphylium blight (*Stemphylium sarciniforme* [Cav.] Wilts.), alternaria blight (*Alternaria alternata* [Fr.] Kiessler), and rust (*Uromyces ciceris-arietini* [Grogn.] Jacz & Beyer). The incidence of these diseases is mainly confined to the chickpea-growing regions between latitudes 25° and 45°, where the weather is cooler and wetter than in growing regions at lower latitudes. As the higher latitude areas have the greater production potential, management of foliar diseases is important for increasing chickpea production.

Research on chickpea diseases has recently been reviewed by Nene and Reddy (1987). Here, we attempt to summarize progress made during the past 10 years, identify the gaps in knowledge as well as research constraints, and to suggest research strategies for the future.

Ascochyta Blight

Ascochyta blight (AB) is most serious between the latitudes 30° and 45°, where relatively low temperatures (15°-25°C) prevail during the crop season and favor its development. Appearance of the blight however is not regular. The disease develops whenever the winter-sown chickpeas in northwest India and Pakistan and spring-sown chickpeas in the Mediterranean region receive rains during the crop season. There is no AB problem if there are no rains but then drought reduces the yield. A good season for the chickpea crop is also favorable for AB and low yields result (Fig. 1). This relationship will have to be considered when we develop effective disease management strategies.

The average yield of spring-sown chickpeas in the Mediterranean region is low (about 0.75 t ha^{-1}) mainly due to drought and heat stress. Advancing the sowing date into autumn results in 50-100% yield increase provided AB is controlled (Hawtin and Singh 1984). Hence control of AB is essential for increasing chickpea production in the countries in the Mediterranean region but also in the major chickpea-producing regions in India and Pakistan.

Botrytis Gray Mold

Botrytis gray mold (BGM) causes concealed damage in chickpea, and its importance has only recently been realized. Without visible symptoms on foliage, the disease can cause flower drop resulting in poor pod setting, and extension of the crop duration. Some pod setting may occur late in the season when the day temperatures exceed 30°C and conditions are unfavorable for the disease. But the yields in such situations

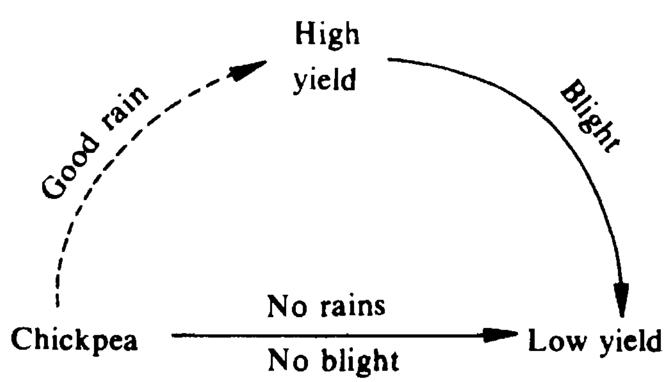


Figure 1. Relationship between chickpea yields and ascochyta blight (*Ascochyta rabiei*).

are drastically reduced owing to drought and heat stress. The regions between 25° and 30° are most liable to BGM. The disease has a slightly higher temperature requirement (25°C) than AB (20°C). It is a regular problem in parts of India, Nepal, and Bangladesh. During 1979-1982 it caused heavy losses in the Indo-Gangetic Plains of India (Grewal and Laha 1983). Reddy et al. (1988) visually estimated about 40% yield loss due to BGM in Nepal during the 1987/88 season. Though winter rains increase the disease problem they do not seem to be essential for BGM development. This is different from the situation for AB, for which rains are essential. Heavy dew in the nights, irrigation, excessive vegetative growth, early sowing, and dense planting predispose the crop to disease.

Other Diseases

Stemphylium blight, alternaria blight, and rust are at present of minor importance. Stemphylium blight causes considerable damage in northwestern parts of Bangladesh in some seasons. Alternaria blight occasionally assumes importance in northeastern India. Rust is more widespread and frequent, but as it occurs late in the season, it does not cause much loss in yield. Hardly any work has been carried out on the management of these diseases, probably because they have been somewhat over-shadowed by AB and BGM. Once these two major diseases are controlled, the potential damage caused by the minor diseases may be better realized.

Table 1. Mean ascochyta blight severity and yield loss estimation[1] under noninoculated and artificially inoculated conditions in a set of resistant chickpea germplasm lines at ICARDA, Tel Hadya, Syria, 1982/83–1985/86.

Chickpea germplasm lines	Blight severity on vegetative parts[2]	Pod infection (%)	Average yield ($t\ ha^{-1}$)		Yield loss/ increase (%)
			Noninoculated	Inoculated	
ILC 72	2.3	8	2.0	2.3	+ 15
ILC 182	2.3	9	2.5	2.6	+ 4
ILC 187	2.4	5	2.2	2.4	+ 9
ILC 191	2.5	12	2.1	2.1	0
ILC 195	2.4	8	2.4	2.4	0
ILC 200	2.4	2	2.5	2.2	- 12
ILC 1757	3.3	36	2.6	1.4	- 46
ILC 2300	2.2	3	2.5	2.5	0
ILC 2506	2.0	9	2.3	2.7	+ 17
ILC 2956	2.7	3	2.0	2.3	+ 15
ILC 3001	2.7	30	1.3	1.8	+ 38
ILC 3274	2.1	4	2.0	2.1	+ 5
ILC 3400	2.7	20	2.2	2.1	- 5
ICC 3634	2.0	16	2.0	2.2	+ 10
ICC 4200	2.9	29	2.3	1.9	- 19
ICC 4248	2.9	32	2.3	1.9	- 17
ICC 5124	2.9	16	2.1	2.2	+ 5
ICC 6262	2.2	2	2.3	2.6	+ 13
ICC 6981	2.0	18	2.3	2.6	+ 13
Mean	2.47	13.8	2.2	2.2	0
ILC 1929 (Susceptible control)	9.0	94	2.6	0.03	99
SE mean	±0.27	±5.3	±0.21	±0.17	
CV (%)	16.5	53.7	16.0	14.0	

1. = Average of 1982/83, 1984/85, and 1985/86 seasons.
2. Scored on a scale of 1-9, where 1 = free and 9 = killed.

Source: M.V. Reddy and K.B. Singh, unpublished.

Progress to Date

Ascochyta blight

Though work on ascochyta blight has been going on for over 80 years, progress towards managing the disease has not been satisfactory. Several effective seed dressing and foliar fungicides have been identified, but their application under field conditions has been neither feasible nor economical. As many as 12 foliar sprays were insufficient to control the disease in a susceptible variety under epiphytotic conditions at the International Center for Agricultural Research in the Dry Areas (ICARDA) in Syria. Fungicides are often needed when it is raining or drizzling and it is not practicable to spray. The resistant varieties released from time to time in India and Pakistan eventually became susceptible due to the appearance of new races of the pathogen (FAO 1963). The extensive resistance breeding work undertaken in the ICARDA-ICRISAT joint program over the past 10 years has helped in the identification and development of several blight-resistant, high-yielding kabuli varieties for the Mediterranean region (Tables 1 and 2). However, none was sufficiently resistant in India and Pakistan, the two major chickpea-producing countries (Table 3). It is now well-established that the fungus *Ascochyta rabiei* is highly variable, and that the races present in Pakistan and India are more aggressive than those prevalent in the Mediterranean region (Singh et al. 1984). Lines with resistance in the vegetative stage to isolates of *A. rabiei* prevalent in India (Singh et al. 1988) and Pakistan are available, but none has resistance in both the vegetative and podding stages. PK 51863 x NEC 138-2 the only line resistant under field conditions in Pakistan (Iqbal et al. 1989), showed resistance in the vegetative stage to Indian isolates of *A. rabiei* but not in the podding stage (Table 3).

Reliable inoculation techniques and disease rating scales have been developed and standardized (Reddy et al. 1984). A system for multilocational evaluation has

Table 2. Ascochyta blight resistant and high-yielding kabuli chickpea cultivars released in the Mediterranean region.

Country	Cultivars released	Year of release	Specific features
Algeria	ILC 482	1988	Wide adaptation
	ILC 3279	1988	Tall
Cyprus	Yialousa (ILC 3279)	1984	Tall
	Kyrenia (ILC 464)	1987	Large seeds
France	TS1009 (ILC 482)	1988	Wide adaptation
	TS1502 (FLIP-81-293)	1988	Cold tolerance
Italy	Califfo (ILC 72)	1987	Tall
	Sultano (ILC 3279)	1987	Tall
Morocco	ILC 195	1987	Mid-tall
	ILC 482	1987	Wide adaptation
Spain	Fardan (ILC 72)	1985	Tall
	Zegri (ILC 200)	1985	Mid-tall
	Almena (ILC 2548)	1985	Tall
	Alcazaba (ILC 2555)	1985	Tall
	Atalaya (ILC 200)	1985	Mid-tall
Syria	Ghab 1 (ILC 482)	1986	Wide adaptation
	Ghab 2 (ILC 3279)	1986	Tall
Tunisia	Chetoui (ILC 3279)	1986	Tall
	Kassab (FLIP 83-46C)	1986	Large seeds
Turkey	ILC 195	1986	Mid-tall
	Gunej Sarisi (ILC 482)	1986	Wide adaptation

Source: K.B. Singh, personal communication.

Table 3. Evaluation of *Cicer* spp accessions for resistance against five isolates of *Ascochyta rabiei* in a growth room at ICRISAT Center, 1988.

Cicer accession	Blight score[1] CPK 2 isolate	C 235 isolate GH	E 100Y isolate	Gurdaspur isolate	IARI isolate	Mixture of isolates
ICC 202 (USSR)	4 (100)[2]	5 (100)	9 (100)	9 (100)	6 (50)	8 (100)
ICC 3996 (Iran)	4 (33)	5 (100)	9 (100)	6 (-)[3]	6 (33)	5 (100)
ILC 72 (USSR)	5 (45)	3 (93)	5 (100)	6 (50)	6 (77)	6 (69)
ILC 3279 (USSR)	4 (0)	4 (59)	4 (89)	6 (85)	6 (100)	5 (75)
ILC 249 (India)	4 (0)	4 (100)	7 (100)	5 (100)	6 (100)	7 (100)
ICC 1903 (Morocco)	4 (33)	5 (100)	8 (90)	6 (80)	8 (100)	7 (100)
I 13 (ISRAD)	3 (25)	5 (100)	6 (100)	7 (100)	7 (89)	6 (91)
EC 26435 (Morocco)	6 (0)	6 (80)	7 (86)	9 (100)	9 (57)	7 (25)
ICC 51276 (India)	4 (44)	3 (94)	6 (100)	4 (75)	7 (91)	5 (100)
C 235 (India)	3 (67)	5 (100)	5 (100)	7 (100)	7 (100)	6 (71)
V 138 (Mexico)	5 (0)	8 (100)	9 (100)	9 (100)	9 (100)	9 (71)
ILC 191 (USSR)	5 (0)	7 (75)	7 (67)	7 (86)	6 (64)	6 (80)
ILC 2380 (USSR)	3 (13)	4 (94)	6 (100)	4 (43)	6 (93)	6 (100)
PCH 128 (Morocco)	4 (9)	6 (73)	6 (58)	5 (85)	8 (-)	7 (100)
CM 72 (Pakistan)	4 (0)	7 (100)	8 (100)	8 (50)	8 (40)	8 (100)
E 100YM (India)	5 (-)	4 (83)	6 (-)	8 (-)	6 (100)	6 (-)
ICC 607 (India)	3 (0)	6 (100)	5 (90)	9 (100)	8 (100)	5 (100)
BG 261 (India)	5 (13)	5 (70)	6 (100)	9 (78)	8 (55)	7 (100)
GG 575 (India)	6 (33)	6 (100)	4 (100)	4 (100)	5 (100)	4 (100)
PB 7 (India)	5 (38)	7 (100)	7 (100)	9 (100)	6 (92)	7 (100)
PANT-G-82-1 (India)	5 (67)	5 (92)	4 (69)	6 (44)	7 (100)	3 (89)
NEC-138-2 (India)	3 (33)	6 (82)	5 (94)	6 (83)	7 (75)	5 (83)
ILC 195 (USSR)	5 (0)	5 (67)	5 (78)	6 (91)	6 (-)	6 (52)
ILC 482 (Turkey)	4 (0)	5 (100)	6 (94)	6 (86)	4 (54)	5 (75)
C. judaicum	4 (-)	4 (100)	6 (100)	4 (0)	7 (100)	6 (75)
C. reticulatum	4 (50)	7 (100)	8 (100)	6 (86)	7 (100)	7 (-)
E-100Y (HAU)	6 (0)	3 (88)	6 (100)	5 (67)	5 (100)	6 (50)
PK51825xCM 72 (Pakistan)	3 (9)	3 (91)	6 (100)	3 (50)	7 (67)	5 (70)
PK51832xCM 72 (Pakistan)	5 (0)	5 (100)	5 (100)	5 (90)	7 (100)	6 (90)
PK51835xCM 72 (Pakistan)	6 (0)	5 (69)	4 (100)	5 (75)	5 (91)	5 (89)
PK51863xNEC-138-2 (Pakistan)	4 (0)	3 (65)	4 (100)	3 (44)	4 (67)	4 (73)

1. Scored on a scale of 1-9, where 1 = free and 9 = killed.
2. Figures in parentheses are % pod infection.
3. (-) = no podset.

Source: M.V. Reddy et al., unpublished.

also been built up (Singh et al. 1984). The potential for integration of host-plant resistance and a limited number of foliar sprays in the management of the disease is shown in Table 4. Two foliar sprays of chlorothalonil at the seedling and early podding stage in a moderately resistant cultivar were most cost-effective (Reddy and Singh, 1990). Limited information on the genetics of resistance to blight exists (Singh and Reddy 1983, 1989). Some information on the development of disease in relation to humidity and temperature has been obtained (Fig. 2). Temperature is a more critical factor than humidity for the epidemic build-up of AB in winter-sown chickpeas in the Mediterranean region where usually the required humidity exists.

Botrytis Gray Mold

Compared to AB, very little work has been carried out on BGM. During the past 5 years, there have been some

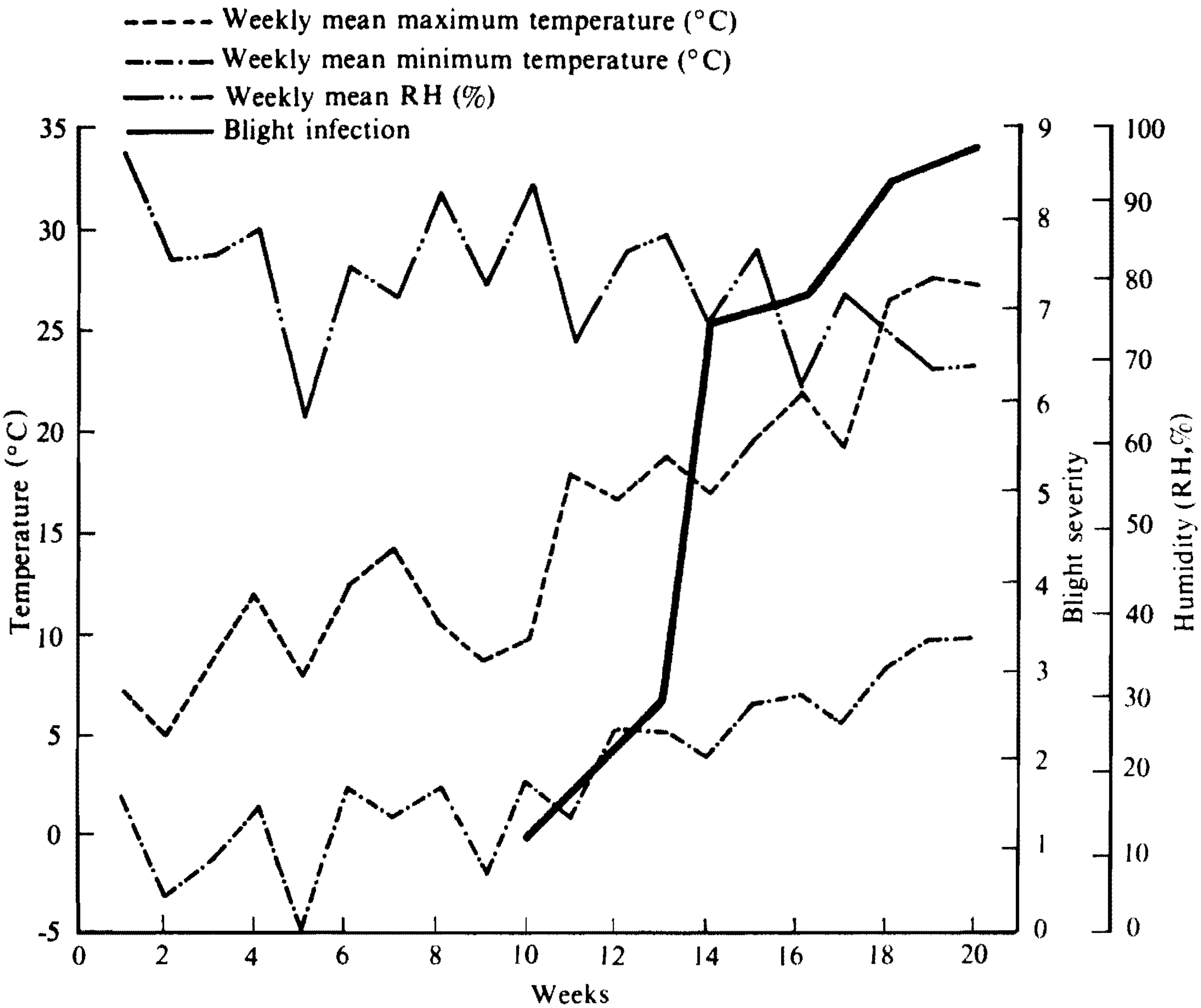


Figure 2. Relationship between temperature, humidity, and development of ascochyta blight infection in chickpea genotype ILC 464, Tel Hadya, Syria, 1982/83.

Table 4. Cost-benefit ratio of two foliar applications of chlorothalonil (Bravo 500®) for control of ascochyta blight in moderately resistant chickpea cultivar ILC 482, Tel Hadya, Syria, 1982/83–1985/86.

Stages of the crop when sprayed with chlorothalonil	Yield ($t\ ha^{-1}$)	Value of additional produce (U.S.$)[3]	Cost-benefit ratio[4]
Seedling and early podding	2.52[1]	209.0	1:5
Mid vegetative and early podding	2.10[2]	159.5	1:4
Seedling and late podding	2.25[1]	115.9	1:3

1. Average of two seasons.
2. Average of three seasons.
3. At the rate of U.S.$ 0.35 kg^{-1} of chickpea seed.
4. Cost of two sprays of chlorothalonil at U.S.$ 38.5 ha^{-1}.

Source: M.V. Reddy and K.B. Singh (1990).

reports on identification of lines with field-resistance to the disease (Table 5) (Rathi et al. 1984; Shukla et al. 1987; Sahu and Sah 1988). However, it appears that the reactions of the lines depend very much on disease pressure. Almost all lines that showed resistance to the disease at Pantnagar (latitude 29°N) in northern India, where the disease pressure is usually moderate, showed high susceptibility, when tested at Rampur (latitude 27°N) in Nepal, where the incidence is much higher. However, several showed some promise at Nepalganj (latitude 28°N) in Nepal, where compared to Rampur the disease pressure is moderate. Whether this variation is also due to different races, or only to environmental factors needs to be investigated. Several seed dressing and foliar fungicides have been found effective (Table 6) (Grewal and Laha 1983; Singh and Bhan 1986a; Singh and Kaur, unpublished), but, the economics of the use of foliar fungicides for management of the disease needs to be worked out. Singh and Bhan (1986b) reported four physiologic races from states in northern India. Observations made at ICRISAT Center also indicate variability in the pathogen. Field observations have shown that kabuli types are comparatively less susceptible than desi types. Also the tall and compact types suffer less than the traditional bushy and spreading types.

Table 5. Chickpea lines resistant to gray mold at Ludhiana, Punjab, India (1982/83–1988/89).

Variety	Average[1] disease score[2]
GL 635	3
GL 699	3
GL 907	3
GL 926	3
GL 930	3
GL 84133	5
GL 84038	4.5
GL 84065	4.5
GL 84212	5
GL 86094	4
ILC 200	5
ICC 1903	4
ICC 1905	4.5
ICC 4000	5
ICC 4018	5
ICC 4065	5
ICC 4950	5
ICC 5033	5
P 1528-1	5
C 8	5
Cicer pinnatifidum	1

1. Average of 6 seasons.
2. Scored on a scale of 1-9, where 1 = free and 9 = killed.

Source: Gurdip Singh, unpublished.

Gaps in Knowledge and Constraints

Ascochyta Blight

The major gap in our knowledge of the disease is in the AB epidemiology. The fungus is known to survive in the seeds and infected debris, and it is also known that its ability to survive in debris under field conditions is less than 2 years. No alternative hosts have been found. The recurrence of the disease in severe form, over extensive areas, after gaps of up to 10 years is quite puzzling. The likelihood of diseased debris or infected seed serving as sources of inoculation in such cases is remote. The logical explanation for such epidemics is that long-distance dispersal of spores has occurred. Hard evidence for this possibility is lacking. The role of the teleomorph in the epidemiology of blight in the Palouse region of USA by long-distance (>8 km) dissemination of airborne ascospores has been recently reported by Kaiser and Muehlbauer (1988). Lack of information on the nature of pathogenic variability in *A. rabiei is* yet another major gap in our knowledge. The major constraint in the management of AB is the lack of strong and stable genetic resistance, also in wild *Cicer* spp.

Botrytis Gray Mold

The epidemiology of the disease, especially the relationship between temperature, humidity, and disease development under field conditions is not understood. High levels of genetic resistance are not available. The pathogenic variability in *B. cinerea* and the distribution of races needs further investigation. The influence of sowing date, plant population, irrigation, crop duration, intercropping, and crop rotation on disease buildup is also not fully comprehended.

Future Research Strategies

Ascochyta Blight

The suggested future research strategies for the management of ascochyta blight are listed below:

1. Concerted efforts should be made to fully under-

Table 6. Effect of seed treatment and one foliar spray on the severity of botrytis gray mold in chickpea, Ludhiana, India.

Fungicide	Dose (gL^{-1} or $g\ kg^{-1}$)	Disease score[1]		Mean
		1986/87	1987/88	
Bavistin®	2	1.3	2.5	1.9
Hexacap®	3	1.0	1.6	1.3
Dithane M.45®	3	1.0	1.5	1.2
Rovral®	3	2.0	2.5	2.2
Thiabendazole	2	1.6	1.3	1.4
Baytan®	2	1.3	1.6	1.4
Thiram®	3	1.6	1.5	1.6
Ronilan®	3	2.3	1.7	2.0
Bayleton®	2	1.3	1.7	1.5
Bavistin® + Thiram® (1:1)	3	1.6	2.0	2.1
Topsin-M®	3	1.6	2.4	2.0
Seed treated (Bavistin® + Thiram®)	3	1.3	2.2	1.7
Control (Seed untreated)	-	6.3	6.3	6.4
CD at 5%		1.4	0.2	0.7

1. Scored on a scale of 1-9, where 1 = free and 9 = killed.

Source: Gurdip Singh and Livinder Kaur, unpublished.

stand the epidemiology of the disease. The primary sources of inoculum for epidemic buildup should be identified. The role of alternative hosts and resting forms of the fungus, if any, in addition to the infected seed, diseased debris, and teleomorph, in the perpetuation of the disease needs to be investigated. The means by which the disease spreads rapidly over very large areas need to be understood.

2. The extent of variability in *A. rabiei*, and its distribution, and the means by which the variability occurs, need to be further investigated. Temperature appears to play some role in the development of variability. Sangwan (1989) showed that certain isolates of *A. rabiei* produce more sectoring at 25°C than at 20°C in petri dishes.
3. Further studies on the genetics of resistance to blight are needed for mapping of the resistance genes, which will help resistance breeding programs.
4. Germplasm enhancement for blight resistance is important. In the absence of complete information on the different genes available for blight resistance in chickpea, intercrossing lines with different types of resistance, and lines resistant to different races of *A. rabiei* can be undertaken. A single dominant gene was found to govern resistance in ILC 72, ILC 183, ILC 200, ILC 202, ILC 2956, ILC 3279, and ICC 4935, whereas resistance in ILC 191 was conferred by a single recessive gene (Singh and Reddy 1983, 1989). In all the former lines the same gene was found to confer resistance, but they did not show the same resistance pattern against a set of six races (Singh and Reddy 1990). Although there are no lines resistant to all races, in both the vegetative and podding stage, lines resistant to individual races are available (Table 7) (Singh and Reddy 1989). Crossing and selection among such lines may result in enhanced resistance.
5. In the past there has been hardly any work on the integrated management of the disease. Most efforts have been on the development of resistant varieties and fungicidal control. Effective seed dressing fungicides such as thiabendazole and Calixin M ® are now available. One or two foliar sprays of chlorothalonil during the podding stage in moderately resistant cultivars have been found very effective in the control of the disease. More effective systemic foliar fungicides with longer residual action will make their application more economical and practical. Taller and more compact genotypes with stronger stems that would not easily break at the site of lesions, and with terminal, exposed pods

Table 7. Chickpea lines showing resistance to several races of *Ascochyta rabiei* in a greenhouse study in Syria.

Genotype	Reaction to races[1]					
	Race 1	Race 2	Race 3	Race 4	Race 5	Race 6
ILC 72	R	R	R	R	S	S
ILC 190	R	S	R	S	R	S
ILC 201	R	R	S	R	R	S
ILC 202	R	R	R	R	R	S
ILC 482	R	R	S	S	R	S
ILC 2506	R	R	S	R	S	R
ILC 2956	R	S	R	S	R	R
ILC 3279	R	S	R	R	R	S
ILC 3856	R	R	R	R	S	R
ILC 5928	R	R	S	R	R	R
FLIP 83-48C	R	R	R	S	R	S
ICC 3996	R	R	R	S	S	S
No. of resistant lines	12	9	8	7	8	4

1. R = resistant (3 to 4 rating);
S = susceptible (6 to 9 rating) on a 1-9 scale, where
1 = free and 9 = killed.

Source: Singh and Reddy 1989.

may also help in minimizing pod infection. Work carried out at ICARDA has shown, that when tall genotypes are mechanically bent to the ground during the podding stage, they develop increased pod infection. Thus, combined use of tall and compact varieties with resistance to blight, use of seed-dressings, and limited foliar sprays of effective systemic fungicides in the podding stage should be helpful in the successful management of blight.

Botrytis Gray Mold

Extensive screening in India and Nepal has failed to identify high levels of genetic resistance in the chickpea germplasm. Lines such as ICC 1069, ICC 1913, ICC 3640, ICC 4954, ICC 6299, and ICC 7111, that showed good promise of resistance at Pantnagar over a period of 5 years were almost completely killed at Rampur in Nepal. Though some lines do not show much damage on vegetative parts, they suffer severe flower infection resulting in no pod formation. In areas where the disease pressure is moderate, there appears to be good scope for integrated management of the disease. A field experiment at Pantnagar during the 1988/89 season indicated that the disease incidence was much lower in a tall and compact genotype (ICCL 87322) than in a bushy and spreading type (H 208) (Table 8). In both genotypes, there was a large increase in yield when interrow spacing was increased from the normal 30 cm to 60 cm, keeping the plant population constant. Intercropping experiments at Nepalganj in Nepal also indicated that when chickpea was intercropped with linseed there was a marginal increase in chickpea yield, and the linseed yield was a bonus (Onkar Singh 1988). Plant architecture changes suggested for reducing susceptibility of AB should also be useful in the management of BGM. Thus combined use of genetic resistance in the tall and compact plant type background, increased interrow spacing and intercropping with crops such as linseed, and a limited number of foliar fungicide sprays during the flowering and podding period may prove very effective in the management of this disease.

Germplasm enhancement and utilization of related wild species are also suggested as promising avenues to attain resistance that could be used in the management of the disease.

Other Diseases

Some of the strategies adopted for management of AB and BGM such as wider row spacing and use of tall and

Table 8. Influence of growth habit of chickpea genotypes and inter and intra-row spacing on botrytis gray mold severity and grain yield, Pantnagar, 1988/89.

Treatments[1]	Disease score on 1-9 scale[2]		Yield (t ha^{-1})
Sprayed with Ronilan®			
ICCL 87322 (30×10cm)	4.3	(1.5)[3]	3.5
ICCL 87322 (60×5cm)	3.3	(1.2)	5.2
H 208 (30×10cm)	6.7	(1.9)	2.8
H 208 (60×5cm)	5.0	(1.6)	3.1
Mean	4.8	(1.6)	3.7
No spray			
ICCL 87322 (30×10cm)	5.0	(1.6)	3.4
ICCL 87322 (60×5cm)	4.1	(1.4)	4.5
H 208 (30×10cm)	8.0	(2.1)	1.0
H 208 (60×5cm)	7.1	(1.9)	1.9
Mean	6.1	(1.8)	2.7
SE	±0.9	(0.2)	±0.14
CV%	15.8	(10.0)	4.3

1. ICCL 87322 is tall and compact and H 208 is bushy and spreading.
2. Scored on a scale of 1-9, where 1 = free and 9 = killed.
3. Figures in parentheses are $\log_e$ values.

Source: M.V. Reddy et al. unpublished.

compact genotypes may also help in minimizing other diseases. For example, in Bangladesh, tall, compact genotypes suffer much less from stemphylium blight than do the traditional spreading genotypes. Search for sources of genetic resistance may prove fruitful. Kabuli types were found to suffer less from stemphylium blight in Bangladesh than did desi types.

Multiple Disease Management

It is essential to develop management practices effective against combinations of foliar diseases. Though the two major diseases have specific zones of occurrence, there are certain regions such as northwestern Uttar Pradesh and Punjab in India, and Punjab in Pakistan where these overlap in certain seasons. Stemphylium and ascochyta blights generally occur along with botrytis gray mold. Unless the research efforts on foliar diseases are considerably increased, it will not be easy to develop management practices for all the foliar diseases in chickpea. Development of cold-tolerant chickpea cultivars that can mature by the end of the winter (end of February) in India, Pakistan, Bangladesh, and Nepal when the temperatures are lower than 15°-25°C may help in avoiding most of the foliar disease problems as the low temperatures will not favor epiphytotics.

References

FAO. 1963. Quarterly report for October-December, 1962, of the Plant Protection Committee for the South-East Asia and Pacific Region. Rome, Italy: Food and Agriculture Organization of the United Nations. 15 pp.

Grewal, J.S., and **Laha, S.K.** 1983. Chemical control of botrytis blight of chickpea. Indian Phytopathology 36:516-520.

Hawtin, G.C., and **Singh, K.B.** 1984. Prospects and potential of winter sowing of chickpeas in the Mediterranean region. Pages 7-16 *in* Ascochyta blight and winter sowing of chickpeas: proceedings of the Workshop, 4-7 May 1981, Aleppo, Syria (Saxena, M.C., and Singh, K.B., eds.). The Hague, Netherlands: Martinus Nijhoff/ W. Junk.

Iqbal, S.M., **Khan, I.A.**, and **Bashir, M.** 1989. Screening of chickpea cultivars against ascochyta blight in Pakistan. International Chickpea Newsletter 20(1):16.

Kaiser, W.J., and **Muehlbaner, F.J.** 1988. An outbreak of ascochyta blight of chickpea in the pacific north-west USA in 1987. International Chickpea Newsletter 18:16-17.

Nene, Y.L., and **Reddy, M.V.** 1987. Chickpea diseases and their control. Pages 233-270 *in* The chickpea (Saxena, M.C., and Singh, K.B., eds.). Wallingford, Oxon, UK: CAB International.

Onkar Singh. 1988. Progress report, July 1987-June 1988, Nepal-ICRISAT technical cooperation program for the improvement of chickpea and pigeonpea in Nepal. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics. 38 pp. (Limited distribution.)

Rathi, Y.P.S., **Tripathi, H.S.**, and **Chaube, H.S.** 1984. Screening of chickpea for resistance to botrytis gray mold. International Chickpea Newsletter 11:31-33.

Reddy, M.V., **Onkar Singh**, **Bharathi, M.P.**, **Sah, R.P.**, and **Joshi,** S. 1988. Botrytis gray mold epiphytotic of chickpea in Nepal. International Chickpea Newsletter 19:15.

Reddy, M.V., and **Singh, K.B.** 1990. Management of ascochyta blight of chickpea through integration of host-plant tolerance and foliar spraying of chlorothalonil. Indian Journal of Plant Protection 18: 65-69.

Reddy, M.V., **Singh, K.B.**, and **Nene, Y.L.** 1984. Screening techniques for ascochyta blight of chickpea. Pages 45-54 *in* Ascochyta blight and winter sowing of chickpeas: proceedings of the Workshop, 4-7 May 1981, Aleppo, Syria (Saxena, M.C., and Singh, K.B., eds.). The Hague, Netherlands: Martinus Nijhoff/W. Junk.

Sahu, R., and **Sah, D.N.** 1988. Effect of botrytis gray mold on chickpea flowers, pod formation, and yield in Nepal. International Chickpea Newsletter 18:13-15.

Sangwan, M.S. 1989. Studies on the variability in chickpea blight pathogen *Ascochyta rabiei* (Pass.) Labr. Ph.D. thesis, Haryana Agricultural University, Hisar, Haryana, India.

Shukla, A., **Tripathi, H.S.**, and **Pandya, B.P.** 1987. Isolation of material resistant to botrytis gray mold from chickpea germplasm. International Chickpea Newsletter 16:10.

Singh, G., and **Bhan, L.K.** 1986a. Chemical control of gray mold in chickpea. International Chickpea Newsletter 15:18-20.

Singh, G., and **Bhan, L.K.** 1986b. Physiological races of *Botrytis cinerea* causing gray mold of chickpea. Plant Disease Research 1:69-74.

Singh, K.B., and **Reddy, M.V.** 1983. Inheritance of resistance to ascochyta blight in chickpea. Crop Science 23:9-10.

Singh, K.B., and **Reddy, M.V.** 1989. Genetics of resistance to ascochyta blight in four chickpea lines. Crop Science 29:657-659.

Singh, K.B., and **Reddy, M.V.** 1990. Patterns of resistance and susceptibility to races of *Ascochyta rabiei* among germplasm accessions and breeding lines of chickpea. Plant Disease 74:127-129.

Singh, K.B., **Reddy, M.V.**, and **Nene, Y.L.** 1984. International testing of chickpeas for resistance to ascochyta blight. Plant Disease 68:782-784.

Singh, G., **Singh, G**, and **Kaur, L.** 1988. Chickpea response to various races of *Ascochyta rabiei*. International Chickpea Newsletter 19:10-13.

Integrated Management of Wilt and Root Rots of Chickpea

M.P. Haware[1], R.M. Jimenez-Diaz[2], K.S. Amin[3], J.C. Phillips[4], and H. Halila[5]

Abstract

Important root diseases of chickpea caused by fungi are wilt (Fusarium oxysporum *f.sp.* ciceri), *dry root rot* (Rhizoctonia bataticola), *black root rot* (F. solani and F. eumartii), *collar rot* (Sclerotium rolfsii), *and damping off* (Pythium ultimum). *All these pathogens are competitive facultative saprophytes which can survive indefinitely in the soil. The existence of races in* F. oxysporum f.sp. ciceri *calls for continued monitoring and multilocational testing of breeding lines. The research conducted in India, Mexico, Spain, Tunisia, USA, and at ICRISAT Center resulted in the development of wilt-resistant chickpea cultivars. Combined resistance to wilt and dry root rot is now available. However, only an integrated disease management system (IDM) can effectively control wilt and root rots in chickpea. IDM employs many strategies that include use of resistant cultivars, production of healthy seeds, modification of cultural practices, seed treatment, and use of biological forms to counter pathogens.*

Résumé

Lutte intégrée contre le flétrissement et les pourritures des racines du pois chiche : *Le flétrissement fusarien (*Fusarium oxysporum *f.sp.* ciceri*), la pourriture sèche des racines (*Rhizoctonia bataticola*), la pourriture noire des racines (*F. solani *et* F. eumartii*), la pourriture du collet (*Sclerotium rolfsii*), et la fonte des semis (*Pythium ultimum*) sont les importantes maladies des racines du pois chiche causées par les champignons. Tous ces agents pathogènes sont des saprophytes facultatifs concurrentiels qui peuvent survivre indéfiniment dans le sol. L'existence de races chez* F. oxysporum *f.sp.* ciceri *exige une surveillance constante et des essais multilocaux de lignées de sélection. Les travaux de recherche entrepris en Inde, au Mexique, en Espagne, en Tunisie, aux Etats-Unis et au Centre ICRISAT ont permis de mettre au point des cultivars de pois chiche résistants au flétrissement. La résistance combinée au flétrissement et à la pourriture sèche des racines est disponible aujourd'hui. Toutefois, seul un système intégré de lutte contre les maladies pourra efficacement lutter contre le flétrissement et les pourritures des racines chez le pois chiche. Le système emploie plusieurs stratégies pour la lutte contre les pathogènes, notamment l'utilisation de cultivars résistants, la production de semences saines, la modification des pratiques culturales, le traitement des semences et l'utilisation des formes biologiques.*

1. Plant Pathologist, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.
2. Professor of Plant Pathology, Departado de Agronomia, Escuela Tecnica Superior de Ingenieros Agronomas (ETSIA), Universidad de Cordoba, CSIC, Apdo, 3048, 14080 Cordoba, Spain.
3. Principal Investigator and Head, Pathology, Directorate of Pulses Research, Kalyanpur, Kanpur 208 024, Uttar Pradesh, India.
4. Professor, Crop Science Department, California Polytechnic State University, San Luis Obispo, CA 93407, USA.
5. Food Legume Coordinator, Institut National de la Recherche Agronomique de Tunisie (INRAT), 2080, Ariana, Tunisia.

ICRISAT Conference Paper no. CP 561.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

Soilborne fungal diseases of chickpea causing seed rot, damping-off, root rots, collar rots and wilt are cosmopolitan. Chickpea wilt caused by *Fusarium oxysporum* Schlecht. emend Snyd. & Hans. f.sp. *ciceri* [Padwick] Snyd. & Hans. (FOC) is widespread and reported from almost all the chickpea growing regions in the world. At least 7 races of FOC are reported (Haware and Nene 1982b; Philips 1988 and Jimenez-Diaz et al. 1989). Wilt caused by *Verticillium albo-atrum* Reinke & Berth has been reported to cause heavy losses in chickpea in Tunisia (Halila and Harrabi 1987). Several fungal pathogens that cause seedling diseases and root rots of chickpea are reported in the literature. The important root rot pathogens are *Rhizoctonia bataticola* (Taub) Butler (=*Macrophomina phaseolina* (Tassi) Goid), *Sclerotium rolfsii* Sacc., *F. solani* (Mart.) Appel & Wr., *F. eumartii* Carpenter, *Thielaviopsis basicola* (Berk. & Br.) Ferr., and *Pythium ultimum* Trow.

No precise information on losses caused by wilt and root rots in chickpea is available. According to a rough estimate, an annual loss of US $ 1 million was reported from Pakistan (Sattar et al. 1953). In Spain an annual yield loss of 12-15% was estimated due to chickpea wilt and root rots (Trapero-Casas and Jimenez-Diaz 1985). The production of chickpea in California has declined in recent years largely because of chickpea wilt. At ICRISAT, attempts were made to estimate losses in yield on a per plant basis. Early wilting caused more loss than late wilting. Seed harvested from late wilted plants was less heavy and duller than that from healthy plants (Haware and Nene 1980).

Soilborne diseases are difficult to control. Integrated management of wilt and root rots thus requires many strategies to maintain plant health. The strategies include minimum use of chemical fungicides to reduce the pathogen population, encouragement of beneficial biological agents to counter the pathogen, modification of cultural practices and use of resistant host species. The purpose of this paper is to identify and integrate logical approaches to chickpea wilt and root rot management.

Ecology and Epidemiology

The root diseases of chickpea are important in areas between latitudes 0° to 25° where the chickpea growing season is dry and warm. The behavior of root-infecting fungi in the soil is a complex subject. Factors important in the epidemiology of root-infecting fungi are inoculum density and pathotype in the soil, plant age, host resistance and its genetic potential, air and soil temperature, soil moisture, soil nutrients, and plant density.

Chickpea wilt can be observed in a highly susceptible cultivar within 25 days after sowing. Affected seedlings show drooping of the leaves and a paler color. Adult plants show typical wilt symptoms. The roots do not show external rotting, but when split vertically they display a brown discoloration of the internal tissues. Isolates of FOC induce either a fast wilting or progressive yellowing syndrome which develops 15 to 40 days after inoculation. The fungus is seed and soilborne. Lentil, pea, and pigeonpea were identified as symptomless carrier of the fungus (Haware and Nene 1982a). It can survive in the soil in the absence of the host for at least 6 years (Haware et al. 1986).

Several fungal pathogens, each causing seedling diseases and root rots of chickpea, have been reported. Dry root rot caused by *R. bataticola* is a serious disease whenever the crop is exposed to temperatures >30° C (Singh and Mehrotra 1982). The disease development is influenced by dry soil conditions especially at flowering. The plant suddenly dries in the field. The leaves and stems of affected plants are usually straw colored. The tap root is dark and quite brittle in dry soil. The dark black sclerotia can be observed on and within host tissues. *Rhizoctonia* is soilborne and sclerotia, formed on the organic residue and in the host tissues, become the chief source of inoculum. The pathogen has a wide host range.

Collar rot caused by *S. rolfsii* is seen in wet soil and at warm temperature in the seedling stage. Despite more or less continuous research over 100 years, the pathogen continues to plague growers and cause considerable loss. High soil moisture, the presence of undecomposed organic matter on the soil surface, low soil pH, and temperature between 25° and 30°C are associated with the incidence of collar rot. Chickpea following rice particularly suffers from collar rot infection. *F. solani*, *F. eumartii*, and *T. basicola* infected chickpea, often has severe black root rot symptoms. *Pythium ultimum* causes seed-rot and seedling blight. These four pathogens are favored by wet soil conditions and mostly attack chickpea in the seedling stage (Bowden et al. 1985; Trapero-Casas and Jimenez-Diaz 1985). Kabuli types are more susceptible to root rot pathogens than desi types. It is common for more than one soilborne pathogen to occur in the same field.

Control Measures

Cultural Practices

Soilborne pathogens persist in the soil. While it is difficult to eliminate the inoculum from the field, an approach that can minimize the effects of these diseases on yield in areas where availability of land is not limiting is to avoid planting in heavily infested fields. The fusarium wilt fungus has the ability to survive in the soil for long periods. Therefore crop rotation is not effective in reducing wilt incidence. Another method of reducing inoculum is deep plowing during the summer and removal of host debris from the field.

Pre-emergence damping-off due to *R. bataticola* does not occur at low temperature, while the disease attack is maximal at 34°C. In India, early sowing of early-maturing cultivars with timely irrigation can avoid high temperature above 30°C during crop maturity, thereby reducing mortality. Research in the Pacific Northwest of USA shows that tillage and residue management can markedly influence the severity of root rot in pea (Kraft et al. 1988). Recommendations for controlling *S. rolfsii* emphasize the importance of sanitary and cultural practices. These include roguing, increasing plant spacing, eliminating weed hosts and removing host tissues from the soil surface. Chickpea should not be sown under wet soil conditions to reduce seed rot and pre-emergence damping off.

Soil solarization. A multidisciplinary team effort at ICRISAT Center during 1984-87 clearly showed, that solarization by covering the soil with transparent polythene sheeting for 6-8 weeks during April-May effectively controls fusarium wilt in chickpea and also improves plant growth and yield (Chauhan et al. 1988).

Seed

It is important to make high quality chickpea seed available to farmers for sowing. A seed production program for food legumes is not taken up by most of the national programs and seed agencies. Seed should give high germination and plant vigor, and be pure and free from seedborne diseases. Emergence differs with color of the testa in chickpea. White seeded kabuli types emerge poorly in comparison with desi types which have brown or black testae (Kaiser and Hannan 1983). The white testae of the kabuli types adhere loosely to the cotyledons compared to the close adherence of colored testae.

Seed Treatment

Combined use of host resistance with fungicide results in better seedling emergence and may delay the onset of root rots. *F. oxysporum* f.sp. *ciceri* is internally seedborne, and seed dressing with Benlate® T (30% benomyl + 30% thiram) at 1.5 g kg^{-1} seed successfully eradicates the seedborne inoculum (Haware et al. 1978). Seed dressing with protectant or systemic fungicides used singly or as a mixture, significantly increased seedling emergence in moderately susceptible chickpea cultivars (Jimenez-Diaz and Trapero-Casas 1985). Seed treatment with Captan, Thiram, or PCNB® at 2.5 g kg^{-1} seed reduces the pre-emergence damping off. Metalaxyl® (0.3 g kg^{-1} a.i.) and Captan (3 g kg^{-1} a.i.) are very effective seed treatment fungicides for preventing seed rot and preemergence damping off caused by *Pythium* sp (Kaiser and Hannan 1983). Seed treatment with Rizolex® 50 WP alone at 3 g kg^{-1} and in a mixture of Rizolex® 50 WP and Thiram 75 WP in 1:1 proportion (3g kg^{-1}) was effective in controlling collar rot of chickpea (Haware, M.P., ICRISAT Center, unpublished data).

Biological Agents

Biological control of soilborne pathogens by means other than thermal inactivation is also encouraged by solarization. *Penicillium pinophilum* was found to be encouraged in solarized soil in wilt-sick plots. The fungus was found antagonistic to FOC when it was introduced in wilt-sick soil in pots in a greenhouse experiment and to some extent in the field (Haware, unpublished data). *Streptomyces diastaticus* is reported to suppress the growth of *S. rolfsii* and reduce seedling mortality (Singh and Reddy 1979). Seed treatment with conidia of *Penicillium oxalicum* significantly reduced seed rot and preemergence damping off of chickpea caused by *P. ultimum* in two naturally infested soils from the Palouse region in eastern Washington, USA (Kaiser and Hannan 1984). The extent to which natural biocontrol is operative is not yet known in soilborne pathogens. It is frequently associated with the addition of organic matter to the soil.

Plant Resistance

At ICRISAT Center, Patancheru, India, effective field-screening and laboratory procedures have been developed and wilt resistance sources identified (Nene and Reddy 1987). Some of them such as ICC 12237 and 12269 have additional resistance to dry root rot and black root rot (Nene 1988). Multilocational testing for fusarium wilt and root rots has been carried out through active cooperation between national programs and ICRISAT, and stable resistance has been found. Over 150 wilt resistant sources are available at ICRISAT. Wilt resistance has been incorporated into high yielding desi and kabuli backgrounds. Wilt-resistant short-duration kabuli cultivars ICCV 2, 3, 4, and 5 escape terminal drought in South and Central India (Kumar et al. 1985). Chickpea lines, Avrodhi, BG 246, ICCC 32, and ICCC 42 were found to be resistant at several locations in India in multilocation testing. In spite of the existence of races in *F. oxysporum* f.sp. *ciceri*, it has not been difficult to identify a high level of resistance that is operative at several locations. Chickpea breeding programs at Culiacan and Sonora in Mexico have several advanced wilt resistant lines (Morales 1986). In California, a wilt-resistant cultivar Surutato 77 from Mexico was introduced in 1980 and presently covers most of the chickpea area. Recently two large seeded kabuli cultivars UC 15 and UC 27 have been released (Buddenhagen et al. 1988). Screening trials in a fusarium wilt sick plot at Cordoba, Spain in 1987 and 1989 indicated the wilt resistance in some small seeded kabuli germplasm from ICARDA. Field screening in a wilt sick plot at Beja, Tunisia resulted in identifying the wilt-resistant chickpea cultivar Amdoun 1 in 1986.

Conclusion

Disease management is an integral component of chickpea crop production. Grain legumes are widely grown in developing countries where resources available to farmers are limited. Only an integrated management system can effectively control root pathogens. The benefit derived from the development of resistant cultivars can be maintained only by using cultural and management practices known to reduce disease severity. The disease development depends on the initial inoculum density, the infection rate, and the duration and stage of the plant host. Therefore, control methods to prevent a disease epidemic should be aimed at reducing the initial inoculum density, the survival and dispersal of inoculum, the rate of infection and the time the crop is exposed to infection.

References

Bowden, R.L., Wiese, M.V., Crock, J.E., and **Auld, D.L.** 1985. Root rot of chickpeas and lentils caused by *Thielaviopsis basicola*. Plant Disease 69:1089-1091.

Buddenhagen, I.W., Workneh, F., and **Bosque-Perez, N.A.** 1988. Chickpea improvement and chickpea diseases in California. International Chickpea Newsletter 19:9-10.

Chauhan, Y.S., Nene, Y.L., Johansen, C., Haware, M.P., Saxena, N.P., Sardar Singh, Sharma, S.B., Sahrawat, K.L., Burford, J.R., Rupela, O.P., Kumar Rao, J.V.D.K., and **Sithanantham, S.** 1988. Effects of soil solarization on pigeonpea and chickpea. Research Bulletin no. 11. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Halila, H.M., and **Harrabi, M.M.** 1987. Wilt of chickpea in Tunisia caused by *Verticillium albo-atrum* Plant Disease 71:101.

Haware, M.P., and **Nene, Y.L.** 1980. Influence of wilt at different stages on the yield loss in chickpea. Tropical Grain Legume Bulletin 19:38-44.

Haware, M.P., and **Nene, Y.L.** 1982a. Symptomless carriers of the chickpea wilt fusarium. Plant Disease 66:250-251.

Haware, M.P., and **Nene, Y.L.** 1982b. Races of *Fusarium oxysporum* f.sp. *ciceri*. Plant Disease 66:809-810.

Haware, M.P., Nene, Y.L., and **Natarajan, M.** 1986. Survival of *Fusarium oxysporum* f.sp. *ciceri* in soil in absence of chickpea. Page 1 *in* Management of soil-borne diseases of crop plants: Proceeding of National Seminar. 8-10 Jan 1986 Coimbatore, India: Tamil Nadu Agricultural University.

Haware, M.P., Nene, Y.L., and **Rajeshwari, R.** 1978. Eradication of *Fusarium oxysporum* f.sp. *ciceri* transmitted in chickpea seed. Phytopathology 68:1364-1367.

Jimenez-Diaz, R.M., and **Trapero-Casas, A.** 1985. Use of fungicide treatments and host resistance to control the wilt and root rot complex of chickpeas. Plant Disease 69:591-595.

Jimenez-Diaz, R.M., Trapero-Casas, A., and **Cabrera de la Colina,** J. 1989. Races of *Fusarium oxysporum* f.sp. *ciceri* infecting chickpeas in southern Spain. Pages 515-520 *in* Vascular wilt diseases of plants (Tjamos, E.C., and Beckman, C., eds.). NATO ASI Series, vol. H28. Berlin, Federal Republic of Germany: North Atlantic Treaty Organization.

Kaiser, W.J., and **Hannan, R.M.** 1983. Etiology and control of seed decay and preemergence damping-off of chickpea by *Pythium ultimum*. Plant Disease 67:77-81.

Kaiser, W.J., and **Hannan, R.M.** 1984. Biological control of seed rot and preemergence damping off of chickpea with *Penicillium oxalicum*. Plant Disease 68:806-811.

Kraft, J.M., Haware, M.P., and Hussein, M.M. 1988. Root rot and wilt diseases of food legumes. Pages 565-575 *in* World crops: cool season food legumes proceedings of the International Food Legume Research Conference on Pea, Lentil, Faba Bean andChickpea, 6-11 Jul 1986, Spokane, Washington, USA (Summerfield, R.J., ed.). Dordrecht, Netherlands: Kluwer Academic Publishers.

Kumar, J., Haware, M.P., and **Smithson, J.B.** 1985. Registration of four short duration fusarium wilt-resistant kabuli (garbanzo) chickpea germplasms. Crop Science 25:576-577.

Morales, G.J.A. 1986. Chickpea breeding program in Sonora,Mexico. International Chickpea Newsletter 15:11-12.

Nene, Y.L. 1988. Multiple-disease resistance in grain legumes. Annual Review of Phytopathology 26:203-217.

Nene, Y.L., and **Reddy, M.V.** 1987. Chickpea diseases and their control. Pages 233-270 *in* The chickpea (Saxena, M.C., and Singh, K.B., eds.). Wallingford, Oxon, UK: CAB International.

Phillips, J.C. 1988. A distinct race of chickpea wilt in California. International Chickpea Newsletter 18:19-21.

Sattar, A., Arif, A.G., and **Mohy-ud-din, M.** 1953. Effect of soil temperature and moisture on the incidence of gram wilt. Pakistan Journal of Scientific Research 5:16-21.

Singh, P.J., and **Mehrotra, R.S.** 1982. Influence of soil moisture and temperature on *Rhizoctonia bataticola* infection of gram. Indian Phytopathology 35:327-329.

Singh, R.S., and **Reddy, C.S.** 1979. Suppression of damping off of tomato and seedling blight of chickpea and sugarbeet by strains of *Streptomyces diastaticus* Indian Phytopathology 32:374-377.

Trapero-Casas, A., and **Jimenez-Diaz, R.M.** 1985. Fungal wilt and root rot diseases of chickpea in southern Spain. Phytopathology 75:1146-1151.

Progress and Problems in the Management of Nematode Diseases

N. Greco[1] and S.B. Sharma[2]

Abstract

Several nematode species have been reported to be associated with chickpea. A few of these cause severe damage to this pulse crop. Root-knot nematodes, Meloidogyne arenaria, M. incognita, *and* M. javanica *infect chickpea in the Indian sub-continent, and* M. artiellia *is noxious in the Mediterranean basin. The cyst nematode,* Heterodera ciceri, *causes yield reduction in northern Syria. The root-lesion nematodes,* Pratylenchus thornei *and* Pratylenchus *spp, and the reniform nematode,* Rotylenchulus reniformis, *have also been reported to reduce yield in chickpea. Nematodes cause root vascular and parenchyma disorders, suppress rhizobium nodulation, and interact with several soilborne fungi. Infested plants suffer drought stress, earlier senescence, and yield poorly. Crop rotation can provide good control of* H. ciceri *and* M. artiellia *because of their rather narrow host ranges, but not of the other* Meloidogyne *species,* Pratylenchus *spp, and* R. reniformis, *which are polyphagous. A suitable chickpea cultivar with resistance to nematodes is not available. Therefore investigations are required to enable development of crop management strategies that can be utilized to maintain nematode populations below threshold levels. Also, sources of nematode resistance in chickpea need to be identified for use in future breeding programs.*

Résumé

Progrès et problèmes de la lutte hcontre les maladies provoquées par les nématodes : *Plusieurs espèces de nématodes ont été signalées en association avec le pois chiche. Quelques espèces provoquent des dégâts importants à cette légumineuse. Les nématodes galligènes,* Meloidogyne arenaria, M. incognita, *et* M. javanica *infestent le pois chiche dans le sous-continent indien et* M. artiellia *est nuisible dans le bassin méditerranéen. Le nématode du kyste,* Heterodera ciceri, *occasionne les pertes de rendement en Syrie du Nord. Les nématodes des lésions,* Pratylenchus thornei *et* Pratylenchus *spp, et le nématode réniforme* Rotylenchulus reniformis, *ont également été liés aux réductions de rendement chez le pois chiche. Les nématodes provoquent des troubles du parenchyme et des tissus vasculaires des racines, suppriment la nodulation du rhizobium et interagissent avec plusieurs champignons transmis par le sol. Les plantes infestées subissent le stress hydrique, la sénescence précoce et les pertes de rendement. La rotation des cultures permet une bonne maîtrise de* H. ciceri *et* M. artiellia, *étant donné leur étendue d'hôtes assez limitée, mais il n'en va pas de même pour les autres espèces* Meloidogyne, *les* Pratylenchus *spp, et* R. reniformis, *qui sont polyphages. On ne dispose pas d'un cultivar convenable de pois chiche résistant aux nématodes. Des recherches sont donc nécessaires pour permettre l'élaboration des stratégies de gestion des cultures qui*

1. Nematologist, Consiglio Nazionale delle Ricerche, Istituto di Nematologia Agraria Applicata ai Vegetali, via Amendola, 165/A, 70126 Bari, Italy.

2. Plant Nematologist, Legumes Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

ICRISAT Conference Paper no. CP 586.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

peuvent être utilisées pour maintenir les populations de nématodes en-deçà des niveaux seuil. Par ailleurs, les sources de résistance aux nématodes chez le pois chiche devraient être identifiées en vu d'une éventuelle exploitation dans des programmes de sélection.

Nematodes are a major constraint in growing chickpea (*Cicer arietinum* L.) (Greco 1987; Sharma 1988; Sikora and Greco, in press). They damage roots causing vascular disorders, and extensive necrosis, suppress rhizobium nodulation, reduce grain quality, and may increase the severity of many soilborne diseases. Symptoms of nematode attack are not specific on aerial parts, their intensity varying with nematode population densities at sowing and environmental conditions. Infected plants are stunted, chlorotic, early senescing, poorly producing, and have a reduced grain protein content (Sikora and Greco, in press).

Even though several nematode species have been reported in chickpea, only a few are very noxious. These are discussed here.

Major Nematodes of Chickpea

Root-knot nematodes, *Meloidogyne* spp., are the world's most widespread and most damaging plant-parasitic nematode group. Among them *Meloidogyne incognita* (Kofoid and White) Chitw., *M. javanica* (Treub) Chitw. and to a less extent, *M. arenaria* (Neal) Chitw., are of importance in the Indian sub-continent, and *M. artiellia* Franklin in the Mediterranean area. Infected roots show characteristic galls, whose size depends upon nematode species and plant cultivar. The first three of these species have wide host ranges, including wild plant species. In India, *M. incognita* and *M. javanica* are reported to attack more than 141 and 232 plant genera, respectively. These species prefer hot weather and can cause serious problems in regions where summers are long and winters are short and mild, such as peninsular India. However, severe damage also occurs in northern India and in the terai region of Nepal where minimum temperatures fall below 15°C for many days during the winter crop season. The tolerance limits of host plants to *Meloidogyne* spp is usually less than 1 egg cm-3 of soil. Consistent efforts have not been made to estimate damage caused by root-knot nematodes to chickpea on a national basis in India, Nepal, or Pakistan. However, some estimates of yield loss based on nematicide tests and on surveys of the crop, indicate that losses due to *Meloidogyne* spp. can be negligible to very high in many parts of India and in the terai region of Nepal.

Meloidogyne artiellia can infect chickpea even at soil temperature below 15°C (Di Vito and Greco 1988a). Galls caused by this nematode are small or may be absent and the only visible symptoms on infected roots are egg masses. These can be seen by early April on roots of winter chickpea. *M. artiellia* survives during dry seasons as anhydrobiotic second-stage juveniles. Its host range is confined to cereals, legumes, and crucifers (Sikora and Greco, in press).

Spring chickpea is more susceptible to *M. artiellia* than winter chickpea, the tolerance limits being of 0.016 and 0.14 egg cm^{-3} of soil, respectively. Complete crop failure would occur in fields infected with more than 1 egg cm^{-3} of soil (Di Vito and Greco 1988b). Although *M. artiellia* is widespread in the Mediterranean area, severe damage to chickpea has only been reported from Italy, Spain, and, especially, from Syria. The chickpea cyst nematode, *Heterodera ciceri* Vovlas, Greco and Di Vito, has been reported from northern Syria and is the only cyst nematode that causes severe damage to chickpea. It develops when soil temperature rises above 10° C. Cysts occur by late April onwards and persist in the soil over several years (Greco et al. 1988). Infected roots show small necrotic spots from which females emerge later.

H. ciceri causes damage whenever its population densities exceed 1 egg g^{-1} of soil (Greco et al. 1988) and complete crop failure occurs at 64 eggs g^{-1} of soil. Its host range is, however, rather narrow compared to root-knot nematodes. Other good hosts are lentil, pea and grass pea, while reproduction on wild legumes is unknown (Sikora and Greco, in press).

Among root-lesion nematodes *Pratylenchus thornei* Sher and Allen is distributed worldwide and damages chickpea in Syria and India (Walia and Seshadri 1985; Sikora and Greco, in press). Other *Pratylenchus* spp. (*P. zeae, P. brachyurus*) are also common on legumes and may infect chickpea as well. They cause cavities within the cortical parenchyma. Infected roots show many necrotic segments. Even though *P. thornei* seems to develop better from fall to early spring, lesion nematodes are adapted to a large variety of environmental conditions and have large host ranges. Damage caused by *P. thornei* is less impressive than that caused by the previous species, but the tolerance limit of chickpea to this species has not been determined in the field.

Rotylenchulus reniformis Linford et Oliveira has been found associated with chickpea decline mainly in India, where it seems to be noxious when its population densities exceeds 0.5 specimen cm^{-3} of soil. The nematode has a wide host range including wild species.

Management Problems

Chickpea is a rather low benefit crop. Chemical control although effective would be uneconomic. The efficacy of seed treatments needs confirmation (Greco and Sikora, in press). Soil solarization, which would be highly effective in most of the chickpea growing areas, is also expensive, and the use of soil amendments is not practicable. Crop rotation still remains an economic and effective way to prevent yield losses. *H. ciceri* can be controlled easily by rotating chickpea with non-leguminous crops. Good control of *M. artiellia* can also be achieved by alternating chickpea with crops other than legumes, cereals, and crucifers. Unfortunately the other *Meloidogyne* spp., *P. thornei*, and *R. reniformis* have large host ranges and their control by crop rotation is more difficult. As reported earlier, in India *M. incognita* and *M. javanica* attack many plant genera. These *Meloidogyne* species usually do not reproduce on winter cereals. Therefore cereals can be satisfactorily rotated with chickpea. While *Pratylenchus thornei* develops better on winter and spring than on summer crops. Care must also be taken to prevent the growth of weed hosts that may support and increase nematode populations. Postponing the sowing of chickpea when the soil temperature is unfavorable to root-knot nematodes, would provide satisfactory control in northern India, Nepal, and Pakistan.

Suggestions for Future Investigations

The above control measures require an accurate extension service and knowledge of the distribution of nematodes, their races, biology, dynamics, host relationship, and the yield losses they cause under different environmental conditions. Unfortunately such information is lacking for most chickpea growing areas. A major problem is the small number of chickpea nematologists involved. When compared with other important crops, very little research has been done on nematode problems of chickpea. However, awareness of nematode problems in chickpea is increasing gradually and this trend is likely to continue. Therefore, surveys should be encouraged to focus more on the nematode problems of the crop. Investigations should be encouraged to identify sources of resistance for future breeding programs. Since several pathogens might affect chickpea in the same area, it is suggested that cooperative breeding programs be undertaken to release cultivars having resistance to more than one pathogen. It is important to acquire information for development of crop management strategies to maintain nematode populations below critical threshold levels.

References

Di Vito, M., and **Greco, N.** 1988a. Investigation on the biology of *Meloidogyne artiellia*. Revue de Nematologie 11:221-225.

Di Vito, M., and **Greco, N.** 1988b. The relationship between initial population densities of *Meloidogyne artiellia* and yield of winter and spring chickpea. Nematologia Mediterranea 16:163-166.

Greco, N. 1987. Nematodes and their control in chickpea. Pages 271-281 *in* The chickpea (Saxena M.C., and Singh, K.B., eds.). Wallingford, Oxon, UK: CAB International.

Greco, N., **Di Vito, M.**, **Reddy, M.V.**, and **Saxena, M.C.** 1988. Effect of *Heterodera ciceri* on yield of chickpea and lentil and development of this nematode on chickpea in Syria. Nematologica 34:98-114.

Sharma, S.B. 1988. Nematode diseases of groundnut, pigeonpea, chickpea, sorghum, and pearl millet. Legume Pathology Progress Report no. 1. Patancheru, A.P. 502 324, India : International Crops Research Institute for the Semi-Arid Tropics. 45 pp. (Limited distribution.)

Sikora, R.A., and **Greco, N.** (in press). Grain Legumes. *In* Plant-parasitic nematodes in sub-tropical and tropical agriculture (Luc, M., Sikora, R.A., and Bridge, J., eds.). Wallingford, Oxon, UK: CAB International.

Walia, R.K., and **Seshadri, A.R.** 1985. Pathogenicity of the root-lesion nematode *Pratylenchus thornei* on chickpea. International Chickpea Newsletter 12:31.

Viral Diseases of Chickpea

W.J. Kaiser[1], A.M. Ghanekar[2], Y.L. Nene[3], B.S. Rao[3], and V. Anjaiah[3]

Abstract

At least 16 viruses have been identified as natural chickpea pathogens in chickpea-producing countries. Chickpea viruses occur in the following groups: alfalfa mosaic virus, carlavirus, ilarvirus, luteovirus, nepovirus, pea enation mosaic virus, potyvirus, and rhabdovirus. The economic importance of these diseases needs to be determined. The relationship of sowing date, plant density, insect vector biology, environmental conditions, and alternative hosts to disease development and spread needs to be studied. Chickpea diseases caused by viruses are frequently attributed to other causes, such as soilborne pathogens. Losses due to virus diseases of chickpea can increase dramatically when the culture of the crop shifts from summer to winter sowing, as occurred recently in California, USA. Improved techniques are needed to detect, identify, and characterize viruses of chickpea, particularly those in the luteovirus group. Efforts at controlling major virus diseases of chickpea by various means, especially by host-plant resistance, need to be intensified. Breeding for disease resistance is an area where new technologies can play an important role in the not-too-distant future.

Résumé

Maladies virales du pois chiche : *Au moins 16 virus ont été identifiés comme étant les pathogènes naturels du pois chiche dans les pays producteurs. Les virus du pois chiche se trouvent dans les groupes suivants : virus de la mosaïque de la luzerne, carlavirus, ilarvirus, lutéovirus, népovirus, virus de la mosaïque verruqueuse du pois, potyvirus et rhabdovirus. L'importance économique de ces maladies devrait être déterminée. Le rapport entre la date de semis, la densité du peuplement, la biologie des insectes vecteurs, les conditions de l'environnement et les hôtes de remplacement d'une part, et le développement et l'extension de la maladie, d'autre part, devrait également être étudié. Les viroses du pois chiche sont souvent attribuées à d'autres causes, comme les pathogènes transmis par le sol. Les pertes occasionnées par les viroses du pois chiche peuvent s'intensifier de manière étonnante lorsque la culture passe des semis d'été aux semis d'hiver, comme cela s'est produit récemment en Californie, aux Etats-Unis. Des techniques améliorées sont nécessaires pour dépister, identifier et caractériser les viroses, particulièrement celles du groupe lutéovirus. Des efforts pour lutter contre les principales viroses du pois chiche par divers moyens, surtout à l'aide de la résistance de la plante-hôte, doivent être intensifiés. La sélection pour la résistance aux maladies est un domaine dans lequel des technologies nouvelles peuvent jouer un rôle important dans un avenir proche.*

1. Research Plant Pathologist, United States Department of Agriculture (USDA), Agricultural Research Service (ARS), Regional Plant Introduction Station, 59 Johnson Hall, Washington State University, Pullman, WA 99164-6402, USA.

2. Plant Pathologist, Legumes Program, ICRISAT Cooperative Research Station, Haryana Agricultural University Campus, Hisar 125 004, Haryana, India.

3. Deputy Director General, and Research Associates, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

ICRISAT Conference Paper No. CP 587.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

References

Anjaiah, V., Reddy, D.V.R., Manohar, S.K., Naidu, R.A., Nene, Y.L., and Ratna, A.S. 1989. Isolation and characterization of a potyvirus associated with bushy dwarf symptom in chickpea, *Cicer arietinum*, in India. Plant Pathology 38:520-526.

Ashby, J.W., and Johnstone, G.R. 1985. Legume luteovirus taxonomy and current research. Australasian Plant Pathology 14:2-7.

Bos, L., Hampton, R.O., and Makkouk, K. M. 1988. Viruses and virus diseases of pea, lentil, faba bean and chickpea. Pages 591-615 *in* World crops: cool season food legumes: Proceedings of the International Food Legume Research Conference on Pea, Lentil, Faba Bean and Chickpea, 6-11 Jul 1986, Spokane, Washington, USA (Summerfield, R.J., ed.). Dordrecht, Netherlands: Kluwer Academic Publishers.

Bosque-Perez, N.A., and Buddenhagen, I.W. (in press). Studieson epidemiology of virus disease of chickpea in California. Plant Disease 74.

Bosque-Perez, N.A., and Buddenhagen, I.W. (In press). Chickpea virus disease epidemiology in California. *In* proceedings of the IV International Plant Virus Epidemiology Workshop, 3-8 Sep 1989, Montpellier, France.

Kaiser, W.J., Wyatt, S.D., Hannan, R.M., and Cody, Y. 1988. Chickpea filiform, a new viral disease of *Cicer arietinum*. Plant Disease 72:70-74.

Waterhouse, P.M., Gildow, F.E., and Johnstone, G.R. 1988. Luteovirus group. Descriptions of plant viruses No. 339. Institute for Horticultural Research, Wellesbourne, Warwick, UK: Association of Applied Biologists.

Session 4

Main Items of Presentations and Discussions

- Foliar diseases are most important in the high-productivity chickpea-growing areas between latitudes 25° to 45° N.
- The main foliar diseases are ascochyta blight and botrytis gray mold. Strongly expressed, durable resistance against these diseases has not been identified in the germplasm or obtained through breeding.
- Scope for control rests with integrating host-plant resistance, row spacing, timely application of foliar fungicides, and suitable plant geometry.
- The ultimate goal of research on ascochyta blight is to develop durable resistant varieties, but 60 years of efforts have not solved the problem. Major reasons for this are inadequate knowledge of pathogen variability, and of environmental effects on disease development. Assumptions on resistance and resistance genetics may thus have been confounded, and therefore, new approaches such as partial resistance breeding, and more information on pathogen/host/environment interactions are needed.
- In Punjab, India, 12 races of ascochyta blight have been reported, and by screening 10 000 germplasm lines, 200 lines graded 3-4 on a 1-9 scoring scale (where 1=free and 9=killed) could be identified.
- Research in Nepal showed that intercropping chickpea with flax reduced damage from botrytis gray mold.
- Wilt and root rots are globally important chickpea diseases, and are particularly damaging under high temperature and drought conditions.
- An integrated management approach, that encompasses host-plant resistance, seed health, appropriate cultural practices, and biological manipulation, are required for wilt and root rot control.
- Race 0 of fusarium wilt, a Spanish isolate, is not pathogenic to JG 62, a cultivar susceptible to six other identified races.
- Although field screening for individual soilborne diseases is complicated by the development of pathogenic mixtures in the soil, the different diseases can often be distinguished as they produce different symptoms, and tend to exclude one another after plant infection.
- Several nematode species are harmful to chickpea. The most important are root-knot (*Meloidogyne* spp.), cyst (*Heterodera ciceri*), and lesion (*Pratylenchus* spp.) nematodes.
- Nematode resistant genotypes need to be identified, and appropriate crop management practices developed for nematode control; these should include crop rotation, adjustment of sowing date, solarization, and nematicide application.
- There may be a relationship between soil type and nematode incidence. For instance, light sandy soils show more nematode incidence than heavier soils.
- There are at least 13 viruses associated with chickpea. Their epidemiology, crop damage potential, distribution and host-plant range are not well documented, while little is known about host-plant resistance.
- Chickpea seed introduced into California contained seedborne viruses in 10% of the samples. A virus-tolerant genotype has been identified in California and recommended for use in breeding programs.

Recommendations

Ascochyta Blight

- There is a need to better understand the biology and ecology of the pathogen.
- High priority must be given to understanding the epidemiology of the disease at different locations. Studies on the teleomorphic stage and the role it plays in the dissemination and survival of the pathogen need to be undertaken in different areas.
- Research on pathogenic variability is needed in terms of host specificity and aggressiveness. Such research should be carried out with standardized methodology.
- A high level of resistance to the pathogen does not exist in currently used cultivars. Therefore, a program for germplasm enhancement for better blight resistance should be undertaken.
- There is a need for innovative resistance breeding programs that include biotechnology, and for a better understanding of the genetics of disease resistance.
- The establishment of an informal working group organized by ICARDA/ICRISAT on ascochyta blight of chickpea is proposed to encourage the exchange of information and cooperation in research on the disease.

Wilt and Root Rot

- There is a need to use the standard technique developed at ICRISAT for the identification of races of the fusarium wilt pathogen and to study the genetics of resistance to these races.

- Sources of resistance to fusarium wilt are available in the chickpea germplasm. However, greater emphasis should be given to identification and development of germplasm with resistance to specific and individual races of this pathogen, and to root rot pathogens.
- There is a need to incorporate resistances to wilt, root rot, and ascochyta blight into large-seeded (100-seed mass > 40 g) kabuli types for North Africa and the Mediterranean regions.
- There is a need for further study of the importance of wilt and root rot diseases in farmers' fields in particular regions, and to identify pathogens and races of these pathogens in the wilt-sick plots used for resistance screening.
- Wilt and root rot resistant cultivars with wider adaptability are needed.

Nematodes

- There is a need to assess the importance of nematode diseases in chickpea-growing areas. Cooperative research between ICARDA and the Instituto Nematologia, Bari, Italy indicates that nematodes can be a problem in some chickpea-growing areas. There is a need to extend cooperative studies.

Viral Diseases

- There is a strong need to survey and identify viruses affecting chickpea in different chickpea-growing areas of the world, and to study their epidemiology.
- Improved techniques are needed to detect, identify, and characterize chickpea viruses.
- Efforts to control major virus diseases of chickpea, especially by host plant resistance, need to be intensified.

Other Important and Potentially Serious Diseases of Chickpea. There are several other diseases that are important in given regions or areas, e.g., botrytis gray mold in northern India, Nepal, and Bangladesh. Modification of cultural practices, such as sowing date and irrigation, may result in heavy crop losses from, for instance, viral diseases, *Orobanche*, and some root rots that are currently considered of minor importance.

Research on the following diseases, considered serious in certain areas, should be encouraged:

- Botrytis gray mold
- Sclerotinia stem rot
- Sclerotium collar rot
- Rust
- *Orobanche*
- Phoma blight
- Stemphylium blight
- Other root rot and foliar diseases
- The use of new technologies in breeding for disease resistance is to be encouraged.
- The development of cultivars with multiple disease resistance for specific situations should be considered.
- Efforts should be made to increase the number of well-trained pathologists, virologists, and nematologists to work on chickpea diseases.
- Economic losses caused by chickpea diseases should be assessed in order to establish research priorities.
- Integrated control of chickpea diseases, including the use of fungicides and other control measures to compensate for the lack of suitable levels of host resistance should be investigated.

Session 4

Principaux thèmes de présentation et de discussion

- Les maladies foliaires sont les plus importantes dans les zones d'exploitation de pois chiche à haute productivité entre les latitudes 25°–45° N.

- Les maladies principales foliaires sont la flétrissure ascochytique et la pourriture grise due à botrytis. Une résistance durable, fortement exprimée, contre ces maladies n'a pas été identifiée dans les ressources génétiques ni obtenue à travers la sélection.

- La lutte peut se faire par l'intégration de la résistance plante-hôte, espacement des rangs, application à temps de fongicides foliaires, et une géométrie de la plante convenable.

- L'objectif ultime de la recherche sur la flétrissure ascochytique est de mettre au point les variétés à résistance durable, mais 60 années d'efforts n'ont pas résolu le problème. Les raisons principales de cela sont la connaissance insuffisante de la variabilité pathogénique, et des effets environnementaux sur le développement de la maladie. Des assomptions sur la résistance et sur la génétique de la résistance auraient pu ainsi être confondues, et, par conséquent, de nouvelles approches tels la sélection pour la résistance partielle et davantage d'informations sur les interactions pathogène-hôte-environnements sont nécessaires.

- Au Punjab, en Inde, 12 races de la flétrissure ascochytique ont été constatées, et le criblage de 10 000 lignées sélectionnes a permis d'identifier 200 lignées classes 3 à 4 sur une échelle de notation allant de 1 à 9 (où 1 = exempte et 9 = détruite).

- Les travaux de recherche au Népal ont montré que l'association du pois chiche avec le lin permet de réduire les dégâts causés par la pourriture grise dû à botrytis.

- Le flétrissement et les pourritures des racines sont des maladies globalement importantes du pois chiche. Elles causent des dégâts particulièrement importants dans des conditions de température élevée et de sécheresse.

- Une approche de lutte intégrée (integrated management), englobant la résistance de la plante-hôte, la santé des semences, des pratiques culturales appropriées et la manipulation biologique sont nécessaires pour lutter contre le flétrissement et la pourriture des racines.

- La race 0 du flétrissement fusarien, un isolat Spanish, n'est pas pathogénique à JG 62, un cultivar susceptible à six autres races identifiées.

- Bien que le criblage au champ pour les maladies individuelles transmises par le sol soit compliqué par le développement de mélanges pathogéniques dans le sol, les différentes maladies peuvent souvent être distinguées car elles produisent de différents symptômes, et tendent à s'exclure l'une et l'autre après l'infection de la plante.

- Plusieurs espèces de nématodes sont nuisibles au pois chiche. Les plus importantes sont les nématodes galligènes (*Meloidogyne* spp.) les nématodes de kyste (*Heterodera ciceri*), et les nématodes des lésions (*Pratylenchus* spp.).

- Des génotypes résistants aux nématodes doivent être identifiés, et les pratiques appropriées d'aménagement des cultures doivent être mises au point pour la lutte contre les nématodes. Celles-ci doivent inclure la rotation des cultures, l'ajustement de la date de semis, la solarisation, et l'application de nématicides.

- Il peut y avoir une relation entre le type du sol et l'incidence des nématodes. Par exemple, des sols légers sableux montrent plus d'incidence de nématodes que les sols plus lourds.

- Il y a au moins 13 virus associés avec le pois chiche. Leur épidemiologie, potentiel de dégâts à la culture, distribution et gamme de plantes-hôtes ne sont pas bien documentés, alors que très peu est connu à l'égard de la résistance de la plante-hôte.

- Les semences de pois chiche introduites en Californie ont contenu des virus transmis par le sol dans 10% des échantillons. Un génotype tolérant au virus a été identifié en Californie et a été recommandé pour l'utilisation dans des programmes de sélection.

Recommandations

Flétrissure ascochytique

- Il est nécessaire de mieux comprendre la biologie et l'écologie de l'agent pathogène.

- Une haute priorité doit être accordée à la compréhension de l'épidemiologie de la maladie à des emplacements différents. Des études sur le stade téléomorphique et le rôle qu'il joue dans la dissémination et la survie du pathogène doivent être entreprises dans des zones différentes.

- La recherche sur la variabilité pathogénique est requise en ce qui concerne la spécificité de l'hôte et l'agressivité. De tels travaux doivent être entrepris avec une méthodologie normalisée.

- Les cultivars exploités actuellement ne disposent pas d'un niveau élevé de résistance au pathogène. Donc, un programme d'amélioration des ressources génétiques en vue d'une meilleure résistance à la flétrissure doit être entrepris.

- Il existe un besoin pour des programmes innovateurs de sélection pour la résistance, qui comprennent la biotechnologie, ainsi que pour une meilleure connaissance de la génétique de la résistance à la maladie.

- L'établissement d'un groupe de travail informel organisé par l'ICARDA/ICRISAT sur la flétrissure ascochytique du pois chiche est proposé pour encourager l'échange d'informations et la coopération en matière de recherche sur la maladie.

Flétrissement et pourriture des racines

- Il faut utiliser la technique standard mise au point à l'ICRISAT pour l'identification des races du pathogène du flétrissement fusarien et pour l'étude de la génétique de la résistance à ces races.

- Les sources de résistance au flétrissement fusarien sont disponibles dans les ressources génétiques du pois chiche. Cependant, un accent plus important doit être accordé à l'identification et à la mise au point de ressources génétiques ayant une résistance aux races spécifiques et individuelles de ce pathogène, et aux pathogènes de la pourriture des racines.

- Il faut incorporer des résistances au flétrissement, à la pourriture des racines et à la flétrissure ascochytique dans des types kabuli à gros grains (masse de 100 graines > 40 g) pour l'Afrique du Nord et les régions méditerranéennes.

- Il faut étudier davantage l'importance des maladies de flétrissement et de pourriture des racines en milieu réel dans certaines régions, et identifier des pathogènes et les races de ces pathogènes dans les parcelles infectées de flétrissement utilisées pour le criblage pour la résistance.

- Des cultivars résistants au flétrissement et à la pourriture des racines avec une adaptabilité plus large sont nécessaires.

Nematodes

- Il existe un besoin pour l'évaluation de l'importance des maladies dues aux nématodes dans les régions d'exploitation du pois chiche. La recherche coopérative entre l'ICARDA et l'Instituto Nematologia, Bari, Italie, indique que les nématodes peuvent constituer un problème dans quelques régions productrices de pois chiche. Il est nécessaire d'étendre les études coopératives.

Maladies virales

- Il est nécessaire de recenser et d'identifier les virus qui atteignent le pois chiche dans différentes régions d'exploitation dans le monde, et d'étudier leur épidemiologie.

- Des techniques améliorées sont nécessaires pour détecter, identifier et caractériser les virus du pois chiche.

- Des efforts pour lutter contre les maladies virales majeures du pois chiche, surtout par la résistance de la plante-hôte, doivent être intensifiés.

D'autres maladies importantes et potentiellement graves de pois chiche

Il y a plusieurs autres maladies qui sont importantes dans des régions ou zones données, par exemple, la pourriture grise due à botrytis en Inde du Nord, au Népal et au Bangladesh. La modification de pratiques culturales, telles date de semis et irrigation, pourraient entraîner des pertes importantes de récoltes dues, par exemple, aux maladies virales, *Orobanche*, et certaines pourritures des racines qui sont actuellement considérées comme d'importance mineure.

La recherche sur les maladies suivantes, considérées comme graves dans quelques régions, doit être encouragée :

- Pourriture grise due à botrytis
- Pourriture sclerotinia
- Pourriture du collet
- Rouille
- *Orobanche*
- Flétrissure Phoma
- Pourriture due à stemphylium
- D'autres maladies foliaires et pourritures des racines
- L'utilisation de nouvelles technologies dans la

sélection pour la résistance aux maladies doit être encouragée.

- La mise au point de cultivars avec la résistance multiple aux maladies pour les situations particulières doit être considérée.

- Des efforts doivent être faits pour augmenter le nombre de pathologistes, de virologistes, et de nématologistes bien formés qui peuvent travailler sur les maladies de pois chiche.

- Des pertes économiques causées par les maladies de pois chiche doivent être évaluées afin d'établir des priorités de recherche.

- La lutte intégrée contre les maladies de pois chiche, y compris l'emploi de fongicides et d'autres mesures de lutte pour compenser pour le manque de niveaux appropriés de résistance de la hôte, doivent être examinés.

Session 5

Insect Pests

Some Future Research Directions for Integrated Pest Management in Chickpea: A Viewpoint

M.P. Pimbert[1]

Abstract

The insect pests (IP) that feed on different parts of the chickpea plant are briefly presented together with a summary of the recent progress that has been made in controlling such key pests as Helicoverpa armigera *and* Liriomyza cicerina.

The value of using maps showing the severity and extent of pest damage to set integrated pest management (IPM) research priorities for different agro-ecological zones is illustrated with reference to H. armigera *in India. The gaps in basic knowledge required to develop sustainable IPM schemes are then identified. Research areas and issues that have been neglected, overlooked, or opened up with recent advances in science and technology are discussed with a view to charting out a possible research agenda for the next decade. The themes that call for more research attention are: host-plant resistance and G x E interactions; vegetation management and biological control; IPM and the selective use of plant diversity; biotechnology and pest control; group action to complement pest controls aimed at individual households and sustainability.*

Résumé

Nouvelles orientations de recherche pour une lutte intégrée contre les ravageurs du pois chiche—un point de vue : *Les insectes ravageurs qui consomment diverses parties de la plante de pois chiche sont brièvement présentés avec un résumé des progrès récents dans la lutte contre les insectes les plus nuisibles, comme* Helicoverpa armigera *et* Liriomyza cicerina. *L'exemple de* H. armigera *en Inde est utilisé pour illustrer comment une cartographie des attaques des ravageurs (intensité, distribution spatiale) peut aider à définir les priorités de recherche pour différentes zones agroécologiques. On identifie ensuite les lacunes dans les connaissances de base nécessaires pour élaborer des formes de lutte intégrée durables ('sustainable'). Les thèmes de recherche et les problèmes qui ont été négligés, oubliés, ou mis en relief grâce aux progrès récents de la science et de la technologie, sont examinés dans le but d'établir une stratégie de recherche pour la prochaine décennie. Les thèmes qui exigent davantage de recherche sont : la résistance variétale et les interactions génotype × environnement; la gestion de la végétation et la lutte biologique; la lutte intégrée et l'usage sélectif de la diversité végétale; les biotechnologies et la lutte contre les ravageurs; l'action collective pour compléter les moyens de lutte individuels et la durabilité des actions ('sustainability').*

---

1. Principal Entomologist, Legumes Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

ICRISAT Conference Paper no. CP 562.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

Compared with most other semi tropical grain legumes, chickpea has relatively few insect pests and generally experiences little pest-induced loss. Many insects and other small animals seem to be deterred by the acidic (pH 1.3) exudates of the glandular hairs that cover the chickpea plant. In addition to this, chickpea is usually sown before, or just after, the winter in most areas of the world where it is of importance. The crop therefore grows when insect activity is low and often matures before populations of potential pests can build up to damaging levels.

Reed et al. (1987) have given an excellent review of the biology of chickpea insect pests and have presented the most recent statement on the art of integrated pest management (IPM) in chickpea. The purpose of this overview is to provide a complementary viewpoint to their perspective. Research areas and issues that have been neglected, overlooked, or opened up with recent advances in science and technology are identified and discussed. This is not done with a view to suggesting a fixed line or strategy for controlling chickpea pests. Instead, the intention is to enrich and broaden the IPM research agenda that workshop participants have been asked to chart out for the next decade.

Table 1. Recorded distribution of the major chickpea pests.

Diptera : Agromyzidae	
Liriomyza cicerina (Rondani)	Europe, West Asia, and northern Africa.
Homoptera : Aphididae	
Aphis craccivora (Koch)	Asia and Africa (as a vector of pea leaf roll virus causing stunt disease)
Lepidoptera : Noctuidae	
Helicoverpa armigera (Hübner)	Asia, Africa, Australia, Europe
Helicoverpa puntigera (Wallengren)	Australia
Helicoverpa virescens (F.)	The Americas
Helicoverpa viriplaca (Hüfnagel)	Eastern Europe and West Asia
Helicoverpa zea (Boddie)	Central America
Spodoptera exigua (Hübner)	Central America and Asia
Coleoptera : Bruchidae	
Callosobruchus analis (Fabricius)	Common in Asia and Africa
Callosobruchus chinensis (Linnaeus)	Very common in all areas especially in Asia
Callosobruchus maculatus (Fabricius)	Very common in all areas

Chickpea Insect Pests

About 60 insect species are known to feed on chickpea (Reed et al. 1987). Figure 1 shows which parts of the chickpea plant are eaten by different types of insects, and Table 1 summarizes the geographical distribution of the major pests of this crop. Broadly speaking, the leafminer, *Liriomyza cicerina* and the pod borers, *Helicoverpa* spp., cause most of the economic losses in the Mediterranean regions of Europe, West Asia, and northern Africa whereas *H. armigera* is the dominant field pest of chickpea in India, Bangladesh, and Pakistan, where more than 85% of the world's chickpea is grown. Other insects such as aphids, cutworms, and termites cause localized problems but bruchid infestations in storage places are more widespread, and can lead to severe losses of valuable protein-rich food in many areas (Labeyrie 1981).

Recent Progress in the Control of Major Chickpea Pests

The emphasis of contemporary pest management research is to find ways of integrating cultural, biological, and chemical controls with host-plant resistance in mutually enhancing and complementary manners. In the case of chickpea appropriate pest management strategies need to be developed for:

- low-input, risk-prone situations where chickpea is grown in resource-poor farming systems under rainfed conditions, and
- higher-input, assured situations where the crop is cultivated in irrigated, higher cash flow systems.

Priority should probably be first given to designing sustainable IPM schemes for the complex, diverse, and fragile low-input agroecosystems of dryland environments. Most chickpea is grown in these areas and this is where the need for food security is, and will be, greatest.

Table 2 summarizes the progress that has recently been made in developing pest-control methods against *H. armigera* and *L. cicerina* in chickpea. The progress or success of the IPM technology listed in Table 2 is probably best evaluated from the point of view of

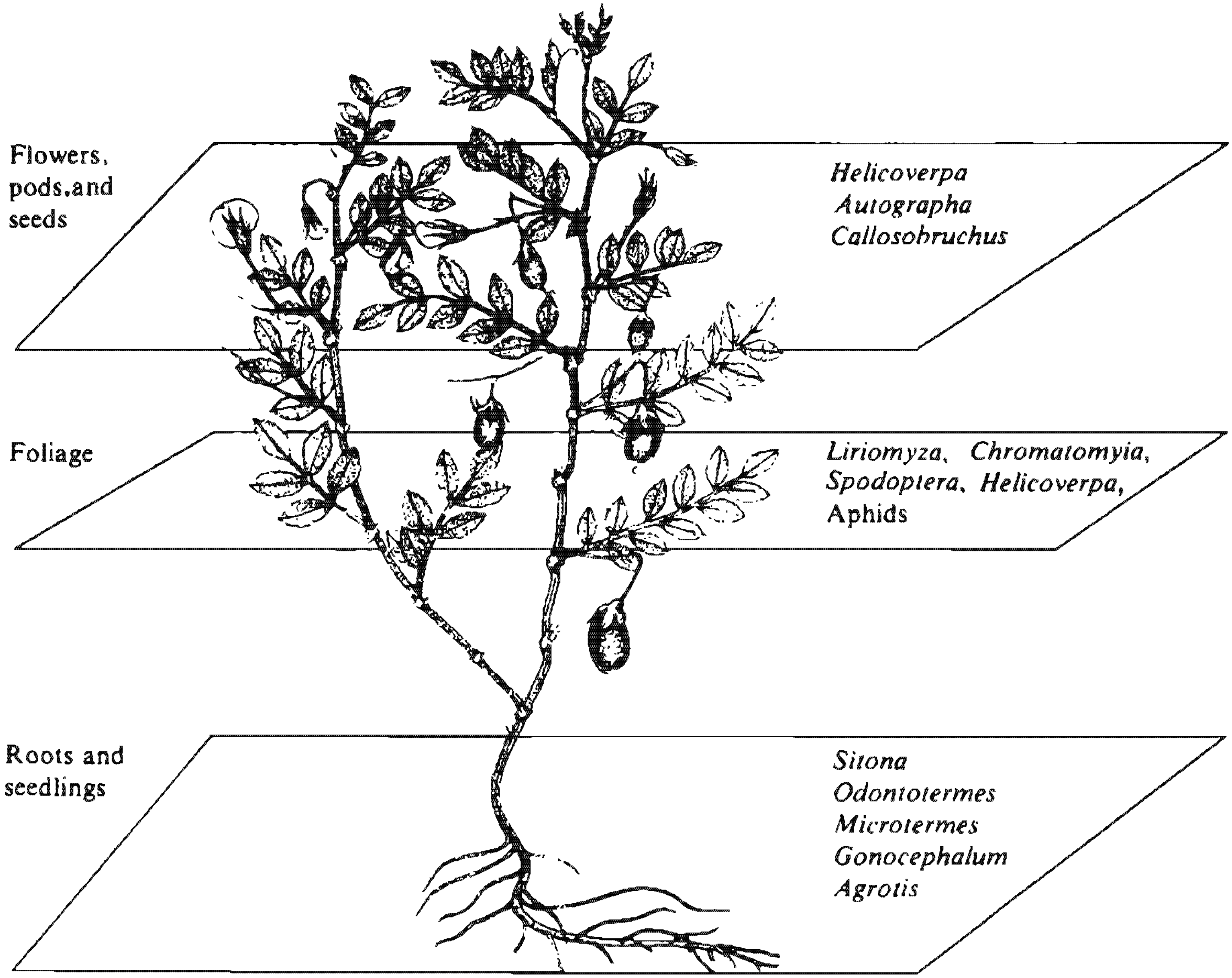


Figure 1. The distribution of insect pests on various parts of a chickpea plant.

resource poor farmers who 'need not messages but methods, not precepts but principles, not a package of practices but a basket of choices, not a fixed menu table d'hote, but a choice a la carte; not instructions on what to adopt, but ideas about what to try with support for their own trials and experimentation' (Chambers 1988).

A Possible Research Agenda for the Next Decade

Crop Improvement within an IPM Context

Setting research priorities with biotic stress maps. Knowledge of the severity and extent of pest damage is clearly an important prerequisite for making pest management research and crop improvement work more sensitive to regional differences and needs. It is all too often simply assumed that a given insect is a ubiquitous chickpea pest and that resistance-conferring genes should, for example, be incorporated in all cultivars, irrespective of the agroecological zone(s) for which they are developed.

The value of biotic stress maps in guiding crop improvement work is best illustrated with reference to *H. armigera* in India. The distribution of chickpea crops was mapped, together with the pest status of the pod borer in different agroecological zones (Pimbert and Sehgal 1989). This recent reevaluation of the assumed importance of *H. armigera* showed that levels of pest damage are low (< 10% pod damage) in most farmers' fields within the chickpea core production zones. This is largely because traditional cultural pest controls (early sowing, intercropping) help protect locally adapted chickpea genotypes from pod borer

Table 2. Recent products of IPM research : a basket of choices for chickpea farmers.

The IPM Menu so far	*Helicoverpa armigera*	*Liriomyza cicerina*
Host-plant resistance	Resistant genotypes available, released or in prelease stage	Genotypes with different degrees of resistance available
Cultural pest controls		
Manipulation of sowing and harvest dates	Early-sown cultivars less damaged than late-sown in many areas	Early-sown cultivars less damaged than late-sown in many areas
Sowing density	Although larval populations increase per unit area as plant densities increase, crop losses do not differ at spacings ranging from 8 to 67 plants m^{-2}	No effect on leaf miner populations
Intercropping chickpea with non-host plants	Chickpea grown either with mustard, or linseed, or barley, or rapeseed, suffers less pest damage than sole chickpea	Intercropping with cereals neither increases nor decreases leaf-miner attack
Biological control		
Nuclear polyhedrosis virus (NPV) spray	Very effective control	
Bacillus thuringiensis (B.t.) spray	Occasional succes	
Conservation of indigenous parasitoid wasps	Ichneumon wasps (*Campoletis* spp) important mortality factors for early instars	Braconid wasps (*Opius* spp) can heavily parasitize first generation larvae
Insecticides		
Insecticide products	Neem tree (*Azadirachta indica*) seed extract, synthetic pyrethroids, endosulfan applied at early podding stage	Monocrotophos, fenthion, methyl demeton give effective control when applied during vegetative stage
Insecticide resistance management (IRM)	Elements of IRM developed for other crops may be applicable to chickpea pests	

attack. However, pest incidence is moderately high (10-20% pod damage) in the North West Plain Zone (NWPZ) and the Central Zone (CZ). Two distinct plant breeding strategies were proposed to minimize crop loss to this insect in these zones:

- introduction of resistance genes into genotypes adapted to the CZ where 28% of the country's chickpea is produced; and
- introduction of cold-tolerant genes into chickpea varieties intended for the NWPZ of India (18% of the recorded production). Chickpea would set pod and seed fill during the cool northern winter when pod borer populations are very low, i.e., it would escape from pod borer attacks.

Pest damage data organized on a matrix of agroecological zones can thus help chickpea breeders achieve a better match between insect resistance breeding programs and the entomological problems that arise in different parts of the semi-arid environment. More accurate pictures of the severity and extent of damage caused by different pests are clearly needed for other chickpea-producing areas e.g., eastern Africa (Ethiopia, Somalia, Kenya), and parts of the Mediterranean region. Although no ideal survey can be planned, a methodology, combining systematic sampling with statistics, sensitive to spatial patterns, has been proposed to generate reliable biotic stress maps (Pimbert and Sehgal 1989).

Mechanisms of host-plant resistance (HPR) to major pests - how much do we know? Equipped with a knowledge of the biochemical and biophysical basis of HPR, entomologists and plant breeders can make rapid progress in developing insect-resistant cultivars. If resistance markers are known, breeders can choose the best parents for their crosses.

However, the identification of markers for resistance breeding can only emerge out of a basic understanding of the pests' host selection behavior. Figure 2 shows a generalized sequence of the simple behavioral steps involved in the process by which an insect pest distinguishes between host and non-host plants (host selection). Host selection has been studied in depth in only a few economically important insects, and there is no example of a plant insect relation where all the behavior cues (signals) involved have been identified (Stadler 1983; Beck and Schoonhoven 1980; Miller and Strickler 1984). Moreover, little is known as to how these multiple sensory cues reinforce each other and are modulated by ecological factors (e.g., photoperiod, temperature, humidity, edaphic factors, and their spatial and seasonal variations) (Dethier 1982; Labeyrie 1977). This is certainly true for the two major chickpea pests that have received most of the research attention so far. What little is known is shown in Figure 2.

Filling these gaps in knowledge will remain a high research priority for the next decade. Identifying the various components of HPR will be an important bias of these basic studies. But the knowledge thus gained on the host selection behavior of key pests will also help entomologists design other IPM components, particularly if these studies consider the ecological factors that modulate insect behavior (either directly or indirectly via the changes they induce in the quality and quantity of the insects' food plants).

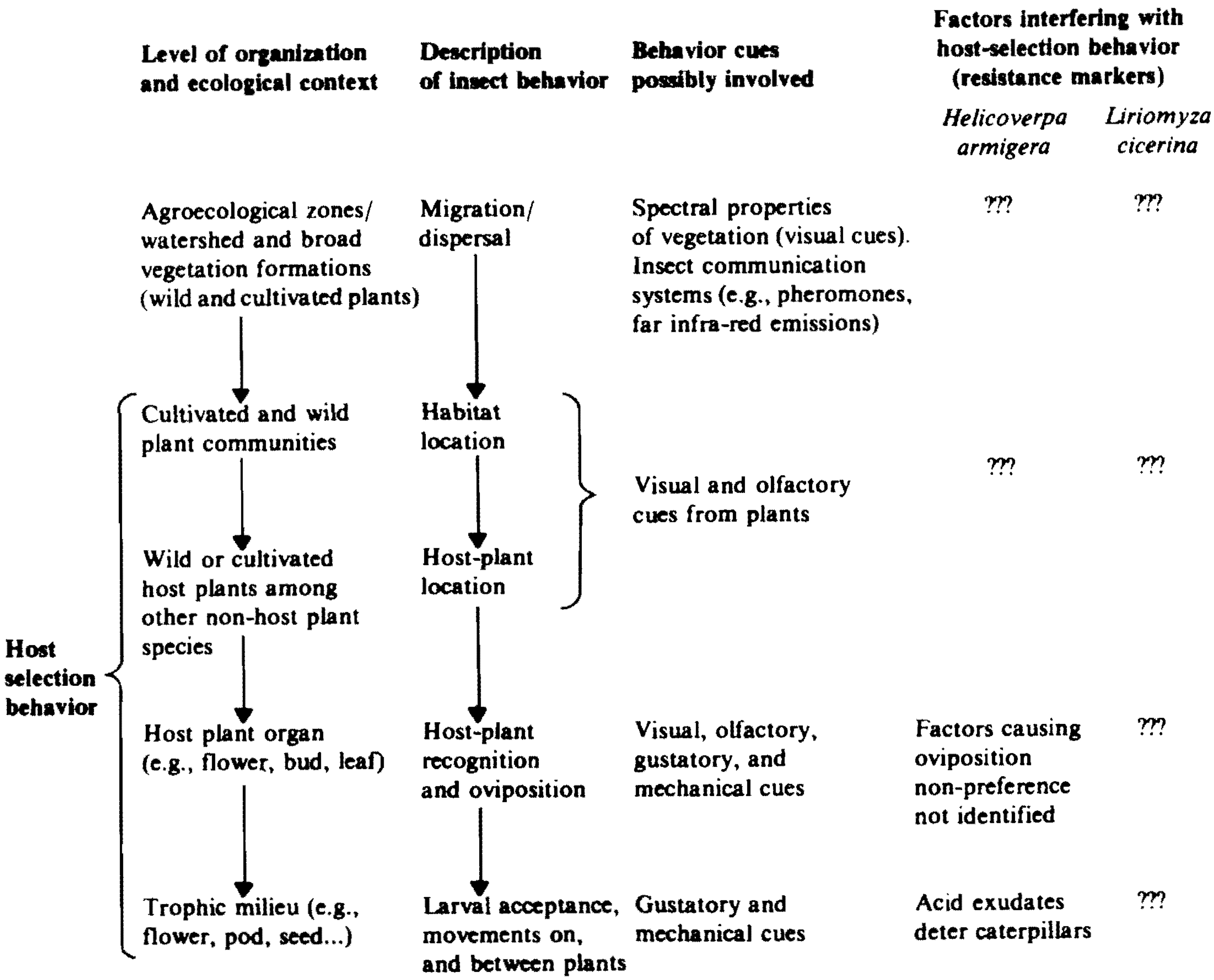


Figure 2. A generalized summary of the behavioral ecology of chickpea insect pests, and a checklist of the factors interfering with the host selection behavior of two major pests.

Agricultural case studies have found insect pests and pathogens that have fully overcome the defenses of some resistant crops within two to ten years of their use on a commercial scale (Johnson 1983; Sosa 1981). Insect herbivores appear to be as genetically variable in terms of host selection as they are in physiology, both within and between populations (Gould 1983; Labeyrie 1977; Mitter and Futuyma 1983). There are always potentially "aberrant" individuals within populations that may become the founders of a biotype capable of nullifying the advantage of plant resistance. But the rate at which pest populations adapt to novel resistant chickpea varieties could be greatly reduced by breeding plants combining repellency with toxicity; at least two independent mutations would have to occur for the insects to be able to colonize and feed on the new varieties. Resistance breeding programs should therefore build up the frequencies of the genes that confer insect resistance both at the behavioral level (oviposition or feeding non-preference/repellency) and the metabolic level (antibiosis/toxicity).

For some insect pests, however, one should first decide if HPR is a feasible pest control strategy. Thus little success has been achieved in selecting chickpea genotypes that are resistant to *Callosobruchus* spp., despite the many attempts made. Rather than pursue the search for bruchid-resistant genotypes it may be more productive to:

- prevent field infestations prior to harvest via appropriate cultural practices. This calls for a much sounder understanding of the ecological relationships between bruchids and their wild and cultivated host plants (Labeyrie 1981); and
- promote good seed storage practices, and retain or improve traditional pest control methods e.g., use of oils and powders of botanical origin that deter oviposition or kill the larvae (De Luca 1980), vernacular designs of airtight storage bins.

G (genotype) x E (environment) interactions and multilocational testing from the perspective of resource-poor farmers. Given that insect biotypes exist and that G x E interactions can lead to the breakdown of host plant resistance, there is a need to improve the efficiency of multilocational testing schemes. Most of the screening and evaluation of promising insect resistant material is done on research stations where agroecological conditions often differ markedly from those of farmers' fields. The contrast between where the resistant lines are developed, and the types of environments for which they are intended can be quite sharp, particularly when the conditions of resource-poor farmers are considered (Table 3).

Methodologies and practices that include farmers in the evaluation of promising resistant material should therefore be developed to complement conventional research approaches organized on the transfer-of-technology model. Ideally, screening practices should allow for early, systematic, and critical feedback from the farmers to the entomologists, breeders, and social scientists. When evaluating the material's performance under resource-poor conditions the farmers' crite-

Table 3. Contrast in physical and socio-economic conditions of research stations vs. resource-poor farms[1].

	Research stations	Resource-poor farms
Topography	Flat or terraces	Undulated or sloped
Soils	Deep, few constraints	Shallow, infertile serious constraints
Nutrient deficiency	Rare, remedial	Quite common
Hazards (fire, landslides, etc.)	Few	Common
Irrigation	Often full control	Rare, unreliable
Size of unit	Large, contiguous	Small, irregular often non-contiguous
Disease, pests, weeds	Controlled with chemicals, labor	Crops vulnerable, infestation
Access to fertilizers, improved seed, etc.	Unlimited, reliable	Low, unreliable
Seed	High quality	Own seed
Credit	Available	Poor access with seasonal shortages
Labor	No constraint	Family, constraining at seasonal peaks
Prices	Irrelevant	Relatively high for inputs. Low for outputs
Priority for food production	-	High

Source: Modified from Chambers and Ghildyal 1985.

ria of acceptance should be taken into account. This more participatory approach to research and the validation of technology would not only help confirm the cultivars' resistance to insects in many environments but would also help avoid some of the problems commonly encountered with varieties bred for farming communities e.g., unacceptable taste, processing and storage problems, and the undermining of the multipurpose value of the crop by an overemphasis on grain yield.

I have indicated in Figure 3 how farmers could become involved in the multilocational testing phase of resistance breeding programs carried out by national and international agricultural research centers. Other schemes whereby farmers sow and evaluate small batches of advanced breeder's lines have been worked out and can be usefully emulated here e.g., prescreening of bush beans and cassava at Centro Internacional de Agricultura Tropical (CIAT) (Ashby et al. 1987), and rice breeding for rainfed areas in India (Maurya et al. 1988).

Promotion of more decentralized and participatory forms of multilocational testing should be a high priority in the next decade. This will of course not replace multilocational trials done by scientists on research stations. Instead, the overall thrust should be to build, and rely on, active complementarities between the so-called formal and informal research sectors. Some of the assumptions underlying this research scenario are that:

- resource-poor farmers are not well served by green revolution packages that need controlled conditions, in which E is stabilized and modified through pesticides and other costly industrial inputs to fit G. Instead, G has to fit E;
- farmers' knowledge and self interest can be trusted;
- research and experimentation are not the sole prerogative of highly trained scientists. Farmers also conduct experiments and develop technologies. This informal R and D largely goes unrecognized because its categories, content, constructs, and practices differ from those of modern science; it is more closely linked to farming experience than formal R and D.

The sceptical scientist is invited to read the following papers that present much evidence supporting these assumptions (Brokensha et al. 1980; Matlon et al. 1984; Rhoades and Bebbington 1988; Richards 1985, 1989; Spitz 1986).

Biotechnology and pest control. It is now technically feasible to introduce *Bacillus thuringiensis* (B.t.) genes into crop plants in order to enhance their toxicity or resistance to insect pests, particularly to the lepidopteran ones (Vaeck et al. 1987; Goodman et al. 1987; Meeusen and Warren 1989). The introduction of B.t. or other toxin-coding genes into chickpea could certainly help protect the crop against several *Helicoverpa* spp. But this technological option should probably not be seen as the panacea for the control of major pests. Entomologists are already questioning the long-term efficacy of genetically engineered "insecticidal" plants because of the development of toxin-resistant insects:

- although pest adaptation to naturally occuring B.t. strains is not often found in the field, some lepidopteran pests have been shown to adapt to B.t. (McGaughey 1985);
- mathematical models of selection pressure predict that if genetically engineered anti-pest plants become a permanent part of the environment, insect resistance would rapidly develop (Knight 1988; Gould 1988). The selective pressure for adaptation would be intense; and
- most pest adaptations are specific but, if adaptation to insecticides is any guide, cross resistance to toxic principles is likely in insect populations (NAS 1986). This may be particularly true for the polyphagous noctuid pests given their eclectic detoxification abilities.

However, a number of strategies could be adopted to curtail the rapid development of insect resistance to transgenic chickpea by:

- using seed mixtures. Mathematical models suggest that if only half the seeds in a field contain genes for B.t. endotoxin production, the rate of pest adaptation could be cut by two thirds or more (Gould 1988; Kennedy et al. 1987); and
- ensuring that the insect resistance genes are expressed only at times and places where they are required. If B.t. genes are expressed in most of the chickpea plant's tissues all *Helicoverpa* larvae that feed on the leaves and pods of the cultivar are targets for the toxin. The pressure for adaptation would be intense. But if genetic engineers developed chickpea lines that only express the B.t. genes in the pod wall tissues then the most important plant parts would be protected. Since fewer generations feed on these fruiting structures selection pressure would be discontinuous.

Unless these evolutionary considerations are kept in mind when engineering and using transgenic chickpea the whole exercise will probably be counter-productive in the very short term.

The legal implications of this pest control option also

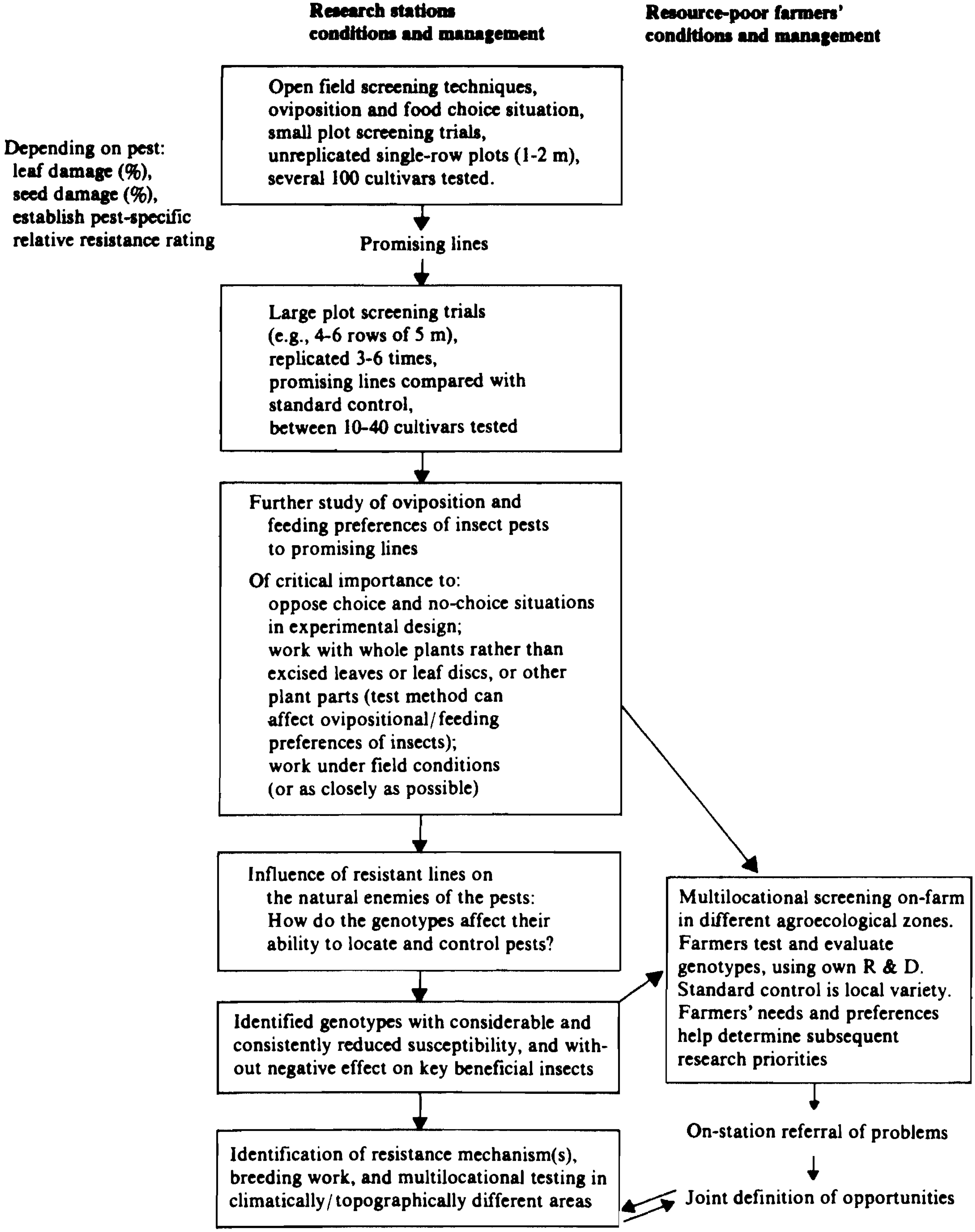


Figure 3. Screening genotypes for resistance to insect pests.

need to be carefully assessed. B.t. genes, like all other genetic resources, are up for patenting and are the raw material of the biotechnology industry, which is largely under corporate control (Fowler et al. 1988; Hobbelink and Velvee 1989; RIS 1988). Will the final product of this research remain in the public sector, or would the patents allow the private companies to control the technology and set seed prices? If access to seed of transgenic chickpea is uneven, what sorts of distortions would be introduced in the rural sectors of the semi-arid tropics?

IPM and the Selective Use of Plant Diversity

Agroecosystems can be made more resilient to pest attacks through conscious design in the same way that pest-resistant varieties can be created by combining suitable building blocks (genes) from different sources. At the agroecosystem level, the building blocks are whole plants, animals, and microorganisms that are woven together in specific patterns through their reciprocal interactions to provide the type of functional diversity which keeps pest populations at a low level. An important assumption underlying this IPM approach is that pest outbreaks in many agroecosystems are normal occurrences because of their lack of diversity, high incidence of stress, and prevention of natural control processes. Methods and principles should therefore be identified to enable farmers to redesign their farm into a self-regulating agroecosystem which echoes the sustainability and balance of the surrounding natural world. This should certainly be a research priority for chickpea IPM in the next decade and recent advances in population biology (ecology, taxonomy, evolutionary biology, and genetics) provide many relevant insights and concepts in this context. A few examples will illustrate this point.

Interfering with the pest's host-selection behavior by promoting the right sort of cropping system's diversity. An insect pest searching for a specific host plant has to locate its host by sight or smell. By concealing this plant amongst others, which do not offer the same kind of stimuli, it should be possible to reduce the efficiency of the pest's host seeking behavior and interfere with its population development and survival.

The pest suppressant potential of intercropping can be exploited at three levels:

- genetic mixtures of the same crop. Since plant species diversity so often reduces insect damage (Risch et al. 1983; Kareiva 1983) it has been suggested that genetic diversity in monospecific stands could produce similar effects. What little experimental data is available certainly does highlight the pest control value of multivarietal plant stands: lower leafhopper damage in genetically diverse maize (Power 1988), reduced whitefly attack in mixtures of resistant and susceptible cassava varieties (Gold et al. 1989). Studies of the response of key chickpea pests to mixtures of resistant and susceptible varieties grown in different ratios are well overdue. Simple experiments can be set up to compare the yields and pest damage of genetic mixtures and monovarietal stands;
- as combinations between chickpea and a non-or less-preferred host plant of the target pest. Experiments carried out by All India Coordinated Pulses Improvement Program (AICPIP) entomologists (1988) in chickpea intercropped with mustard, barley, or linseed indicate that the cropping patterns traditionally used by Indian farmers significantly reduce pod borer damage when compared with sole chickpea. The presence of the companion crop either interferes with the pest's host selection behavior, or enhances the activity of its natural enemies, or both–the exact mechanisms involved are unknown. This phenomenon, known as "associational resistance" (Tahvanainen and Root 1972; Root 1973) has been demonstrated in several other traditional farming systems (Risch et al. 1983; Altieri and Liebman 1986; Matteson et al. 1984). We need to find out if similar pest suppressant features operate against other major pests in the diverse, traditional chickpea-growing areas outside South Asia. These traditional methods of pest control can then be retained as such or improved upon in the light of modern knowledge (Altieri and Liebman 1986; Levins and Wilson 1979). They can also be modified for large-scale chickpea production e.g., design strip-cropping schemes that both retain the functional diversity of traditional systems and allow for mechanisation; and
- designing for synergistic effects. Research on coevolution suggests that the cropping systems' resilience to pests and host-plant resistance would be more effective and long lasting if the apparency of the resistant genotypes were held down by *simultaneously*: mixing different chickpea varieties (e.g., genetic mixtures of local cultivars with improved resistant genotypes in various proportions), and intercropping chickpea with non host-plants of the target pest.

These organizing principles clearly need to be subjected to critical experimentation in the near future.

Vegetation management and the biological control of chickpea pests. The enhancement of the indigenous natural enemy complex of major chickpea pests may be possible by the planned diversification of chickpea agroecosystems. The type of diversity introduced should help enhance parasite and predator attraction to the agroecosystem as well as their efficiency within it. This can be done by providing alternative hosts on non-crop vegetation, nectar-rich plants for adult parasitoid wasps, and suitable ground cover for predators (Altieri and Letourneau 1982; Andow 1988). Such plants should be non- or less-preferred host plants of the target pests. A random approach to complexity may exacerbate the pest problem by providing more food plants to the insect pest, and may not favor the right sort of plant and animal community which specific beneficial insects require.

The presence of acid leaf exudates deters many, but by no means all, natural enemies from preying on major pests in chickpea (Reed et al. 1987). Thus, among the few natural enemies able to feed on *H. armigera* in chickpea, the ichneumon parasitoid, *Campoletis chlorideae* (Uchida) is a particularly suitable candidate for improving the biological control of the pod borer through the addition of selective plant diversity. This is an important parasite because it can kill the caterpillars before they have a chance to cause much damage. Experiments done on ICRISAT farm showed that the numbers of pod borer larvae parasitized by *C. chloridae* were significantly greater in chickpea grown with a coriander border crop than in sole chickpea (Pimbert and Srivastava 1990). Flowering plants that provide food for natural enemies, but not for the pest, can thus be worked into the design of chickpea agroecosystems using patterns that maximize beneficial functional connections.

The emphasis of this approach is to help restore natural control processes through the addition of the type of diversity that provides essential ecological elements for the activity of biocontrol agents. Its potential should be assessed for other pests shown in Table 1, wherever they are particularly virulent.

IPM and Group Action

The polyphagous nature and the high mobility of many major chickpea pests dictate that research and pest management be applied on an area-wide basis. This is particularly true for the *Helicoverpa* spp. (Fitt 1989). Thus, many of the cultural pest controls against *H. armigera* in chickpea undoubtedly involve group action and inter-farm cooperation to realize their full potential (e.g., synchronous sowing and harvesting at optimum time, use of less-susceptible cultivar, intercropping/strip cropping with non-host plants of the pod borer, management of refuges and food plants for natural enemies...).

Village-based collective pest management practices are needed to complement pest controls aimed at individual households in dryland areas. But promoting group-based pest management strategies is not easy, and this approach has been neglected by applied entomologists partly for that reason. Progress in the next decade will probably only emerge out of close collaboration between entomologists and social scientists involved in action research in different chickpea-growing zones. The style of research called for will necessarily be participatory and decentralized, with farmers analyzing, collectively designing their farming landscapes, and experimenting with advice and support from outsiders (scientists acting as catalysts, facilitators, and consultants). Understanding the determinants of group action under resource-poor conditions will be a high research priority in this process, for the farmers themselves and the policy makers.

Sustainability

IPM must reflect and reinforce the goals of a more sustainable agriculture. Over the long term a sustainable agriculture enhances environmental quality and the natural resource base on which agriculture depends, meets basic human food and fiber needs, is economically viable, and improves the health and quality of life for farmers and society as a whole.

In practical terms this means that the design of IPM in chickpea should be much more based on:

- the maximum use of production inputs that are internal to the system e.g., incorporating indigenous knowledge on pest controls in the IPM design process, enhancing local natural control processes via vegetation management;
- the development (or redevelopment) of germplasm well adapted to local conditions and pest problems (as opposed to germplasm with "broad adaptability");
- the selective use of diversity in time and space, both at the genetic and agroecological levels;
- the wise and judicious use of insecticides and an economics which does not leave out social and environmental costs ("externalities") when defining threshold levels;
- a frame of reference and set of concepts that allows us to visualize IPM programs centered more on *pest* management than *pesticide* management (or any other single "magic bullet" tactic). At the very least, this calls for the integration of the historically distinct fields of crop management and pest manage-

ment, the end of disciplinary myopia, and a more holistic appreciation of the potential role of functional diversity, interdependance, patterning, complementarity, and synergy in IPM; and

- a more open partnership with farmers that involves them in the conception, implementation, and evaluation of IPM tools. This participatory process should help stimulate the acquisition and use of technological information by farmers. This is critical because IPM in the context of a more sustainable agriculture requires more management time, substituting thoughtful observation and information for capital and resource intensive external inputs.

If we allow these organizing principles to direct and frame our inquiry in the next decade, we can anticipate much progress in the control of chickpea insect pests in the fragile, risk prone, dryland environments.

Acknowledgments

S. Bhatnagar and P. Satyanarayana did the artwork and A.R.R. Swamy and B.V.R. Sastry the typing. I thank them all.

References

AICPIP (All India Coordinated Pulses Improvement Project). 1988. Annual report on "rabi" pulses, entomology, 1988. Kanpur, Uttar Pradesh, India: Directorate of Pulses Research.

Altieri, M.A., and **Letourneau, D.K.** 1982. Vegetation management and biological control in agroecosystems. Crop Protection 1:405-430.

Altieri, M.A., and **Liebman, M.Z.** 1986. Insect, weed and plant disease management in multiple cropping systems. Pages 183-218 *in* Multiple cropping systems. (Francis, C.A., ed.) New York, USA: Macmillan.

Andow, D.A. 1988. Management of weeds for insect manipulation in agroecoystems. Pages 265-301 *in* Weed management in agroecosystems : ecological approaches (Altieri, M.A., and Liebman, M., eds.). Boca Raton, Florida, USA: CRC Press.

Ashby, J., **Quiros, C.**, and **Riviera, Y.** 1987. Farmer participation in on-farm varietal trials. Discussion Paper, Agricultural Administration Network no. 22. UK: Overseas Development Institute.

Beck, S.D., and **Schoonhoven, L.M.** 1980. Insect behavior and plant resistance. Pages 115-135 *in* In Breeding plants resistant to insects (Maxwell, F.G., and Jennings, P.R., eds.). New York, USA: John Wiley.

Brokensha, D.W., **Warren, D.M.**, and **Werner, O.** 1980. Indigenous knowledge systems and development. Lanham, Maryland, USA: University Press of America.

Chambers, R. 1988. Farmer first. International Agricultural Development 8(6):10-12.

Chambers, R., and **Ghildyal, B.P.** 1985. Agricultural research for resource-poor farmers: the farmer-first-and-last model. Agricultural Administration 20:1-30.

De Luca, Y. 1980. Produits d'origine vegetale opposables aux bruchides (Col.). Frustula Entomologica, Nuova Serie 2:15.

Dethier, V.G. 1982. Mechanisms of host-plant recognition. Entomologia Experimentalis et Applicata 31:4-56.

Fitt, G.P. 1989. The ecology of *Heliothis* spp. in relation to agroecosystems. Annual Review of Entomology 34:17-52.

Fowler, C., **Lachkovics, E.**, **Mooney, P.**, and **Shand, H.** 1988. The laws of life: another development and the new biotechnologies. Development Dialogue 1-2.350 pp.

Gold, C.S., **Altieri, M.**, and **Bellotti, A.** 1989. Effects of cassava varietal mixtures. Entomologia Experimentalis et Applicata 53:195-202.

Goodman, R.M., **Haupatli, H.**, **Crossway, A.**, and **Knauf, V.C.** 1987. Gene transfer in crop improvement. Science 236:48-54.

Gould, F. 1983. Genetics of plant–herbivore systems: interactions between applied and basic study. Pages 599-653 *in* Variable plants and herbivores in natural and managed systems (Denno, R.F., and McClure, M.S., eds.). New York, USA: Academic Press.

Gould, F. 1988. Evolutionary biology and genetically engineered crops. Bioscience 38(1):26-33.

Hobberlink, H., and **Vellve, R.** (eds.). 1989. Patenting life forms in Europe: proceedings of an International Conference at the European Parliament, 7-8 Feb 1989, Brussels, Belgium. Barcelona, Spain: International Coalition for Development Action.

Johnson, R. 1983. Genetic background of durable resistance. Pages 5-26 *in* Durable resistance in crops (Lamberti, F., Waller, J.M., and van der Graaff, N.A., eds.). New York, USA: Plenum Press.

Kareiva, P. 1983. Influence of vegetation texture on herbivore populations : resource concentration and herbivore movement. Pages 259-289 *in* Variable plants and herbivores in natural and managed systems (Denno, R.F., and McClure, M.S., eds.). New York, USA: Academic Press.

Kennedy, G., Gould, F., Deponti, O.M., and **Stinner, R.E.** 1987. Ecological, agricultural, genetic and commercial considerations in deployment of insect resistant germplasm. Environmental Entomology 16(2):327-338.

Knight, P. 1988. Biological controls squash insect pests.Biotechnology 6:1137.

Labeyrie, V. 1977. Environnement sensoriel et coevolution des insectes. (In Fr.) Pages 15-35 *in* Le comportement des insectes et les signaux issus du milieu tropique (Labeyrie, V., ed.). Paris, France: Centre National de la Recherche Scientifique.

Labeyrie, V. 1981. Vaincre la carence proteique par le developpement des legumineuses alimentaires et la protection de leurs recoltes contre les bruches. (In Fr.) Food and Nutrition Bulletin 3(1):24-38.

Levins, R., and **Wilson, M.** 1979. Ecological theory and pest management. Annual Review of Entomology 25:7-19.

Matlon, P., Cantrell, R., King, D., and **Benoit-Cattin, M.** (eds.). 1984. Coming full circle : farmers' participation in the development of technology. Ottawa, Canada: International Development Research Centre. 179 pp.

Matteson, P.C., Altieri, M.A., and **Gagne, W.C.** 1984. Modification of small farmer practices for better pest management. Annual Review of Entomology 29:383-402.

Maurya, D.M., Bottrall, A., and **Farrington, J.** 1988. Improved livelihoods, genetic diversity and farmer participation : a strategy for rice breeding in rainfed areas of India. Experimental Agriculture 24:311-320.

McGaughey, W.H. 1985. Insect resistance to the biological insecticide *Bacillus thuringiensis*. Science 229:193-195.

Meeusen, R.L., and **Warren, G.** 1989. Insect control with genetically engineered crops. Annual Review of Entomology 34:373-381.

Miller, J.R. and **Strickler, K.L.** 1984. Finding and accepting host plants. Pages 127-157 *in* Chemical ecology of insects (Bell, W.J., and Carde, R.J. (eds.). Sunderland, Massachusetts, USA: Sinauer Associates.

Mitter, C., and **Futuyma, D.J.** 1983. An evolutionary – genetic view of host-plant utilization by insects. Pages 427-459 *in* Variable plants and herbivores in natural and managed systems (Denno, R.F., and McClure, M.S., eds.). New York, USA: Academic Press.

NAS (National Academy of Sciences). 1986. Pesticide resistance: strategies and tactics for management. Washington, D.C., USA: National Academy Press.

Pimbert, M.P., and **Sehgal, V.K.** 1989. The relative importance of *Helicoverpa armigera* (Hübner) on chickpea in different agroecological zones of India : implications for pest management. Legumes Entomology Discussion Paper no. 1. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics. (Limited distribution.)

Pimbert, M.P., and **Srivastava, C.P.** 1990. Vegetation management and the biological control of *Helicoverpa armigera* (Lep : Noctuidae) in chickpea. International Chickpea Newsletter 21:16-19.

Power, A.G. 1988. Leafhopper response to genetically diverse maize stands. Entomologia Experimentalis et Applicata 49:213-219.

Reed, W., Cardona, C., Sithanantham, S., and **Lateef, S.S.** 1987. Chickpea insect pests and their control. Pages 283-318 *in* The chickpea (Saxena, M.C., and Singh, K.B., eds.). Wallingford, Oxon, UK: CAB International.

Rhoades, R., and **Bebbington, A.** 1988. Farmers who experiment : an untapped resource for agricultural research and development. Presented at the International Congress on Plant Physiology, 15-20 Feb 1988, New Delhi, India.

Richards, P. 1985. Indigeneous agricultural revolution : ecology and food production in West Africa. London, UK: Hutchinson.

Richards, P. 1989. Experimenting farmers and agricultural research. Pages 55-56 *in* Proceedings of the ILEIA Workshop on Operational Approaches for Participatory Technology Development in Sustainable Agriculture. Leusden, Netherlands: Information Centre for Low External Input and Sustainable Agriculture.

Risch, S.J., Andow, D., and **Altieri, M.A.** 1983. Agroecosystem diversity and pest control : data, tentative conclusions and new research directions. Environmental Entomology 12:625-629.

RIS (Research and Information System for the Non-Aligned and Other Developing Countries). 1988. Biotechnology revolution and the Third World: challenges and policy options. New Delhi, India: RIS.

Root, R.B. 1973. Organization of a plant arthropod association in simple and diverse habitats: the fauna of collards. Ecological Monographs 43:95-124.

Sosa, O. 1981. Biotypes J and L of the Hessian fly discovered in an Indiana wheat field. Journal of Economic Entomology 74:180-182.

Spitz, P. 1986. Sysèmes alimentaires et société en Inde : genese d'une recherche interdisciplinaire. (In Fr.) Revue Internationale des Sciences Sociales 105:403-420.

Stadler, E. 1983. Attractants, arrestants, feeding and oviposition stimulants in insect–plant relationships : application for pest control. Pages 243-258 *in* Natural products for innovative pest management (Whitehead, D.L., and Bowers, W.S., eds.). Current Themes in Tropical Science vol. 2. Oxford, UK: Pergamon Press.

Tahvanainen, J.O., and **Root, R.B.** 1972. The influence of vegetational diversity on the population ecology of a specialised herbivore, *Phyllotreta crucifera* (Coleoptera: Chrysomelidae). Oecologia 10:321-346.

Vaeck, M., Reynaerts, A., Hofte, H., Jansens, S., De Beuckeleer, M., Dean, C., Zabeau, M., van Montagu, M., and **Leemans, J.** 1987. Transgenic plants protected from insect attack. Nature 328(6125):33-37.

Insect Pest Problems and Recent Approaches to Solving them on Chickpea in South Asia

K. Ahmed[1], S.S. Lal[3], H. Morris[4], F. Khalique[1], and B.A. Malik[2]

Abstract

Fast growing human population pressure in the South Asian countries has necessitated effective, economical, and non-polluting means of insect control. Work on various aspects of Helicoverpa (Heliothis) armigera *(Hübner) management on chickpea, including some recent approaches is reviewed. It covers population studies through pheromone traps; insecticide use; use of bacteria, viruses and parasitoids; cultural practices and host-plant resistance and breeding. Encouraging results were obtained with* Bacillus thuringiensis *(Berliner) preparations even in the presence of malic acid. Relative susceptibility studies indicated clear differences between desi and kabuli chickpea to attack from* Callosobruchus maculatus *F.*

Résumé

Problèmes des insectes nuisibles et les solutions récentes pour le pois chiche en Asie du Sud : *Les pressions démographiques en pleine croissance dans les pays de l'Asie du Sud ont rendu indispensable des moyens de lutte contre les insectes qui soient efficaces, économiques et non polluants. Les travaux sur divers aspects de la maîtrise de* Helicoverpa (Heliothis) armigera *(Hübner) sur le pois chiche, y compris certains efforts récents, font l'objet d'une revue. Ils couvrent les études des populations à l'aide des pièges à phéromone; l'usage d'insecticides; l'usage de bactéries, de virus et de parasitoïdes; les pratiques culturales et la résistance de la plante-hôte et la sélection. Des résultats encourageants ont été obtenus avec des préparations de* Bacillus thuringiensis *(Berliner), même en présence d'acide malique. Les études sur la sensibilité relative ont indiqué des différences nettes entre les pois chiches 'desi' et 'kabuli' à l'égard des attaques de* Callosobruchus maculatus *F.*

About 87% of the world chickpea crop is grown in South Asia (Jodha and Rao 1987). *Helicoverpa armigera* (Hübner) is a major pest of chickpea and is common in most places where chickpea is grown. In some parts of India and Pakistan a semilooper, *Autographa nigrisigna* (Walker) was also found to damage chickpea pods. *Spodoptera exigua* (Hübner), which is of minor importance in this region, attacks the crop at the vegetative stage. In India, ICRISAT surveys of chickpea-growing areas from 1977 to 1982 indicated a range of 0 to 84.4% chickpea pod damage at different states, with an overall average of 8% pod damage by *H. armigera* (Sithanantham et al. 1983). In northern Pakistan up to 90% pod damage was recorded in

1. Entomologists (Pulses), and 2. Coordinator (Pulses), National Agricultural Research Centre (NARC), P.O. National Institute of Health, National Park Road, Islamabad, Pakistan.
3. Senior Entomologist, Directorate of Pulses Research, Kalyanpur, Kanpur 208 024, Uttar Pradesh, India.
4. Entomologist, Food Legumes, Agricultural Research Institute, Yezin, Myanmar.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

unprotected fields (NARC 1986; 1987), but in Myanmar, less than 10% borer damage to chickpea pods was recorded during 1989.

In stores, chickpea can be severely damaged by bruchids (*Callosobruchus* spp) which are common pests throughout the semi-arid tropics, but more devastating in South Asia than elsewhere.

This paper describes the problems encountered, and progress made to date in suppressing *H. armigera* populations on chickpea in South Asia.

Changing Insect Pest Problems

Earlier, the chickpea pod borer *H. armigera* was confined to a few places in central and southern India and in southern Pakistan, but it has now spread throughout Pakistan, India, and to some parts of Myanmar. Large-scale cultivation of cotton and pigeonpea in India has aggravated the pest situation. Population fluctuation studies based on larval counts in unprotected chickpea crops from 1986 to 1989 in India revealed that *H. armigera* populations were decreasing at Kanpur, India. Populations of the semilooper, *A. migricana* considerably have increased over the years (Lal et al. 1981). *Spodoptera exigua* was active during 1986 and 1987, but it was observed in low numbers and for only a short period during the 1988/89 chickpea-cropping season. The cowpea aphid, *Aphis craccivora* Koch gained importance in northern India and *Tanymecus indicus* F. earlier reported to be a pest of chickpea has now lost its pest status.

Recent Approaches to Solving Chickpea Insect Pest Problems

Screening and Breeding for Insect Resistance

In South Asia the most appropriate way of reducing losses caused by *H. armigera* in chickpea is by breeding for resistance or tolerance. Accordingly, since 1976 extensive germplasm collections and breeders' lines have been screened at ICRISAT Center, India. During the past 8–10 years of screening and testing ICC 506, 10667, 10619, 6663, 10817, ICCX 730008-8, ICCX 730041-8, ICCX 730094-18, ICCX 730020-11-1, ICC 10870, and ICC 5264 have been identified as borer-resistant (Lateef 1985). Subsequently these genotypes were used in breeding programs at ICRISAT Center to combine borer resistance with high yield potential. At the Directorate of Pulses Research, Kanpur, PDE 1, PDE 2, PDE 5, PDE 7, DPR/CE 1-2, DPR/CE 2-3, DPR/CE 3-1, and DPR/CE 7-2 showed some degree of resistance to *Helicoverpa* pod borer in northern India. ICCX 730008-8 and PDE 2 were selected as donor parents for the national *Helicoverpa* resistance breeding program in India. The borer-resistant genotypes identified by ICRISAT entomologists were also tested in Pakistan and in Myanmar in the International Chickpea *Helicoverpa* Resistance Nursery (ICHRN) multilocational testing program. Selections ICC 4935-E2793, ICCX 730020-11-1, and ICC 10243 were found promising in Pakistan, and ICCX 730008-8 and ICC 506 showed comparatively low pod borer damage in Myanmar.

In Pakistan laboratory studies conducted at NARC on the resistance to bruchids in chickpea indicated a high level of resistance to *Callosobruchus maculatus* (Fabricius) in variety CM 72 (K. Ahmed and F. Khalique, unpublished data). Ahmed et al. (1989) reported that number of bruchid emergence holes is a better indicator of seed resistance to *C. maculatus*.

Biological Control

Although several species of parasites and predators are known to attack *H. armigera* larvae, they do not cause a rapid population reduction. Parasites are very uncommon in *H. armigera* eggs, laid on chickpea. Pawar et al. (1986) reported a maximum of 31% larval parasitism of *H. armigera* by *Campoletis chlorideae* (Uchida) on chickpea in India. Laboratory studies at NARC, Islamabad, Pakistan indicated 31 to 58% larval parasitism of *Helicoverpa* by *C. chlorideae* (NARC 1986). These studies have also shown that there was a high parasitism (48-57%) in 1st and 2nd instar (1-5 day-old) larvae (Table 1). This parasite can be effectively

Table 1. *Helicoverpa armigera* larval susceptibility to *Campoletis chlorideae* in laboratory at NARC, Islamabad, Pakistan during 1986/87.

Larval age (h)	Larvae exposed to parasitism	Larvae parasitized	Parasitism (%) ± SE
0–24	400	222	55.5 ± 3.49
24–48	442	213	48.5 ± 1.65
48–72	419	206	48.4 ± 2.89
72–96	404	190	47.5 ± 3.91
96–120	407	231	56.7 ± 0.74

Source: NARC 1987.

used in managing *H. armigera* on chickpea in conjuction with other pest control practices.

Helicoverpa armigera larvae also suffer from a disease caused by a nuclear polyhedrosis virus (NPV) in chickpea fields. This virus would appear to offer attractive control possibilities. It is now being commercially used in the USA and Australia to control *Helicoverpa* spp. The cheapest and the easiest means of using the virus would be to encourage farmers to apply sprays that contain mashed-up larvae that have been killed by the virus.

Jayaraj et al. (1987) reported that NPV at 250 LE ha^{-1} has successfully controlled *H. armigera* larvae on chickpea in India. In Pakistan, the author's laboratory studies with neonate larvae exposed to different concentrations of *Bacillus thuringiensis* (B.t.), malic acid and their combinations mixed in the artificial diet on which larvae were reared for 7 days at a room temperature of $25° \pm 4°C$ showed a high larval mortality of more than 80% when fed on a diet containing B.t. and 4-8% malic acid. The studies also indicated a synergistic effect of malic acid on B.t.

Cultural Control

To date cultural practices have not offered much scope for pest control in chickpea. The potential of intercrops to reduce pest damage has been studied to some extent. *Helicoverpa* damage tends to be reduced, if chickpea is grown with non-legume intercrops such as mustard, linseed, or wheat.

The scope for pest damage reduction by altering the seed rate (plant density) has been extensively assessed at ICRISAT Center. Reed et al. (1987) reported that the *Helicoverpa* population increases with increase in plant density. No significant yield difference was observed at densities ranging from 8-87 plants m^{-2} (Sithanantham and Reed 1979). These studies revealed no beneficial advantage for chickpea with enhanced seed rates.

Insecticide Use

Several insecticides found to be effective against *H. armigera* are also useful in controlling other lepidopteran insects. Large quantities of water are required for insecticide spraying and are difficult to obtain in the dry areas. Although it is easier to apply dusts, it may be difficult to ensure good coverage. Some farmers apply dusts, using muslin bags tied to sticks that are shaken over the crop. In a few areas, high-volume, rocker-type or lever-operated knapsack sprayers are sometimes used. Motorized, knapsack, medium-volume, mist blowers are expensive, and generally not used by farmers' on chickpea. Controlled droplet application (CDA) could also be used relatively easily on this crop. Tests of neem (*Azadirachta indica* A. Juss.) products such as the kernel extract were found to be as effective as pyrethroids against *H. armigera* on chickpea (Lal and Sachan 1987; Reed et al. 1987). However, their adoption is a problem, since ensuring local availability of the material requires considerable attention.

Pest Prediction and Monitoring

Very little is known about the population dynamics of *H. armigera* on chickpea in farmers' fields. There is a real need to assemble and analyse relevant data, so that simple population dynamics models of the pest, particularly in relation to climatic factors, may be constructed.

Lal et al. (1981) observed a highly erratic and variable cyclic incidence of *H. armigera* on chickpea in northern India. Pheromone trap catch studies over 4 years at NARC, Islamabad indicated that the population of *H. armigera* peaks from 15 March to 11 May. Afzal et al. (1985) reported that multiple regression on humidity and temperature gave the best trap-catch prediction. Such studies will help in taking judicious plant protection measures at the right time.

References

Afzal, M., Ahmed, K., Azhar Hussain, S., Malik, B.A., and **Khalique, F.** 1985. Effect of environmental factors on pheromone trap catches of *Heliothis armigera* (Hubn.). Chemosphere 14:1921-1924.

Ahmed, K., Khalique, M., Afzal, M., Tahir, M., and **Malik, B.A.** 1989. Variability in chickpea (*Cicer arietinum* L.) genotypes for resistance to *Callosobruchus* maculatus F. (Bruchidae). Journal of Stored Products Research 25:97-99.

Jayaraj, S., Rabindra, R.J., and **Santharam, G.** 1987. Control of *Heliothis armigera* (Hübner) on chickpea and lablab bean by nuclear polyhedrosis virus. Indian Journal of Agricultural Sciences 57:738-741.

Jodha, N.S., and **Subba Rao, K.V.** 1987. Chickpea: world importance and distribution. Pages 1-10 *in* The chickpea. (Saxena, M.C., and Singh, K.B., eds.). Wallingford, Oxon, UK: CAB International.

Lal, S.S., and **Sachan, J.N.** 1987. Recent advances in pest management in pulses. Indian Farming 37(7):29-35.

Lal, S.S., Yadava, C.P., and **Dias, C.A.R.** 1981. Changing status of insect pests infesting chickpea. Pulse Crops Newsletter 1:45-46.

NARC (National Agricultural Research Centre). 1986. Entomology of chickpea Pages 4-10 *in* Annual technical report (July 1, 1986 to June 30, 1987) on Food Legume Improvement Project in Pakistan (Phase-II). Islamabad, Pakistan: NARC.

NARC (National Agricultural Research Centre). 1987. Entomology of chickpea Pages 121-134 *in* Annual technical report (July 1, 1986 to June 30, 1987) on Food Legume Improvement Project in Pakistan (Phase-II). Islamabad, Pakistan: NARC.

Lateef, S.S. 1985. Gram pod boer *Heliothis amigera* (Hübn) resistance in chickpea. Agriculture, Ecosystems and Environment, 14:95-102.

Pawar, C.S., Bhatnagar, V.A., and **Jadhav, D.R.** 1986. *Heliothis* species and their natural enemies with their potential for biological control. Proceedings of the Indian Academy of Sciences (Animal Sciences) 95:695-703.

Reed, W., Cardona, C., Sithanantham, S., and **Lateef, S.S.** 1987. Chickpea insect pests and their control. Pages 283-318 *in* The chickpea (Saxena, M.C., and Singh, K.B., eds.). Wallingford, Oxon, UK: CAB International.

Sithanantham, S., Rao, V.R., and **Ghaffar, M.A.** 1983. International review of crop losses caused by insects on chickpea. Pages 269-283 *in* Proceedings of the National Seminar on Crop Losses due to Insect Pests, 7-9 Jan 1983, Hyderabad, India (Rao, B.H.K., and Murty, K.S.R.K., eds.). Hyderabad, Andhra Pradesh, India: Entomological Society of India. (Special issue, Indian Journal of Entomology, vol. 11.)

Sithanantham, S., and **Reed, W.** 1979. Plant density and pest damage in chickpea. International Chickpea Newsletter 1:9-10.

Chickpea Insect Pests in the Mediterranean Zones and New Approaches to their Management

S. Weigand and O. Tahhan[1]

Abstract

In the Mediterranean region, chickpea (Cicer arietinum *L.) is attacked by several insect pests in the field and during storage. The most important field insect is leaf miner* (Liriomyza cicerina). *Host-plant resistance has been the main approach for its control at ICARDA. Several lines with different degrees of resistance have been identified, and their resistance mechanism is being studied. Possibilities of biological control are being investigated and already several species of parasitoids have been found in nature.* Helicoverpa armigera, Heliothis viriplaca *and* Heliothis peltigera *are secondary pests, as heavy infestations are restricted to only some regions and years. In southern Syria, where pod infestations ranged from 30 to 50%, insect populations were monitored for four seasons and some aspects of integrated control are being studied.* Aphis craccivora *is important as a vector of the chickpea stunt disease causal agent (bean leafroll virus). In preliminary studies, differences in the pH of leaf exudates of some susceptible and resistant chickpea cultivars were found. The most important storage pests are different species of* Callosobruchus, *of which* C. chinensis *is the most dominant. A detailed survey revealed that infestations range from 0 to 79% in Syria. Screening did not reveal any acceptable degree of resistance, but some accessions of wild* Cicer *species were found to be resistant. In testing different traditional methods of seed protection, olive oil with salt showed 90% effectiveness during 4 months of storage.*

Résumé

***Insectes ravageurs du pois chiche dans les zones méditerranéennes et de nouvelles approches de lutte** : Dans la région méditerranéenne, le pois chiche (*Cicer arietinum *L.) est l'objet d'attaques par plusieurs insectes ravageurs dans les champs ainsi que pendant le stockage. L'insecte le plus important des champs est la mineuse,* Liriomyza cicerina. *La résistance de la plante-hôte a été le moyen principal de lutte contre cet insecte à l'ICARDA. Plusieurs lignées ayant des dégrés de résistance variés ont été identifiées, et les études actuelles portent sur leur mécanisme de résistance. On examine les possibilités de lutte biologique; diverses espèces de parasitoïdes ont déjà été repérées dans la nature.* Helicoverpa armigera, Heliothis viriplaca, *et* Heliothis peltigera *sont des ravageurs secondaires, car des infestations importantes se limitent uniquement à certaines régions et années. En Syrie du Sud, où les infestations de gousses varient entre 30 à 50%, les populations des insectes étaient surveillées pendant quatre saisons, et des études sont en cours sur quelques aspects de la lutte intégrée.* Aphis craccivora *se manifeste comme un vecteur important du virus du nanisme du pois chiche (virus de l'enroulement du haricot). Des études préliminaires ont révélé des différences de pH des exsudats foliaires de quelques cultivars sensibles ou résistants de pois chiche. Les ravageurs des stocks les plus importants sont les espèces différentes de* Callosobruchus, *dont* C.

1. Entomologist and Postdoctoral Fellow, Food Legume Improvement Program, International Center for Agricultural Research in the Dry Areas (ICARDA), P.O. Box 5466, Aleppo, Syria.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

chinensis, la plus dominante. Une étude détaillée a montré que les infestations varient de 0 à 79% en Syrie. Le criblage n'a pas mis en évidence de niveau acceptable de résistance, mais certaines introductions d'espèces sauvages de Cicer *se sont révélées résistantes. Dans les essais des méthodes traditionnelles de protection de semences, la combinaison huile d'olives et sel a montré une efficacité de 90% pendant quatre mois de stockage.*

In general chickpea (*Cicer arietinum*) is not much favored for insect feeding and thus is attacked by only a few species. However, some of these do cause extensive damage, and control methods need to be developed. Here the main chickpea insect pests in the Mediterranean region and approaches to their control are discussed.

Field Insect Pests

Chickpea Leafminer

Liriomyza cicerina (Rondani) is the dominant leafminer species in the International Center for Agricultural Research in the Dry Areas (ICARDA) region. Two other species attacking chickpea in Syria were identified as *Chromatomyia horticola* (Goureau) and *Agromyza* spp by Dr B. Pitkin, British Museum, Natural History, London, but their relative importance needs further study. In Syria, the leafminer starts emerging from its diapause in early April. Sampling of adult populations with the D-Vac revealed two generations, the first reaching peak populations in the beginning of May, the second in early June (Fig. 1). As the adult population decreased, larval populations increased, as revealed by sampling, using water-filled trays placed between the plant rows to collect the full-grown larvae dropping to the soil for pupation. The increase in the larval population paralleled the increase in the proportion of leaflets mined. With the onset of crop maturity the leafminers disappear and survive the summer and winter as diapausing pupae in the soil.

At ICARDA resistance screening is conducted in the field under natural leafminer infestations using a visual damage score. The first rating in the vegetative stage, estimating the percentage of the plant mined, was highly correlated (r = 0.8) with actual percentage of leaflets mined. The second rating in the reproductive stage estimates the defoliation, indicating whether the plant could tolerate the mining and/or had any effective defense reactions to the initial mining. To date 6800 chickpea lines have been screened. Of 31 lines initially rated resistant, 10 lines consistently showed low leafminer damage. Most of these lines have smaller leaflets and particularly small seeds, but factors such as plant height, days to flowering and maturity were not apparently correlated with resistance to leafminer (Table 1). These chickpea lines are now being studied for possible resistance mechanisms, especially the composition and amount of leaf exudates, since the amount of malic acid in leaf exudates was found to be correlated with the degree of resistance to *Helicoverpa armigera* (Rembold and Winter 1982) .

Preliminary studies at ICARDA revealed that a whole complex of leafminer parasitoids is present in the region. The two dominant species occuring in high densities were identified as *Diglyphus isaea* (Walker) (Eulophidae) and *Opius monilicornis* (Fischer) (Braconidae) (T. Huddleston, British Museum, Natural History, London). In Morocco up to 20% parasitization of leafminer by *O. monilicornis* was found. The distribution, seasonal occurrence, and biology and effectiveness of these will be studied. If they prove to be effective, biological control could be combined with the use of chickpea lines with resistance to leafminer.

Pod Borer

In Syria chickpea is attacked by *Helicoverpa armigera* (Hübner), *Heliothis viriplaca* (Hufnagel) and *Heliothis peltigera* (Denis and Schiffermuller), the latter being only of minor importance. In most years *H. armigera* and *Heliothis* spp do not cause major damage in chickpea in northern Syria, but infestations are high in southern Syria. During a survey in April 1989, a season with high infestation, mean pod infestations in farmers fields in northern Syria ranged from 6 to 13% as compared to 20 to 40% in the south (Table 2). Population density and development was monitored by pheromone traps over 4 years (1986-89) in southern Syria. Both *H. armigera* and *H. viriplaca* emerge in March/April. In all years *H. viriplaca* had only one peak or generation and disappeared after 4 weeks, whereas *H. armigera* had 3 peaks and was present throughout the growing season until harvest (Fig.2). Temperature and rainfall had major effects on the population. In 1986

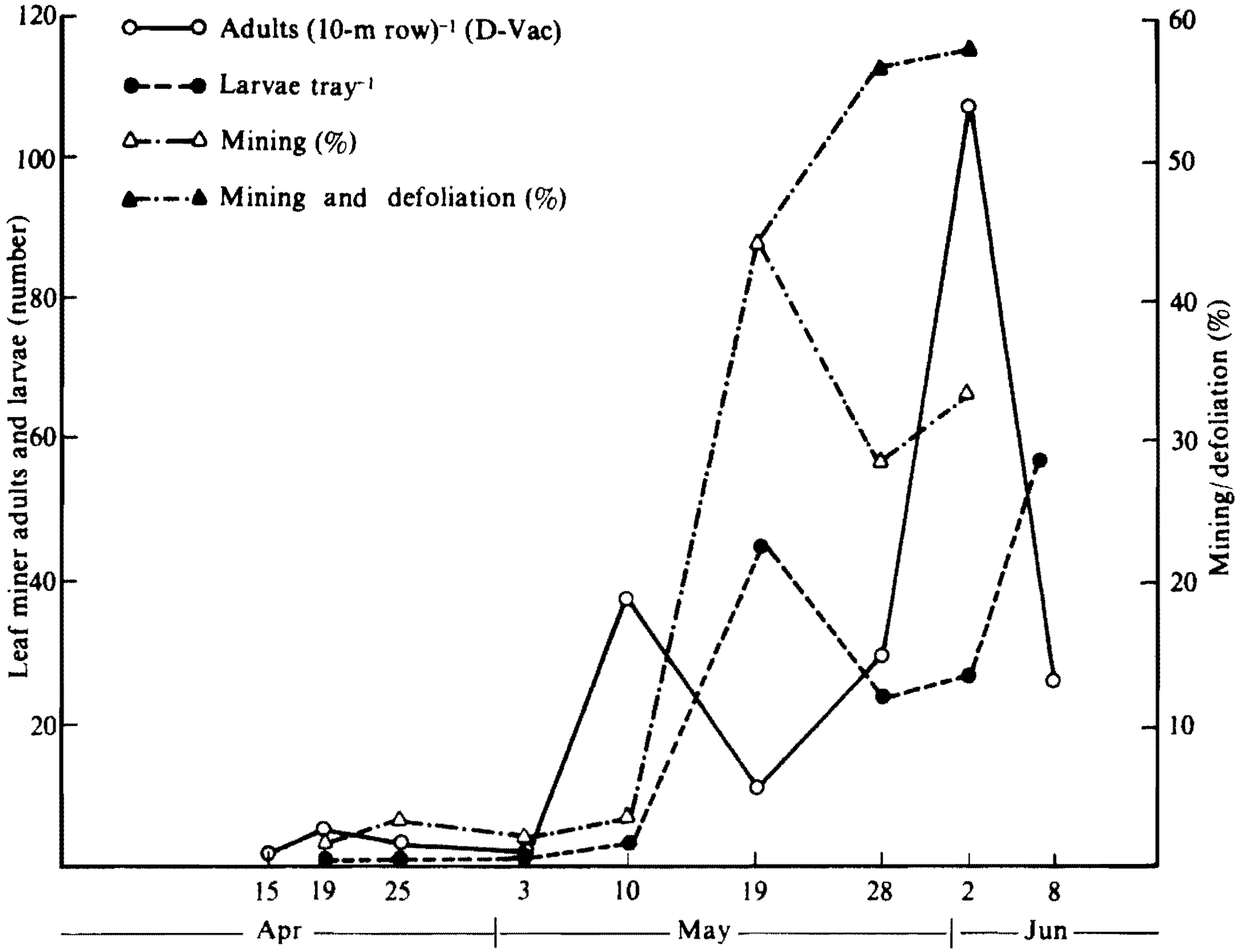


Figure 1. Chickpea leaf miner adult and larval population development, and percentage of leaflets mined, Syria 1986/87.

Table 1. Leafminer resistance ratings and plant characteristics of some selected chickpea lines, Tel Hadya, 1987/88.

Chickpea line (ILC No.)	VDS[1]	Leaf area (cm²)	100-seed mass (g)	Plant height (cm)	Days to Flowering	Days to Maturity
316	4	4.6	20.5	52	155	187
394	4	5.3	20.3	59	151	185
655	4	4.5	23.0	57	153	185
822	5	3.2	20.9	55	146	181
922	4	3.9	23.8	49	149	185
1003	4	4.5	23.1	49	151	185
1009	4	4.4	21.9	49	149	185
1048	4	4.5	19.1	47	155	185
1216	4	4.0	22.4	54	151	185
3828	4	4.9	25.6	50	149	199
5655	4	3.0	20.6	41	134	180
5667	5	3.7	19.0	40	134	180
5901	3	4.8	23.8	50	146	182
3397	9	4.2	59.4	58	122	182

1. VDS = Visual damage score on a scale of 1-9, where 1 = no damage; 9 = most severely damaged.

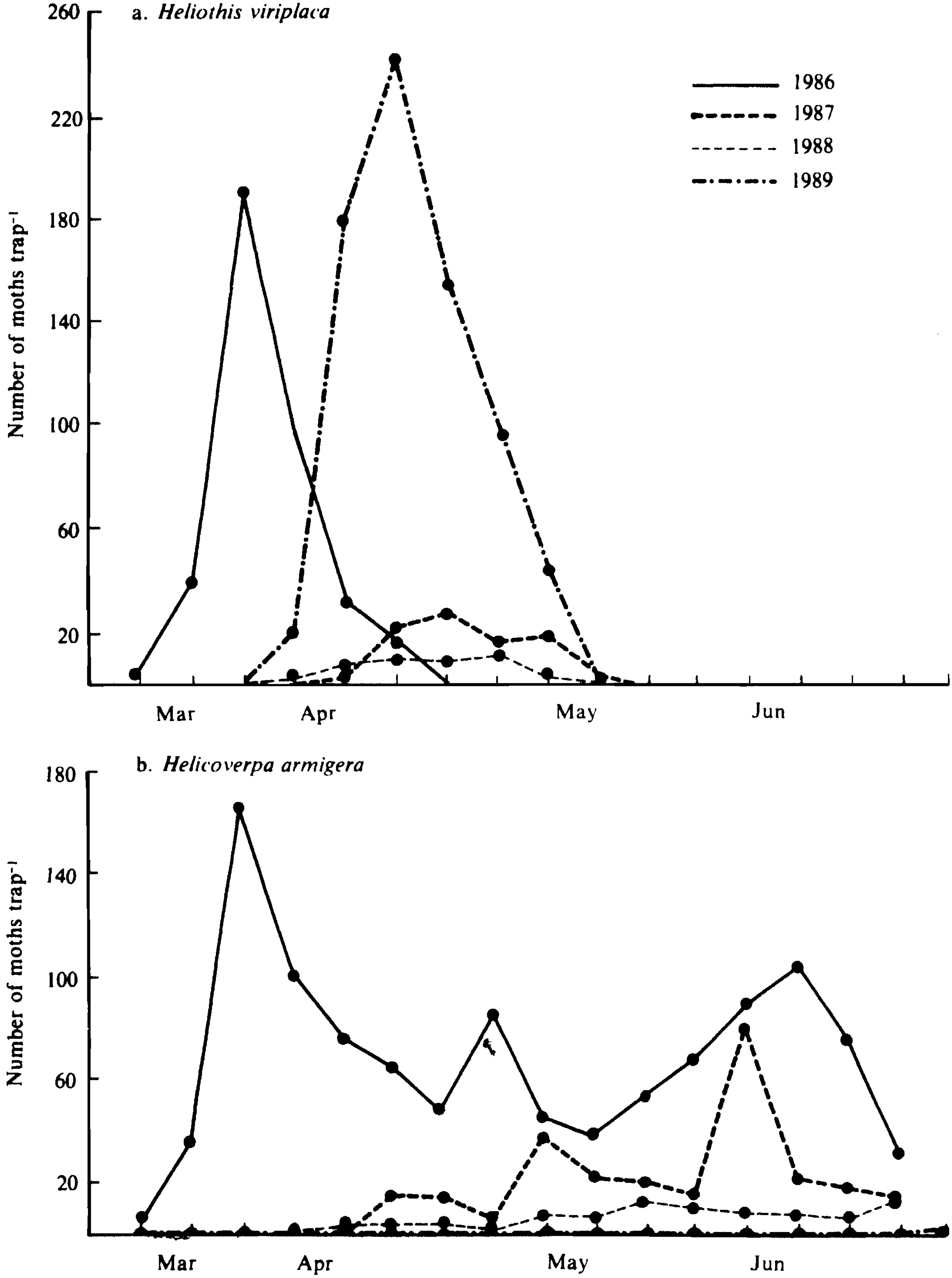


Figure 2. Pheromone trap catches of a. *Heliothis viriplaca* and b. *Helicoverpa armigera* during 4 seasons in southern Syria.

Table 2. Mean percentage pod infestation of *Helicoverpa armigera* and *Heliothis viriplaca* in two chickpea cultivars in Syria, April 1989.

	Ghab 1		Ghab 2	
Province	No. of samples	Pod infestations (%)	No. of samples	Pod infestations (%)
Kamihly	3	4.3	6	2.6
Aleppo	6	6.1	4	10.0
Idlib	2	7.3	2	19.8
Hama	3	6.8	3	11.4
Homs	1	5.1	1	13.4
Tartous	1	2.3	1	2.0
Dara'a	4	33.1	1	20.0
Suweida	2	21.9	1	40.9

and 1989 pheromone trap catches were high, probably due to high temperatures and low rainfall during March/April. Low temperatures during March 1987 and high rainfall in spring 1988 resulted in low population densities of pod borer. Interestingly, in 1989 no *H. armigera*, but only *H. viriplaca* was found in the pheromone traps and on the chickpea plants. The reason for this is not known, and more study is needed. Winter sowing of chickpea might give an opportunity for an earlier build up of populations of *H. armigera* and *H. viriplaca*, resulting in higher infestations in the chickpea crop itself as well as in the following summer crops. Experiments are therefore being conducted on the effect of different sowing dates, plant density, and chickpea genotype on pod borer infestation.

Aphids

Aphis craccivora (Koch) is the main aphid species feeding on chickpea and an important vector of the bean leaf roll virus causing chickpea stunt disease. Early in the season *A. craccivora* feeds on chickpea only for a short time, which is, however, sufficient for virus transmission. High aphid densities usually occur later in the season. Since differences in aphid infestations of different chickpea lines were observed at ICARDA, three chickpea lines with very low and one with high aphid infestation were selected for study of a possible mechanism of resistance by measuring the pH of leaf washings. Six young and 6 middle-aged leaves per plant were submersed in 40 mL of de-ionized water and shaken for 10 seconds.

The pH of leaf washings from the susceptible chickpea line ILC 1929 was higher than those from the three resistant lines (Fig.3). A higher pH correlated with a higher number of aphid colonies per plant. In all four chickpea lines, the pH of the leaf washings of older leaves was higher than that of young leaves, suggesting that the production of leaf exudates and malic acid might be decreasing with aging of the leaves. Further studies under controlled conditions are underway to elucidate this mechanism.

Storage Insect Pests

The most common and important storage pests of chickpea are the multivoltine species *Callosobruchus chinensis* (L.) and *Callosobruchus maculatus* (F.) of which the first is the most common. In 1987 and 1989 a survey of the importance and distribution of chickpea storage pests was conducted in Syria and Jordan during which 228 seed samples were collected from 136 farmers and merchants. In Syria 7% of the samples were infested. Infestations were higher in the south, reaching a maximum of 70%. In Jordan 24% of the samples were infested and the highest infestation of 100% was found in the north.

The survey also revealed that fumigation with phostoxin is commonly used for seeds that are to be sown, whereas seeds for consumption sometimes are traditionally protected by mixing them with olive oil, or salt, or a mixture of both.

In a laboratory experiment the effectiveness of olive oil, cotton seed oil, sunflower oil, corn oil, and olive oil with salt was compared to that of two insecticides, K-Othrin® and Actellic®. Every 2 months 50 seeds were infested with 4 female and 4 male *C. chinensis*, and the number of progeny per female counted after 1 month.

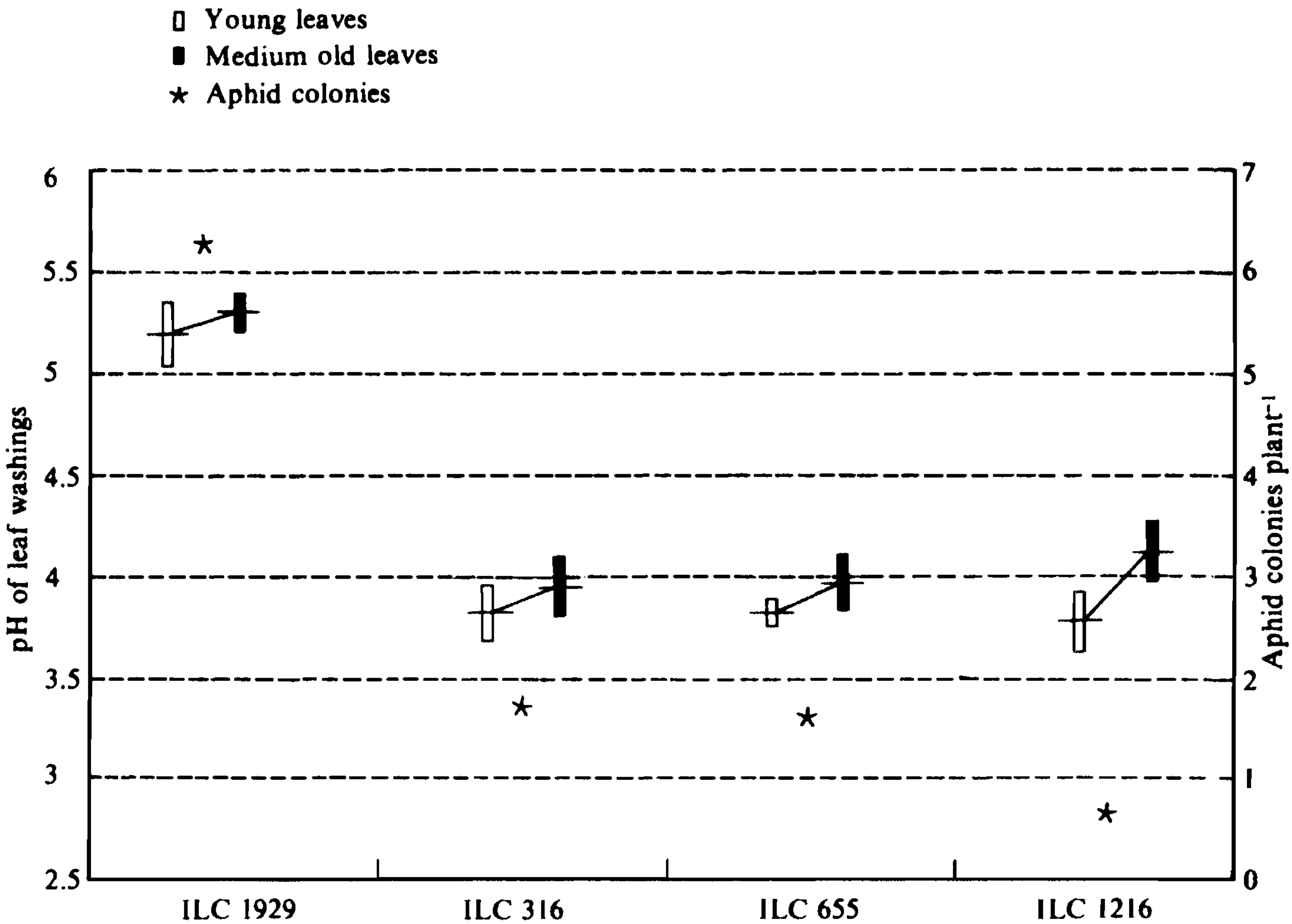


Figure 3. The pH of leaf washings and number of aphid colonies on four chickpea lines with different degrees of susceptibility to *Aphis craccivora*.

Immediately after treatment all substances were 100% effective in controlling the infestations. The insecticides were 100% efficient even 12 months after treatment (Fig. 4). The effectiveness of cotton seed, sunflower and corn oil was short-lived and decreased to about 10% after only 2 months. Olive oil with salt, however, showed 90% effectiveness after 4 months although the effectiveness decreased to 37% after 12 months.

To reduce the use of insecticides a screening program was carried out at ICARDA to identify chickpea lines with resistance to *C. chinensis*. In the screening of 6697 kabuli chickpea lines seed infestation ranged from 32 to 100%, and the progeny per female from 5 to 97. No acceptable degree of resistance was found. In the screening of 137 accessions of 8 wild *Cicer* species however, 61 accessions with some resistance were

Table 3. Resistance of 61 selected accessions of 8 wild *Cicer* species to *Callosobruchus chinensis* measured by number of progeny per female and percentage seed infestation.

Cicer species	No. of accessions	Progeny female⁻¹ (Range)	Seed infestation (%) (Range)
C. bijugum	20	0 - 0.5	0- 4
C. judacium	19	0 -10.5	0-80
C. reticulatum	12	0 - 4.0	0-24
C. cuneatum	3	0 - 1.3	0- 8
C. echinospermum	3	0	0
C. pinnatifidum	3	6.3-11.8	50-81
C. chorassanicum	1	2.5	20
Susceptible control		46	100

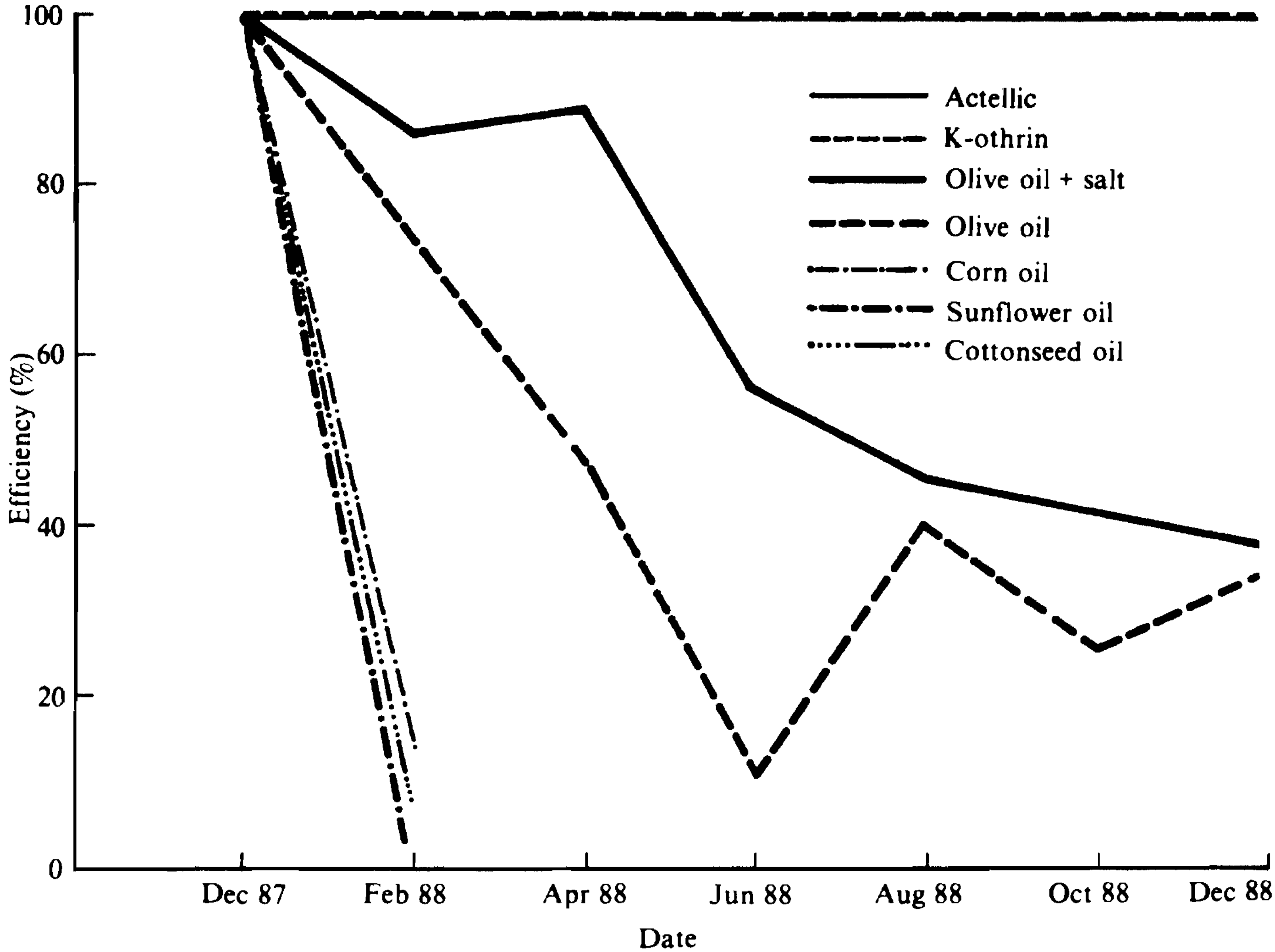


Figure 4. The percentage efficiency (measured by progeny female^{-1} over a 1-year period) of different plant oils and two insecticides for control of *Callosobruchus chinensis* on stored chickpea seeds.

selected (Table 3). Considering accessions with less than 4 progenies per female and 30% seed infestation as resistant, 38 accessions were selected for more detailed studies. *Cicer echinospermum*, which allowed neither bruchid progeny production, nor seed infestation, is particularly promising. This species will be studied for mechanisms of resistance, to determine whether resistance is due to seed morphology or chemical properties.

Reference

Rembold, H., and **Winter, E.** 1982. The chemist's role in host-plant resistance studies. Pages 241-250 *in* Proceedings of the International Workshop on *Heliothis* Management, 15-20 Nov 1982, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Damage/Yield Relationships due to *Helicoverpa armigera* (Hübner) Larvae in Chickpea in India

V.K. Sehgal[1]

Abstract

Information on damage/yield relationships (DYRs) is essential to establish economic injury levels. Linear correlations between yield reduction and pod damage (PD) in unprotected compared with protected crops in All India Coordinated Pulses Improvement Project (AICPIP) (1982–88) insecticide trials showed significant positive values for Pantnagar and Hisar in the north and Coimbatore in the south. Severe PD close to maturity cannot be compensated for and is reflected in yield reduction. However, foliar damage, common in warmer southern India, can well be compensated for by plants resulting in insignificant DYRs.

Résumé

Relations dégâts/rendement dues aux larves de* Helicoverpa armigera *(Hübner) chez le pois chiche en Inde : *Des informations sur les relations dégâts/rendement sont indispensables à l'établissement des seuils de nuisibilité. Dans le cadre des essais insecticide du Projet coordonné indien d'amélioration des légumineuses (AICPIP), de 1982 à 1988, les corrélations linéaires entre la réduction de rendement et les dégâts aux gousses, dans les cultures protégées vis-à-vis les cultures non protégées, ont montré des valeurs positives significatives pour Pantnagar et Hisar dans le nord et pour Coimbatore dans le sud. Des dégâts très importants aux gousses vers le stade de maturation ne peuvent pas être compensés et se manifestent dans les réductions de rendement. Cependant, les dégâts foliaires, très répandus dans la région plus chaude du sud de l'Inde, peuvent être compensés par les plantes permettant ainsi des relations dégâts/rendement insignifiantes.*

Most economic insect damage to chickpea in India, is due to larval feeding on flowers and pods. Crop losses caused by insect pests are known to vary considerably between years and areas, because of differences in agronomic practices and environmental factors (Matthews 1984). Chickpea pod borer damage (PD) also varies in different agroecological regions (Sehgal and Pimbert, unpublished). Although information on damage yield relationships (DYRs) are essential to establish economic injury levels, this area has not received much attention from chickpea entomologists. The main objective of this paper is to evaluate the available data in India, and use it to assess DYRs in chickpea.

Methodology

To study DYRs in different agroecological regions, correlations between percentage yield reduction in unprotected and protected plots in All India Coordinated Pulses Improvement Project (AICPIP) (1982–88) insecticide trials, and % PD, applying Abbott's

1. Senior Entomologist (Pulses), Department of Entomology, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar 263 145, Uttar Pradesh, India.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

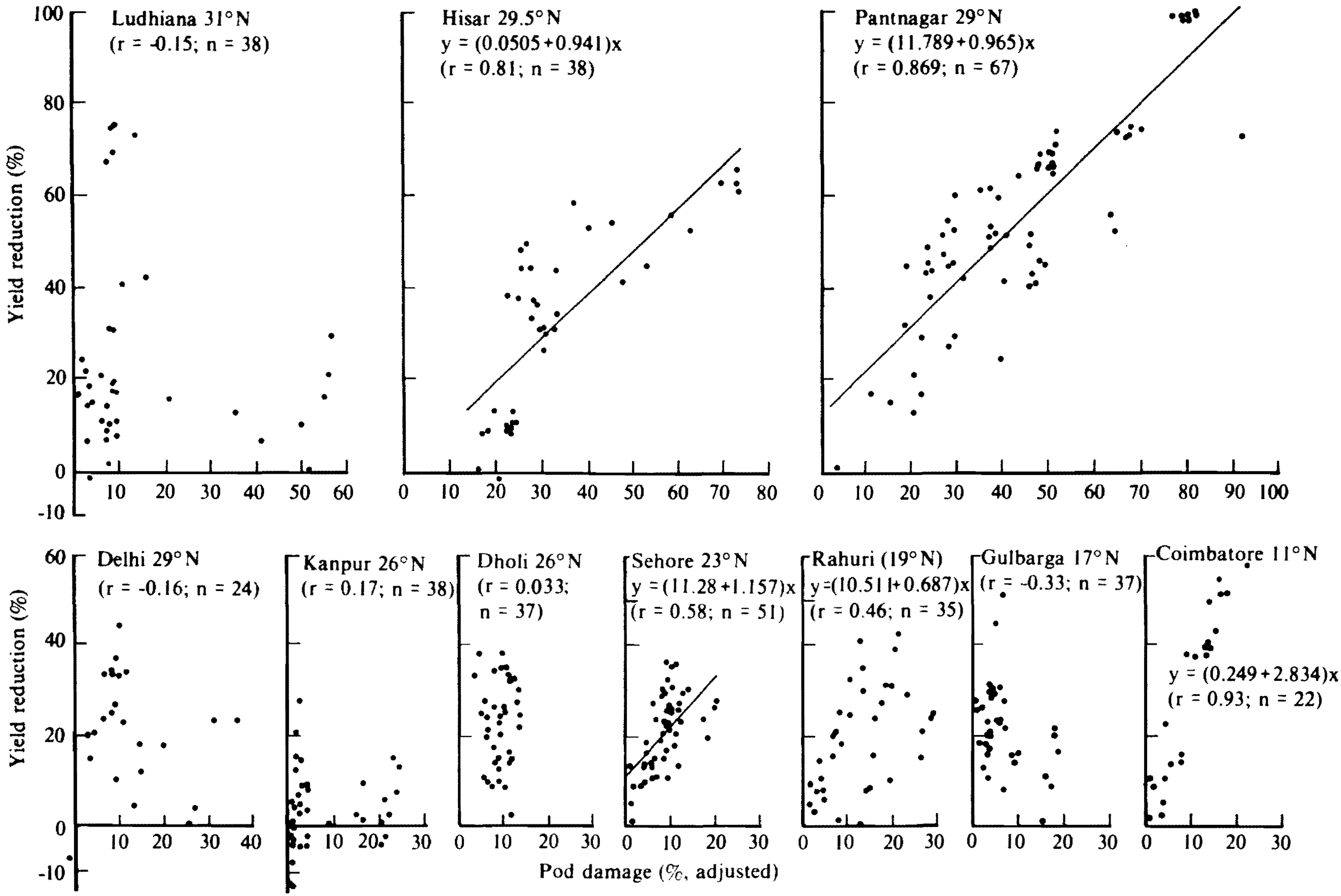


Figure 1. Relationship between yield reduction (%) in unprotected treatments in All India Coordinated Pulses Improvement Project (AICPIP) insecticide trials (1982–88) and pod damage (%, adjusted) by *Helicoverpa armigera*, for data from Ludhiana, Hisar, Pantnagar, Delhi, Kanpur, Dholi, Sehore, Rahuri, Gulbarga, and Coimbatore.

formula as below, were computed for various data sets from Ludhiana 31°N, Hisar 29.5°N, Pantnagar 29°N, Delhi 29°N, Kanpur 26°N, Dholi 26° N, Sehore 23°N, Rahuri 19°N, Gulberga 17°N and Coimbatore 11°N.

$$\text{Adjusted \% PD} = \frac{(\text{\% PD in unprotected plots} - \text{\% PD in protected plots}) \times 100}{(100 - \text{\% PD in protected plots})}$$

Results and Discussion

Data sets collected in AICPIP insecticide trials between 1982 and 1988, were analyzed for linear relationships between yield reduction and adjusted pod damage. The results of the analyses are shown in Figure 1. Highly significant positive linear correlations were obtained for data from Pantnagar and Hisar in northern, and Coimbatore in southern India. Less significant, but positive linear correlations were also obtaianed for data from Sehore and Rahuri. At other places the percentage reduction in yield could not be directly related to PD.

Reed et al. (1987) suggested that % PD cannot be directly related to yield loss, as foliar damage may reduce the number of pods that are carried by the plants. In the major chickpea-producing areas of northern India, little foliar damage occurs during the vegetative stage, due to the low mean winter temperatures that inhibit larval activity. Yet the crop often suffers substantial pod damage in 'hot spots' such as Pantnagar and Hisar, where peak larval populations are synchronized with pod development. At such places there is little compensation for pod damage, because damage occurs when the crop is near maturity. Here PD shows a significant positive relationship with yield loss as it did in an experiment at ICRISAT Center, where there was insufficient time to allow compensatory pods to form or mature (Sehgal et al., unpublished). Pod damage and yield, adjusted for variability between years, had significant negative linear correlations at Pantnagar (Sehgal and Ram Ujagir 1990). At other places in central and southern India, the chickpea crop often suffers low to moderate damage, because of the nonsynchrony of pest populations and pod development (Sehgal and Pimbert, unpublished). At such places compensation, first for foliar and then for flower and pod damage, is continuous so long as growth conditions permit such compensation.

Conclusion

Chickpea yields vary in different agroecological regions, due to variations in pest pressure, agronomic practice, and environmental factors. Severe pod damage close to maturity cannot be compensated for, and shows a direct relationship with yield. Moderate foliar or early pod damage stimulates compensation, and plants often recover and form pods if subsequent pest pressure eases, and growth conditions so permit. DYR studies are essential to establish meaningful economic injury levels under local pest pressures, and to develop safe and economic pest management practices.

Acknowledgments

I express my gratitude to ICRISAT and G.B. Pant University of Agriculture and Technology, for the opportunity to conduct the studies reported here.

References

AICPIP (All India Coordinated Pulses Improvement Project). 1982-1988. Annual reports on 'rabi' pulses, Entomology. Kanpur, Uttar Pradesh, India: Directorate of Pulses Research.

Matthews, G.A. 1984. Pest management. London, UK: Longmans.

Reed, W., Cardona, C., Sithanantham, S., and **Lateef, S.S.** 1987. Chickpea insect pests and their control. Pages 283-318 *in* The chickpea (Saxena, M.C., and Singh, K.B., (eds.). Wallingford, Oxon, UK: CAB International.

Sehgal, V.K. and **Ram Ujagir.** 1990. Effect of synthetic pyrethroids, neem extracts and other insecticides for the control of pod damage by *Helicoverpa armigera* (Hübner) on chickpea and pod damage-yield relationships at Pantnagar in northern India. Crop Protection 9(1):29-32.

Host-plant Resistance to *Helicoverpa armigera* in Different Agroecological Contexts

S.S. Lateef[1] and J.N. Sachan[2]

Abstract

Helicoverpa (Heliothis) armigera *(Hübner) is a major pest of chickpeas* (Cicer arietinum *L.) in many areas of the world and causes substantial losses in yields. To reduce such losses host-plant resistance is an important strategy. Since 1976, more than 14 000 germplasm accessions and breeding lines have been screened under open-field, unsprayed conditions at ICRISAT Center in India. Some of the lines were found to suffer considerably less borer damage than others, and subsequent tests confirmed the level of resistance/tolerance to* Helicoverpa. *Since 1980, these selections and breeding lines were assessed for their performance together with the borer-tolerant genotypes identified by the AICPIP entomologists in different agroecological zones of India. The results obtained from the collaborating centers are discussed. A comparison of the varietal performance was made by giving Relative Resistance Ratings. The selections ICC 506, ICCV 7 (ICCX 730008-8-1-1P-BP), ICC 6663, ICC 10817, ICCL 86102,ICCL 86103, ICC 4935-E2793, ICCX 730041-8-1-B-BP, PDE-2, and PDE-5 were found to have a good level of resistance to* H. armigera *across the agroecological zones of India in comparison with the standard controls of the relevant maturity groups. International Chickpea* Heliocoverpa *Resistance Nurseries were supplied in 1985 by ICRISAT to collaborating scientists in India and elsewhere for a systematic assessment of* Helicoverpa *resistance in germplasm selections and breeding lines. Results indicated the suitability of certain selections in different regions. The limitations and problems in undertaking such testing are also discussed. As most of the borer-resistant selections were found to be susceptible to fusarium wilt and ascochyta blight, it is essential to incorporate the disease resistances in them for a stable production.*

Résumé

Résistance de la plante-hôte à* Helicoverpa armigera *dans des contextes agroécologiques variés : *Helicoverpa (Heliothis) armigera (Hübner) est un ennemi majeur du pois chiche (*Cicer arietinum *L.) dans bien des régions du monde et occasionne des pertes de rendement importantes. Pour réduire ces pertes, une stratégie importante est celle de la résistance de la plante-hôte. Depuis 1976, plus de 14 000 introductions de matériel génétique et lignées de sélection ont été criblées dans des conditions de culture en champs ouverts, sans pulvérisation, au Centre ICRISAT en Inde. On a constaté que certaines des lignées subissent considérablement moins de dégâts par les foreurs que d'autres lignées. Les essais ultérieurs ont aussi confirmé le niveau de résistance/tolérance à* Helicoverpa. *Depuis 1980, ces plantes sélectionnées et lignées de sélection ont été évaluées pour leurs performances, conjointement avec les génotypes tolérants aux foreurs, identifiés par les entomologistes de l'AICPIP dans différentes*

1. Entomologist, Legumes Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

2. Principal Scientist (Entomology), Directorate of Pulses Research, Kalyanpur, Kanpur 208 024, Uttar Pradesh, India.

ICRISAT Conference Paper no. CP 563.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

zones agroécologiques de l'Inde. Les résultats obtenus en provenance des centres coopératifs sont exposés et examinés. Une comparaison de la performance variétale a été effectuée en désignant les niveaux de résistance relative. On a constaté que les lignées sélectionnées ICC 506, ICCV 7 (ICCX 730008-8-1-1P-BP), ICC 6663, ICC 10817, ICCL 86102, ICCL 86103, ICC 4935-E2793, ICCX 730041-8-1-B-BP, PDE-2, et PDE-5 ont un bon niveau de résistance à H. armigera *dans les diverses zones agroécologiques de l'Inde, en comparaison avec les témoins standard des groupes de maturité correspondants. Des pépinières internationales pour la résistance du pois chiche à* Helicoverpa *ont été fournies par l'ICRISAT, en 1985, à des chercheurs coopératifs en Inde et ailleurs, en vue d'une évaluation systématique de la résistance à* Helicoverpa *dans des plantes sélectionnées et des lignées de sélection. Les résultats ont indiqué comment certaines sélections conviennent dans différentes régions. Les limites et les problèmes imposés à la réalisation de tels essais sont également discutés. La plupart des lignées résistantes aux foreurs étant sensibles au flétrissement fusarien et à la flétrissure ascochytique, il est essentiel de leur incorporer la résistance aux maladies, afin d'assurer la stabilité de la production.*

The lepidopteran pod borers, *Helicoverpa armigera* (Hübner), *Helicoverpa zea* (Boddie), *Heliothis virescens* (Fab.), and *Heliothis viriplaca* (Hufnagel) have been reported as important widespread pests of chickpea (*Cicer arietinum* L.) (Lateef 1985; Reed et al. 1987). Among these *H. armigera* is the major pest, and can cause substantial crop losses in almost all countries where chickpea is grown, particularly in Africa, Asia, Australia, and Europe.

Considering the losses caused by *H. armigera* over areas and years, an intensive pest resistance screening program was initiated in 1976 at ICRISAT Center (Lateef 1985). Several lines were found to possess good levels of resistance/tolerance to *H. armigera*. These lines were incorporated in breeding programs to enhance the level of resistance in high-yielding varieties (Gowda et al. 1985; Reed et al. 1988). Since 1980, resistant/tolerant selections and breeding lines have been assessed for their performance along with borer-tolerant selections identified by entomologists from the All India Coordinated Pulses Improvement Project (AICPIP) working in different agroecological zones in India under the AICPIP Program of Advance Stage Testing of Chickpea Promising Selections. Due to certain limitations in this multilocational testing and to problems in maintaining uniformity in testing across locations in India and elsewhere, International Chickpea *Helicoverpa* Resistance Nurseries (ICHRN) were established in 1985 (ICRISAT 1987). A set of genotypes representing different maturity groups was supplied to cooperators in India and other chickpea-growing countries. We summarize here data on the overall performance of *Helicoverpa* resistant varieties grown in different agroecological zones of the semi-arid tropics.

Screening of Germplasm and Breeding Lines

A method of screening genotypes in separate trials under open-field conditions was developed at ICRISAT, wherein entries have a narrow range of maturities and the "control" cultivar is of similar maturity. The percentage of pods damaged at maturity in the test entries was compared with that of the controls in the trial. The test entries were rated for relative resistance (RR) using a formula suggested by Lateef and Reed (1985).

Since 1976, more than 14 000 chickpea germplasm accessions and breeding lines have been screened at ICRISAT Center, under open-field pesticide-free conditions. Entries that yielded less, and suffered greater pest damage than the controls were rejected. In this way several lines with considerably and consistently reduced susceptibility to *H. armigera* have been identified (Table 1). The results of testing lines bred for *Helicoverpa* resistance since 1985 are presented in Table 2.

Multilocational Testing of Promising Selections by ICRISAT/ICAR

Since 1980, the genotypes found to be promising at ICRISAT were made available every year to several collaborators from different research centers in five agroecological zones in India, viz., West Zone (WZ), North West Plain Zone (NWPZ), North East Plain Zone (NEPZ), Central Zone (CZ), and Southern Zone

Table 1. Mean Relative Resistance Rating (RR) and Percentage Borer Damage (BD) of chickpea genotypes resistant to *Helicoverpa armigera* (Hübner) under pesticide-free conditions at ICRISAT Center, 1979-89.

Chickpea genotypes	Mean RR[1]	BD (%)[2]
Desi short-duration group		
ICC 506	3.0 (9)[3]	1.1-12.8
ICC 10667	3.1 (9)	1.7-14.2
ICC 10619	3.4 (9)	2.7-21.0
ICC 6663	3.5 (10)	1.1-31.8
ICC 10817	3.6 (10)	2.4-30.0
ICCV 7(ICCX 730008-8)	3.8 (8)	3.8-11.8
Controls		
Annigeri 1	6.0 (10)	13.2-36.3
ICCX 730266 (susceptible)	7.1 (9)	14.9-33.0
Desi medium-duration group		
ICC 4935-E2793	2.8 (10)	2.3-11.9
ICCX 730041-8-1-B-BP-EB	3.8 (10)	1.7-38.2
ICCX 730094-18-2-1P-BP-EB	4.6 (10)	3.8-20.0
Controls		
K 850	6.0 (10)	11.4-40.9
ICC 3137 (susceptible)	8.5 (10)	13.5-65.5
Desi long-duration group		
ICCX 730020-11-1-1H-B-EB	4.3 (10)	2.8-26.9
Control		
H 208	6.0 (10)	3.8-44.3
Kabuli medium-/long-duration group		
ICC 10870	4.3 (9)	4.4-39.3
ICC 5264-E10	3.8 (10)	2.5-28.3
ICC 8835	5.4 (8)	11.6-26.7
Control		
L 550	6.0 (10)	2.8-39.4

1. Relative Resistance Rating (RR) scored on a scale of 1-9, where 1 = resistant, 9 = susceptible (Lateef and Reed 1985).
2. Range of percentage borer damage to pods 1979-89.
3. Figures in parentheses indicate number of years in trial.

(SZ). The data received from the collaborators—as summarized in AICPIP Entomology Reports on Rabi-Pulses 1981-89—were processed, and relative resistance ratings were given. The zonewise overall means of these ratings for the promising selections grouped by maturity are given in Table 3. The data from these multilocational trials indicate that borer incidence varied greatly from place to place and season to season. At some trial locations borer incidence was too low for a good comparison to be made. Often there was no uniformity in grouping the material, no consistency in testing, and no means of proper comparison. At many places appropriate controls were not grown. Yield data were also missing for some tests. Many selections were tested only once or twice during a period of 10 years. However, from the data available it can be seen that the selections ICC 506, ICCX 730008 (ICCV 7), ICC 6663, ICC 10817, ICCL 86102, ICCL 86103, PDE 2, and PDE 5 in the desi short-duration; ICC 4935-E2793 and ICCX 730041 in the desi medium-duration; and ICCX 730020-11-2 in the long-duration groups showed resistance to *Helicoverpa* across agroecological zones. Most of these selections have produced greater yields than the control cultivars, wherever they were tested more than once. Two of these selections, ICCX 730008 (ICCV 7) and PDE 2 were identified by AICPIP in 1986 as donor parents for *Helicoverpa* resistance breeding programs in India.

International Chickpea *Helicoverpa* Resistance Nurseries (ICHRN)

To overcome some of the problems faced in maintaining uniformity across locations in the multilocational testing program in collaboration with AICPIP entomologists, International Chickpea *Helicoverpa* Resistance Nurseries (ICHRN) were established at ICRISAT in 1985 (ICRISAT 1987). These nurseries were offered to chickpea scientists in India and other countries. Collaborators from Australia, Bangladesh, Brazil, Ethiopia, India, Iran, Kenya, Mexico, Myanmar, Nepal, Pakistan, the Philippines, Sudan, Syria, Tanzania and Tunisia were supplied with the seed material of the maturity trials they requested along with all the details required to conduct trials uniformly and to collect information on; agroclimatologic conditions of the region, resistance levels, and the regional adaptability of the test entries. The borer resistant/tolerant selections which have to date been found promising in seven countries are presented in Table 4. The interpretation of the results in connection with agroecological zonation is in progress, and will be finalized when information from all the participating countries has been received.

In general, these nurseries provide useful results fairly quickly because the testing is uniform and allows comparisons to be made across locations. A major drawback to multilocational testing has been that the seed failed to reach collaborators in some countries on time. Moreover, entomologists were not always available to record pest activity at all locations, although other scientists were very cooperative in providing relevant information.

Table 2. Relative Resistance Rating (RR) and yield (t ha^{-1}) of chickpea lines bred for *Helicoverpa* resistance under pesticide-free conditions, at ICRISAT Center, 1985-89.

Chickpea lines	1985/86		1986/87		1987/88		1988/89		Mean		Yield (% of control)
	RR[1]	Yield	RR	Yield	RR	Yield	RR	Yield	RR	Yield	
ICCL 86101	2	0.97	5	1.18	3	1.26	5	1.04	3.3	1.11	103
ICCL 86102	3	1.16	3	1.26	3	1.12	4	1.02	3.3	1.14	106
ICCL 86103		NT[2]	3	1.19	3	1.53	2	0.90	2.7	1.21	112
ICCL 86104		NT	4	1.37	4	1.39	8	0.89	5.3	1.22	113
ICCV 7	3	0.81	5	1.19	3	1.28	3	1.01	3.5	1.07	99
Control											
Annigeri	6	0.86	6	1.16	6	1.19	6	1.12	6.0	1.08	
SE		±0.096 (36)[4]		±0.125 (20)		±0.113 (20)		-[3]			
BD%[5] control									8-19		
ICCL 86105		NT	3	2.03	7	1.16	9	0.90	6.3	1.36	108
Control											
K 850		NT	6	1.35	6	1.29	6	1.13	6.0	1.26	
SE				±0.112 (24)		±0.113 (20)		-			
BD% control									10-36		
ICCL 86106		NT	5	0.95	3	0.84	8	0.95	5.3	0.91	100
Control											
H 208		NT	6	0.76	6	0.92	6	1.05	6.0	0.91	
SE				±0.120 (16)		±0.103 (14)		-			
BD(%) control									4-28		

1. Relative Resistance Rating (RR) scored on a scale of 1-9, where 1 = resistant and 9 = susceptible (Lateef and Reed 1985).
2. NT = not tested.
3. - = no SE because yields were from large unreplicated plots.
4. Figures in parentheses indicate number of trials.
5. BD(%) = percentage borer damage to pods (range).

Table 3. Mean Relative Resistance Ratings (RR)[1] in ICRISAT/ICAR advanced stage testing of promising chickpea selections under pesticide-free conditions in different agroecological zones in India, 1980–89.

Promising selections and control cultivars	Indian zones: South (SZ)	Central (CZ)	Northeast plains (NEPZ)	Northwest plains (NWPZ)	West (WZ)
Desi short-duration					
ICC 506	4.0 (8)[2]R[3]	5.7 (3)R	4.0 (2)R	5.0 (3)R	-[4]
ICCX 730008-8-1-1P-BP-EB	3.4(15)R	4.8 (8)R	4.6 (9)R	5.3(11)R	-
ICCX 730162-2-1P-B-EB	6.0 (4)	-	-	5.0 (2)R	-
ICCX 730213-9-1-3H-B	5.0 (4)R	9.0 (1)	-	-	-
ICC 6663	4.4 (5)R	5.0 (3)R	3.5 (2)R	5.5 (2)R	-
ICC 10817	3.7 (3)R	3.5 (2)R	3.8 (4)R	4.8 (5)R	-
ICCL 86101	3.2 (5)R	3.0 (3)R	4.0 (4)R	6.2 (6)	-
ICCL 86102	3.0 (5)R	5.7 (3)R	4.5 (4)R	4.8 (5)R	-
ICCL 86103	2.7 (3)R	5.0 (2)R	-	-	-
ICCL 86104	3.3 (3)R	4.0 (2)R	6.0 (1)	8.0 (1)	-
C 10	6.0 (1)	3.0 (1)	3.0 (2)R	-	-
PDE 2	4.8 (5)R	5.8 (4)R	3.9 (7)R	5.6 (8)R	-
PDE 5	4.0 (5)R	5.8 (4)R	2.8 (4)R	5.8 (7)R	-
DPR/CE 7-2	-	4.0 (1)	6.0 (1)	5.8 (6)R	-
DPR/CE 1-2	-	4.0 (1)	4.7 (3)R	7.0 (5)	-
DPR/CE 3-1	-	4.0 (1)	4.0 (3)R	6.0 (6)	-
DPR/CE 2-3	-	3.0 (1)	4.7 (3)R	6.7 (6)	-
Control					
Annigeri	6.0(11)	6.0 (2)	-	6.0 (3)	-
BD%[5] control	2-35	1-30	3-18	8-65	-
Desi medium-duration					
ICC 4935-E2793	4.9(13)R	4.8(12)R	4.3(18)R	5.7(24)R	6.0 (1)
ICCX 730041-8-1-B-BP-EB	4.5 (8)R	4.8 (4)R	3.0 (4)R	5.2 (7)R	-
BDN 9-3	5.0 (1)	5.0 (3)R	6.0 (1)	8.0 (1)	-
ICCX 730185-2-4-1H-EB	7.3 (4)	4.8 (6)R	5.3 (7)R	5.5 (4)R	5.0 (1)
ICCX 730179-24-1-1H-B-EB	5.3 (4)R	5.2 (6)R	5.7 (6)R	6.7 (4)	5.0 (1)
ICC 3474-4EB	5.3 (3)R	5.6 (4)R	5.7 (3)R	6.0 (4)	6.0 (1)
ICCX 730190-12-1H-B-EB	6.0 (3)	5.3 (3)R	6.0 (4)	6.0 (2)	6.0 (1)
ICCX 730025-11-3-1H-EB	6.0 (3)	4.5 (2)R	5.2 (5)R	6.0 (2)	6.0 (1)
ICC 5800	7.3 (3)	4.3 (3)R	8.7 (3)	7.0 (2)	-
S 76	3.1 (1)	3.0 (1)	3.5 (2)R	5.5 (2)R	6.0 (1)
N 37	4.6 (5)R	6.3 (4)	4.3 (4)R	6.8 (9)	-
PDE 1	4.0 (1)	3.0 (1)	5.0 (2)R	-	-
ICC 3473-4EB	7.7 (3)	5.6 (1)	5.4 (5)R	7.0 (2)	6.0 (1)
Control					
C 235	6.0 (4)	6.0 (8)	6.0 (8)	6.0(16)	6.0 (1)
BD% control	3-41	3-57	< 1-35	5-74	2-3
Desi long-duration					
ICCX 730020-11-1-1H-EB	6.1(10)	4.7 (3)R	4.0(12)R	5.9(22)R	-
ICCX 730020-11-2-1H-EB	5.0 (3)R	4.7 (3)R	5.8 (4)R	5.2 (4)R	6.0(1)
ICC 10243	5.2 (6)R	6.3 (4)	4.6 (7)R	5.6(18)R	-

continued

Table 3. *continued*

Promising selections and control cultivars	Indian zones				
	South (SZ)	Central (CZ)	Northeast plains (NEPZ)	Northwest plains (NWPZ)	West (WZ)
GL 1002	-	8.0 (2)	4.0 (2)R	4.6 (8)R	-
Pant G-114	-	-	-	4.7 (3)R	-
PDE 7	6.0 (5)	9.0 (3)	4.7 (6)R	6.7 (9)	-
Controls					
H 208	6.0 (4)	6.0 (5)	6.0 (4)	6.0(19)	-
G 130	6.0 (5)	6.0 (5)	6.0 (4)	6.0(6)	6.0(1)
BD% control	4-28	4-30	1-24	3-74	3-4
Kabuli medium and long-duration					
ICCX 730244-17-2-2H-EB	7.0 (3)	-	3.7 (6)R	5.1(13)R	-
ICC 5264-E10	–	-	5.0 (2)R	5.0 (5)R	-
ICC 4856	5.0 (3)R	9.0 (1)	6.3 (3)	6.3 (3)	-
ICC 5264-E9	3.0 (1)	7.0 (1)	3.0 (2)R	4.0 (1)	-
ICC 7966	5.0 (2)R	6.0 (1)	-	5.0 (2)R	7.0(1)
ICC 7559-4EB	5.5 (2)R	7.0 (1)	4.0 (1)	5.0 (2)R	6.0(1)
ICC 2553-3EB	4.0 (2)R	6.0 (1)	6.0 (1)	7.0 (4)	5.0(1)
ICC 2695-3EB	4.5 (2)R	6.0 (1)	9.0 (1)	6.8 (4)	7.0(1)
Control					
L 550	6.0 (5)	6.0 (2)	6.7 (3)	5.3 (8)R	6.0(1)
BD% control	6-23	< 3.0	5-21[6]	3-79[7]	3-4

1. Relative Resistance Rating (RR) scored on a scale of 1-9, where 1 = resistant and 9 = susceptible (Lateef and Reed 1985).
2. Figures in parentheses indicate number of trials.
3. R = resistant.
4. - = no data.
5. BD% = percentage borer damage to pods (range).
6. Compared with ICC 3137.
7. Compared with C 235.

Conclusions

As the result of the intensive screening program at ICRISAT Center, AICPIP Centers, and from multilocational testing several genotypes resistant to *H. armigera*, have been identified and most of these are being used in breeding better borer-resistant genotypes with high-yielding characters. Many of these genotypes have also been found resistant in different agroecological zones under the infestation conditions at the test locations.

ICRISAT breeders have now initiated a germplasm enhancement program to increase the levels of pest resistance in chickpea, that should produce high-yielding genotypes with greater levels of resistance in the near future.

Yields of selections tested in different zones are not presented in this paper. However, in ascertaining their suitability for a given location, the yield potential in that environment is also taken into consideration. Most of the borer resistant/tolerant selections were found to be susceptible to diseases, particularly to fusarium wilt and ascochyta blight. A few of the borer-resistant lines are resistant to fusarium wilt and some are resistant to ascochyta blight. In view of the increase in the incidence of diseases in chickpea-growing areas, it is essential to incorporate multiple disease resistant characters into high-yielding borer-resistant material to ensure yield stability.

Acknowledgments

The authors are grateful to collaborating entomologists and other scientists of the national agricultural research

Table 4. Mean Relative Resistance Rating (RR) in International Chickpea *Helicoverpa* Resistance Nurseries (ICHRN) tested in different countries and in different agroecological zones in India, 1985-89.

	Indian zones										
Chickpea genotypes	South (SZ)	Central (CZ)	South-eastern (SEZ)	North-west plains (NWPZ)	North-east plains (NEPZ)	Bangla-desh	Mexico	Myanmar	Pakistan	Syria	Tanzania
Short-duration group											
ICCX 730008-8-1-1P-BP	3.4(5)[2]R[3]	5.7(8)R	4.0(1)	-[4]	-	-	3.0(1)	5.2(4)R	-	-	2.0(1)
ICC 506	3.2(5)R	4.5(8)R	4.0(1)	-	-	-	3.0(1)	5.3(4)R	-	-	2.0(1)
ICCL 86103	2.5(2)R	5.5(4)R	3.2(1)	-	-	-	-	4.0(1)	-	2.0(1)	-
ICCL 86104	2.5(2)R	5.2(4)R	3.0(1)	-	-	-	-	5.0(1)	-	3.0(1)	-
ICCL 86101	3.0(2)R	5.5(4)R	3.0(1)	-	-	-	-	7.0(1)	-	-	-
ICCL 86102	3.0(2)R	4.7(4)R	3.0(1)				-	6.0(1)	-	-	-
Controls											
Annigeri 1	6.0(5)	6.0(8)	6.0(1)	-	-	-	6.0(1)	6.0(4)	-	-	6.0(1)
Local	5.0(3)R	6.3(8)	3.5(2)R				4.0(1)	7.5(4)	-	-	3.0(1)
BD%[5] control	5-26	5-28	27	-	-	-	30	< 1-17	-	47	4
Medium-duration group											
ICC 4935-E2793	3.0(2)R	4.8(5)R	5.7(3)R	5.0(1)	3.0(1)	8.0(1)	8.0(1)	-	5.5(2)R	3.0(1)	3.0(1)
ICCX 730041-8-1-B-BP	4.0(2)R	4.8(4)R	5.4(2)R	6.0(1)	2.0(1)	8.0(1)	8.0(1)	-	8.5(2)	-	3.0(1)
ICCL 86105	-	6.0(1)	5.0(1)	-	-	-	-	-	-	3.0(1)	-
Controls											
Local	-	5.0(5)	6.0(3)	-	2.0(1)	7.0(1)	4.0(1)	-	6.0(2)	-	3.0(1)
K 850	6.0(2)	6.0(5)	6.0(3)	6.0(1)	6.0(1)	6.0(1)	-	-	-	6.0(1)	6.0(1)
BD% control	11-16	3-13	8-31	14	16	3	13	-	2-13	-	3
ICC 5264-E10	7.0(2)	5.2(4)R	6.7(3)	9.0(1)	6.0(1)	8.0(1)	6.0(1)	-	7.0(2)	-	5.0(1)
Control											
L 550	6.0(2)	6.0(5)	6.0(2)	6.0(1)	6.0(1)	6.0(1)	6.0(1)	-	6.0(2)	-	6.0(1)
BD% control	13-14	3-21	13-17	3	26	4	30	-	3-12	-	4
Long-duration group											
ICCX 730020-11-1-1H-B	6.0(1)	6.5(2)	5.3(3)R	5.7(3)R	-	9.0(1)	5.0(1)	-	3.5(2)R	3.0(1)	5.0(1)
ICC 10243	4.0(1)	4.0(3)R	4.0(3)R	5.0(3)	-	9.0(1)	6.0(1)	-	3.0(2)R	-	2.0(1)

Continued

Table 4. *Continued.*

Chickpea genotypes	Indian zones: South (SZ)	Central (CZ)	South-eastern (SEZ)	North-west plains (NWPZ)	North-east plains (NEPZ)	Bangla-desh	Mexico	Myanmar	Pakistan	Syria	Tanzania
ICCL 86106	-	9.0(1)	-	-	-	-	-	-	-	3.0(1)	3.0(1)
Control											
Local	-	6.5(2)	4.0(3)R	8.5(2)	-	5.0(1)	7.0(1)	-	3.5(2)R	6.0(1)	2.0(1)
H 208	6.0(1)	6.0(2)	6.0(3)	6.0(3)	-	6.0(1)	6.0(1)	-	6.0(2)	6.0(1)	6.0(1)
BD% control	7	3-10	9-30	20-32	-	< 3	3-22	-	1-28	-	3
ICCX 730244-17-2-2H	6.0(1)	7.0(2)	8.0(3)	5.3(3)R	-	7.0(2)	6.0(1)	-	7.0(2)	-	4.0(1)
Control											
Rabat	6.0(1)	6.0(2)	5.7(3)R	6.0(3)	-	6.0(1)	6.0(1)	-	6.0(2)	-	6.0(1)
BD% control	-	5-13	12-33	10-43	-	< 5	27	-	2-13	-	5

1. Relative Resistance Rating (RR) score on a scale of 1-9, where 1 = resistant and 9 = susceptible (Lateef and Reed 1985).
2. Figures in parentheses indicate number of trials.
3. R = resistant.
4. - = no data.
5. BD% = percentage borer damage to pods (range).

systems of India and other countries, who helped to conduct these tests. Thanks are also due to the staff of Legumes Entomology Unit, ICRISAT, particularly to M.A. Ghaffar, Research Associate, for processing the data, A.R.R. Swamy and B.V.R. Sastry for typing, M.P. Pimbert for reviewing the manuscript, and to D. Neely, Consultant Statistician at ICRISAT for his suggestions on the presentation of data.

References

Gowda, C.L.L., Lateef, S.S., Smithson, J.B., and **Reed, W.** 1985. Breeding for resistance to *Heliothis armigera* in chickpea. Pages 36-39 *In* National Seminar on Breeding Crop Plants for Resistance to Pests and Diseases, 25-27 May 1983, Coimbatore, India. Coimbatore, Tamil Nadu, India: Tamil Nadu Agricultural University.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1987. Page 138 *in* Annual report 1986. Patancheru, 502 324, A.P., India: International Crops Research Institute for the Semi-Arid Tropics.

Lateef, S.S. 1985. Gram pod borer (*Heliothis armigera*) (Hüb.) resistance in chickpeas. Agriculture, Ecosystems, and Environment 14:95-102.

Lateef, S.S., and **Reed, W.** 1985. A suggested system of rating pigeonpea and chickpea entries for field resistance to *Heliothis armigera*. Pages 127-131 *in* National Seminar on Breeding Crop Plants for Resistance to Pests and Diseases, 25-27 May 1983, Coimbatore, India. Coimbatore, Tamil Nadu, India: Tamil Nadu Agricultural University.

Reed, W., Cardona, C., Lateef, S.S., and **Bishara, S.I.** 1988. Screening and breeding for insect resistance in pea, lentil, faba bean and chickpea. Pages 107-115 *in* World crops: cool season food legumes: proceedings of the International Food Legume Research Conference on Pea, Lentil, Faba Bean, and Chickpea, 6-11 Jul 1986, Spokane, Washington, USA (Summerfield, R.J., ed.). Dordrecht, Netherlands: Kluwer Academic Publishers.

Reed, W., Cardona, C., Sithanantham, S., and **Lateef, S.S.** 1987. Chickpea insect pests and their control. Pages 283-318 *in* The chickpea (Saxena, M.C., and Singh, K.B., (eds.). Wallingford, Oxon, UK: CAB International.

Mechanisms of Host-plant Resistance with Special Emphasis on Biochemical Factors

H. Rembold[1], P. Wallner[2], A. Köhne[2], S.S. Lateef[3], M. Grüne[2], and Ch. Weigner[2]

Abstract

Chickpea (Cicer arietinum) *semiochemicals are one component of its resistance/susceptibility against attack by phytophagous insects. These signal chemicals have been studied on the basis of field resistance data and of insect behavior by use of olfactometer (larvae) and flight tunnel (adults) assays. In collaboration with ICRISAT, the main emphasis has been placed on the gram podborer,* Helicoverpa (Heliothis) armigera. *In collaboration with ICARDA the leafminer,* Liriomyza cicerina, *has been recently included as another pest of chickpea. From the distance-perceivable signals, four volatiles (pentan-1-ol, Δ-3-carene, myrcene, ∝-pinene) have been identified as components of the chickpea kairomone. Their 2:5:1:9 mixture is highly attractive to* H. armigera *under laboratory conditions, to larvae as well as to the female adults. It elicits attractiveness specifically to the egg-laying moth. Chickpea exudates are candidates for contact resistance. The main components of exudates are malate and oxalate which are present in variable absolute and relative concentrations. However, there are characteristic differences, depending on varieties, diurnal cycles, and growth stage. Interrelation of these semiochemicals with other resistance factors are discussed on the basis of their use as biochemical markers for breeding strategies.*

Résumé

***Mécanismes de la résistance de la plante-hôte—facteurs biochimiques** : Les substances sémiochimiques du pois chiche (*Cicer arietinum*) représentent une composante de sa résistance/sensibilité aux attaques par les insectes phytophages. Ces substances ont été étudiées sur la base de données de résistance sur le terrain et du comportement des insectes par l'usage de l'olfactomètre (larves) et du tunnel de vol (adultes). En collaboration avec l'ICRISAT, on s'est surtout préoccupé du foreur des gousses* Helicoverpa (Heliothis) armigera. *En collaboration avec l'ICARDA, la mineuse des feuilles,* Liriomyza cicerina *a récemment été reconnu comme un autre ennemi du pois chiche. D'après les signaux perceptibles à distance, quatre composés volatils (pentane-1-ol, Δ-3-carène, myrcène, ∝-pinene) ont été identifiés comme composants du kairomone du pois chiche. En laboratoire, leur mélange 2:5:1:9 est très attrayant pour* H. armigera, *pour les larves aussi bien que pour les adultes femelles. Il attire spécifiquement les noctuelles pondant les oeufs. Des exsudats de pois chiche sont des candidats à la résistance au contact. Les principaux composants d'exsudats sont le malate et l'oxalate, qui se présentent à des concentrations absolues et relatives variables. Toutefois, il existe des différences caractéristiques, selon les variétés, les cycles diurnes et le stade de croissance. Les rapports réciproques entre ces substances sémiochimiques et d'autres facteurs de résistance sont examinés sur la base de leur usage comme marqueurs biochimiques pour des stratégies de sélection.*

---

1. Professor, University of Munich, and Head, Research Unit for Insect Biochemistry, and
2. Research Associates, Max-Planck Institute for Biochemistry, D-8033 Martinsried, Federal Republic of Germany.
3. Entomologist, Legumes Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

Charles Baudelaire reflects in a letter that "perfumes, colors, and sounds echo one another". Although he may have only thought of our own attitudes, his comment mirrors the interdependency of the many and often most different environmental signals which control not only our own, but also the behavior of a phytophagous insect in relation to its host plant. Most important cues in this connection may be foliar forms, surface textures, or color stimuli which influence host acceptance by the larva and by the ovipositioning insect. The day–night cycle influences egg laying. Field data (Topper 1987) and laboratory observations (Singh and Rembold 1989) of *Helicoverpa (Heliothis) armigera* show that egg number rapidly increases to a peak in the dark period succeeding dusk. The peak egg-laying period occurs between 5 and 8 days after emergence under field conditions (Reed 1965), and 5 to 9 days under laboratory conditions (Singh and Rembold 1989). Maximum individual lifetime fecundity of 3000 and highest number of 950 eggs delivered in one day were found under laboratory conditions (Singh and Rembold 1989). Raina (1988) suggests that together with the photoperiod a signal from the host plant is essential to induce sex pheromone production in the virgin *H. zea* moth. What kind of chemical signals are involved in the expression of the pest insect's explosive reproductive potential? In other words - what role does the natural products' chemist play in the study of host-plant versus insect relations? Can modern analytical chemistry, in combination with efficient bioassays, elucidate biochemical markers for resistance phenomena and consequently add to new techniques in plant breeding? A few facets from our own studies will demonstrate the efficiency of such an approach.

Microanalytical methods like capillary gas chromatography (GC) or high-performance liquid chromatography (HPLC), eventually, after microderivatization, have become routine. It is for the chemist to establish a highly sensitive, quantitative, and typical procedure that can be used for mass screening of pedigrees under different environmental conditions. First applications of such methods and the results obtained have already been summarized in a preceding workshop (Rembold and Winter 1982). In continuation of this work and using behavioral assays, chickpea seed volatiles were adsorbed on a polymer and, after desorption, were screened for their attractiveness to *H. armigera* larvae and adults. In our search for contact signals we made exudate analyses from field- and greenhouse-grown chickpea plants and related them to their susceptibility to pest insects.

In Search of a Synthetic Kairomone

The fantastic reproductive power of *H. armigera* females makes them a promising target for crop protection strategies. Knowing more about the volatile attractants (kairomones) could help in catching females (and eventually also the larvae) in traps or, after they have layed their eggs on trap plants, their progeny (Rembold 1989a,b). Such results will, through identification of biochemical markers, finally be useful for crop improvement programs.

In our initial studies we found that volatiles from chickpea seed powder strongly attract first instar *H. armigera* larvae (Saxena and Rembold 1984). Headspace material from seed flour was analyzed by capillary GC-mass spectrometry, and 132 aroma components were structurally assigned. The dominant chemical classes were terpenoids (35%), alcohols (18%), and aromatic compounds (13%) (Rembold et al. 1989a). Interestingly, the aromagrams from chickpea seed keep a constant pattern over years and therefore can be used for the characterization of different chickpea varieties. The 16 most prominent aroma components were individually tested in a special trident olfactometer assay with newly hatched first instar *H. armigera* larvae. Only pentan-1-ol induced a significant positive, and 2-trans-heptenal a significant negative, repelling reaction. A blend of three terpenes (Δ-3-carene, myrcene, D,L α-pinene) elicited the same larval reaction as pentan-1-ol, and a mixture of all the four compounds in their natural ratio of 2 pentan-1-ol : 5 Δ-3-carene : 1 myrcene : 9 D, L-α-pinene induced the strongest attraction which was similar to the natural bouquet (Rembold et al. 1989b).

With this synthetic kairomone we tested the behavior of adult moths in a flight tunnel as described earlier (Rembold and Tober 1985) which, after slight modification, allows observations under different experimental conditions. Egg- laying moths were attracted near the source, irrespective of its kairomone concentration. Mated females showed a much stronger reaction than unmated females, and males were almost without any response. However, the kairomone-containing rubber septum was almost never contacted. Observations under laboratory conditions as recorded in these experiments are important for a better understanding of the insect's behavior in the field where such cues as flowers, pods, shape and color of the leaves may mask the kairomone effect. Under our experimental situation the insects' behavior clearly shows that the volatiles are principally functioning as a distance information which guides the egg-laying moth near to its host plant.

Chemical Composition of Exudates and *H. armigera* Resistance

The chickpea secretes on its total green surface a highly acidic exudate which seems to be correlated with insect resistance, mainly through its malic acid content (Rembold 1981). We therefore followed changes of malate and other organic acids in the exudate in more detail. Two sampling techniques were applied. Either the droplets were collected from the plant surface with cotton wool, or the twigs were dipped into water. Three types of analyses were applied: enzymatic estimation with L-malate dehydrogenase (L-MDH), GC quantification of the trimethylsilyl (TMS) derivative, and HPLC analysis. In addition, total acidity was titrated, and the total water contents measured by dry matter estimation and by Karl-Fischer titration.

Susceptibility of chickpea genotypes to *H. armigera* attack varies with the growth stage of the plant, and with the population density of the insect. This primarily explains the enormous variations in field data. Exudates were collected from 12 chickpea cultivars on ICRISAT fields. The exudate dry matter of these genotypes, which were sampled under identical conditions, varied by almost 500% and the same was found for their malic acid contents, whereas other organic acids (oxalic, formic, acetic) varied by about 200%. There is a clear diurnal rhythm in dry matter, which has a minimum in the early morning and a maximum at sunset with a variation by 250-450% Some varieties clearly correlate between borer damage and malate contents, if its concentration is in the range of 250-400 mg mL^{-1} exudate. The same holds true for the chickpea varieties with high borer damage, which have malate contents of 100 mg or less mL^{-1} of exudate. However, the groups with moderate damage and malate contents of 100 - 250 mg mL^{-1} are less open to a simple interpretation. Some of them have fairly low malate in their dry matter together with reduced acidity in their exudates. Here obviously other factors come into play. They may be based on surface texture, kairomone composition, or nutritional factors. This question can now be approached on the basis of our present knowledge and expertise.

Is malic acid a general insect repellent? The leafminer, *Liriomyza cicerina*, is an important chickpea pest at the International Center for Agricultural Research in the Dry Areas (ICARDA). We therefore selected in a preliminary study six kabuli-type cultivars with known susceptibility/resistance to the leafminer. They were grown under controlled conditions in the greenhouse of the Max-Planck Institute (MPI) at Martinsried, Federal Republic of Germany. Analysis of these greenhouse-grown ICARDA genotypes indeed showed enormous differences in the dry-matter composition, if malate, and oxalate, as the second most prominent organic acid in chickpea exudate, were compared.

Interestingly, as with *H. armigera*, the cultivar with high resistance to *L. cicerina* had the highest amount of malic acid, and the susceptible one had the lowest level of malic acid. And there is an intermediate range which must be explained by other factors. If malate concentration is compared with that of oxalate, some interesting differences become apparent on the basis of substance per leaf surface. During the day, total malate is constant, but oxalate is variable for each cultivar. Total malate per leaf surface area is also constant, and oxalate variable, during the maturation period of each cultivar. For both malate and oxalate the studied ICARDA cultivars differed from each other with high significance.

Basic Research in the Laboratory for the Field

Our study of two of the many signals which bring the pest insect to its host plant for egg-laying, and which keep the larva on it, have shown a clear behavioral response to the synthetic kairomone under laboratory conditions. Also our first field tests under high infestation pressure brought catches with the synthetic kairomone. Almost exclusively egg-laying *H. armigera* moths were caught in batches of more than 100 individuals when using pheromone traps in ICRISAT fields (unpublished results). In order to improve the synthetic kairomone, we are now investigating the sesquiterpenoid components which also add to the natural signal. Here too, sensitive bioassays are a prerequisite. With such an improved synthetic bouquet, and with specially designed traps we expect to obtain good catches in the field. Such positive results could then feed into breeding programs. One could either select for plants with high kairomone production and consequently use them as trap plants, or reduce the attractiveness by selecting for low kairomone release. The second field of interest, the contact chemicals, is of equal importance for resistance breeding. Plants grown at the ICRISAT Cooperative Research Stations at Hisar or Gwalior under high humidity, suffered from high fungal infestation, and concomitantly had practically no malate in their exudate (unpublished results). Breeding for high malic acid release could be interesting both from the point of resistance against insects and fungal infection. Here too, a sensitive analytical technique like HPLC can help. It is our intention therefore, with this heuristic approach, to transfer analytical methods to the breeder and to the entomologist at a routine level, and in that way to assist them in effectively developing resistant genotypes.

Acknowledgment

These studies were financially supported by the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Eschborn, Federal Republic of Germany.

References

Raina, A.K. 1988. Selected factors influencing neurohormonal regulation of sex pheromone production in *Heliothis* species. Journal of Chemical Ecology 14:2063-2069.

Reed, W. 1965. *Heliothis armigera* (Hbn.) (Noctuidae) in western Tanganyika. I. Biology with special reference to the pupal stage. Bulletin of Entomological Research 50:117-125.

Rembold, H. 1981. Malic acid in chickpea exudate - a marker for *Heliothis* resistance. International Chickpea Newsletter 4:18-19.

Rembold, H. 1989a. Kairomones—chemical signals related to plant resistance against insect attack. Pages 352 - 364 *in* New crops for food and industry (Wickens G.E., Haq, N., and Day, P., eds.) London, UK: Chapman and Hall.

Rembold, H. 1989b. Behavioral chemicals in insect–plant interactions. Pages 71-78 *in* Dynamics of insect–plant interaction (Ananthakrishnan, T.N., and Raman, A., eds.) New Delhi, India: Oxford and IBH Publishing Co.

Rembold, H., and Tober, H. 1985. Kairomones as pigeonpea resistance factors against *Heliothis armigera*. Insect Science and its Application 6:249-252.

Rembold, H., Wallner, P., Nitz, S., Kollmannsberger, H., and Drawert, F. 1989a. Volatile components of chickpea (*Cicer arietinum*) seed. Journal of Agricultural and Food Chemistry 37:659-662.

Rembold, H., Wallner, P., and Singh, A.K. 1989b. Attractiveness of volatile chickpea (*Cicer arietinum* L.) seed components to *Heliothis armigera* larvae (Lep., Noctuidae). Journal of Applied Entomology 107:65-70.

Rembold, H., and Winter, E. 1982. The chemist's role in host-plant resistance studies. Pages 241-250 *in* Proceedings of the International Workshop on *Heliothis* Management, 15-20 Nov 1981, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Saxena, K.N., and Rembold, H. 1984. Attraction of *Heliothis armigera* (Hübner) larvae by chickpea seed powder constituents. Journal of Applied Entomology 97:145-153.

Singh, A.K., and Rembold, H. 1989. Oviposition behaviour of *Heliothis armigera* (Lepidoptera: Noctuidae) in relation to the day–night cycle. Insect Science and its Application 10:393-400.

Topper, C.P. 1987. Nocturnal behavior of adults of *Heliothis armigera* (Hübner) (Lepidoptera: Noctuidae) in Sudan Gezira and pest control implications. Bulletin of Entomological Research 77:541-554.

Insecticide Resistance of *Helicoverpa* and its Management

A.B.S. King[1] and R.M. Sawicki[2]

Abstract

The recent upsurge of Helicoverpa (Heliothis) armigera *(Hübner) resistance to synthetic pyrethroids (SPs) on cotton in eastern Andhra Pradesh has followed the previously recorded pattern of resistance developing after excessive use of insecticides as seen elsewhere in the world. It has, however, alerted crop protection scientists in India of the need to take urgent steps to curtail its spread, and to develop appropriate management strategies. Recent demonstrations of* H. armigera *resistance to DDT and, to a lesser extent endosulfan and monocrotophos, and a general flattening of dosage/mortality curves in susceptible insects, emphasize the need for regular resistance monitoring, more stringent control of the use of pesticides against* H. armigera, *and the development of alternative control technologies. The evident inland dispersal of resistant insects from coastal Andhra Pradesh, by a distance of some 250 km, and the resulting establishment of resistance in local, previously susceptible populations, has serious implications. While at present there is rapid reversion to susceptibility in the rainy season through dilution by interbreeding with the predominating susceptible populations, low levels of resistance may remain and lead to more rapid resurgence once selection pressure (by insecticides) is reapplied. Although only low levels of SPs resistance have so far been recorded from the major chickpea areas in northern India, where insecticides are applied for* H. armigera *control, vigilance must be maintained. There is a need for regular resistance monitoring and improved pesticide management, especially with the SPs. All the IPM desiderata of increased use of resistant or tolerant cultivars, timely pesticide applications targetted against neonate larvae based on scouting and economic thresholds, and rotation of insecticides, especially the SPs have to be actively applied if insecticide resistence of* H. armigera *is to be managed.*

Résumé

Résistance aux insecticides de* Helicoverpa *et sa maîtrise : *La récente intensification de la résistance de* Helicoverpa (Heliothis) armigera *(Hübner) aux pyréthroïdes de synthèse sur le cotonnier dans l'est de la province d'Andhra Pradesh a suivi le cours déjà constaté des événements dans d'autres pays du monde : la résistance se développe après un usage excessif d'insecticides. Néanmoins, cela a mis en garde les spécialistes de la protection des cultures de l'Inde quant à la nécessité de prendre des mesures d'urgence pour en empêcher la diffusion et pour mettre au point des stratégies de lutte appropriées. De récentes démonstrations de la résistance de* H. armigera *au DDT et, dans une moindre mesure, à l'endosulfan et au monocrotophos, ainsi qu'un applatissement général des courbes de dosage/mortalité chez les insectes sensibles, met en relief la nécessité de surveiller régulièrement la résistance, de contrôler plus rigoureusement l'usage des pesticides contre* H. armigera *et de mettre au point de nouvelles technologies de lutte. La dispersion évidente vers l'intérieur des insectes résistants*

1. Principal Entomologist, Natural Resources Institute (NRI), Central Avenue, Chatham Maritime, Chatham, Kent ME4 4TB, UK.
2. Senior Principal Entomologist, Agriculture and Food Research Council, Institute of Arable Crops Research, Rothamsted Experimental Station, Harpenden, Herts AL5 2JQ, UK.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

à partir de la zone côtière d'Andhra Pradesh, jusqu'à une distance d'environ 250 km, et l'établissement conséquente de la résistance dans des populations d'insectes locaux et précédemment sensibles, a de graves implications. Même si à présent les insectes reprennent leur sensibilité pendant la saison des pluies, par suite d'une dilution de la résistance par croisement avec des populations sensibles prédominantes, il peut rester de faibles niveaux de résistance qui pourraient mener à une résurgence plus rapide lorsque la pression de sélection est appliquée de nouveau par l'usage d'insecticides. Bien qu'on n'a constaté que de faibles niveaux de résistance aux pyréthroïdes de synthèse jusqu'à présent dans les principales zones de culture du pois chiche dans le nord de l'Inde, région où des insecticides sont utilisés pour lutter contre H. armigera, *il est indispensable de maintenir la vigilance. Il est nécessaire de surveiller régulièrement la résistance et d'améliorer l'utilisation des pesticides, particulièrement dans le cas des pyréthroïdes. Les compléments de la lutte intégrée, à savoir : usage accru de cultivars résistants ou tolérants, épandages opportuns de pesticides visant les larves nouveau-nées sur la base d'études et des seuils économiques, et rotation des insecticides, particulièrement des pyréthroïdes de synthèse, doivent être tous activement appliqués, afin de pouvoir maîtriser la résistance de* H. armigera *aux insecticides.*

Extensive use of wide spectrum insecticides, such as DDT in cotton, has given rise to pest resistance in various parts of the world (e.g., Peru, Egypt, Zimbabwe, Nicaragua). This has led to the development of Integrated Pest Management (IPM) strategies which involved strict rotation of insecticides, curtailment of their use and a heavy investment in scouting as a basis for application. Although they were effective, these systems tended to be abandoned when the relatively cheap, safe, and effective synthetic pyrethroids (SPs) came onto the market in the late 1970s. Subsequently, excessive reliance on, and abuse of SPs, which were forgiving of poor management, led to the rapid development of resistance.

There has now been a tendency in India to attribute all instances of poor control to insecticide resistance, especially where SPs have been used, while more often it has been no more than a contributary factor in a complex interaction of causes. These have included high pest population pressure, inadequate application and equipment, poor timing, low insecticide quality and environmental constraints such as drought and flood. All of these factors appear to have contributed to the disastrous situation for cotton in eastern Andhra Pradesh during recent years.

Development of Insecticide Resistance in India

The high levels of DDT resistance in *Helicoverpa* recently recorded at ICRISAT Center and Guntur (Table 1) are likely to be far more widespread, in view of the prevalence of the cheaper organochlorine insecticides (DDT and BHC) traditionally used on food crops by the poorer farming community. The dearth of base-line insecticide susceptibility data in India has led to the continued use of insecticides long after their effectiveness had substantially declined.

Poor control of *Helicoverpa* by SPs was first noted on pigeonpea at Lam Station, Guntur in 1986 (A. Satyanarayana Reddy personal communication); it was not evident in farmers' cotton because population densities were low.

In October 1987, farmers from Juzzuru, Krishna district, Andhra Pradesh alerted us to the poor control of *Helicoverpa* larvae that they were experiencing. Pyrethroid resistance was suspected and subsequently confirmed independently by McCaffery at Reading, UK and Mehrotra in New Delhi. In November of the same year, poor control of *Helicoverpa* on pigeonpea was recorded at ICRISAT Center for the first time and later confirmed to be due to resistance to fenvalerate (Table 2).

As the season progressed, the SP resistance ratio at ICRISAT Center increased from 40 in early November 1987 to 750 in March 1988. [The resistance ratio is expressed as the LD50 of the tested (resistant) strain divided by the LD50 of the control (susceptible) strain: in this case the 'Reading' strain held at Reading University, UK where the tests were done.] Larvae originating from chickpea, which had not been sprayed, were less resistant. By September 1988 populations of larvae in the rainy season (on millet, sorghum, and early pigeonpea) were again susceptible to SP. Tests con-

Table 1. Toxicity of DDT to *Helicoverpa armigera*.

Collection date	Location	Crop	LD_{50} (μg $larva^{-1}$)	LD_{90} (μg $larva^{-1}$)	LD_{50} resistanc ratio
20 Jul 86	ICRISAT	Chickpea	42 (27-62)[1]	624	70
1-7 Nov 87	ICRISAT	Pigeonpea	182 (62-∝)	(x)[2]	303
17 Mar 88	ICRISAT	Pigeonpea	181 (101-730)	(1724)[3]	302
Control	Reading strain	-	0.60 (0.53-0.68)	0.99	-

1. 95% F.L. in parentheses.
2. (x) = values not computed.
3. Extrapolated value.

All tests were performed as topical applications to 3rd-instar larvae, the F_1 of those collected from the field. Numbers tested varied between 200 and 450 larvae per test (McCaffery et al. 1989).

ducted during November on *Helicoverpa* from cotton in Prakasam and Juzzuru and for pigeonpea at ICRISAT Center showed that SP resistance had fallen significantly (Table 3). This suggests that farmers had followed government advice to restrict the use of SP and that the poor control experienced by many cotton farmers in Andhra Pradesh this year (1988) was not primarily caused by insecticide resistance. Sawicki identified high *Helicoverpa* populations, drought, and inability of farmers to obtain credit to buy insecticides as being the major causes of crop failure in 1988.

Resistance to endosulfan was only significant at Juzzuru, in 1987 (not tested in 1988), but resistance to monocrotophos remained low to virtually nil in both years at all locations (Tables 4 and 5). It is therefore surprising that field control with these insecticides was so poor. A possible explanation might be that application techniques were inadequate against unprecedentedly high pest pressures or that insecticides were of inferior quality.

Migration/Dispersal of Resistant Moths

The appearance of SP resistance at ICRISAT Center coincided with the build-up of resistant populations in

Table 2. Toxicity of fenvalerate to *Helicoverpa armigera*.

Collection date	Location	Crop	LD_{50} (μg $larva^{-1}$)	LD_{90} (μg $larva^{-1}$)	LD_{50} resistance ratio
20 Jul 86	ICRISAT	Chickpea	0.012 (0.009-0.014)[1]	0.033	0.8
1-7 Nov 87	ICRISAT	Pigeonpea	1.8 (1.1-4.0)	17	120
17 Mar 88	ICRISAT	Pigeonpea	4.3 (2.9-6.5)	112	287
Control	Reading strain	-	0.015 (0.013-0.017)	0.030	-

1. 95% F.L. in parentheses.

All tests were performed as topical applications to 3rd-instar larvae, the F_1 of those collected from the field. Numbers tested varied between 200 and 450 larvae per test (McCaffery et al. 1989).

Table 3. Toxicity of cypermethrin to *Helicoverpa armigera*.

Collection date	Location	Crop	LD_{50} (μg larva^{-1})	LD_{90} (μg larva^{-1})	LD_{50} resistance ratio
Cis-cypermethrin					
20 Jul 86	ICRISAT	Chickpea	0.005 (0.004-0.006)[1]	0.020	0.6
Control	Reading strain	-	0.009 (0.008-0.011)	0.025	-
Cis/trans cypermethrin					
23 Oct 87	Juzzuru	Cotton	6.5 (4.7-9.0)	57	325
1-7 Nov 87	ICRISAT	Pigeonpea	0.80 (0.57-1.2)	11	40
15-18 Nov 87	ICRISAT	Pigeonpea	2.5 (1.8-3.5)	9.7	125
30 Nov 87	ICRISAT	Chickpea	1.7 (1.3-2.7)	7.9	85
17 Mar 88	ICRISAT	Pigeonpea	15 (9.1-29.0)	627	750
Control	Reading strain	-	0.020 (0.017-0.024)	0.050	-
17 Sep 88	Aurepalle	Pigeonpea	0.016 (x)[2]	0.20	0.8
15-16 Sep 88	ICRISAT	Pigeonpea	0.036 (x)	0.70	1.8
Nov 88	Prakasam	Cotton	1.19 (x)	(x)	60
Nov 88	Juzzuru	Cotton	0.60 (x)	(x)	30
Dec 88	ICRISAT	Pigeonpea	0.029 (x)	(x)	1.5
Dec 88	Shankarpalle	Tomato	0.104 (x)	(x)	5.2
Control	Reading strain	-	0.020	-	-

1. 95% F.L. in parentheses.
2. (x) = values not completed.

All tests were performed as topical applications to 3rd-instar larvae, the F_1 of those collected from the field. Numbers tested varied between 200 and 450 larvae per test (McCaffery et al. 1989).

cotton in eastern Andhra Pradesh, and could not have arisen locally because SPs had not been used extensively or for long in the area. This strongly implies dispersal or migratory movement of resistant insects inland, over a distance of at least 250 km (McCaffery et al. 1989).

Samples taken in September 1988 at ICRISAT and Aurepalle (100 km south of Hyderabad) again showed almost total susceptibility to SPs. This suggests that resident resistant populations had been replaced or diluted by susceptible moths flying into the area from unsprayed crops and weed hosts. The higher LD90 values, however, suggest that some resistance still remained. The relatively low levels of resistance in the cotton belt in 1988 further suggests a substantial dilution by susceptible moths which had probably moved in on the predominantly westerly monsoon.

The implication for chickpea is that resistant insects may invade unsprayed fields from crops on which resistance may have developed. As most chickpea is grown in northern India, where insecticide resistance is not (yet) of major importance (Mehrotra unpublished

Table 4. Toxicity of endosulfan to *Helicoverpa armigera*.

Collection date	Location	Crop	LD_{50} (μg larva^{-1})	LD_{90} (μg larva^{-1})	LD_{50} resistance ratio
20 Jul 86	ICRISAT	Chickpea	0.56 (0.47-0.68)[1]	1.4	0.5
23 Oct 87	Juzzuru	Cotton	15.0 (11-20)	91.0	12.5
1-7 Nov 87	ICRISAT	Pigeonpea	2.6 (2.1-3.3)	13.0	2.2
15-18 Nov 87	ICRISAT	Pigeonpea	5.3 (3.7-7.6)	88.0	4.4
30 Nov 87	ICRISAT	Chickpea	1.1 (0.75-1.6)	5.1	0.9
Control	Reading strain	-	1.2 (1.1-1.4)	2.4	-

1. 95% F.L. in parentheses.

All tests were performed as topical applications to 3rd-instar larvae, the F_1 of those collected from the field. Numbers tested varied between 200 and 450 larvae per test (McCaffery et al. 1989).

Table 5. Toxicity of monocrotophos to *Helicoverpa armigera*.

Collection date	Location	Crop	LD_{50} (μg larva^{-1})	LD_{90} (μg larva^{-1})	LD_{50} resistance ratio
20 Jul 86	ICRISAT	Chickpea	0.29 (0.22-0.35)[1]	0.51	0.3
23 Oct 87	Juzzuru	Cotton	3.9 (x)[2]	87	3.6
1-7 Nov 87	ICRISAT	Pigeonpea	2.1 (0.5-4.0)	13	1.9
Dec 88	ICRISAT	Pigeonpea	0.57 (x)	(x)	0.5
Dec 88	Shankarpalle	Tomato	2.07 (x)	(x)	1.9
Control	Reading strain	-	1.1 (0.9-1.4)	4.6	-

1. 95% F.L. in parentheses.
2. (x) = values not computed.

All tests were performed as topical applications to 3rd-instar larvae, the F_1 of those collected from the field. Numbers tested varied between 200 and 450 larvae per test (McCaffery et al. 1989).

report), this is at present not an important consideration.

Resistance Management

The development of resistant insect populations is encouraged by high pest pressure, static populations, sublethal doses, and the continued use of the same insecticide group. Under these conditions selection pressure is strongest and leads to the rapid development of resistance. Sublethal doses cannot be avoided as they inevitably result from normal leaf expansion and decomposition of the insecticide. However, they can be minimized by good application methodology, using adequate dosage levels, targetted principally against young larvae and using good quality insecticides.

Since both resistant and susceptible larvae are equally and most readily killed during the first instar (Daly et al. 1988) applications should be targetted at this stage, or shortly after eggs are sampled. As larvae age, resistance becomes increasingly expressed and all large larvae, including those susceptible to insecticides require much higher lethal dosages of insecticide. The tendency of larvae to become more inaccessible as they bore into squares and bolls in cotton is not, however, a problem with chickpea.

The relative efficacy of mixtures or rotation of insecticide groups in preventing or combatting resistance is the subject of some controversy. Based on simple models, Holloway and McCaffery (1988) showed that mixtures were more effective in delaying the development of resistance, but that rotation was preferred when some resistance was already present. Since it is not possible to detect very low levels of resistance in a population using conventional techniques (Sawicki et al. 1989) and because some resistance is nearly always present in routinely sprayed crops, the rotation approach should be adopted in all but exceptional circumstances.

The only national strategy for insectide resistance management (IRM) for *H. armigera* currently in operation is in Australia. This is based on a spraying schedule which restricts the use of SPs to only one generation in four, namely the mid-season generation which is considered to be most damaging. Similar but less stringent restrictions are placed on the use of endosulfan, to which there is also some resistance. Spraying is based on monitoring densities of the brown, i.e., pre-hatching, egg stage. Samples of young larvae are collected regularly from a wide range of locations in eastern Australia for resistance testing, using a discriminating dose test (Forrester and Cahill 1987). To date, this method has been successful in keeping SP resistance at a manageable level. However, the expected decline of resistance at the end of each winter season is dependent upon dilution by susceptible moths from unsprayed hosts. Levels of SP resistance in these unsprayed populations have recently increased (Gunning and Easton 1989), and there is now some doubt whether they can still exert sufficient influence under high population pressures (Forrester, in press). This is clearly relevant to Andhra Pradesh, India, where a similar situation may develop.

Relevance to *Helicoverpa* Management in Chickpea

At present, infestation of chickpea does not demand the extensive control regimes applied to cotton in Andhra Pradesh, so there is much less likelihood of a similar ursurge of resistance. However, Dhingra et al. (1988) detected low levels of SP resistance in *Helicoverpa* sampled from chickpea at Karnal in Haryana, although it is not known whether this was of local origin or had resulted from immigration. Fortunately, *Helicoverpa* infestation of cotton in northern India is low (Mehrotra, unpublished) and does not therefore pose a threat to chickpea comparable to that in southern India. However, there remains a need for vigilance in regular resistance testing, and adoption of management strategies aimed at curtailing further resistance development by insecticide rotation and restricting the use of SPs to specific periods.

Conclusions

The upsurge of SP resistance in *H. armigera* in cotton in eastern Andhra Pradesh in 1987 has followed the same classic pattern of resistance development seen in other parts of the world. The significant decline in resistance in 1988 gives hope that if appropriate management is adopted and maintained, cotton production in the affected districts may continue for some time to come.

The appearance of SP resistant insects some 250 km distant from the cotton source must alert scientists to the dangers of moth migration or dispersal spreading resistant genes into hitherto susceptible populations distant from the origin or cause of this resistance. Even low frequencies of resistance in new populations will increase the rapidity of selection for resistance once insecticide selection pressure is applied. Although LD50 may drop again at the end of the summer, the warning is implicit in the lower dosage-mortality slopes and higher LD90 values. There is, accordingly, an urgent need for better information on the susceptibility of *Helicoverpa* to the range of insecticides available in India. These should be monitored regularly at a number of locations and from crops in which *Helicoverpa* is an important pest, so that insecticide strategies may be modified accordingly.

Acknowledgments

The authors wish to thank ICRISAT for providing facilities and support and Dr A. McCaffery for the use of resistance data, obtained under extramural contract with NRI.

References

Daly, J.C., Fisk, J.H., and **Forrester, N.W.** 1988. Selective mortality in field trials between strains of *Heliothis armigera* (Hübner) (Lepidoptera: Noctuidae) resistant and susceptible to synthetic pyrethroids: functional dominance of resistance and age class. Journal of Economic Entomology 81:1000-1007.

Dhingra, S., Phokela, A., and **Mehrotra, K.N.** 1988. Cypermethrin resistance in the populations of *Heliothis armigera* (Hübner). National Academy Science Letters (India) 11:123-125.

Forrester, N.W. (In press.) Pyrethroid and endosulfan resistance in *Heliothis* - an update. Cotton Newsletter.

Forrester, N.W., and **Cahill, M.** 1987. Management of insecticide resistance in *Heliothis armigera* (Hübner) in Australia. Pages 127-137 *in* Combating resistance to xenobiotics: biological and chemical approaches (Ford, M.G., Hollomon, D.W., Khambray, B.P.S., and Sawicki, R.M., eds.). Chichester, UK: Ellis Horwood.

Gunning, R.V., and **Easton, C.S.** 1989. Pyrethroid resistance in *Heliothis armigera* (Hübner) collected from unsprayed crops in New South Wales 1983-1987. Journal of the Australian Entomological Society 28:157-161.

Holloway, G.J., and **McCaffery, A.R.** 1988. Reactive and preventative strategies for the management of insecticide resistance. Pages 465-469 *in* Proceedings of the British Crop Protection Council Conference, Brighton, 1988, Nottingham, UK: British Crop Protection Council.

McCaffery, A.R., King, A.B.S., Walker, A.J., and **El Nayir, H.** 1989. Resistance to synthetic pyrethroids in the bollworm *Heliothis armigera* from Andhra Pradesh, India. Pesticide Science. 27: 65-76.

Mehrotra, K.N. 1989. Susceptibility/resistance status of *Heliothis armigera* (cotton bollworm) in Andhra Pradesh. New Delhi, India: Indian Agricultural Research Institute, Division of Entomology. (Limited distribution.)

Sawicki, R.M. 1989. Report on the control of cotton pests in central and southern India. Unpublished report of the Department of Insecticides and Fungicides, AFRC Institute of Arable Crops Research. Harpenden, Herts, UK: Rothamsted Experimental Station. (Limited distribution.)

Sawicki, R.M., Denholm, I., Forrester, N.W., and **Kershaw, C.D.** 1989. Present insecticide resistance management strategies in cotton. Pages 31-43 *in* Pest management in cotton (Green, M.B., and Lyon, D.J. de B., eds.) Chichester, UK: Ellis Horwood.

Session 5

Main Items of Presentations and Discussions

- Mapping the severity of insect pests is of great importance in setting priorities for integrated pest management (IPM) research.
- The usefulness of computer models in IPM research is undisputed, but most of the required data to feed into such models are not available for chickpea.
- In view of possible health hazards, the use of the Bt gene for insect control in food crops needs medical and nutritional approval.
- The observation that resistance of chickpea to aphids is related to the pH of leaf exudates is important, and warrants biochemical and genetical study.
- Data obtained from damage/yield relationship studies are important in establishing economic threshold levels for insect control.
- The chickpea plant's ability to compensate for pod borer (*Helicoverpa armigera*) damage by producing new flowers decreases as the podding stage advances.
- Resistance to *Helicoverpa* is often linked with susceptibility to fusarium wilt and possibly also to ascochyta blight. Breaking of the linkage can be achieved in breeding programs.
- The study of kairomones that attract *Helicoverpa* adults is important in pod-borer resistance breeding, and for the identification of genotypes to which the insect is relatively strongly attracted.
- The recently recorded build-up of resistance to insecticides in *Helicoverpa* emphasizes the importance of IPM. Where spraying of insecticides is required, it is advisable to apply different chemicals in rotation, and not to reduce insecticide concentration, as the latter will increase the chances of the insects developing resistance.

Recommendations

- Future studies should concentrate on the insect species found to be the main pests of chickpea in most production areas, i.e., pod borers (*Helicoverpa* spp.), leafminer (*Liriomyza cicerina*), and storage pests (bruchids).
- There is need for more information on the occurrence and distribution of key pests. Extensive surveys are required to map the severity and extent of pest damage in different agroecological zones and cropping systems. This is viewed as an important pre-requisite for (i) tailoring pest management research to the needs of different chickpea growing areas; and (ii) relating the population dynamics of major pests to agroclimatic features.
- Although general information on damage/yield relationships has been acquired for some major pests, further data are required to determine critical damage levels in different areas.

Host-plant Resistance (HPR)

- There is a need to establish and improve mass rearing methods for *L. cicerina* and *H. armigera* and to carry out studies on the insects' host selection behavior and the mechanisms of HPR.
- In order to identify resistance markers for breeding programs major emphasis should be placed on furthering the understanding of the biophysical and biochemical basis of HPR.
- Studies on the mechanisms of resistance should not be restricted to malic and oxalic acids, but should also include other chemical substances, as well as biophysical factors.
- Further studies on the inheritance and physiological aspects of resistance are needed.
- More emphasis should be given to developing varieties with multiple pest and disease resistance according to the requirements of specific environments.

Biological Control

- The effectiveness and practicability of applying microbial insecticides (e.g., NPV and Bt) for the control of *Helicoverpa* spp. need further study.
- Studies of the occurrence and effectiveness of indigenous parasitoids and predators need to be strengthened. Methods and principles should be identified to enhance the activity of local biocontrol agents through manipulations of the farm environment.

Cultural Control

- Studies on the effects of intercropping, crop diversification, and the use of genetic mixtures to limit pest damage should be intensified. The effects of sowing dates, stand density, and fertilizer use should be studied in cooperation with agronomists.
- The scientific basis of traditional methods of pest control prevalent in different parts of the world

where chickpea is grown should be established and these also need further investigation.

Chemical Control

- The development of insecticide resistance in *Helicoverpa* spp. should be monitored, particularly in areas where pesticide use is high.
- The possibilities of using botanical insecticides for the management of key pests and conservation of their natural enemies should be explored further.

Session 5

Principaux thèmes de présentation et de discussion

- La réalisation des cartes de forte incidence des insectes ravageurs est d'une importance particulière dans l'établissement des priorités pour la recherche sur la lutte intégrée contre les insectes.

- L'utilité des modèles informatisés en matière de la recherche sur la lutte intégrée n'est pas contestable, mais la plupart des données requises pour de tels modèles ne sont pas disponibles pour le pois chiche.

- En vue d'éventuels dangers pour la santé, l'emploi du gène Bt pour la lutte contre les insectes dans les cultures vivrières demande l'autorisation médicale et nutritionnelle.

- L'observation que la résistance du pois chiche aux pucerons est liée au pH des exsudats foliaires est importante, et nécessite l'étude biochimique et génétique.

- Les données obtenues à partir des études des relations dégâts/rendements sont importantes dans l'établissement des seuils économiques pour la lutte contre les insectes.

- L'aptitude de la plante de pois chiche à compenser pour les dégâts causés par le foreur des gousses (*Helicoverpa armigera*), en produisant de nouvelles fleurs, diminue au fur et à mesure que le stade de formation des gousses s'avance.

- La résistance à *Helicoverpa* est souvent liée à la sensibilité au flétrissement fusarien et probablement à la flétrissure ascochytique en plus. Ce lien peut être coupé dans le cadre des programmes de sélection.

- L'étude des kairomones qui attirent les adultes de *Helicoverpa* est importante dans la sélection pour la résistance contre le foreur des gousses, ainsi que dans l'identification de génotypes auxquels l'insecte est relativement fort attiré.

- L'accroissement de la résistance aux insecticides récemment constaté chez *Helicoverpa*, souligne l'importance de la lutte intégrée. Là où la pulvérisation des insecticides est exigée, il est conseillé d'appliquer des produits différents en rotation. La concentration d'insecticide ne doit pas être réduite car elle augmentera la possibilité de développement de la résistance chez les insectes.

Recommandations

- Des études futures doivent concentrer sur les espèces d'insectes constituant les principaux ravageurs du pois chiche dans la plupart des zones de production, à savoir : les foreurs des gousses (*Helicoverpa* spp.), la mineuse des feuilles (*Liriomyza cicerina*), et des ravageurs de stocks (bruches).

- Il est nécessaire de disposer de plus d'informations sur la manifestation et la distribution de ravageurs-clés. Des études extensives sont nécessaires pour établir les cartes de l'incidence ainsi que l'étendue de dégâts causés par les ravageurs dans des zones agroécologiques et des systèmes de culture différents. Cela est considéré comme essentiel pour i) la réalisation de la recherche sur la lutte contre les ravageurs adaptée aux besoins des différentes zones de culture du pois chiche, et ii) la mise en relation de la dynamique de populations des ravageurs majeurs aux caractéristiques agroclimatiques.

- Bien que des informations générales sur les relations dégâts/rendements ont été acquises pour certains ravageurs importants, des données supplémentaires sont nécessaires pour déterminer les niveaux de dégâts critiques dans différentes régions.

Résistance de la plante-hôte

- Il est nécessaire d'établir et améliorer les méthodes d'élevage en masse pour *L. cicerina* et *H. armigera* ainsi que d'effectuer des études sur le comportement de recherche de la plante-hôte des insectes et sur les mécanismes de la résistance de la plante-hôte.

- Afin d'identifier les marqueurs de résistance pour les programmes de sélection, il faut accorder l'importance à la connaissance plus approfondie des bases biophysiques et biochimiques de la résistance de la plante-hôte.

- Les études sur les mécanismes de résistance ne doivent pas être limitées aux acides maliques et oxaliques, mais doivent également inclure d'autres substances chimiques ainsi que des facteurs biophysiques.

- Des études plus approfondies sur l'hérédité et les aspects physiologiques de la résistance sont nécessaires.

- Plus d'attention doit être accordée à la mise au point de variétés ayant une résistance multiple aux ravageurs et aux maladies en fonction des exigences des milieux spécifiques.

Lutte biologique

- L'efficacité et l'aspect pratique de l'application des insecticides microbiales (par exemple, NPV et Bt) pour la lutte contre *Helicoverpa* spp. doivent être étudiés plus en détail.

- Des études de l'existence et l'efficacité des parasitoïdes et des prédateurs indigènes doivent être renforcées. Il faut identifier des méthodes et des principes qui permettent d'améliorer l'activité des agents locaux de lutte biologique par l'intermédiaire des manipulations du milieu rural.

Lutte culturale

- Des études sur les effets de la culture associée, sur la diversification des cultures, et sur l'utilisation de mélanges génétiques pour limiter les dégâts causés par les ravageurs doivent être intensifiées. Les effets de dates de semis, de la densité de peuplement, et de l'utilisation d'engrais doivent être étudiées en coopération avec des agronomes.

- Les bases scientifiques des méthodes traditionnelles de lutte contre les ravageurs pratiquées dans différentes parties du monde où l'on exploite le pois chiche doivent être établies et celles-ci nécessitent également des études en détail.

Lutte chimique

- Le développement de la résistance aux insecticides chez *Helicoverpa* spp. doit être suivi, en particulier dans les zones où l'utilisation des pesticides est très élevée.

- Les possibilités d'utilisation des insecticides botaniques pour la maîtrise des ravageurs-clés ainsi que la conservation de leurs ennemis naturels doivent être examinées davantage.

Session 6

Breeding Strategies and Techniques - New Approaches to Crop Improvement

Genetic Improvement of Chickpea: Key Factors to be considered for a Breakthrough in Productivity

F.J. Muehlbauer[1], C.J. Simon[1], S.C. Spaeth[1], and N.I. Haddad[2]

Abstract

Genetic improvement of chickpea has been an ongoing process since the crop was domesticated. The most striking example of significant productivity improvement was recognition and use of ascochyta blight resistance to make it possible to sow the crop in the winter in the Mediterranean region and take maximum advantage of limited water resources. Similar improvements in productivity are not obvious elsewhere, but continued development of genetic information about Cicer *may lead the way to significant improvements. Linkage groups are currently being established for* Cicer *and include morphological, isozyme, and DNA markers. Accurate and detailed linkage maps are needed to locate genes of importance for breeding and also to identify 'tags' for those genes. Once such genes are tagged they can then be recombined with other important genes in otherwise desirable genetic backgrounds. An extension of the 'tagging' procedure to the study of quantitative trait loci would make it possible to foster gene flow not only between cultivated material but also possibly more importantly, between the cultigen and distantly related species.*

Although genetic engineering for legume crops is still not an established procedure, its possibilities for solving chronic problems make it potentially important for the future. Candidates for transfer by these methods might be coat protein genes for certain viruses to provide cross protection against problem virus diseases in the chickpea crop. Proteinase inhibitor genes and 'anti-sense' genes for virus disease control might also deserve consideration for transfer. How these approaches might be used in applied chickpea breeding is described and discussed.

Résumé

Amélioration génétique du pois chiche—facteurs-clés à envisager pour un grand progrès de la productivité : *L'amélioration génétique du pois chiche a suivi un processus constant depuis que cette culture a été domestiquée. L'exemple le plus frappant d'amélioration significative de la productivité a été la reconnaissance et l'usage de la résistance à la flétrissure ascochytique pour permettre de faire des semis de cette culture en hiver dans la région méditerranéenne et de profiter au maximum des ressources hydriques limitées. Des améliorations analogues de la productivité ne se manifestent pas ailleurs mais le progrès soutenu en matière d'informations génétiques sur* Cicer *pourrait ouvrir la voie à des améliorations significatives. L'établissement des groupes de linkage est actuellement en cours pour* Cicer *et ils comprennent des marqueurs morphologiques, de l'isozyme et de l'ADN. Des cartes précises et détaillées de linkage sont nécessaires pour localiser les gènes d'importance pour la sélection et aussi pour identifier des "étiquettes" pour ces gènes. Une fois étiquetés, les gènes peuvent être recombinés avec d'autres gènes importants dans des milieux génétiques souhaitables à d'autres égards. L'extension de la*

1. Research Geneticists, United States Department of Agriculture, Agricultural Research Service (USDA-ARS), 215 Johnson Hall, Washington State University, Pullman, WA 99164-6420, USA.

2. Plant Breeder, School of Agriculture, University of Jordan, Amman, Jordan.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

procédure d'"étiquetage" à l'étude des loci des caractères quantitatifs, permettrait de favoriser l'échange de gènes non seulement entre matériel cultivé, mais aussi, ce qui serait probablement encore plus important, entre le cultigène et des espèces de parentée éloignée.

Bien que le génie génétique des cultures légumineuses ne soit pas encore une procédure établie, ses possibilités pour la solution de problèmes chroniques lui confèrent une importance potentielle pour l'avenir. Les candidats pour le transfert par ces méthodes pourraient être des gènes de revêtement de cellules de protéine pour certains virus afin d'assurer une protection croisée contre des viroses qui affectent les cultures de pois chiche. On pourrait également envisager le transfert de gènes inhibiteurs de protéinase et les gènes "anti-directionnels" pour la lutte contre les viroses. Comment ces méthodes pourraient-elles être utilisées dans la sélection appliquée du pois chiche, les auteurs le disent et l'examinent.

Chickpea yields have stagnated in comparison with other important food crops, most notably the cereal grains. Susceptibility to diseases and pests, and sensitivity to salinity and drought stresses contribute to the poor yields often encountered (Smithson et al. 1985). Researchers at ICARDA and its predecessor the Arid Land Agricultural Development Program have shown the potential for winter sowing of chickpea in the Mediterranean region as a breakthrough in productivity (Hawtin and Singh 1984; Singh and Reddy 1989; Singh et al. 1989). The winter cropping breakthrough should be consolidated and extended.

Susceptibility to ascochyta initially restricted the use of winter sowing (Hawtin and Singh 1984). Existing cultivars generally have sufficient cold or frost tolerance to survive mild Mediterranean winters (Hawtin and Singh 1984). Insufficient cold tolerance in current cultivars is a source of risk for the more severe Mediterranean winters and prevents the extension of the practice of winter sowing to more inclement regions (Singh et al. 1989).

Changes in botanical structure of cereal grain cultivars from typically tall types to stiff-strawed semi-dwarfs has made it possible to increase yields by applying greater amounts of nitrogen fertilizer. An alternative strategy to change of chickpea morphology to tall, upright, and compact plants that can be grown at greater plant densities has been repeatedly suggested. Data from Saxena and Sheldrake (1978), however, do not support that contention.

More favorable partitioning into seeds is also seen to be an acceptable approach to improving economic returns from grain legume crops. Plant ideotypes have been proposed and are based on reports that certain traits are highly correlated with yield, e.g., branch numbers, podding habit, double podding, seeds per pod, seed mass, canopy development, and others (including altered phenology).

Various chronic problems of the chickpea crop appear to be ideally suited to several evolving approaches to the study and characterization of genetic variation in crop plants. These would include the ascochyta blight problem, which is widely distributed, the sensitivity of chickpea to environmental stresses, and the overall yield potential of the crop.

Most chickpeas are grown in subsistence farming systems in developing countries. In those production systems chickpea productivity could benefit most from improved farming practices and timely control of pests and weeds. The promise of biotechnological approaches to increase genetic knowledge of gene systems that will facilitate genetic enhancement of chickpea cultivars may eventually be fulfilled. In time, it may be possible to incorporate disease and insect resistance genes into chickpea cultivars to improve production under these farming practices.

The rapidly evolving approaches to the study of plant genetics include the use of molecular markers to establish high-density gene maps for crop species (McCouch et al. 1988), the tagging of genes of interest with molecular markers to facilitate their transfer to otherwise acceptable backgrounds, and the identification of Quantitative Trait Loci (QTL). A necessary prerequisite for such investigations is an accurate and detailed map of the *Cicer* genome. A map for *Cicer* is now feasible and would be based on joint segregation of morphological, isozyme, and Restriction Fragment Length Polymorphisms (RFLP). The map can be made sufficiently detailed to permit the study of quantitative variation in chickpea, 'tag' important loci, and finally establish the locations of QTL. Information derived from these studies could then be used to advantage to assemble advanced material. A well-defined genome is also necessary in order to locate genes of interest, if and when cloning technology and genetic engineering become of more general use in crop improvement programs.

Conventional Breeding

Breakthroughs in chickpea breeding are needed in the following four areas: (1) improved resistance to ascochyta blight; (2) desi x kabuli introgression; (3) gene transfer from wild species to the cultigen; and (4) the development of high-density gene maps. If progress could be made in these four areas, the chickpea crop could benefit greatly through increased productivity and resistance to pests and environmentally induced stresses.

Excellent progress has been made by International Center for Agricultural Research in the Dry Areas (ICARDA) and national programs in finding germplasm and breeding lines resistant to ascochyta blight. However, as each new report is forthcoming, there are additional genes postulated to have an influence on disease reaction. Currently, for resistance four genes have been designated and assigned gene symbols (Ahmad et al. 1952; Singh and Reddy, 1983; Muehlbauer and Singh 1987; Tewari and Pandey 1986; Vir et al. 1975). In addition six races of the fungus have been postulated (Singh and Reddy 1989). Three of the genes are reportedly dominant for resistance (R_1, R_2 and Rar_2) while the other is reportedly recessive for resistance (rar_1). What is not clear is whether two or more of the genes reported thus far as confering resistance to ascochyta blight are identical and if fewer genes are actually involved. Unfortunately the studies were performed independently and appropriate tests for allelism of the genes were not conducted. Combination of the four genes for resistance is not now possible because their genome locations are unknown and the subjective nature of disease scoring does not permit the genetic identification of presumed resistant segregants. The genetics of disease resistance would be clarified if the individual genes responsible were placed into an accurate genome map for chickpea. As a result, breeding for greater resistance is mostly done by empirical methods.

Development of cultivars with resistance to ascochyta blight is essential to the proposed change to winter sowing in the Mediterranean region. This possibility is well documented and needs no further comment (Singh 1987).

Excellent progress has also been made in finding winter hardiness in germplasm (Singh et al. 1989). Unfortunately, incorporation of winter hardiness into cultivars will probably be more challenging than the incorporation of ascochyta blight resistance. Winter hardiness is a complicated trait (Blum 1988). Winter hardiness includes chilling and frost tolerance, growth at low temperature, and resistance to diseases other than ascochyta. The advantages of fall sowing come largely from improvements in the water-use efficiency of a fall sown crop (Saxena 1984). While the genetic control of various plant diseases is reasonably understood, the understanding of genetic and environmental control of plant responses to stresses is limited (Blum 1988).

Existing cultivars have sufficient winter hardiness to survive mild Mediterranean winters. Sources of additional winter hardiness have been identified which should allow survival in harsher climates (Singh et al. 1989). While levels of winter hardiness which are sufficient for severe winters in Washington State have been found in lentils (Spaeth and Muehlbauer, unpublished observations), even the most winter hardy chickpea lines are not sufficiently hardy to survive consistently here (Spaeth and Muehlbauer, unpublished observations).

Sources of winter hardiness are essential but not sufficient for improvement in crop productivity. The hardiness must be transferred to types with necessary resistance to ascochyta, acceptable seed qualities, and desired agronomic type. Since winter hardiness is such complex trait, QTL and marker assisted introgression should be important to realizing the potential of this breakthrough.

Exploitation of desi x kabuli crosses has been proposed. The isolation of the two chickpea types for centuries and the great contrast of plant and seed characteristics suggest that there are genes present that could be introgressed between types. However, populations from desi x kabuli crosses need to be three to four times as large as those from crosses within the two types in order to recover useful segregants.

Alternatively, backcrossing has been suggested to recover desired types (Singh 1987). Desi x kabuli crosses are not widely used by chickpea breeders, presumably because of the difficulty in obtaining useful segregants. It may be that desi x kabuli introgression studies have not yielded promising segregants because the two types are not so divergent as they appear phenotypically. Studies of isozme variation within and between the two groups have uncovered remarkably little genetic variation (Muehlbauer, personal observation).

Introgression of genes from related wild species has also been suggested to improve the cultigen (Ladizinsky et al. 1988; Singh 1987). However, of the wild species of *Cicer* only *C. reticulatum* is readily crossable to *C. arietinum* producing fully fertile hybrids and progenies. *C. echinospermum* is crossable to chickpea, but the F_1 hybrids are partially sterile and the F_2 progenies are also mostly sterile. Introgression of genes from *C. reticulatum* to *C. arietinum* is currently underway at

International Crops Research Center for the Semi-Arid Tropics (ICRISAT), ICARDA, and in the US. Current techniques for identification and transfer of useful genes to otherwise acceptable backgrounds rely mostly random incorporation. Areas where introgression from wild sources is expected to yield significant improvement include tolerance to cold, heat and drought, greater biological yield and resistance to pests. For all these traits the inheritance is apparently complex even in crosses within the cultigen. The successful incorporation of useful genes would seem to require a more directed approach to ensure that portions of the genome were, in fact, transferred to an acceptable background. Technology now is available for extensively mapping the *Cicer* genome. The aim of mapping this genome is to integrate known genes that affect morphology, disease resistance, and quality traits with molecular markers, including both allozymic variation and RFLP. If these goals were achieved they would assist in locating important genes and facilitate their transfer to cultivars with greater productive potential.

Current Status of Chickpea Genetics

Single Gene Qualitative Traits

Nearly 50 genes affecting morphology and coloration of chickpea plants, flowers, pods, and seeds have been identified and described according to a recent review by Muehlbauer and Singh (1987). In addition, genes affecting resistance to ascochyta blight and fusarium wilt have been reported. Linkages among these genes involve one three-gene linkage group of Lvco-26.5-Rs-23.0-Bsc and several two-gene linkage groups. Expansion of the linkage map for chickpea could be accelerated with the use of molecular markers, and in fact this approach would be more helpful because useful genes would then be 'tagged' to facilitate their transfer in breeding programs.

Isozyme Variation

Isozyme and restriction fragment length polymorphisms are two classes of molecular markers that have a number of desirable properties when used for breeding purposes. These markers are generally naturally occurring, are non-deleterious, usually have co-dominant expression, can be cytoplasmic or nuclear, and generally are not influenced by environment. Isozyme polymorphisms are readily and easily used in plant genetics and have rapidly become popular among plant breeders.

Techniques for isozyme analysis have been adequately described (Shaw and Prasad 1970; Brewbaker 1980; Tanksley and Orton 1983; Soltis et al. 1983). Recently, isozyme polymorphisms have been identified in interspecific crosses between *C. arietinum* and *C. reticulatum* (Muehlbauer, unpublished; Guar and Slinkard, personal communication). The isozyme polymorphisms are currently being used to establish a gene-linkage map for *Cicer* that will include isozyme loci, morphological markers, and disease resistance genes. Currently, isozyme polymorphisms have been identified in our laboratory for phosphoglucose isomerase (PGI); phosphoglucomutase (PGM), protein; L-alanyl-b-naphthylamide aminopeptidase (AAP); glutamic pyruvic transaminase (GPT); glucose-1-phosphate transferase (GIPT); aconitase (ACON); aldolase (Aldo); diaphorase (DIAP); acid phosphatase (ACP); 6-phosphogluconate dehydrogenase (6PGD); 4-methylumbelliferyl-b-galactosidase (Gal pH 4.5); 4-methylumbelliferyl acetate (Mm-Est); and adenylate kinase (ADK). These polymorphisms represent a group of markers that can be used effectively in conjunction with other genes to establish the beginnings of a linkage map for chickpea.

The use of isozymes is, however, limited by the number of assays that are available and the degree of polymorphism in the materials being studied. Restriction fragment length polymorphisms seem to be nearly unlimited although a greater degree of technical expertise is required to effectively work with them.

Restriction Fragment Length Polymorphisms

Restriction fragment length polymorphisms (RFLP) are a class of molecular markers at the DNA level that are virtually unlimited in number and distribution throughout the genome. Simply speaking, short segments of DNA from the organism (in this case chickpea) are isolated and processed so that they can be used as marker loci. These short segments or probes, as they are called, are characterized on restricted DNA from both parents of a cross. Scoring is on the basis of the length of the restriction fragment corresponding to the probe sequence. In cases where the restriction fragment lengths are different (polymorphic) for the two parents, DNA from the F_2 is scored by parental type. The segregation data can then be analyzed by computer using a linkage analysis program. These linkage data are then used to construct a molecular map. Procedures for RFLP analysis are well documented (Southern 1975; Maniatis et al. 1982; Beckmann and Soller 1983;

Helentjaris et al. 1985; Helentjaris 1987; Perbal 1988; Tanksley et al. 1989; and others).

As with isozyme markers, RFLP have co-dominant expression, are considered to be of neutral character, and they generally do not interact with other characters. The fact that RFLP markers can be quite numerous and well distributed throughout the genome implies that close linkages with genes of interest will be found through systematic mapping (Lander and Botstein 1989; Paterson et al. 1988; Osborn et al. 1987). Limitations to the use of RFLP for genetical analyses include the need to use radioactive ^{32}P for labeling the DNA probes, and the relatively high degree of technology requires suitably trained personnel to do the work. Progress is being made in developing techniques with non-radioactive labeling to enable the techique to be used more widely.

Establishment of a High-density Gene Map for Chickpea

A gene map for *Cicer* can be developed rather quickly when compared to some other major food crops. The advantages for chickpea are derived from its annual growth habit, diploid chromosome complement, and the relatively small chromosome number of 2n = 16. These factors combine to make chickpea a relatively simple genetic system that can be studied using molecular markers and classical genetic principles. An additional advantage that should and will be exploited for chickpea is the apparent conservation of certain linkage groups between the Cicereae and Vicieae tribes (Muehlbauer and Weeden, unpublished). Conserved linkage groups between *Pisum*, an extensively mapped genus, and *Lens*, are currently being used effectively to extend the lentil gene map. Similarly conserved segments of the genome have been discovered between *Lens* and *Cicer*. Steps involved in establishing a high-density gene map for *Cicer* would be as follows:

1. Crosses between lines that differ for qualitative traits, isozyme markers and RFLP.
2. Genetic analyses of patterns of inheritance and gene interaction of the progenies. This is usually done in F_2 but recently the use of recombinant inbreds has received greater attention. This matter will be discussed in more detail below.
3. Detection of abnormal joint segregation ratios among genes and calculation of linkage estimates.
4. Placement of linked segments into a linear arrangement corresponding to chromosomes or at least to linkage groups that might later be assigned to specific chromosomes.

Recombinant inbreds can be very useful for gene mapping (Burr et al. 1988). Recombinant inbreds (RI) lines can be developed quickly in self-pollinating crops such as *Cicer* by following the single-seed descent method from an F_2 of a hybrid population to the F_6 or F_7. At the later generation, the RI lines become homozygous and fixed for linkage blocks within the genome. Each RI line is then fully characterized for molecular markers and traits of interest. Where two loci follow the same distribution pattern among the population of RI lines, linkage is indicated. Map distances can be determined by the frequency of recombinations within the RI lines.

Recombinant inbreds have several advantages when compared to other materials used for mapping. After six or seven generations of selfing, segregation is nearly complete and they then represent a population which can be increased and utilized indefinitely. The lines can be shared among several laboratories.

Molecular Marker Based Breeding

"Tagging" of Genes of Interest with Molecular Markers

The concept of "tagging" genes of interest involves the identification of a presumed neutral molecular marker closely linked to an important gene (Tanksley 1983). Close linkages between molecular markers and major gene alleles encoding for such factors as pathogen resistance enable breeders to preselect progenies in the laboratory. This can be particularly valuable in cases where quantities of material are very limited, or where material or pathogens are under quarantine restrictions. Estimates by Tanksley et al. (1989) indicate greater efficiency from selecting for molecular markers the more closely they are linked to the gene(s) of interest. Estimates for backcross breeding indicate that the recurrent parent genotype can be completely recovered with three backcrosses using molecular markers, whereas at least six backcrosses are required using conventional breeding.

It may be difficult to propagate a pest for screening tests as is the case for instance with stem nematode in tomato. An easily assayed allozyme was shown to be closely linked to a gene for nematode resistance (Rick and Fobes 1974). The easily assayed enzyme is now widely used by public and private breeders of tomato. Screening with closely linked markers is now feasible for an increasing number of traits in a wide array of crop species (Apuya et al. 1988; Havey and Muehlbauer

1989; Stuber et al. 1982; Stuber et al. 1987; Tanksley et al. 1984; Tanksley and Hewett 1988).

Studies of Quantitative Trait Loci

Traits considered to be quantitatively inherited have been studied repeatedly using biometrical techniques; however, the results have been of limited use for breeding purposes. Estimates of the number of genes influencing quantitative traits have been made but their chromosonal locations, and individual and interactive effects with other genes is largely unknown.

High-density gene maps can be used effectively to locate genes that affect quantitative variation (Michelmore and Shaw 1988; Lander and Botstein 1989). The method involves the comparison of segregating progenies with contrasting alleles at numerous loci. Where significant differences are detected between individuals differing at marker loci, conclusions can be made about the linkage between markers and loci that influence the expression of the quantitative trait. The method has some drawbacks when a single locus is used in the analyses. Recombinations of marker loci with alternative alleles for a quantitative trait bias the estimate of the effects of quantitative trait loci. This disadvantage can be alleviated by interval mapping as suggested by Tanksley et al. (1989).

Interval mapping involves the use of linked markers to determine the influence of the genome segment bound by the two markers. Since the probability of a double crossover in the linked segment is remote, interval mapping holds promise for great precision in the location of QTL.

Pyramiding Genes of Interest

For ascochyta blight in chickpea it may be desirable to combine a number of resistance genes. Numerous genes have been reported (Singh and Reddy 1983, 1989; Muehlbauer and Singh 1987) to confer resistance to the ascochyta blight pathogen; however, the actual genes involved have not been located in the chickpea genome. Precise location of these genes and linkage to molecular markers would facilitate their recombination and thus pyramiding in otherwise acceptable genetic backgrounds. Other important traits now believed to be controlled by a number of genes could also be improved by the employment of molecular marker based selection.

Utilization of Exotic Germplasm

Wild relatives of crop plants are generally considered to have genes that would enhance the cultivated form. However, the utilization of that source of genetic variation is limited due to the difficulty in making the crosses and the sterility problems often encountered. Where full fertility is found between cultivated and exotic germplasm, transfer of desirable genes from the wild progenitor is often accompanied by closely linked genes with deleterious effects. Using RFLP Tanksley et al. (1989) have shown that it is possible to select for desirable genes while retaining little unwanted DNA from the donor species.

Other Uses of High-density Gene Maps

Conservation of linkage groups between closely related genera appears to be quite common and has been observed in the Gramineae (maize and sorghum), Solanaceae (potato, tomato, and pepper), and *Brassica* (cabbage, turnip, and rape) (Tanksley et al. 1989). Similar conservation of linkage groups have been observed in *Lens* and *Pisum* of the Viceae (Weeden et al. 1988) and in *Cicer* (Muehlbauer and Weeden, in preparation).

Conservation of linkage groups between closely related genera facilitates mapping efforts and may indicate potential sites for important genes. Also substitutions of entire chromosomes from one genus to another has been suggested as a possibility (Tanksley et al. 1989).

Gene cloning for the eventual development of transgenic plants is at present a remote possibility for *Cicer* and many other crop plants. Prospects for transgenic plants depend on determinations of the gene products to enable cloning of the gene, and upon the presence of systems to introduce the foreign gene. Unfortunately the products of most important genes at the present time are largely unknown. Identification of closely linked RFLP markers may permit cloning; however, even small map distances translate into great distances at the DNA level.

There are several novel approaches involving genetic engineering that have had some success in other crops. The development of herbicide resistant cultivars and the incorporation of the coat protein gene of certain viruses to provide cross protection from a wide range of viruses are two examples. Regeneration of transgenic plants, however, is currently hindering the use of these techniques for chickpea. The use of particle accelerators appears to be a promising method of introducing foreign DNA into cells and avoids the difficulties of regeneration of plants from protoplasts by tissue culture techniques.

Prospects

The chronic problems of chickpea including ascochyta blight, susceptibility to environmental stresses and poor yield, might be understood more fully with expanded genetic knowledge of the crop. To that end, a concerted effort is currently underway to map the *Cicer* genome. That effort is ongoing at Saskatoon, Canada and at Pullman, Washington USA using both conventional markers, isozyme loci, and RFLP. The beginnings of linkage groups have emerged and additional loci are currently being added. Analysis of the inheritance of ascochyta blight resistance, tagging of important genes, identification of quantitative loci, and marker assisted introgression between desi and kabuli types and from wild species to the cultigen are considered to be the primary benefits to be derived from this mapping effort. These areas could eventually represent breakthroughs for chickpea crop productivity.

References

Ahmad, M. D., Hafiz, A., and **Ashraf, M.** 1952. Some studies on the inheritance of blight resistance. Proceedings of the Pakistan Science Conference 4:15-16.

Apuya, N.R., Frazier, B.L., Keim, P., Roth, E.J., and **Lark, K.G.** 1988. Restriction fragment length polymorphisms as genetic markers in soybean, *Glycine max* (L.) Merrill. Theoretical and Applied Genetics 75:889-901.

Beckmann, J., and **Soller, M.** 1983. Restriction fragment length polymorphisms in genetic improvement: methodologies, mapping and costs. Theoretical and Applied Genetics 67:35-43.

Blum, A. 1988. Plant Breeding for Stress Environments. CRC Press, Boca Raton, Florida, USA. pp. 99-162.

Brewbaker, J.L., Upadhya, M.D., Makimen, Y., and **McDonald, T.** 1980. Isozyme polymorphism in flowering plants. III. Gel electrophoresis methods and applications. Physiologia Plantarum 21:930-940.

Burr, B., Burr, F.A., Thompson, K.H., Albertson, M.C., and **Stuber, C.W.** 1988. Gene mapping with recombinant inbreds in maize. Genetics 118:519-526.

Hawtin, G.C., and **Singh, K.B.** 1984. Prospects and potential of winter sowing of chickpeas in the Mediterranean region. In: Proceedings of the Workshop on Ascochyta Blight and Winter Sowing of Chickpeas. Saxena, M.C. and Singh, K.B., eds. ICARDA, Aleppo, Syria. pp. 7-16.

Havey, M.J., and **Muehlbauer, F.J.** 1989. Linkages between restriction fragment length, isozyme, and morphological markers in lentils. Theoretical and Applied Genetics 77:395-401.

Helentjaris, T. 1987. A genetic map for maize based on RFLPs. Trends in Genetics 3:217-221.

Helentjaris, T., King, G., Slocum, M., Siedenstrang, C., and **Wegman, S.** 1985. Restriction fragment length polymorphisms as probes for plant diversity and their development as tools for applied plant breeding. Plant Molecular Biology 5:109-118.

Ladizinsky, G., Pickersgill, B., and **Yamamoto, K.** 1988. Exploitation of wild relatives of the food legumes. Pages 967-978 *in* World crops: cool season food legumes: proceedings of the International Food Legume Research Conference on Pea, Lentil, Faba Bean and Chickpea, 6-11 Jul 1986, Spokane, Washington, USA (Summerfield, R.J., ed.). Dordrecht, Netherlands: Kluwer Academic Publishers.

Lander, E.S., and **Botstein, B.** 1989. Mapping Mendelian factors underlying quantitative traits using RFLP linkage maps. Genetics 121:185-199.

Maniatus, T., Fritsch, E.F., and **Sambrook, J.** 1982. Molecular cloning: a laboratory manual. Cold Spring Harbor, New York, USA: Cold Spring Harbor Laboratory.

McCouch, S.R., Kochert, G., Yu, Z.H., Wang, Z.Y., Khush, G.S., Coffman, W.R., and **Tanksley, S.D.** 1988. Molecular mapping of rice chromosomes. Theoretical and Applied Genetics 76:815-829.

Michelmore, R.W., and **Shaw, D.V.** 1988. Character dissection. Nature 335:672-673.

Muehlbauer, F.J., and **Singh, K.B.** 1987. Genetics of chickpea. Pages 99-125 *in* The chickpea (Saxena, M.C., and Singh, K.B., eds.). Wallingford, Oxon, UK: CAB International.

Osborn, T.C., Alexander, D.C., and **Fobes, J.F.** 1987. Identification of restriction fragment length polymorphisms linked to genes controlling soluble solids content in tomato fruit. Theoretical and Applied Genetics 73:350-356.

Paterson, A.H., Lander, E.S., Hewitt, J.D., Peterson, S.. Lincoln, S.E., and **Tanksley, S.D.** 1988. Resolution of quantitative traits into Mendelian factors by using a complete linkage map of restriction fragment length polymorphisms. Nature 335:721-726.

Perbal, B. 1988. A practical guide to molecular cloning. New York, USA: Wiley Interscience. 811 pp.

Rick, C.M., and **Fobes, J.F.** 1974. Association of an allozyme with nematode resistance. Report, Tomato Genetics Cooperative 24:25.

Saxena, M.C. 1984. Agronomic studies on winter chickpeas. In: Proceedings of the Workshop on Ascochyta Blight and Winter Sowing of Chickpeas. Saxena, M.C. and Singh, K.B., eds. ICARDA, Aleppo, Syria. pp. 123-139.

Saxena, N.P., and **Sheldrake, A.R.** 1978. Pulse physiology progress report 1977/78. Part II. Chickpea physiology. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics. (Limited distribution.)

Shaw, C.R. and **Prasad, R.** 1970. Starch gel electrophoresis - a compilation of recipes. Biochemical Genetics 4:297-320.

Singh, K. B. 1987. Chickpea breeding. Pages 127-162 *in* The chickpea (Saxena, M.C., and Singh, K.B., eds.). Wallingford, Oxon, UK: CAB International.

Singh, K.B., Malhotra, R.S., and **Saxena, M.C.** 1989. Chickpea evaluation for cold tolerance under field conditions. Crop Science 29:282-285.

Singh, K.B., and **Reddy, M.V.** 1983. Inheritance of resistance to ascochyta blight in chickpea. Crop Science 23:9-10.

Singh, K.B., and **Reddy, M.V.** 1989. Genetics of resistance to ascochyta blight in four chickpea lines. Crop Science 29:657-659.

Smithson, J.B., Thompson, J.A., and **Summerfield, R.J.** 1985. Chickpea (*Cicer arietinum* L.). Pages 312-390 *in* Grain legume crops (Summerfield, R.J., and Roberts, E.H., eds.). London, UK: Collins.

Soltis, D.E., Haufler, C.H., Darrow, D.C., and **Gastony, G.J.** 1983. A compilation of grinding buffers, gel and electrode buffers and staining schedules. American Fern Journal 73:7-27.

Southern, E. M. 1975. Detection of specific sequences among DNA fragments separated by gel electrophoresis. Journal of Molecular Biology 98:503-517.

Stuber, C., Goodman, M., and **Moll, R.** 1982. Improvement of yield and ear number resulting from selection at allozyme loci in a maize population. Crop Science 22:737-740.

Stuber, C.W., Edwards, M.D., and **Wendel, J.F.** 1987. Molecular marker- facilitated investigations of quantitative trait loci in maize. II. Factors influencing yield and its component traits. Crop Science 27:639-648.

Tanksley, S. D. 1983. Molecular markers in plant breeding. Plant Molecular Biology Report 1:3-8.

Tanksley, S.D., and **Hewett, J.** 1988. Use of molecular markers in breeding for soluble solids content in tomato-a re-examination. Theoretical and Applied Genetics 73:350-356.

Tanksley, S.D. and **Orton, T.J. 1983.** Isozymes in plant genetics and breeding. Amsterdam, Netherlands: Elsevier.

Tanksley, S.D., Rick, C.M., and **Vallejas, C.E.** 1984. Tight linkage between a nuclear male-sterile locus and an enzyme marker in tomato. Theoretical and Applied Genetics 68:109-113.

Tanksley S.D., Young, N.D., Paterson, A.H., and **Bonierbale, M.W.** 1989. RF L mapping in plant breeding: new tools for an old science. Biotechnology 7:257-264.

Tewari, S.K., and **Pandey, M.P.** 1986. Genetics of resistance to ascochyta blight in chickpea (*Cicer arietinum* L). Euphytica 35:211-215.

Vir, S., Grewal, J.S., and **Gupta, V.P.** 1975. Inheritance of resistance to ascochyta blight in chickpea. Euphytica 24:209-211.

Weeden, N.F., Zamir, D., and **Tadmor, Y.** 1988. Applications of isozyme analysis in pulse crops. Pages 979-987 *in* World crops: cool season food legumes: proceedings of the International Food Legume Research Conference on Pea, Lentil, Faba Bean and Chickpea, 6-11 Jul 1986, Spokane, Washington, USA (Summerfield, R.J., ed.). Dordrecht, Netherlands: Kluwer Academic Publishers.

Breeding Methodologies for Chickpea: New Avenues to Greater Productivity

J.E. Specht and G.L. Graef[1]

Abstract

New approaches for enhancing the annual rate of genetic improvement in chickpea may possibly be discerned from a retrospective analysis of genetic improvement in the primary USA grain legume, the soybean. Soybean genetic improvement in the USA averaged about 18.8 kg ha^{-1} annually in the period 1900-1980, a cumulative 80-year increase of 1.5 t ha^{-1}. However, a large portion of this total genetic gain occurred as a one-time 'quantum jump' of about 0.6 t ha^{-1} in the mid-1940s. Since then, annual genetic gain has been only 12.5 kg ha^{-1}. The quantum jump in yield improvement was attributed to a change from a breeding system comprised solely of evaluating and releasing the best available plant introductions to a system comprised of biparental matings, generation advance via selfing, and selection of superior progeny for release (then remating the selections to repeat the cycle continuously). The introduction of genetic recombination was the key, for it substantially increased the amount of genetic variability that could be exploited for selection purposes. This historical precedent led us to design a breeding scheme that fully optimizes genetic recombination (and thus also genetic variability). This scheme employs a soybean population which: (a) is forced to annually intermate (via genetic male-sterility) with each year's newly chosen parental array of elite lines and varieties: and (b) is used to annually generate (via F_1 advance through a winter nursery) F_2 progeny,the latter serving both as the source of breeding material for an F_3 to F_n generation advance of a typical breeding program, and as the recurring source of male-sterile plants for intermating with the next set of elite parents. The advantages of this system are: (a) convenient production of many F_1 individuals from many crosses; and (b) a more rapid 'recombinational link between successive cycles.

Résumé

***Méthodologies de sélection pour le pois chiche—Nouvelles formules pour accroître la productivité :** De nouvelles formules pour relever le taux annuel d'amélioration génétique du pois chiche peuvent probablement se dégager d'une analyse rétrospective de l'amélioration génétique de la principale légumineuse à grains des Etats-Unis, le soja. L'amélioration génétique du soja aux Etats-Unis a atteint la moyenne de 18,8 kg ha^{-1} environ annuellement pendant la période 1900 à 1980, soit une augmentation cumulative pendant 80 ans de 1,5 t ha^{-1}. Toutefois, une grande proportion de ce gain génétique total s'est produite en un seul "bond" spectaculaire d'environ 0,6 t ha^{-1} au milieu des années 40. Depuis lors, le gain génétique annuel n'a été que de 12,5 kg ha^{-1}. Le "bond" d'amélioration du rendement a été attribué à l'abandon du système de sélection qui ne comprenait que l'évaluation et la vulgarisation des meilleures introductions disponibles, en faveur d'un système composé de fécondations biparentales, d'avancement de générations par l'autofécondation et de sélection de descendances supérieures pour la vulgarisation (puis la refécondation des plantes sélectionnées pour répéter continuellement le cycle). L'introduction de la recombinaison génétique était la clé, car elle a permis d'augmenter nettement l'ampleur de la variabilité génétique qui pouvait être exploitée à des fins de*

1. Professor, and Assistant Professor, Department of Agronomy, University of Nebraska, Lincoln, NE 68583-0915, USA.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

sélection. Ce précédent historique nous a mené à concevoir un système de sélection qui optimise la recombinaison génétique (et donc aussi la variabilité génétique). Ce système emploie une population de soja qui : (a) est forcée à croiser annuellement (à travers la stérilité mâle génétique) avec la gamme parentale choisie nouvellement chaque année de lignées et de variétés élite; et (b) sert à réaliser annuellement (à travers un avancement de F_1 dans la pépinière d'hiver) des descendances F_2, qui servent tant de source de matériel de sélection pour un avancement de génération de F_2 à F_n dans le cadre d'un programme typique de sélection, que de source récurrente de plantes mâles stériles pour croisement avec le jeu suivant de géniteurs élite. Les avantages de ce système sont : (a) une production pratique d'un grand nombre d'individus F_3 provenant de plusieurs croisements; et (b) un "lien de recombinaison" plus rapide entre les cycles successifs.

The ultimate objective in the breeding of an autogamous crop species is to increase the frequency of, and to eventually fix, a favorable allele at every genetic locus in some specified germplasm undergoing selection. When desirable alleles are continually being fixed at an ever-increasing fraction of the available loci, the breeding program can be said to be successful, since the selected germplasm will contain an ever-greater number of genotypes with the desired phenotypes. For chickpea (*Cicer arietinum* L.), and soybean (*Glycine max* (L.) Merr.), the germplasm that is undergoing improvement is, in effect, a "population" of elite, high-yielding, homozygous genotypes (i.e., the parental material entering each breeding cycle). Because a comparison between chickpea and soybean breeding may offer some useful insights, a retrospective look at past soybean breeding is warranted.

Some Retrospective Insights on Soybean Breeding

Using 3-year yield data collected on 240 soybean cultivars that had been released in the northern USA during this Century, Specht and Williams (1984) calculated that US breeders had improved soybean yield by about 18.8 kg ha^{-1} annually during 1900-1980. However, a major portion of the 80-year cumulative genetic gain of 1.5 t ha^{-1} occurred as a one-time "quantum jump" of about 0.6 t ha^{-1} in the mid-1940s. When this was removed from the analysis, the pre-1940 annual genetic gain was estimated to be 0.7 kg ha^{-1}, but the post-1940 gain was found to be significant at 12.5 kg ha^{-1}.

The nonrecurrent "quantum jump" in soybean yield improvement was attributable to the adoption of a fundamental change in soybean breeding methodology (Specht and Williams 1984). The pre-1940 breeding system consisted solely of evaluating plant introductions, followed by selection of the superior ones for release as named cultivars. However, the post-1940 breeding system consisted of three phases: (1) biparental matings of annually chosen parents; (2) generation advance of the progeny to some desired level of homozygosity; and (3) evaluation of lines extracted from each of the biparental populations, followed by selection of the superior lines for release as named cultivars. The biparental hybridization feature allowed parental genes to be rearranged (via Mendelian sorting of unlinked loci and chromosomal crossing over between linked loci) into a near-infinite array of selectable recombinant genotypes. The 3-phase procedure could also be repetitively cycled, in the sense that the "output materials" of any prior breeding cycle (i.e., cultivar releases) supplied the "parental inputs" for a subsequent breeding cycle. In effect, the new procedure essentially made genetic recombination and recurrent selection intrinsically routine features of soybean breeding.

Subsequent to its rapid adoption by soybean breeders in the mid-1940s, some modifications of the foregoing breeding method have occurred. Most notably, greenhouses and tropical nurseries are now employed to attain one or two selfing generations during the winter season, and single-seed-descent (SSD) has been adopted as a convenient means of achieving a rapid generation advance in these settings (Brim 1966). The first yield test now commences at an earlier selfing stage, typically with $F_{4,5}$ lines in many programs, and even $F_{3,4}$ lines in a few programs. Off-season generation advance has significantly reduced the number of years needed to complete a cycle of selection. Mechanization of plot sowing and harvesting methods, coupled with the use of better experimental designs and computerized data collection techniques, have greatly improved the accuracy and precision of performance testing. The resultant reduction in experimental error has effectively decreased the nongenetic fraction of the phenotypic variance, leading to higher heritabilities. Fehr (1987) can be consulted for more details of the salient aspects of contemporary soybean breeding methods.

Some Contemporary Thoughts on Soybean Breeding

Plant breeders continually search for methods to improve the effectiveness of cultivar development programs. However, any proposal that calls for the adoption of a new breeding method must satisfy two criteria if the new method is to attain acceptance by "practicing" plant breeders. First, the new method must have a theoretical advantage that is firmly founded on modern plant breeding theory. Second, the new method must have an empirically demonstrable advantage, that is, the benefits accruing from its use must be worth more than the costs of its implementation.

Relative to the first criterion, the breeder would simply compare the annual genetic gains obtainable with the new and existing methods of breeding, using comparable assumptions. The following mathematical expression is commonly used to predict the annual change in the mean of a population subjected to one cycle of recurrent selection (Brim 1973; Burton 1987; Fehr 1983):

$$G_y = c\ k\ r^2_A / y\ r_{ph}$$

where: G_y = genetic gain per year; c = index of parental control; k = standardized selection differential; r^2_A = additive genetic variance; y = years required per cycle of selection; and r_{ph} = square root of the phenotypic variance.

Analysis of the above mathematical expression makes it clear that annual genetic gain can be increased by altering the breeding method in ways that will enhance the magnitude of the parameters in the numerator, and/or reduce the magnitude of the parameters in the denominator. For the reader who desires more details, Fehr (1983) provides examples of how the genetic gain equation can be used to identify effective breeding strategies. The new soybean breeding method proposed in this paper was the outcome of the authors' efforts to amplify the genetic variability component of the genetic gain equation.

Based on quantitative genetic theory, formal recurrent selection schemes offer significant advantages relative to conventional breeding systems (Brim 1973; Burton 1987). However, none of these recurrent selection schemes has been adopted by US soybean breeders for their primary cultivar development programs, i.e., the ones that involve populations composed of the most elite, highest-yielding genotypes. Formal recurrent selection schemes rely on populations that are "closed" to outside parental inputs (Brim and Stuber 1973). In contrast, the success of the primary cultivar development programs is very much dependent on the use of populations that are "open" to external parental inputs. This dependency is due to the fact that the internally and externally generated elite materials possess a degree of "unrelatedness" (a relative distinction, to be sure!) that can bestow upon an elite x elite breeding program the potential to create genetic variability and (more importantly) new transgressive segregants.

Are there deficiencies in the contemporary soybean breeding system? The authors think so, as did Jensen (1970), who some 20 years ago, enumerated the various defects in the pedigree-based, biparental hybridization methods that were being used for the breeding of autogamous crops. Two of these are worth reiterating here.

The most obvious defect is a continued reliance on the biparental hybridization of homozygous parents for the cyclic creation of selectable genetic variability. In a biparental population, the initial frequency of the favorable allele (p) at each locus will be one of three possible quantities: p=1.0 (favorable allele fixed), p=0.0 (unfavorable allele fixed), or p=0.5 (biparental allelic contrast led to heterozygosity). The mean of the population will, of course, be directly related to the collective frequency of the favorable alleles. The amount of the additive genetic variance in the population will be a function of the number of p=0.5 loci generated by the biparental mating. In an ideal breeding program, a mechanistic technique would be used to annually identify, in the recurrently selected germplasm of interest, the elite x elite matings that (a) would maximize the number of p=1.0 loci brought to each mating combination (to protect these loci from a counterproductive reversion to the p=0.5 state), and (b) would also convert p=0.0 loci to a p=0.5 state (in sufficient numbers to allow further conversion to a p=1.0 state via selection of the appropriate segregants from the progeny). Obviously such a technique does not exist, and until it is provided by molecular genetic research, breeders will have to rely on empirical techniques to select elite lines for paired crosses.

Another major deficiency arises because in most premier cultivar development programs, the mating phase of a specific selection cycle typically does not include any more than just the two-parent hybridization. That is, the F_1 progenies are not intermated, but instead are immediately selfed to initiate the rapid generation advance to near-homozygosity that consumes the bulk of the selection cycle length in most cultivar development schemes. Selfing is, of course, a necessary feature since it generates the homozygous lines that will be tested, selected, and released as named cultivars. However, the intervention of an interminably long selfing phase (especially one that goes to near-homozygosity) between the intermating of parents in one selection cycle and the intermating of their progeny in the next cycle, has a serious drawback; intra-locus heterozygosity is reduced by one-half in each selfing generation. This rapid loss is incompatible with the need to maintain heterozygosity at a level that will provide chromosomal crossovers with an opportunity to recombine the undesirable repulsion linkages in the parental genotypes into selectable recombinant progeny possessing the desirable coupling linkages.

Jensen (1970) observed that both of the foregoing defects could be alleviated by use of his "diallel selective mating" (DSM) system. In the DSM system, each breeding cycle still retains a phase consisting of selfing the progeny to near-homozygosity. However, the selfing phase no longer intervenes between successive matings, but instead is "spun-off" from the population undergoing continuously repetitive intermatings. This "spin-off" feature represented a fairly radical departure from the then existing breeding practices, and because it also required large numbers of crosses each year, it has not been adopted by many soybean breeders. However, when the *Ms_2/ms_2* form of soybean genetic male-sterility became available (Bernard 1975), it was immediately used to construct a parentally diverse (in the cytoplasmic and genomic sense) random-mating population. Given the name SG1, this population was released to breeders in 1985 (Specht et al. 1985). The convenience of male-sterility has made DSM a feasible breeding method, but the authors have modified it to develop a breeding method that warrants future theoretical and empirical comparisons with the conventional soybean breeding method.

The Conventional Soybean Breeding Method

The basic aspects of a contemporary soybean cultivar development program are illustrated in Figure 1. Such a program would likely be used when the sole objective is an incessant search for cultivars with ever-greater yields. The mating phase consists of single crosses made between pairs of homozygous parents. At Nebraska, for example, 10 unrelated genotypes (some breeders use more than 10) are selected each year from the germplasm emanating from local and external breeding programs. The criterion for selection is exceptional yield performance relative to the best recent cultivar releases of a similar maturity. The 10 parents would, in most instances, comprise promising breeding lines and/or recent cultivar releases. A 10-parent diallel (no selfs or reciprocals) is used to generate the 45 possible single-crosses commencing each cycle (Fig. 1).

The selfing phase of each selection cycle includes a two-generation advance (some breeders do three or four generations) by SSD in a winter nursery. The following summer, about 150 F_3 plants per cross are harvested. The evaluation and selection phase of each selection cycle begins with a 3-replicate hill-plot test of about 6750 $F_{3,4}$ lines. About half of these are discarded prior to harvest (based on visual selection), and of the harvested remainder, only the best 20-25% (ca. 600-800) are tested as $F_{3,5}$ lines in the following year's 2-replicate 2-row-plot yield trials at six Nebraska locations. Only the best-yielding 5% (ca. 20-40) will be tested as $F_{3,6}$ lines the following year in the Northcentral USA Soybean Preliminary Tests. Superior lines from the Preliminary Tests are then tested for up to two years in the multilocational Northcentral USA Uniform Tests, with possible release depending upon yield performance vs the recent cultivar releases that serve as controls. With this system (Fig. 1), it is anticipated that F_9 seed of the released variety would be made available to Nebraska certified growers, who would increase and sell the F_{10} certified seed to all other Nebraska producers the following year. Thus, a cycle of variety development would span 8 years from the year of the mating to the year of first commercial production.

An Alternative Soybean Breeding Method

The authors have designed an alternative breeding method that attempts to combine the best features of the DSM system and the conventional breeding (CB) system into a male-sterile-facilitated cyclic breeding scheme (MSFCB). In the new method, the 10 annually chosen elite parents are not directly mated to each other (as in the CB system), but are placed instead in an isolation nursery containing male-sterile plants. Insects randomly transfer pollen from the 10 elite parents to the male-sterile plants. At least one F_1 seed is harvested from each of the available male-sterile plants,

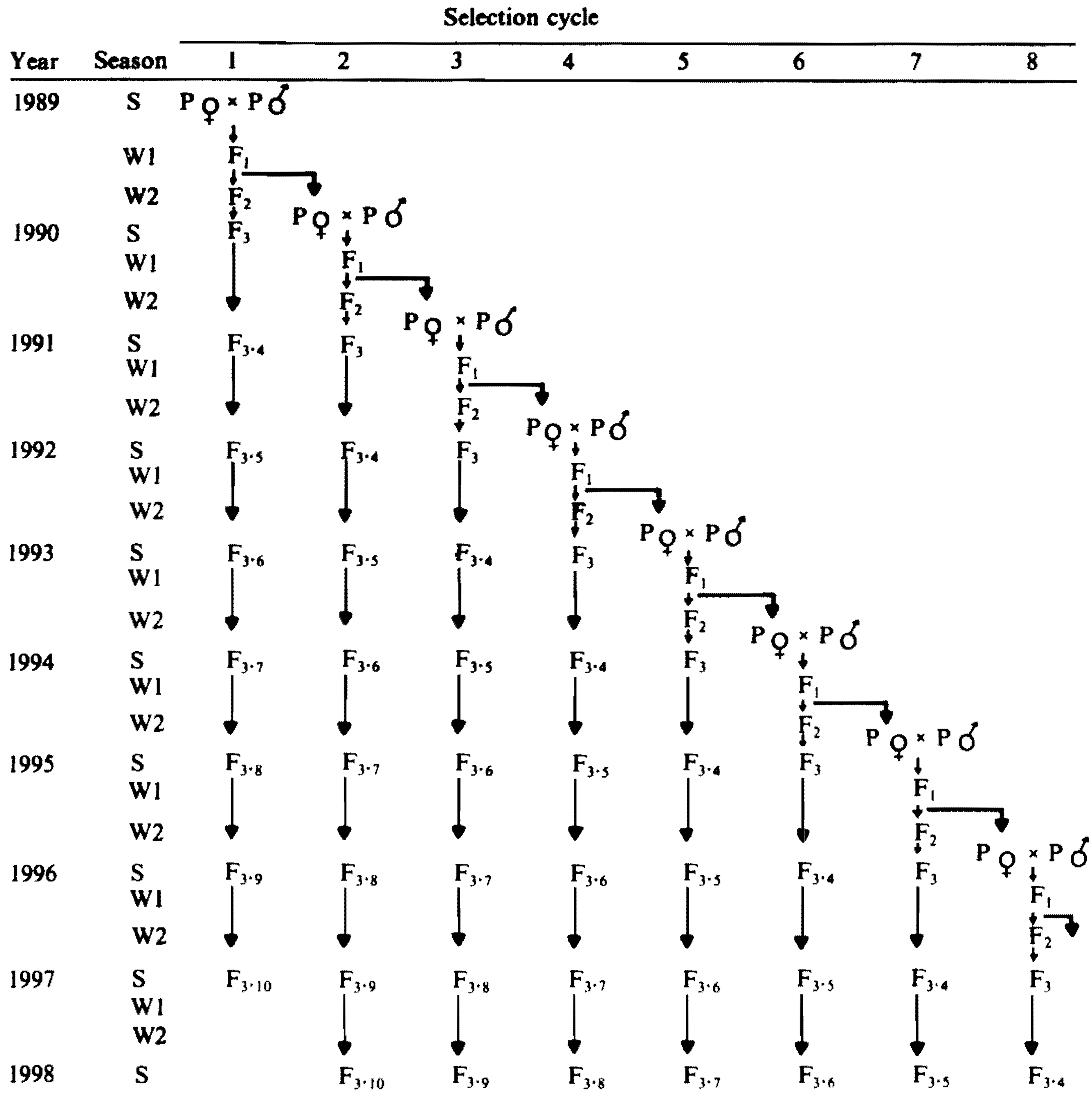


Figure 1. The conventional breeding (CB) method vis-a-vis the male-sterile facilitated cyclic breeding (MSFCB) includes a mating phase, a selfing phase, and a testing phase for identifing superior lines for release as named cultivars. The P♀× P♂ symbolism in the CB method represents the annual matings generated by a partial diallel of 10 parents, which are selected by the breeder from local and external germplasm sources. In the MSFCB method, P♂ represents the same set of 10 parents, but P♀ represents male-sterile F_2 plants emanating from the F_1 plants previous year's P♀ × P♂ matings (arrows). See also text.

and when sown in a winter nursery, provides the F_1 plants that will be bulk-threshed to generate F_2 seed. Most of this seed proceeds through the breeding program (Fig. 1), but a portion of the F_2 seed is cycled to the next year's isolation nursery, thus providing the source of the male-sterile plants that will be mated to the next set of 10 elite parents. The F_2 plants in the isolation nurseries segregate 3 male-fertile to 1 male-sterile plants (genotypic ratio: 1 Ms_2Ms_2 : 2 Ms_2ms_2 : 1 ms_2ms_2), but the male-fertile plants are rogued as soon as they produce an examinable flower (in ms_2ms_2 flowers, the shrunken anthers bear no pollen). One major modification that makes the MSFCB system comparable to the CB system, but distinguishes it from the DSM system is the annual inflow of 10 new parents. St. Martin (1985) suggested that such breeding methods are more aptly termed "recurrent introgression" than recurrent selection. In any case, the MSFCB mating design provides a "recombinational link or connection" between the intermating phases that commence each successive annual breeding cycle. The consequences of this can be illuminated by the following reference to the scheme in Figure 1. If the collective genome of the F_1 crosses made in 1994 were to be allocated on the basis of ancestral source, 50% would trace to the 10 male parents used in that same year, 25% would trace to the 10 male parents used in 1993, 12.5% to 10 male parents of 1992, 6.25% to the 10 male parents of 1991, and so on, ad infinitum. In the CB system, however, the "recombinational link" would be established only over a much longer period of time. For example, progeny emanating from 1989 crosses would not be used as parents until perhaps 1996 (Fig. 1), and then only if their yield performance in the 1995 uniform trials justified their inclusion in the 1996 set of ten parents.

The MSFCB method does have a complication that is not present in the CB method. Male-sterile plants appear in the breeding material that is "spun-off" after each intermating cycle. Only male-fertile plants will be sampled by SSD in the F_2 generation, and only individual male-fertile plants will be harvested in the F_3 generation (Fig. 1), which will segregate 5 male-fertile to 1 male-sterile. The male-fertile F_3 plants will have a genotypic ratio of 3 Ms_2Ms_2 : 2 Ms_2ms_2. Thus, 40% of the $F_{3,4}$ entries in a hill-plot test will segregate for sterility, and thus must be discarded. Therefore, a valid cost comparison of the new and CB methods must take into account that the numbers of F_2 and F_3 plants, and $F_{3,4}$ lines, will have to be multiplied by factors of 1.33, 1.20, and 1.66, respectively, in the new method. The breeder can, of course, delay individual plant harvest to the F_4 or F_5 generation, when the number of homozygous male-fertile plants is a greater fraction of the whole.

Summary

The authors have laid the groundwork that will allow them to perform a rigorous empirical comparison of the MSFCB procedure with the CB method. An elite version of the SG1 population, which will be released in 1990, provided the initial male-sterile parents when the new method was initiated in 1989 (Fig. 1). The 10 male parents chosen each year will be the same for both procedures. It is of interest to note that the MSFCB technique will also allow empirical testing of the use of SSD beginning with F_1 seed rather than the traditional F_2 seed (Compton 1968). This and other ideas that originate from the comparative evaluation process, which will probably take a decade to complete, will provide some interesting dissertation research projects for present and future graduate students.

Are there any lessons in the soybean model that are of value to the chickpea breeder? The authors think there are at least three. First, a good genetic male-sterility system is of paramount importance if recurrent introgression schemes are to be conveniently applied to chickpea. Second, cooperative testing programs and a policy that rigorously promotes the exchange of breeding lines are essential. Such testing programs and germplasm exchange were key elements in the merging of recurrently selected local populations into regional and national populations of elite germplasm, from which local breeders now draw parents for their local breeding programs. Finally, a retrospective and contemporary analysis of breeding methods in other crop species may provide the chickpea breeder with some invigorating ideas and alternative approaches to what may currently seem to be insoluble breeding problems. It is hoped that this contribution on soybean breeding will have some use in that context.

References

Bernard, R. L. 1975. Inheritance of the Eldorado male-sterile trait. Soybean Genetics Newsletter 3:37-39.

Brim, C.A. 1966. A modified pedigree method of selection in soybeans. Crop Science 6:220.

Brim, C. A. 1973. Quantitative genetics and breeding. Pages 155-186 *in* Soybeans: improvement, production, and uses (Caldwell, B.E., Howell, R.W., Judd, R.W., and Johnson, H.W., eds.). Agronomy no. 16. Madison, Wisconsin, USA: American Society of Agronomy.

Brim, C.A., and **Stuber, C. W.** 1973. Application of genetic male sterility to recurrent selection schemes in soybeans. Crop Science 13:528-530.

Burton, J. W. 1987. Quantitative genetics: results relevant to soybean breeding. Pages 211-247 *in* Soybeans: improvement, production, and uses (Wilcox, J.R., ed.). 2nd edn. Agronomy no. 16. Madison, Wisconsin, USA: American Society of Agronomy.

Compton, W. A. 1968. Recurrent selection in self-pollinated crops without extensive crossing. Crop Science 8:773.

Fehr, W. R. 1983. Applied plant breeding. Ames, Iowa, USA: Iowa State University.

Fehr, W. R. 1987. Breeding methods for cultivar development. Pages 249-293 *in* Soybeans: improvement, production, and uses (Wilcox, J. R., ed.). 2nd edn. Agronomy no. 16. Madison, Wisconsin, USA: American Society of Agronomy.

Jensen, N. F. 1970. A diallel selective mating system for cereal breeding. Crop Science 10:629-635.

Specht, J.E., and **Williams, J.H.** 1984. Contribution of genetic technology to soybean productivity - retrospect and prospect. Pages 49-74 *in* Genetic contributions to yield gains in five major crop plants (Fehr, W.R., ed.). Madison, Wisconsin, USA: Crop Science Society of America.

Specht, J. E., Williams, J. H., Kenworthy, W. J., Orf, J. H., Helsel, D. G., and **St. Martin, S. K.** 1985. Registration of SG1 germplasm. Crop Science 25:717-718.

St. Martin, S. K. 1985. The application of quantitative genetics theory to plant breeding problems. Pages 311-317 *in* Proceedings of the World Soybean Conference III. 12-17 Aug 1984, Ames, Iowa, USA. Boulder, Colorado, USA: Westview Press.

New Approaches in Chickpea Breeding and Prospects in the Nineties

P.N. Bahl[1], P.M. Salimath[2], B.A. Malik[3], B.S. Dahiya[4], R.B. Deshmukh[5], and P. Rangasamy[6]

Abstract

To increase per capita availability of pulses in the 1990s, it is necessary to bring about major gains in the productivity of chickpea, the main pulse crop of the Indian sub-continent. Within cultivated species of chickpea, the two groups, desi and kabuli, and within these groups tall and bushy types show differential expression for certain agronomic traits. Non-hierarchical Euclidean cluster analysis of 200 entries specified 15 and 2 clusters suggesting kabuli and desi as distinct groups within the cultivated taxon. Multivariate analysis brought out a clear demarcation between tall and bushy types. Backcrossing was successful for introgressing desi germplasm to kabuli background and vice versa. In terms of yield performance, tall types favored late sowing, compared with bushy types, which do better under normal sowing. Tall types offer possibilities for non-traditional cropping patterns and seasons to extend their area of cultivation. Stability of production is possible when adequate control of diseases through resistant cultivars is achieved. Development of near-isogenic lines, by incorporating genes for resistance to major diseases, has been proposed as a long-term goal for effective disease control. Different agro-climatic situations on the Indian sub-continent have been covered in case studies to project regional constraints and to suggest strategies to overcome them in the 1990s, so that there will be an adequate per capita availability of proteins by the year 2000.

Résumé

Nouvelles approches à la sélection du pois chiche et possibilités pour les années 90 : *Pour augmenter la disponibilité par habitant des légumineuses au cours des années 90, il est nécessaire de réaliser des gains importants de la productivité du pois chiche, qui est la principale culture légumineuse du sous-continent indien. Parmi les espèces cultivées de pois chiche, les deux groupes 'desi' et 'kabuli' et, au sein de ces groupes, les types grands et buissonnants, manifestent une expression différentielle pour certains caractères agronomiques. Une analyse euclidienne non hiérarchique des grappes réalisée sur 200 entrées a spécifié 15 et 2 grappes, ce qui ferait de kabuli et desi des groupes distincts dans le taxon cultivé. Une analyse à plusieurs variables a fait ressortir une démarcation nette entre les types grands et buissonnants. Le rétrocroisement donnait de bons résultats pour l'introgression du matériel desi dans un milieu kabuli et vice versa. En ce qui concerne les rendements, les types grands favorisent les semis tardifs, en comparaison avec des types buissonnants, qui se*

1. Assistant Director General (Food Crops), Indian Council of Agricultural Research (ICAR), Krishi Bhavan, New Delhi 110 001, India.
2. Scientist-in-charge, Indian Agricultural Research Institute (IARI), Centre for Improvement of Pulses in South, Dharwad 580 002, Karnataka, India.
3. Coordinator (Pulses), National Agricultural Research Centre (NARC), P.O. National Institute of Health, National Park Road, Islamabad, Pakistan.
4. Senior Chickpea Breeder, Department of Plant Breeding, Haryana Agricultural University, Hisar 125 004, Haryana, India.
5. Plant Breeder (Pulses), Pulses Improvement Project, Mahatma Phule Agricultural University, Rahuri 413 722, Maharashtra, India.
6. Professor (Pulses), School of Genetics, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu, India.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

comportent mieux avec des semis normaux. Les types grands offrent des possibilités de systèmes de culture et de saisons non traditionnelles pour élargir leurs zones de culture. La stabilité de la production est possible lorsqu' on réussit à lutter efficacement contre les maladies à l'aide des cultivars résistants. La mise au point de lignées quasi isogéniques, en incorporant des gènes de résistance aux principales maladies, a été proposé comme objectif à long terme pour assurer une maîtrise efficace des maladies. Des situations agro-climatiques différentes sur le sous-continent indien ont été couvertes dans des études de cas pour projeter les contraintes régionales et suggérer des stratégies pour les surmonter au cours des années 90, afin de prévoir une disponibilité adéquate en protéines par habitant d'ici l'an 2000.

Chickpea has an extensive geographical distribution covering the Indian subcontinent, the Mediterranean region, western and eastern Asia, northern and eastern Africa, and southern Europe. Although India has the largest global share (76%), both in area and production, the productivity of this crop is low compared to yields in some other parts of the world. To make India self sufficient in pulses and to adequately meet the nutritional requirements of its growing population, major strides in pulse production should be made during the 1990s. Because the prospects of increasing the area under pulses are bleak, increased production should come from increased productivity. Accordingly, breeding strategies will have to be based on new priorities and objectives.

The major objective in the 1990s should be to develop a sustainable agriculture at a high level of productivity. Chickpea breeders should meet this challenge by making major gains in chickpea productivity. Evidently this requires a multidirectional attack on some of the basic problems relating to the breaking of yield barriers in chickpea.

Historically, yield improvement in any crop can be traced back to exploitation of new sources of germplasm or traits that harness genetic variability. Progress in a breeding program depends upon the extent of variability present, and the amount of variability recombined during hybridization which becomes available for selection. The transfer of such variability to the adapted genotypes in chickpea would involve intervarietal, intergroup (within a species), or interspecific cross combinations. To execute this program, it may be necessary to follow several innovative breeding approaches because chickpea breeding objectives are complex and demanding.

Exploitation of Alien Germplasm

Diminished genetic variability within the cultivated gene pools of crop species is a phenomenon of contemporary agricultural systems. To meet the present and future aims and objectives of ever-expanding breeding programs, it is essential to augment the available genetic variability by infusing alien germplasm into the breeding populations. The introgression of exotic germplasm from wild and cultivated relatives, must consequently be an integral part of a breeding program (Stalker 1980). Besides affecting yield, alien germplasm can be a source of several desirable traits including nutritional attributes, resistance to abiotic and biotic stresses, and duration of maturity.

Kabuli–Desi Introgression

Within the cultivated species of chickpea, kabuli and desi are considered distinct groups of cultivars (Bahl 1980; Hawtin and Singh 1980). More recently, Mani (1987) studied 200 entries, representing 100 each of desi and kabuli types, from six major chickpea-growing regions of the world and evaluated them for variation, using multivariate and electrophoretic methods. The 200 entries, grouped into 15 clusters, showed a tendency to form separate clusters for desi and kabuli types (Table 1). As many as 10 clusters comprised exclusively desi or kabuli entries. The remaining five mixed clusters had predominance of either one type or the other. Furthermore, non-hierarchial Euclidean cluster analysis specified 15 and 2 clusters, confirming the presence of specific genotypes with differential expressions in respect of specific agronomic traits forming two sub-groups within chickpea. Whatever the magnitude of differentiation or genetic distance between kabuli and desi types, crosses between them can help in transferring desirable characters from one sub-group to the other.

Following this approach, Ugale and Bahl (1983) studied the pattern of transgressive segregation in three single crosses, each involving a desi and a kabuli parent, to investigate the possibility of incorporating kabuli traits into desi types and vice versa. Transgres-

Table 1. Pattern of distribution of 200 chickpea entries in 15 clusters sown at Delhi during 1984/85[1].

Cluster no.	No. of entries		Percentage of entries	
	Desi	Kabuli	Desi	Kabuli
1	7	2	77.8	22.2
2	-	10	-	100.0
3	13	1	92.9	7.1
4	-	19	-	100.0
5	17	4	81.0	19.0
6	-	18	-	100.0
7	12	-	100.0	-
8	-	12	-	100.0
9	5	-	100.0	-
10	-	14	-	100.0
11	11	-	100.0	-
12	4	11	26.7	73.3
13	10	-	100.0	-
14	17	-	100.0	-
15	3	10	23.1	76.9

Source: Mani 1987.

sants for yield and its components were studied in F_2s, F_3s and progenies of backcrosses (BC_1F_2 and BC_2F_2, using both desi and kabuli as recurrent parents). Relative proportions of transgressive segregants for different agronomic characters were higher in progenies of backcrosses than in selfing series. Thus reciprocal backcrossing was successful in introgressing desi germplasm into kabuli backgrounds and vice versa. Several high-yielding and widely adapted varieties such as L 104, L 144, L 550, and Pusa 267 among kabuli types and Pusa 244, Pusa 256, and Pusa 261 among desis have emanated from crosses in which kabuli and desi germplasms have been recombined in single, 2-way, or double crosses (Bahl 1988). However, kabuli–desi introgression, which seems to have tremendous possibilities, has yet to receive concerted and consistent efforts to realize the full potential of this approach.

Interspecific Hybridization

Interspecific hybridization can play an important role through introgression of important genes from one species into another. In the case of *Cicer*, a number of desirable traits such as resistance to diseases, high seed number per pod, and drought resistance are available in the wild annual species (van der Maesen and Pundir 1984). Some of them such as *C. judaicum* and *C. bijugum* possess resistance to fusarium wilt and ascochyta blight, both important diseases of chickpea. However, there are crossability barriers to interspecific hybridization, and most of the wild species, possessing certain useful characters which the breeders are looking for, belong to the tertiary gene pool (Ladizinsky and Adler 1976; Ahmed et al. 1988; Ladizinsky et al. 1988). The problems and prospects for application of biotechnological tools to overcome these barriers have been discussed by Ladizinsky et al. (1988) and van Rheenen et al. (1988). Integration of these techniques in chickpea breeding would facilitate gene flow from wild to cultivated species.

Breeding Chickpea for Adaptation in Terms of Time and Space

Adaptation to Late-sown Conditions in Northern India

With the emergence of new cropping patterns in northwestern and northeastern India, farmers are looking for chickpea varieties that can be fitted into double-cropping systems. For traditional bushy cultivars, the yields are drastically reduced when they are sown late. Tall genotypes, differing distinctly from those with a bushy growth habit, may provide a suitable option for cultivation under late-sown conditions.

Growth habit is known to have played an important role in the domestication and evolution of pulse crops (Smartt 1976). As a first step in testing different growth habits, 19 chickpea genotypes, comprising 10 bushy and 9 tall types, were studied for possible genetic differentiation through multivariate analysis, based on pooled data of 2 years with two environments in each year (Yadav 1986). The pattern of clustering in respect of tall and bushy genotypes provided a very interesting picture. Of the five clusters, two exclusively included bushy types and the remaining three only included tall genotypes. While the bushy types were all of Indian origin, the tall types invariably had a variety from USSR in their parentage. The clear demarcation between the two types, based on both agronomic characters and origin, led to the conclusion that either tall types diverged from bushy types during the course of evolution or the two types possess differentiated characters as a result of area-specific adaptations.

In broader perspective the genetic potential of tall and bushy plant types, can be assessed by estimates of biomass production, grain yield, and harvest index in a fixed span of growth period. Of the different agronomic characters, branching pattern, number of effective pods, and seed mass would exert marked influence on these parameters. Yadav and Bahl (1988) studied the mean performance of 11 bushy and 9 tall genotypes for some of these characters under normal and late-sown conditions (Table 2). Significant differences, between bushy and tall types under normal sowing in respect of grain yield, pod number, and biomass production, were reduced to non-significant levels when late sown. In bushy types there was a marked reduction in these parameters when sown late, but such decreases were of low magnitude for tall genotypes. Interestingly, the harvest index increased appreciably in tall types and only marginally in bushy types when they were sown late. Similar observations on tall genotypes were earlier reported by Bahl et al. (1984). Probably, tall types have evolved to withstand the adverse effects of late germination. An important implication of this study is that tall types offer opportunities for non-conventional cropping patterns.

To improve the yielding capacity of tall and compact types for normal sowing conditions, they were crossed with bushy types in order to decrease internodal length and increase the number of pod-bearing nodes. This brings about some phenological changes and favorable partitioning of the biomass production (Dahiya et al. 1988). Some derivatives were semi-tall in growth habit with podding starting a few inches above ground level. They were tolerant to cold, and continued pod formation in the cold weather under northern Indian conditions when traditional bushy types stop podding.

Adaptation to Early Sowing Conditions in Peninsular India

The chickpea crop in peninsular India is rainfed, and grown either on rainy-season fallows or after a short-duration millet or pulse crop. Chickpea, normally sown in October, is forced to mature after mid-February owing to rising temperatures and drought stress. These conditions, involving a short growing season (90-120 days) and limited water, are responsible for low productivity. By sowing a month earlier (mid-September), a longer growing period is provided, which in turn would be expected to raise yield levels. Moreover, the good moisture conditions in September would also ensure better germination and crop establishment, compared to normal sowing. The yield advantage of early sowing over normal sowing ranged from 35% to 120% (ICRISAT 1986). More research effort is required to develop varieties suitable for these growing conditions and to overcome some of the constraints associated with early sowing.

Development of Near-isogenic Lines with Resistance to Major Diseases

Vulnerability to diseases is one of the major constraints to chickpea production. Among the important diseases of chickpea, ascochyta blight caused by *Ascochyta rabiei* (Pass) Lab. is the main limitation in northwestern India and Pakistan, whereas wilt caused by *Fusarium oxysporum* f.sp. *ciceri* partially accounts for poor and unstable yields in many countries including India, Pakistan, northwestern Africa, Spain, Mexico, and USA (Hawtin et al. 1988). Fortunately, considerable progress has already been made in the development of screening techniques and identification of sources of resistance against these and several other diseases (Nene et al. 1981). Resistance to ascochyta blight is controlled by a single dominant or recessive gene (Vir et al. 1975; Singh and Reddy 1983; Tiwari and Pandey 1986; Singh and Reddy 1989); and two recessive genes (Upadhyaya et al. 1983a, 1983b) or a combination of one recessive gene and one dominant gene (Smithson et al. 1983) in the case of wilt. Therefore, breeding for resistance against these diseases should not pose unsurmountable difficulties.

Table 2. Means of some agronomic characters in 11 bushy and 9 tall chickpea genotypes under normal and late-sown conditions, Delhi 1983/84.

	Normal sowing (2 Nov 1983)			Late sowing (26 Nov 1983)		
Character	Bushy	Tall	CD	Bushy	Tall	CD
Grain yield plant^{-1} (g)	31.62	17.35	11.62	17.31	17.81	9.91
Pods plant^{-1}	190	98	68	105	86	50
Total biomass plant^{-1} (g)	86.45	60.14	22.28	42.60	42.52	15.60
100-seed mass (g)	12.51	14.52	1.52	11.81	14.33	1.62
Harvest index (%)	36.53	28.29	8.33	40.41	40.46	10.37

With this background information, a breeding program has been initiated at the Division of Genetics, IARI, to develop near-isogenic lines (NILs) of the widely adopted variety Pusa 256, aimed to be individually resistant to ascochyta blight or fusarium wilt. The ultimate goal is to develop several NILs of Pusa 256 for different regions, and to blend the appropriate ones, depending on the races of a pathogen and number of diseases prevalent in a particular region.

To achieve this, donors of resistance genes will be crossed and backcrossed five or six times to Pusa 256. In the final step, homozygous resistant BC_5F_2 or BC_6F_2 plants will be selected for phenotypic similarity to Pusa 256. Depending upon the initial success of the program, it is proposed to start the production of NILs, using several donors of resistance to these pathogens. The long-term goal will be to generate a continuous flow of NILs that carry different resistance genes. In the event of a breakdown in resistance of certain genes, corresponding NILs will be dropped from the breeding program. Kolster et al. (1986) followed a similar approach in barley to produce NILs with genes for resistance to powdery mildew, and produced 24 NILs that differed in their genetic constitution.

Case Studies

Northwestern India and Pakistan

During the last two decades, chickpea cultivation in this part of the Indian subcontinent has been pushed to marginal and dry areas mostly as a result of a backlash from the "green revolution". Though the crop is predominantly grown under rainfed conditions, particularly in the Thal desert of Pakistan, on the sandy soils of southern Haryana and northern Rajasthan states of India, about 15% of the area receives irrigation. Among the constraints to production, ascochyta blight is a potential danger to the crop especially in northern Pakistan and northwestern India. Besides this, fusarium wilt and root rot, widespread over the entire Indian subcontinent, also cause extensive damage to the chickpea crop. Under irrigated conditions, excessive vegetative growth, often resulting from frequent irrigations or winter rains, aggravates disease problems and reduces yield. Varieties that can respond to late sowing after the rice harvest can help to extend chickpea cultivation in the rice-growing areas of the region.

To realize the production potential of this region, chickpea breeders should develop varieties that are:

- resistant to major diseases prevalent in the region,
- suitable for double cropping,
- tolerant to salinity/alkalinity, drought and cold, and
- responsive to irrigation and phosphatic fertilizer.

Central and Peninsular India

Chickpea is mostly grown after the rainy season on black soils with residual moisture. During its productive period, the crop is exposed to rising temperatures and drought stress which restrict the flowering period, hasten maturity, and result in low yields. Wilt and dry root rot are the major diseases of the region, and pod borer is a serious pest often causing heavy crop losses. To increase productivity, chickpea breeders should evolve varieties that are:

- resistant to fusarium wilt and dry root rot,
- tolerant to early sowing at relatively high temperature, and
- productive and stable under limited moisture supply.

Northeastern India and Bangladesh

In the rice and jute fallows of West Bengal and Bangladesh and rainy-season fallows in the Tal areas of Bihar, chickpea is sown in the second half of October. Late sowing of chickpea after the harvest of rice is also common throughout the region. Among the diseases, fusarium wilt and botrytis gray mold are major impediments to production.

Specific research needs include:

- development of varieties suitable for late sowing,
- breeding varieties with resistance to fusarium wilt and botrytis gray mold, and
- management of cut worm and pod borer.

References

Ahmad, F., Slinkard, A.E., and Scoles, G.J. 1988. Investigations into the barrier(s) to interspecific hybridization between *Cicer arietinum* L. and eight other annual *Cicer* species. Plant Breeding 100:193-198.

Bahl, P.N. 1980. *Kabuli–desi* introgression and genesis of new plant type in chickpea. Pages 75-80 *in* Proceedings of International Workshop on Chickpea Improvement, 28 Feb-2 Mar 1979, ICRISAT, Hyderabad, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Bahl, P.N. 1988. Chickpea. Pages 95-131 *in* Pulse crops (Baldev B., Ramanujum, S., and Jain, H.K. eds.). New Delhi, India: Oxford and IBH publishing Co. Pvt. Ltd.

Bahl, P.N., Singh, K.P., and **Singh Daljeet.** 1984. Evaluation of tall chickpea genotypes for normal and late sowings. Indian Journal of Agricultural Sciences 54:110-113.

Dahiya, B.S., Naidu, M.R., Ram Kumar, and **Mehla, B.S.** 1988. Introduction of major phenological changes in chickpea to improve biological and seed yield. International Chickpea Newsletter 19:4-6.

Hawtin, G.C., Muehlbauer, F.J., Slinkard, A.E., and **Singh, K.B.** 1988. Current status of cool season food legume crop improvement: an assessment of critical needs. Pages 67-80 *in* Proceedings of the International Food Legume Research Conference on Pea, Lentil, Faba Bean, and Chickpea (Summerfield, R.J., ed.), 6-11 July 1986, Spokane, Washington, USA. Dordrecht/Boston/London: Kluwer Academic Publishers.

Hawtin, G.C., and **Singh, K.B.** 1980. *Kabuli–desi* introgression: problems and prospects. Pages 51-60 *in* Proceedings of International Workshop on Chickpea Improvement, 28 Feb-2 Mar 1979, ICRISAT, Hyderabad, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1986. Chickpea Breeding Progress Report 32, Report of Work, June 1985 to May 1986. Patancheru A.P. 502 324, India: Legumes Program, ICRISAT. (Limited distribution.)

Kolster, Per, Munk, Lisa, Stolon, Olar, and **Lohde, Jorgan.** 1986. Near isogenic barley lines with genes for resistance to powdery mildew. Crop Science 26:903-907.

Ladizinsky, G., and **Adler, A.** 1976. Genetic relationships among the annual species of *Cicer* L. Theoretical and Applied Genetics 48:197-203.

Ladizinsky, G., Pickersgill, B., and **Yamamoto, K.** 1988. Exploitation of wild relatives of the food legumes. Pages 967-978 *in* Proceedings of the International Food Legume Research Conference on Pea, Lentil, Faba Bean, and Chickpea (Summerfield, R.J. ed.). 6-11 July 1986, Spokane, Washington, USA: Dordrecht/Boston/London: Kluwer Academic Publishers.

Mani, M. 1987. Intraspecific variation and combining ability in chickpea (*Cicer arietinum* L.). Ph.D. thesis, IARI, New Delhi, India. 133 pp.

Nene, Y.L., Haware, M.P., and **Reddy, M.V.** 1981. Chickpea diseases: Resistance screening techniques. Information Bulletin no. 10. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Singh, K.B., and **Reddy, M.V.** 1983. Inheritance of resistance to ascochyta blight in chickpea. Crop Science 23:9-10.

Singh, K.B., and **Reddy, M.V.** 1989. Genetics of resistance to ascochyta blight in four chickpea lines. Crop Science 29:657-659.

Smartt, J. 1976. Comparative evaluation of pulse crops. Euphytica 25:139-143.

Smithson, J.B., Kumar, J., and **Singh, H.** 1983. Inheritance of resistance to fusarium wilt in chickpea. International Chickpea Newsletter 9:21-22.

Stalker, H.T. 1980. Utilization of wild species for crop improvement. Advances in Agronomy 33:111-147.

Tiwari, S.K., and **Pandey, M.P.** 1986. Genetics of resistance to ascochyta blight in chickpea (*Cicer arietinum* L.). Euphytica 35:211-215.

Ugale, S.D., and **Bahl, P.N.** 1983. Incroporation of germplasm from *kabuli* to *desi* and *vice versa* in chickpea. Page 646 *in* Proceedings of XV International Congress of Genetics, 12–21 Dec 1983, New Delhi, India. New Delhi, India: Oxford and IBH Publishing Co. Pvt. Ltd. (Abstract.)

Upadhyaya, H.D., Haware, M.P., Kumar, J., and **Smithson, J.B.** 1983a. Resistance to wilt in chickpea. I. Inheritance of late wilting in response to race 1. Euphytica 32:447-452.

Upadhyaya, H.D., Smithson, J.B., Haware, M.P., and **Kumar, J.** 1983b. Resistance to wilt in chickpea. II. Further evidence for two genes for resistance to race 1. Euphytica 32:749-755.

van der Maesen, L.J.G., and **Pundir, R.P.S.** 1984. Availability and use of wild *Cicer* germplasm. Plant Genetic Resources Newsletter 57:19-24.

van Rheenen, H.A., Bond, D.A., Erskine, W., and **Sharma, B.** 1988. Future breeding strategies for pea, lentil, faba bean and chickpea. Pages 1013-1030 *in* Proceedings of the International Food Legume Research Conference on Pea, Lentil, Faba Bean, and Chickpea (Summerfield, R.J., ed.). 6-11 July 1986, Spokane, Washington, USA. Dordrecht/Boston/London: Kluwer Academic Publishers.

Vir, S., Grewal, J.S., and **Gupta, V.P.** 1975. Inheritance of resistance to ascochyta blight in chickpea. Euphytica 24:209-211.

Yadav, S.S. 1986. Morphogenetic architecture of plant type in chickpea (*Cicer arietinum* L.). Ph.D. thesis, IARI, New Delhi, India. 193 pp.

Yadav, S.S., and **Bahl, P.N.** 1990. Morpho-physiological architecture of structural and yield components in bushy and tall chickpea (*Cicer arietinum* L.). Pages 299-306 *in* Proceedings of International Congress of Plant Physiology, Volume 2 (Sinha, S.K., Sane, P.V., Bhargava, S.C., and Agarwal, P.K. eds.). 15–20 Feb 1988. New Delhi 110 012, India: Society for Plant Physiology and Biochemistry.

Disease and Pest Resistance Breeding: Which Way to Go in the Nineties?

K.B. Singh[1], Jagdish Kumar[2], M.P. Haware[2], and S.S. Lateef[2]

Abstract

*Forty-seven diseases and 54 insect-pests have been reported in chickpea (*Cicer arietinum *L.). Among the diseases, ascochyta blight, fusarium wilt, dry root rot, botrytis gray mold, and stunt are important; among insect pests, pod borer, leaf miner, aphids, and seed beetle are serious. Diseases and insects together cause considerable yield loss and, most importantly, destabilize production. Host-plant resistance represents the best strategy to control them. Reliable field screening techniques have been developed, and much germplasm has been screened and resistance sources have been identified for major diseases and insect pests. Lines with resistance to ascochyta blight and to fusarium wilt have been bred and released as cultivars in the Indian subcontinent, Mediterranean region, and the Americas.*

Future efforts need to be intensified to breed cultivars resistant to dry rot, botrytis gray mold, and stunt, and to pod-borer and leaf-miner. Lines with multiple diseases and/or insect-pest resistance to meet the requirements of different agroecological zones need to be developed. Transfer of genes for resistance from wild Cicer *species to the cultivated species through in vitro culture and protoplast fusion should be given priority. The importance of mapping the incidence of serious diseases and insect-pests in the world has been emphasized.*

Résumé

***Sélection pour la résistance aux maladies et aux ravageurs—quelle orientation pour les années 90?**: Quarante-sept maladies et 54 insectes ravageurs ont été repérés chez le pois chiche (*Cicer arietinum *L.). La flétrissure ascochytique, le flétrissement fusarien, la pourriture sèche des racines, la pourriture grise due à botrytis, et le nanisme sont les maladies importantes. Le foreur des gousses, la mineuse des feuilles, les pucerons, et les bruches du pois chiche causent des dégâts importants. Les maladies et les insectes occasionnent des pertes de rendement considérables et, en particulier, déstabilisent la production. La résistance de la plante-hôte constitue la meilleure stratégie de lutte. Des techniques fiables de criblage au champ ont été mises au point, et le criblage d'une grande quantité de matériel génétique a permis d'identifier des sources de résistance aux maladies et aux insectes ravageurs importants. Des lignées présentant une résistance à la flétrissure ascochytique et au flétrissement fusarien ont été sélectionnées et vulgarisées en tant que cultivars dans le sous-continent indien, la région méditerranéenne et aux Amériques.*

Des efforts plus intensifs sont nécessaires, dans les années à venir, pour la sélection de cultivars résistants à la pourriture sèche, à la pourriture grise due à botrytis, au nanisme, ainsi qu'au foreur des gousses et à la mineuse des feuilles. Des lignées avec une résistance multiple

1. Principal Chickpea Breeder (ICRISAT), Food Legume Improvement Program, International Center for Agricultural Research in the Dry Areas (ICARDA), P.O. Box 5466, Aleppo, Syria.

2. Plant Breeder, Plant Pathologist, and Entomologist, Legumes Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

ICRISAT Conference Paper no. CP 564.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

aux maladies et/ou insectes ravageurs doivent être mises au point afin de satisfaire les besoins des différentes zones agroécologiques. Il faut accorder la priorité au transfert de gènes de résistance des espèces sauvages de Cicer *aux espèces cultivées, à l'aide de la culture in vitro et de la fusion des protoplastes. L'importance de l'établissement des cartes d'incidence mondiale pour les maladies et les insectes ravageurs majeurs a été soulignée.*

The chickpea (*Cicer arietinum* L.) plant is known to be attacked by 47 diseases and 54 insect pests (Nene and Reddy 1987; Reed et al. 1987). The seed can be infested by three storage pests. The most serious diseases are ascochyta blight (*Ascochyta rabiei* [Pass.] Labr.), fusarium wilt (*Fusarium oxysporum* Schlecht. emnd Snyd. & Hans. f.sp. *ciceri* [Padwick] Snyd. & Hans.), dry root-rot (*Rhizoctonia bataticola* [Taub] Butler), botrytis gray mold (*Botrytis cinerea* Pers. ex. Fr.), and stunt (bean leaf roll virus). Pod borer (*Helicoverpa* spp and *Heliothis* spp), leaf miner (*Liriomyza cicerina* Rondani and *Phytomyza* sp near *lathyri* Hended), and seed beetle (*Callosobruchus* spp) are the most important insect pests of chickpea. All these diseases and insect pests inflict serious yield losses, and destabilize production. Chemical measures to control some of the diseases and insect pests are known, but most are impractical and uneconomical. Host-plant resistance seems to be the best strategy for achieving control.

It is believed that selection for resistant plants began with the domestication of the chickpea plant. But systematic disease resistance breeding began with work on ascochyta blight in the 1930s in India (Singh 1987). Studies on insect pest resistance were initiated at the Indian Agricultural Research Institute, New Delhi, India in the 1960s. Progress made in disease and insect resistance breeding has recently been summarized by Singh 1987, Nene and Reddy 1987, and Reed et al. 1987. This paper discusses different ways to manage the diseases and insect pests of chickpeas through the use of resistant cultivars, and thus to stabilize world chickpea production.

Mapping Major Diseases and Insect Pests

If the disease and insect problems of chickpea are to be tackled systematically, they need to be mapped to indicate their importance in each growing region. While detailed maps based on precise surveys need to be developed, an attempt has been made here already, based on the observations of several chickpea scientists (van Rheenen, personal communication), to indicate the importance of different diseases and insects (Table 1). Clearly two diseases, fusarium wilt and ascochyta blight, and one insect pest, pod borer, assume global importance.

Table 1. Important diseases and insect pests in different zones of the world.

	Zone (latitude)			
Biotic stress	I (0°-20°)	II (20°-25°)	III (25°-30°)	IV (30°-45°)
Diseases				
Fusarium wilt	1-2[1]	1-2	1-2	5
Ascochyta blight	9	9	5	1
Botrytis gray mold	9	2-3	3	9
Root rots	3	3	5	7
Stunt	4	4	4	7
Insects				
Pod borer	1-2	1-2	1-2	5
Leaf miner	9	9	9	1
Nematodes				
All combined	?	?	7?	7?

1. Rated on a scale of 1-9, where 1 = extremely important, 5 = occasionally important, and 9 = not important.

Screening Techniques

Diseases

Efficient field inoculation techniques are available to allow rapid and large-scale screening of germplasm lines and breeding materials for important chickpea diseases. These are routinely used in crop improvement programs at ICRISAT, ICARDA, and in several national programs (Nene et al. 1981; Nene and Reddy 1987). However, screening techniques are not well developed for diseases of secondary importance.

Insect Pests

Fairly suitable techniques to screen germplasm and breeding lines for resistance to pod borer (Lateef and Reed 1981 and 1985) and leaf miner (Weigand 1988) have been developed. However, there is a great need to improve these techniques because the results of screening are only reliable if repeated for three seasons.

Miniaturization of Screening Technique

A water-culture technique has been developed to screen chickpea for resistance to fusarium wilt and black root rot (*Fusarium solani* [Mart.] Appel & Wr.) (Nene et al. 1981). Using a paper-towel technique resistance to dry root rot can be identified within a week of inoculation (Nene et al. 1981). At ICRISAT, a growth room with controlled temperature, light, and humidity conditions is used for screening for ascochyta blight resistance. At ICARDA, a similar facility has been developed in a greenhouse. Using these facilities, thousands of lines can be screened in a short period.

Screening techniques for insects and other diseases also need to be miniaturized.

Rating Scale

Diseases

A 1- to 9-point scale is being used to score plant diseases (Nene et al. 1981). This scale can be used for reaction to evaluate materials in field or greenhouse.

Insect Pests

Lateef and Reed (1981 and 1985) have described a method for assessing and rating genotypes for resistance to pod borer, and Weigand (1988) has described a rating scale for leaf miner.

Sources of Resistance

Diseases

Several sources of resistance to fusarium wilt that are stable across locations are now available in chickpea germplasm (Nene and Haware 1980). These sources (e.g., ICCs 10803, 11550, 11551, 11322 and 11323) are stable and have retained their resistance under high levels of inoculum pressure. ICRISAT scientists have been able to identify combined resistance/tolerance to fusarium wilt, and to root rots caused by *R. bataticola* and *F. solani*. e.g., ICC 12237 and ICC 12269 (Nene 1988). Three kabuli lines, FLIP 82-78C, FLIP 84-43C, and FLIP 84-130C developed at ICARDA were found to have resistance to fusarium wilt when evaluated in Cordoba, Spain.

At ICARDA, several sources of resistance to ascochyta blight have been reported (Reddy and Singh 1984; Singh et al. 1984). Some of these lines (e.g., ILCs 72, 182, 187, 200, 2380, 2506, 2956, 3279, 3856, 4421, 5586, 5902, 5921, 6043, ?6090, and 6198) also have resistance in several other countries.

Insect Pests

Although high levels of resistance to pod borer have not been available, ICC 506, ICC 10619, ICC 6663, ICC 10667, ICCV 7, ICCX 730041-8-1-B, and ICCX 730020-11-1-1H-B have shown some resistance (Lateef 1985). The best source of resistance to leaf miner found at ICARDA is ILC 5901 which has a multipinnate leaf. Sources of resistance to other insects are yet to be identified.

Inheritance of Resistance

Singh et al. (1987) reviewed the literature on inheritance of resistance to fusarium wilt and found that two recessive genes, and in one case, a partially dominant gene, conditioned late wilting. The combination of any two conferred complete resistance. Singh and Reddy (1989) reviewed the literature on the genetics of resistance to ascochyta blight and reported that a single dominant or a recessive gene controls the resistance. Gowda et al. (1985) reported that additive genes confer resistance to *H. armigera*. There are indications that the inheritance of resistance to fusarium wilt and ascochyta blight is not so simple as has been reported and further study is required. The genetics of resistance to other diseases and insects needs to be investigated.

Germplasm Enhancement

Diseases

Systematic studies on races of chickpea diseases have not been made. However, races have been reported for fusarium wilt (Haware and Nene 1982) and ascochyta blight (Reddy and Kabbabeh 1985), and lines with resistance to these races have been identified. Lines, partially resistant to 6 races of *A. rabiei* have been developed at ICARDA, and likewise, success has been achieved at ICRISAT Center in identifying lines resistant to more than one race of fusarium wilt. Such lines may have a longer life span than those that only have resistance to a single race. For other diseases similar achievements are required.

Insects

So far, no race differences have been reported for pod borer and leaf miner. Most of the *Helicoverpa* resistant chickpea lines are highly susceptible to fusarium wilt and to ascochyta blight.

Combining Resistance to Diseases

ICRISAT Center has been concentrating on the development of fusarium wilt and root-rot resistant lines, while the Tunisian national program and ICARDA have worked on the development of ascochyta blight and fusarium wilt resistant cultivars. Success has been reported from all three centers.

Combining Genes for Resistance

ICRISAT is making efforts to combine genes for resistance to pod borer and fusarium wilt, and has successfully made the combination in line ICCL 86111. ICARDA has succeeded in combining genes for resistance to cold and ascochyta blight. There is a need to combine resistances to stresses, as indicated in the following examples:

- Foliar diseases (ascochyta blight and botrytis gray mold) + soilborne diseases (fusarium wilt and root rots) + stunt virus + pod borer for the Indian subcontinent.
- Ascochyta blight + fusarium wilt + other soilborne diseases + leaf miner + pod borer for the Mediterranean region.
- Soilborne diseases (fusarium wilt + root rots) and viruses for the Americas.
- Botrytis gray mold + pythium root and stem rot + pod borer for Australia.

Resistance Breeding

Ascochyta Blight

The progress made in ascochyta blight resistance breeding from the 1930s until 1984 has been summarized by Singh (1987). Since 1978, ICARDA directed most of its resources in breeding, pathology, and physiology towards the development of cold tolerance, ascochyta blight resistant, and high-yielding cultivars. Resistance sources for both stresses have been identified. High-yielding lines, combining resistance to both stresses, have been developed and furnished to cooperators in the Mediterranean region. The success of these lines is evidenced by the release of 22 cultivars in 10 countries. Ascochyta blight resistance breeding work is now being conducted throughout the Mediterranean region, eastern Europe, USSR, India, Pakistan, and the USA. Good progress has been made in many countries.

Fusarium Wilt

The Mexican National Program was the first to develop and release wilt-resistant cultivars. The Indian National Program has also released several resistant cultivars, including WR 315 and CPS 1. ICRISAT supported the efforts in breeding wilt-resistant lines. Some of these have been released, for example, ICCV 2 in India, an extra short duration kabuli, that is resistant to two races of fusarium wilt. The Tunisian National Program has developed and released Amdoun 1 as a wilt-resistant cultivar. The University of California has released two wilt-resistant cultivars: UC 15 and UC 27.

Other Diseases and Pests

At ICRISAT efforts have been made to breed for pod borer resistance. Some success has been achieved, but there has been little or no success in breeding for resistance to leaf miner, botrytis gray mold, and several other diseases. Future efforts should be directed towards the development of lines with multiple disease and insect resistance.

Need for Additional Germplasm of Cultivated and Wild Species

ICRISAT Center maintains 15 500 accessions of desi and kabuli chickpeas, and ICARDA 7250 accessions of kabuli chickpeas. There are duplications and by eliminating them the total number will come down to about 20 000. Most of these have been evaluated for resistance to ascochyta blight, but no line has been found to be highly resistant. Evaluation of the germplasm collection for resistance to other diseases, such as stunt, revealed only moderate levels of resistance. Evaluation of more than 5000 germplasm accessions to cyst nematode and seed beetle yielded no source of resistance (Singh 1989). This underlines the need for additional germplasm collection to support resistant breeding programs.

As in other crops, wild annual *Cicer* species possess a wealth of genes for resistance (Singh et al. 1989). We found higher levels of resistance to ascochyta blight, leaf miner, and cold in wild species than in the cultivated species. Resistance to cyst nematode and seed beetle were found only in wild species. The number of wild species accessions is small and needs to be enlarged by additional collection.

Application of in vitro Techniques

The use of tissue culture techniques, for instance in embryo rescue and protoplast fusion, is essential for the transfer of genes for stress resistance from wild *Cicer* species to the cultivated species. No success has been achieved so far, but systematic work is underway at several institutions, including ICRISAT Center, India; ICARDA, Syria; Indian Agricultural Research Institute, and Osmania University, India; University of Napoli, Italy; and the University of Saskatchewan, Canada. Successful crosses have been reported betweem *C. arietinum* and *C. reticulatum* (Ladizinsky and Adler 1976). Crosses between *C. arietinum* and *C. echinospermum* resulted in F_1 plants, but F_2 seeds could not be obtained. At ICARDA, F_2 seeds have been produced by F_1 plants of this cross combination.

Future Strategy

1. In order to develop a suitable global strategy for resistance breeding, there is a need to zone diseases and insect-pests according to their importance. Zoning should start with the most important diseases; ascochyta blight or fusarium wilt, and then be extended to other stress conditions.
2. Detailed genetic analysis of resistance to diseases and insect pests is important in formulating an appropriate breeding strategy.
3. Additional accessions of wild species should be collected and evaluated for resistance to different diseases and insect pests.
4. Techniques to transfer genes for resistance from wild to cultivated species should be developed.
5. Meaningful pyramiding of genes for resistance to different races of a pathogen, to different diseases, to insects, or to diseases and insects would go a long way in laying a solid foundation for crop improvement.
6. Basic research in the area of tissue culture, somaclonal variation, *Bacillus thuringiensis* (B.t.) genes for the control of *Helicoverpa* spp, restriction fragment length polymorphism (RFLP) is recommended to strengthen the resistance breeding.
7. Studies on the mechanism of resistance to diseases and insect pests are urgently needed.
8. Efforts should be directed toward developing cultivars resistant to multiple diseases and insect-pests.
9. Faster progress in all these areas requires a team approach by breeders, pathologists, entomologists, and other scientists, and this should be encouraged.

References

Gowda, C.L.L., Lateef, S.S., Smithson, J.B., and **Reed, W.** 1985. Breeding for resistance to *Heliothis armigera* in chickpea. Pages 36-39 *In* National Seminar on Breeding Crop Plants for Resistance to Pests and Diseases, 25-27 May 1983, Coimbatore, India: Coimbatore, Tamil Nadu, India: Tamil Nadu Agricultural University.

Haware, M.P., and **Nene, Y.L.** 1982. Races of *Fusarium oxysporum* f.sp. *ciceri*. Plant Disease 66:809-810.

Ladizinsky, G., and **Adler, A.** 1976. Genetic relationship among the annual species of *Cicer* L. Theoretical and Applied Genetics 48:197-203.

Lateef, S.S. 1985. Gram pod borer (*Heliothis armigera*) (Hub.) resistance in chickpeas. Agriculture, Ecosystems and Environment 14:95-102.

Lateef, S.S., and **Reed, W.** 1981. Development of a methodology for open-field screening for insect pest resistance in pigeonpea. Pages 315-322 *in* Proceedings of the International Workshop on Pigeonpeas, 15-19 Dec 1980, ICRISAT Center, India. vol. 2. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Lateef, S.S., and **Reed, W.** 1985. A suggested system of rating pigeonpea and chickpea entries for field resistance to *Heliothis armigera*. Pages 127-131 *in* National Seminar on Breeding Crop Plants for Resistance to Pests and Diseases, 25–27 May 1983, Coimbatore, India: Coimbatore, Tamil Nadu, India: Tamil Nadu Agricultural University.

Nene, Y.L. 1988. Multiple disease resistance in grain legumes. Annual Review of Phytopathology 26:203-217.

Nene, Y.L., and **Haware, M.P.** 1980. Screening chickpea for resistance to wilt. Plant Disease 64:379-380.

Nene, Y.L., Haware, M.P., and **Reddy, M.V.** 1981. Chickpea diseases: resistance-screening techniques. (Summary in Fr.) Information Bulletin no. 10. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Nene, Y.L., and **Reddy, M.V.** 1987. Chickpea diseases and their control. Pages 233-270 *in* The chickpea (Saxena, M.C., and Singh, K.B., eds.). Wallingford, Oxon, UK: CAB International.

Reddy, M.V., and **Kabbabeh, S.** 1985. Pathogenic variability in *Ascochyta rabiei* (Pass.) Lab. in Syria and Lebanon. Phytopathologia Mediterranea 24:265-266.

Reddy, M.V., and **Singh, K.B.** 1984. Evaluation of a world collection of chickpea germ plasm accessions for resistance to ascochyta blight. Plant Disease 68:900-901.

Reed, W., Cardona, C., Sithanantham, S., and **Lateef, S.S.** 1987. Chickpea insect pests and their control. Pages 283-318 *in* The chickpea (Saxena, M.C., and Singh, K.B., (eds.). Wallingford, Oxon, UK: CAB International.

Singh, H., Kumar, J., Smithson, J.B., and **Haware, M.P.** 1987. Complementation between genes for resistance to race 1 of *Fusarium*. Pages 339-342 *in* Genetics and plant pathogenesis (Day, P.R., and Jellis, G.J., eds.). Oxford, UK: Blackwell Scientific Publications.

Singh, K.B. 1987. Chickpea breeding. Pages 127-162 *in* The chickpea (Saxena, M.C., and Singh, K.B., eds.). Wallingford, Oxon, UK: CAB International.

Singh, K.B. 1989. Breeding chickpea (*Cicer arietinum* L.) for stress resistance. Presented at the 6th International Congress, Society for the Advancement of Breeding Researches in Asia and Oceania (SABRAO), 21-25 Aug 1989, Tsukuba, Japan.

Singh, K.B., and **Reddy, M.V.** 1989. Genetics of resistance to ascochyta blight in four chickpea lines. Crop Science 29:657-659.

Singh, K.B., Reddy, M.V., and **Nene, Y.L.** 1984. International testing of chickpeas for resistance to ascochyta blight. Plant Disease 68:782-784.

Singh, K.B., Weigand, S., Haware, M.P. Di Vito, M., Malhotra, R.S., Tahhan, O., Saxena, M.C. and **Holly, L.** 1989. Evaluation of wild species to biotic and abiotic stresses in chickpea. Poster abstract 14-13 presented at the XII Eucarpia Congress, 27 Feb-4 Mar 1989, Gottingen, Federal Republic of Germany. Vortrage fur Pflanzenzuchtung 15-1.

Weigand, S. (In press). Insect pests of chickpea in the Mediterranean areas and possibilities for resistance. *In* proceedings of the CIHEAM, ECC (AGRIMED), and ICARDA Conference on Present Status and Future Prospects of Chickpea Crop Production and Improvement in the Mediterranean Countries, 11-13 Jul 1988, Zaragoza, Spain (Cubero, J.I., Saxena, M.C., and Wery, J., eds.). Zaragoza, Spain: Centre International de Hautes Etudes Agronomiques Mediterraneennes.

Breeding Chickpea for Resistance to Abiotic Stresses: What are the Problems and How can We Solve Them?

H.A. van Rheenen[1], N.P. Saxena[1], K.B. Singh[2], S.C. Sethi[1], and J.A. Acosta-Gallegos[3]

Abstract

Chickpea has a number of potential abiotic stress problems that can individually or jointly cause severe yield losses and contribute to yield instability. Some problems, such as drought can be solved by cultural practices, but others, for instance high temperature, cannot. The importance, screening techniques and present status in resistance breeding of these two stress factors and of low temperature, and salinity are evaluated and further solutions to the problems are proposed.

Résumé

Sélection du pois chiche pour la résistance à des contraintes abiotiques—Quels sont les problèmes et comment faut-il les résoudre? : *Le pois chiche subit un certain nombre de problèmes potentiels dus à des contraintes abiotiques qui peuvent individuellement ou conjointement causer de graves pertes de rendement et contribuer à l'instabilité des rendements. Certains problèmes, comme la sécheresse, peuvent être résolus par des pratiques culturales, alors que d'autres, par exemple les fortes températures, ne peuvent pas l'être. L'importance, les techniques de criblage et le bilan actuel de la sélection pour la résistance à ces deux facteurs de contraintes, ainsi qu'aux faibles températures et à la salinité, sont évalués et de nouvelles solutions à ces problèmes sont proposées.*

The importance of abiotic factors having an adverse effect on chickpea, varies from place to place. In Table 1 we generalize the importance of abiotic stress factors in the major geographic chickpea production belts of the world (ICRISAT 1989, unpublished).

Some of the abiotic stress factors can, at least in principle, be taken care of by agronomic practices, but temperature extremes and rainfall and humidity are normally beyond our control.

Here we discuss the latest developments in breeding for resistance against abiotic stresses, dealing first with high and low temperatures, factors that give little scope

1. Principal Plant Breeder (Chickpea), Senior Crop Physiologist, and Plant Breeder, Legumes Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

2. Principal Chickpea Breeder (ICRISAT), Food Legume Improvement Program, International Center for Agricultural Research in the Dry Areas (ICARDA), P.O. Box 5466, Aleppo, Syria.

3. Food Legume National Expert, Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP), A.P. 20, Pabellon, AGS 20660, Mexico.

ICRISAT Conference Paper no. CP 565.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

Table 1. Abiotic stress factors ranked according to importance.

Abiotic stress factor	Zone (latitude) I (0°-20°)	II (20°-25°)	III (25°-30°)	IV[1] (30°-45°) W	S
Drought	1	1	1	-	1
High temperature	2	2	4	-	2
Low temperature	-	-	3	1	-
High moisture	-	4	5	2	-
Soil toxicities	3	3	2	-	-

1. W = Winter sown, S = Spring sown.

for alleviation by cultural practices. Then we discuss drought and soil toxicity, with particular reference to salinity.

Abiotic Stresses where Cultural Practices have little Effect

High Temperature

Although chickpea is referred to as a cool season, subtropical legume (Smithson et al. 1985; Summerfield 1988), a large proportion of its production falls outside the sub-tropics, where at least during part of the growing season the weather is often far from cool. Van der Maesen (1972) observed that optimal growth and development of chickpea took place under temperature ranges 15°-21° to 23°-29°C. Temperatures above 29°C were harmful especially during flowering and podding. He further showed mean monthly maximum and minimum temperatures for 11 locations in several major chickpea producing countries. It appeared that the maxima often exceeded 30°C. Saxena (1984) gave temperature data for Khartoum, Sudan (15° 36'N) represented by zone I in Table 1. When flowering starts, the maximum/minimum temperatures at Khartoum are 30°-33°/14°-16°C and increase progressively thereafter.

The dramatic reduction in yield, observed by Summerfield et al. (1984) when plants were exposed after flower initiation to a diurnal temperature regime of 35°-10°C as compared with that of 30°-10°C demonstrates how sensitive chickpea is to temperature increases beyond 30°C. This was confirmed by B. Baldev (personal communication), who noted that, at Delhi, a 1°C increase over the normal temperature during the podding stage caused a seed loss of 0.15 t ha^{-1}. Van Rheenen and Miranda (1986) recorded significant temperature effects on the growth and yield of *Cicer* plants grown in pots. Similarly in a field experiment, where white cotton cloth was used to cover the inter-row space, and temperatures were reduced by as much as 2.5°C at 10 cm soil depth, yield increased by 14%. Genotypic differences were noted (ICRISAT 1988 Annual Report 1987 pp. 140-141). Saxena et al. (1988a) observed that cool-season food legumes often suffer from heat and drought stress and they confirmed the need to investigate the scope for reliable heat stress tolerance screening in cool-season food legumes.

ICRISAT's Pulse Physiology Unit (Saxena and Sheldrake 1978; Saxena and Krishnamurthy 1979) compared 32 genotypes, sown at the normal (cool) time in October and during the hot months of January to March in 1977–1979 and noted significant interactions between varieties and sowing dates for Net Assimilation Rate and Relative Growth Rate. Crop growth observations during the hot off-season period from June to September 1987 at Coimbatore and Bhavanisagar, India, and from January to March 1989 at ICRISAT Center suggest there is scope for screening against hot conditions at these locations.

Temperatures in excess of the optimal are quite common in chickpea growing areas, they can adversely affect crop yield, and are responded to differentially by different genotypes. However, no effective screening technique has yet been developed and no special breeding program for heat resistance is being conducted at present. The authors support suggestions by Summerfield et al. (1984), and Baldev (unpublished report 1987) that breeding for resistance to heat is important and needs urgent attention. Screening is possible in controlled environments, and also in off-season nurseries as mentioned earlier.

Low Temperature

Optimal temperatures for the germination of chickpea range from 15° to 35°C (van der Maesen 1972). Covell et al. (1986) however found the base temperature to be 0°C. For normal sowing times in the main chickpea producing areas the prevailing temperatures are satisfactory for germination and crop establishment. Soil temperatures do not remain below the optimal minimum range of 15°-21°C for long periods. In areas of higher latitude, for instance in the Indian states of

Haryana and Punjab, the temperatures decrease after sowing to minima below 5°C, causing flower abortion (Saxena 1980); abortion does not occur when temperatures rise later. In 1980/81 at ICRISAT Cooperative Research Station at Hisar a few plants were detected in F_3 segregating populations of the crosses G 130 x (K 1189 x Chaffa) and Pant G-115 x (K 1189 x Chaffa), that showed pod formation at low temperatures and were thus chilling resistant (Buddenhagen and Richards 1988). By further breeding and selection it is expected to obtain a plant type that, under northern Indian and similar conditions, not only is able to form pods at low temperature, but will also mature before foliar diseases and pod borers cause major problems. The plants will grow less prolifically and therefore will not lodge as normal types often do under good growing conditions (Saxena et al. 1988b).

In West Asia and the Mediterranean region chickpeas are traditionally grown as a summer crop. However, insufficient water often results in poor yields. Winter-sown crops face two major problems, namely ascochyta blight disease and temperatures below 0°C, but water availability favors winter-sown rather than spring-sown chickpeas. The first attempt to screen chickpea germplasm for resistance to temperatures below 0°C, called freezing resistance by Buddenhagen and Richards (1988), was made by ICARDA during the 1978/79 season in Syria and Lebanon, where 3000 lines were grown, but failed to show the desired differences (Singh et al. 1984). A second effort, to evaluate over 3000 lines in cooperation with the Turkish National Program at Hymana during 1979/80, was successful in that some freezing resistant entries could be selected (Singh et al. 1981). The third attempt was more successful because of improvements in the screening technique. The sowing date had been advanced to October to enable the crop to grow into the late vegetative stage before the onset of the severe winter; susceptible controls were grown at frequent intervals and only after they had died was the resistance scored on a 1-9 scale. Using this technique 3276 germplasm accessions and breeding lines were screened and 21 were identified as freezing resistant. Inheritance studies showed that the resistance character was dominant, and that it was controlled by at least five genes with both additive and non-additive effects and high heritability estimates. In the breeding program segregating populations and progenies are sown in early November, in advance of the recommended December sowing, and plants or lines that suffer cold injury are rejected. This procedure has resulted in the selection and release of freezing resistant cultivars for the Mediterranean region (Singh et al. 1989).

Abiotic Stresses where Cultural Practices can be Effective

Drought

The major abiotic stress factor of chickpea worldwide is drought (Table 1). Although irrigation can alleviate drought stress, and under conditions of lower latitudes can double yields (Saxena 1987b), irrigation water is often not available. Two breeding approaches can reduce the problem of drought. One has been to breed for short-duration varieties that can escape the problem; the other to breed and select genuinely drought-resistant plants. A good example of the short-duration approach is the development of the kabuli cultivar ICCV 2 (Kumar et al. 1985). Further breeding work has resulted in the development of similar desi lines such as ICCV 88201 and ICCV 88202.

The screening technique followed is simple. The plants that flower earliest, for instance in 28-30 days at ICRISAT Center, are tagged, and their progenies are further tested.

For drought–resistance breeding a scheme is followed that is called Diversified Bulk Population Breeding after van Rheenen and Muigai (1984). It was started at ICRISAT Center in 1985/86, the parents used for the first crosses being Annigeri (adapted), ICC 4958 = GW 5/7 (drought resistant), and ICC 12237 (wilt and root rot resistant) (ICRISAT 1986). ICC 4958 was identified as drought resistant in 1984/85 (Saxena 1987b). The program is in progress and the F_5 populations are planned to be grown in 1989/90.

The drought resistance breeding referred to here deals mainly with terminal drought. Earlier work was initiated to identify genotypes capable of germinating under low moisture conditions (Saxena 1987b), but field validation was not possible because of persistent rains. Facilities are now available for field validation during 1989/90.

Soil Toxicity - Salinity

Reclamation of saline land is possible but costly. Legumes in general and chickpea and lentil in particular are sensitive to salinity (Chandra 1980).

Although genotypic differences in salinity resistance have been observed in chickpea (Chandra 1980), the extent and use of these differences have been and are still being disputed. Saxena (1987a) proposed the screening of large numbers of genotypes for salinity resistance, and described field and greenhouse methods for this purpose. However, Johansen (1987) suggested that mechanistic differences be identified as both the cultivated chickpea and its wild relatives show a limited range of variation for salt resistance. In several crop species salt resistance has been used successfully in improvement programs, and efforts for further improvement are continuing. Blum (1988) gives examples of salt resistance in tomato, pearl millet, barley, and other crops.

Chickpeas are affected by salinity levels of 3 mmhos cm^{-1}, and total yield losses occur at EC values ≥ 5 mmhos cm^{-1}.

No salinity resistance breeding program for chickpea is being conducted at present, and it was also not considered to be of high priority (Frey unpublished report 1988). Only some large-scale screening of γ-irradiated material is being done at Hisar in fields affected by salinity. We are interested in the use of tissue culture methods, where cell suspensions in salt solutions are used to select salt-resistant cells for the production of calli and the regeneration of plants that show salinity resistance (van Rheenen et al. 1988; Tissue Culture for Crops Project 1987).

Discussion

Chickpea is sensitive to a number of abiotic stress factors that cause severe yield losses, and contribute to yield instability. We expect that high temperature often in association with drought plays a key role in major chickpea production areas. Salinity areas are usually avoided for chickpea production; and low temperatures, in the present agricultural systems, likely pose no major problem to stability and high yield. However, where winter sowing is adopted in the Mediterranean region, freezing resistance is most important.

It is likely that biotic and abiotic factors, rather than yield potential, have caused low yield and production records for chickpea. Deliberate breeding for resistance is recommended but simple and reliable techniques need to be developed or perfected for resistance screening for high temperature and drought, possibly by using environments, where these stresses occur naturally. The techniques currently available for low temperature resistance screening seem to be adequate. Major contributions to chickpea improvement would result from the development of stress-resistant varieties.

References

Blum, A. 1988. Plant breeding for stress environments. Boca Raton, Florida, USA: CRC Press.

Buddenhagen, I.W., and **Richards, R.A.** 1988. Breeding cool season food legumes for improved performance in stress environments. Pages 81-96 *in* World crops: cool season food legumes: proceedings of the International Food Legume Research Conference on Pea, Lentil, Faba Bean, and Chickpea, 6-11 Jul 1986, Spokane, Washington, USA (Summerfield, R.J., ed.). Dordrecht, Netherlands: Kluwer Academic Publishers.

Chandra, S. 1980. Effect of edaphic factors on chickpea. Pages 97-105 *in* Proceedings of the International Workshop on Chickpea Improvement, 28 Feb-2 Mar 1979, Hyderabad, India: Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Covell, S., Ellis, R.H., Roberts, E.H., and **Summerfield, R.J.** 1986. The influence of temperature on seed germination rate in grain legumes I. A comparison of chickpea, lentil, soybean and cowpea at constant temperatures. Journal of Experimental Botany 37:705-715.

ICARDA (International Center for Agricultural Research in the Dry Areas). 1988. Page 114 *in* Annual report 1987. Aleppo, Syria: ICARDA.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1986. Introduction. Pages 1-9 *in* Genetic improvement of drought resistance: Proceedings of a Discussion Series of the Drought Research Seminar Forum held during 1985/86. Patancheru, A.P. 502 324, India: ICRISAT. (Limited distribution.)

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1988. Pages 140-141 *in* Annual report 1987. Patancheru, A.P. 502 324, India: ICRISAT.

Johansen, C. 1987. Mechanisms of salt tolerance and their relevance. Pages 109-113 *in* Adaptation of chickpea and pigeonpea to abiotic stresses: proceedings of the Consultants' Workshop, 19-21 Dec 1984, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Kumar, J., Haware, M.P., and Smithson, J.B. 1985. Registration of four short duration fusarium wilt-resistant kabuli (garbanzo) chickpea germplams. Crop Science 25:576-577.

Saxena, M.C., Saxena, N.P., and Mohamed, A.K. 1988a. High temperature stress. Pages 845-856 *in* World crops: cool season food legumes: proceedings of the International Food Legume Research Conference on Pea, Lentil, Faba Bean and Chickpea, 6-11 Jul 1986, Spokane, Washington, USA (Summerfield, R.J., ed.). Dordrecht, Netherlands: Kluwer Academic Publishers.

Saxena, N.P. 1980. Pod setting in relation to temperature at Hisar. International Chickpea Newsletter 2:11-12.

Saxena, N.P. 1987a. Problems and prospects to screen and breed for tolerance to soil salinity: a case study with chickpea. Pages 115-120 *in* Adaptation of chickpea and pigeonpea to abiotic stresses: proceedings of the Consultants' Workshop, 19-21 Dec 1984, ICRISAT Center, India: Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Saxena, N.P. 1987b. Screening for adaptation to drought: case studies with chickpea and pigeonpea. Pages 63-76 *in* Adaptation of chickpea and pigeonpea to abiotic stresses: proceedings of the Consultants' Workshop, 19-21 Dec 1984, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Saxena, N.P., Johansen, C., Sethi, S.C., Talwar, H.S., and Krishnamurthy, L. 1988b. Improving harvest index in chickpea through incorporation of cold tolerance. International Chickpea Newsletter 19:17-19.

Saxena, N.P., and Krishnamurthy, L. 1979. Pulse physiology progress report 5, 1978-79. Part II. Chickpea physiology. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics. (Limited distribution.)

Saxena, N.P., and Sheldrake, A.R. 1978. Pulse physiology progress report 3, 1977-78. Part II. Chickpea physiology. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics. (Limited distribution.)

Singh, K.B., Malhotra, R.S., and Saxena, M.C. 1989. Chickpea evaluation for cold tolerance under field conditions. Crop Science 29:282-285.

Singh, K.B., Meyoeci, K., Izgin, N., and Tuwafe, S. 1981. Screening kabuli chickpea for cold tolerance. International Chickpea Newsletter 4:11-12.

Singh, K.B., Saxena, M.C., and Gridley, H.E. 1984. Screening chickpeas for cold tolerance and frost resistance. Pages 167-177 *in* Ascochyta blight and winter sowing of chickpeas: proceedings of the Workshop, 4-7 May 1981, Aleppo, Syria (Saxena, M.C., and Singh, K.B., eds.). World Crops: Production, Utilization and Description vol. 9. The Hague, Netherlands: Martinus Nijhoff/W. Junk.

Smithson, J.B., Thompson, J.A., and Summerfield, R.J. 1985. Chickpea (*Cicer arietinum* L.). Pages 312-390 *in* Grain legume crops (Summerfield, R.J., and Roberts, E.H., eds.). London, UK: Collins.

Summerfield, R.J., (e.d.). 1988. World crops: cool season food legumes proceedings of the International Food Legume Research Conference on Pea, Lentil, Faba Bean and Chickpea, 6-11 Jul 1986, Spokane, Washington, USA. Dordrecht, Netherlands: Kluwer Academic Publishers.

Summerfield, R.J., Hadley, P., Roberts, E.H., Minchin, F.R., and Rawsthorne, S. 1984. Sensitivity of chickpeas (*Cicer arietinum*) to hot temperatures during the reproductive period. Experimental Agriculture 20:77-93.

TCCP (Tissue Culture for Crops Project). 1987. Progress report 1987. Fort Collins, Colorado, USA: Colorado State University. 87 pp.

van der Maesen, L.J.G. 1972. *Cicer* L., a monograph of the genus, with special reference to the chickpea (*Cicer arietinum* L.), its ecology and cultivation. Wageningen, Netherlands: Veenman and Zonen N.V.

van Rheenen, H.A., Bond, D.A., Erskine, W., and Sharma, B. 1988. Future breeding strategies for pea, lentil, faba bean and chickpea. Pages 1013-1029 *in* World crops: cool season food legumes proceedings of the International Food Legume Research Conference on Pea, Lentil, Faba Bean and Chickpea, 6-11 Jul 1986, Spokane, Washington, USA (Summerfield, R.J., ed.). Dordrecht, Netherlands: Kluwer Academic Publishers.

van Rheenen, H.A., and Miranda, J.H. 1986. Improving the growth of *Cicer* plants in pots. Pulse Crops Newsletter 6:37-40.

van Rheenen, H.A., and Muigai, S.G.S. 1984. Improvement of field beans by diversified bulk population breeding. Annual Report of the Bean Improvement Cooperative 27:129-130.

Breeding Chickpea for New Applications

K.B. Singh[1], N.P. Saxena[2], Onkar Singh[2], F. Saccardo[3], N. Acikgoz[4], and E.J. Knights[5]

Abstract

*World chickpea (*Cicer arietinum *L.) production has increased only marginally in the past 30 years. The main reason is inadequate support for research on this crop. There is evidence that application of recent research findings could result in substantially increased global chickpea production. Adoption of winter chickpea technology, as developed and demonstrated at ICARDA, alone can increase chickpea production in the Mediterranean region. Likewise, an advance in sowing dates in the southern latitude regions of India and Ethiopia is expected to produce significantly higher yields compared to traditional chickpea cropping.*

Fallow replacement by chickpea in the fallow–cereal rotation of Turkey's Anatolian Plateau has resulted in a several-fold increase in production. Similar fallow replacement by chickpea in Afghanistan, Iran, Iraq, and Syria, has great potential. Chickpea can be introduced into new areas and expand rapidly as has been demonstrated in Australia.

Possibilities are being explored to develop genotypes that would flower and set pods at low temperature and mature during early March in latitudes between 25° and 30°N, and thereby prevent losses due to foliar diseases which periodically devastate the crop. The extra-short duration genotypes developed at ICRISAT have shown promise in late sowing following rice, cotton, and coarse cereals. The feasibility of developing chickpea genotypes for high-input agriculture, and as cattle feed has been discussed, as well as the possibility for full-scale mechanization of operations.

Résumé

Sélection du pois chiche pour de nouvelles applications : *Dans les trente dernières années, la production mondiale du pois chiche (*Cicer arietinum *L.) n'a augmentée que très légèrement. La raison principale en est l'insuffisance de soutien en matière de recherche sur cette culture. On a constaté que l'application des résultats de recherche récents pourrait amener une augmentation considérable de la production globale du pois chiche. L'adoption de la technologie de l'hiver pour le pois chiche, mise au point et démontrée à l'ICARDA, pourrait à elle seule améliorer la production dans la région méditerranéenne. De même l'avancement des dates de semis dans les régions de latitude Sud de l'Inde et de l'Ethiopie devrait produire des rendements considérablement élevés par rapport à la culture traditionnelle de pois chiche.*

1. Principal Chickpea Breeder (ICRISAT), Food Legume Improvement Program, International Center for Agricultural Research in the Dry Areas (ICARDA), P.O. Box 5466, Aleppo, Syria.
2. Senior Crop Physiologist, and Plant Breeder, Legumes Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.
3. Instituto di Agronomia e Coltivazioni Erbacee, Cattedra di Miglioramento, Genetico delle Piante Agrarie, via Universita 100, 80055, Portici (NA), Italy.
4. Aegeon Agricultural Research Institute, Menemen, Izmir, Turkey.
5. Chickpea Breeder, New South Wales Department of Agriculture and Fisheries, Agricultural Research Centre, RMB 944, Tamworth, NSW 2340, Australia.

ICRISAT Conference Paper no. CP 566.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

Le remplacement de la jachère par le pois chiche dans le cadre de la rotation jachère-céréale pratiquée sur le Plateau d'Anatolie de la Turquie a rendu possible une augmentation multiple de la production. Un tel remplacement de la jachère par le pois chiche peut se révéler très prometteur en Afghanistan, en Iran, en Irak, et en Syrie. Le pois chiche peut aussi être introduit dans de nouvelles régions et se répandre rapidement comme il a été démontré en Australie.

On étudie les possibilités en vue de mettre au point des génotypes qui atteindraient la floraison et la formation des gousses à des températures basses, et la maturation pendant début mars, à des latitudes entre 25° et 30° N. Cela permettrait d'éviter les pertes dues aux maladies foliaires qui causent les dégâts périodiquement sur les cultures. Les génotypes à cycle très court mis au point à l'ICRISAT se sont révélés prometteurs en semis tardif suivant le riz, le coton, et les céréales secondaires. La possibilité de réaliser des génotypes de pois chiche pour l'agriculture à niveau élevé d'intrants et pour l'utilisation comme aliments de bétail, ainsi que la possibilité de la mécanisation complète des opérations, sont examinées.

Chickpea (*Cicer arietinum* L.) ranks third in world production among pulses, fifth among food legumes, and fifteenth among grain crops. It is the most drought-tolerant cool-season legume, and hence fits well into many farming systems. Chickpea production has increased, but only marginally, in the last three decades, and its per caput availability has decreased, primarily due to the lack of adequate research. The research efforts have not yet resulted in the development of input-responsive cultivars for mechanized cultivation, cultivars with stable yields in the existing systems of production, and types that fit into new, non-traditional systems of cropping. If the crop is to remain as an important food legume, our research efforts need to be substantially increased for both traditional and new cropping systems. Some important applications are discussed in this paper.

Winter Sowing of Chickpea for the Mediterranean Region

Chickpea is grown as a springsown crop in the Mediterranean region, where other cool-season edible legumes, such as faba bean (*Vicia faba* L.), lentil (*Lens culinaris* L.) and pea (*Pisum sativum* L.), are grown as wintersown crops. Research at ICARDA has shown that chickpea can be successfully grown as a wintersown crop, provided ascochyta blight resistant and cold tolerant genotypes are made available (Singh and Hawtin 1979). Prospects for and constraints to winter sowing of chickpea in the Mediterranean region were discussed in depth at a workshop in 1981 (Saxena and Singh 1984). The historical development of wintersown chickpea at ICARDA (Singh and Malhotra 1984) and the present status (Singh 1988) are well documented.

Varieties with promise in adaptation to winter sowing have been developed at ICARDA and supplied to the national agricultural research systems through an international testing program. The yield advantage of wintersown over springsown chickpea has been demonstrated in all countries of the Mediterranean basin, from North Africa through West Asia to Southern Europe. This resulted in the release of 22 cultivars in 10 countries: Algeria, Cyprus, France, Italy, Morocco, Portugal, Spain, Syria, Tunisia, and Turkey.

Some major advantages of wintersown chickpea are:

1. Yield is 50-100% higher than that from spring sowings.
2. Greater water use efficiency enables the crop to be grown in drier areas.
3. Biological nitrogen fixation is more than double that of springsown chickpea.
4. Fusarium wilt is not a serious constraint.
5. Production can be fully mechanized.

Despite these advantages the adoption rate is slow because: extension programs are weak, seed and herbicides are not available, cultural operations i.e., sowing and harvesting overlaps with cereal crops, and because of other socioeconomic implications.

ICARDA economists estimate that the net profit from winter sowings exceeds spring sowings by 50%. A conservative estimate is that farm yields will be increased by 0.5 t ha^{-1} if winter sowing is adopted, this could result in 500 000 t of additional annual production in the Mediterranean region. The yield increase obtained by advancing the sowing date from spring to winter is a major breakthrough resulting from food legumes research in the Mediterranean region.

Breeding Chickpea for Adaptation to Early Sowing in Peninsular India

Chickpea seed yield is directly proportional to the length of the crop's duration. Possibilities of increasing the crop duration, and thus the seed yield by advancing its sowing date from mid-October to mid-September, have been explored at ICRISAT Center (IC).

Screening of germplasm and breeding lines for adaptation to early sowing showed that several genotypes of medium maturity, notably P 1329, P 1067-1, P 18 and P 4089-1, consistently out-yielded the control cultivar Annigeri at IC when sown in September (Singh et al. 1983). The average yield from September sowings was 25% more than for October sowings over 5 years. The interaction of sowing dates x genotypes was significant in 3 of these years. The best breeding lines developed from crosses involving adapted parents produced 38% more yield than a control cultivar in 1986/87 and 31% more in 1987/88, suggesting that breeding for adaptation to early sowing was effective. The experience at IC shows that although the early sowing results in better crop establishment, the crop runs the risk of water logging and damage by collar rot, and colletotrichum blight in the seedling stages. It also has to endure slightly higher temperatures. Hence, there is a need to incorporate resistance/tolerance to such stresses in adapted genotypes, and to explore the possibility of further increasing yield through agronomic manipulations.

Development of Chickpea as a Fallow Replacement on the Anatolian Plateau in Turkey

Nearly 40% of the total cultivated area in Turkey can be characterized as semi-arid. Sixty per cent of it falls in central Anatolia, and the rest lies in southeastern Anatolia, the North and West regions, where the elevation is 1000 m or more. Until the mid-1970s, the traditional farming practice in these regions was a fallow–cereal rotation that helps to conserve soil moisture.

The first experiment of replacing fallow with food legumes in the fallow–cereal rotation was conducted in the provinces of Corum and Cankiri. Results indicated that chickpea and lentil can be considered as fallow replacements in southeastern Anatolia, and chickpea, green lentil, and vetch in the rest of the fallow lands. Implementation of the first part of the 'Fallow Land Limitation Project' resulted in the replacement of 2 500 000 ha of fallow by cereals and legumes, that included 136 000 ha of chickpea. In the second part of the project (1989-93), nearly 250 000 ha of fallow land is expected to be sown to chickpea.

Chickpea grown as a springsown crop suffers from two major problems: (1) damage from *Ascochyta rabiei*; and, (2) terminal drought and heat stress. Therefore, efforts are underway to breed genotypes with resistance to ascochyta blight and early maturity. The drought problem is being tackled by introducing wintersown chickpea.

Conditions similar to those of Turkey are found in Afghanistan, Iran, Iraq, and Syria and fallow replacement by chickpea has great scope here.

Introducing Chickpea to the Farming System of Australia

One of the most notable features of Australian agriculture during the last two decades has been the introduction of a range of new, mostly non-cereal crops. This diversification, initially in response to wheat marketing difficulties, has been sustained by problems of soil nitrogen decline and cereal diseases. Chickpea has been one of the more recent of these 'new crops.'

Commercial production of chickpea commenced in 1979 and was based on the Indian desi cultivar C 235. The first major breeding advance was its replacement by a taller and more lodging-resistant, crossbred cultivar, that was adapted to mechanical harvesting. The cultivar fitted in two distinct farming systems: mixed winter/summer cropping in the summer dominant rainfall regions of Queensland and northern New South Wales, and winter cropping/pasture ley rotations in the Mediterranean-type environments of southern New South Wales, Victoria, and South Australia. In both systems chickpea is strictly a winter crop, sown from May to July and harvested from late October to January, depending on latitude and season. Although the cultivation is too young to have established rotations, some are now emerging as more reliable and profitable than others. A fundamental requirement of all rotations, however, is the effective control of grass weeds and volunteer cereals. This maximizes the suppression of cereal diseases. In summer-dominant rainfall areas, chickpea often follows a summer cereal, usually sorghum.

The development of a significant chickpea industry (70 000 ha in 1988) has revealed deficiencies in the imported cultivars, particularly in the more important northern areas. Susceptibility to phytophthora root rot has been the most notable problem. Current chickpea cultivars are also highly susceptible to the root lesion nematode (*Pratylenchus thornei*), a major wheat pathogen in some districts. A third problem encountered in the northern areas is susceptibility to *Helicoverpa*. A general requirement is for tolerance to herbicides, both residual and applied. Therefore, to sustain and expand the chickpea industry in Australia more efforts are needed to breed disease, insect, and herbicide resistant cultivars.

Breeding Extra-short Duration Chickpeas as Catch Crops

Extra-short duration desi (ICCV 88201, ICCV 88202) and kabuli cultivars (ICCV 2) which mature in about 75-80 days have been developed at IC. Preliminary reports from tests in India, Myanmar, Nepal, and Bangladesh indicate that these genotypes may escape terminal drought and heat stress. Such genotypes may be suitable for rotation with rice and other summer crops and thus have potential as catch crops in various situations and cropping systems.

Development of Chickpea Suited for Late Sowing

Good potential exists for introducing chickpea into new areas and cropping systems, particularly in rotation with cotton, maize, and several coarse cereals in the northern latitudes of the Indian subcontinent. The present-day cultivars, developed for sowing at the normal time, are poorly adapted to late sowing. Many research centers in this region, especially in India, have made progress in identifying genotypes adapted to late sowing. At the ICRISAT Cooperative Research Center, Hisar, a number of germplasm lines has been screened for adaptation to late sowing. Several genotypes have produced consistently better yields under latesown conditions. These genotypes have been crossed with sources of resistance to ascochyta blight, botrytis gray mold, stunt, and fusarium wilt to improve their disease resistance. These lines are currently under evaluation in All India Coordinated Trials (ICRISAT 1986, 1988).

Development of Chickpea Cultivars to Escape Foliar Disease

In India and Pakistan 4.31 x 10^6 ha between the latitudes 25°N and 30°N are sown to chickpea. Climatic conditions during spring in the region favor the development of such foliar diseases, as ascochyta blight and botrytis gray mold, that can cause total crop failure (Aslam 1984). Conventional cultivars grown in the region pass through a period of ineffective flowering during the cool winter months (Saxena and Sheldrake 1980). Pod setting begins with the onset of spring and an associated rise in minimum temperature (Saxena 1980) thus coinciding with the period of potential disease incidence, sometimes even in epidemic form. Genotypes have now been identified at ICRISAT that set pods in the cool winter months and mature in early spring (Saxena et al. 1989). Since their performance has been inconsistent and is influenced by weather conditions, it is necessary to further evaluate their merit in foliar disease management.

Development of Chickpea Responsive to Inputs

Studies at ICRISAT have shown that phosphorus (P) inefficient genotypes, bordering on genetic cripples, respond to P application, but their yields at the highest levels of such application do not exceed the yield of non-responsive cultivars grown without P fertilizer (Saxena et al. 1988). Studies at ICARDA, in collaboration with the University of Hohenheim, Federal Republic of Germany, indicated genotypic differences in P utilization. Continuing research has been designed to select plants from segregating populations that are both efficient in P uptake and high yielding. These populations have been developed from crosses between lines efficient in P uptake, but low yielding, and lines inefficient in P uptake, but high yielding.

In the relatively warm winter season of south Asia and the Nile Valley, and in the spring in West Asia irrigation can produce large increases in yield. However, due to lodging or differential genotypic response, application of water does not always result in substantial increases in yield. Scientists at IC have identified lodging resistant lines and at ICARDA lines have been identified that are highly responsive to irrigation. Studies have been planned on the genetics of response to irrigation, a characteristic that has not previously been investigated. There are also plans to develop irrigation-responsive, high-yielding, non-lodging genotypes through hybridization.

Development of Chickpea as a Cattle Feed

One of the major uses of chickpea before World War II was as cattle feed. Chickpea was considered a good muscle builder in horses and draft cattle, and for milk production in cows and buffaloes. The use of chickpea as a cattle feed has dwindled, mainly because it costs more than cereals. In most developing countries where chickpea is grown, emphasis is on the production of cereals to feed the human population rather than on production of legumes to support livestock and milk production industries. Mexico is an exception. Here desi chickpeas, called *garbanzo porquero*, are produced to feed pigs.

It is uncertain whether chickpea will regain its position as a major cattle feed on the Indian subcontinent because of its high price, but the prospects seem good in Mediterranean Europe and Turkey. Chickpea, with 20% protein, 6.5% lipids, 4.3% raw fiber, and 50% starch, can be a partial substitute for soybean meal in livestock feed. Before chickpea is accepted as a cattle feed in these areas, more research will be required. First, trials need to determine whether both desi and kabuli types can be used as a cattle feed. Second, experiments comparing the nutritive value of chickpea with that of other commonly used legumes such as soybean, faba bean, pea, and lupins are required. Third, cultivars and a package of practices specifically for chickpea production as a cattle feed have to be developed. Therefore, it is advocated that more research in this field be conducted.

Mechanization of Operations

In most parts of the world, operations such as sowing, weeding, harvesting, and threshing are performed manually. Rising labour costs, especially in the Mediterranean region and Latin America, have forced resourceful farmers with no family labor to replace chickpea with crops suitable for mechanization. At ICARDA, research on the mechanization of chickpea production has been initiated. Springsown chickpea generally attains a height of 25-35 cm which is too low for machine harvesting. By bringing forward the sowing date from spring to winter, the height of the plant has been increased to 40-60 cm. Research is in progress to develop tall genotypes 40-50 cm high for spring sowing. It has been possible to modify a wheat combine harvester to harvest wintersown chickpea in Syria. This technology has already been adopted by some farmers. Suitable herbicides have been identified that can be mechanically sprayed to control weeds. A corn planter has been used successfully to sow large areas of chickpea. A wheat planter with modification in aperture opening and adjustment in row spacing has been demonstrated to farmers in Syria. There is a need to popularize these findings.

References

Aslam, M. 1984. A review of research studies on chickpea blight fungus in Pakistan. Pages 237-245 *in* Ascochyta blight and winter sowing of chickpeas: Proceedings of the Workshop, 4-7 May 1981, Aleppo, Syria (Saxena, M.C., and Singh, K.B., eds.). The Hague, Netherlands: Martinus Nijhoff/W. Junk.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1986. Annual report 1985. Patancheru, A.P. 502 324, India: ICRISAT.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1988. Annual report 1987. Patancheru, A.P. 502 324, India: ICRISAT.

Saxena, M.C., and **Singh, K.B.** (eds.). 1984. Ascochyta blight and winter sowing of chickpeas: proceedings of the Workshop, 4-7 May 1981, Aleppo, Syria. World Crops: Production, Utilization, Description vol. 9. The Hague, Netherlands: Martinus Nijhoff/W. Junk.

Saxena, N.P. 1980. Pod setting in relation to temperature at Hissar. International Chickpea Newsletter 2:11-12.

Saxena, N.P., Johansen, C., Sethi, S.C., Talwar, H.S., and **Krishnamurthy, L.** 1989. Improving harvest index in chickpea through incorporation of cold tolerance. International Chickpea Newsletter 19:17-19.

Saxena, N.P., Krishnamurthy, L., and **Sheldrake, A.R.** 1988. Responses of chickpea to phosphorus application on a Vertisol in a semi-arid environment. Phosphorus in Indian Vertisols: summary proceedings of a Workshop, 23-26 Aug 1988, ICRISAT Center, India: Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Saxena, N.P., and **Sheldrake, A.R.** 1980. Physiology of growth, development, and yield of chickpeas in India. Pages 106-120 *in* Proceedings of the International Workshop on Chickpea Improvement, 28 Feb-2 Mar 1979, ICRISAT, Hyderabad, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Singh, K.B. (In press). Winter chickpea: problems and potentials in the Mediterranean region. *In* proceedings of the CIHEAM, ECC (AGRIMED), and ICARDA Conference on Present Status and Future Prospects of Chickpea Crop Production and Improvement in the Mediterranean Countries, 11-13 Jul 1988, Zaragoza, Spain (Cubero, J.I., Saxena, M.C., and Wery, J., eds.). Zaragoza, Spain: Centre International de Hautes Etudes Agronomiques Mediterraneennes.

Singh, K.B., and **Hawtin, G.C.** 1979. Winter planting of chickpea. International Chickpea Newsletter 1:4.

Singh, K.B., and **Malhotra, R.S.** 1984. Exploitation of chickpea genetic resources. Pages 123-130 *in* Genetic resources and their exploitation–chickpeas, faba beans, and lentils (Witcombe, J.R., and Erskine, W., eds.). The Hague, Netherlands: Martinus Nijhoff/W. Junk.

Singh, O., Smithson, J.B., and **Gowda, C.L.L.** 1983. P-1329 – a superior chickpea cultivar adapted to early sowing in peninsular India. International Chickpea Newsletter 9:8-9.

Progress in Breeding Chickpeas in Arid Regions of the USSR

K. Eshmirzaev[1]

Abstract

Chickpea, a drought resistant and high protein crop, has been known in Middle Asia since ancient times.

Many foods prepared in Uzbekistan have chickpea grain as a component. Under dryland conditions where cultivation of other legumes is limited, chickpea is a valuable crop after fallow.

Observations over many years have shown that simultaneous emasculation and pollination increased the pod setting percentage, and pollination without emasculation was more effective compared with pollination after emasculation. Also, chickpea pollen had a relatively long viability when stored at relative humidity between 20 and 40%.

Studies in segregating generations showed that seed yield was positively correlated with number of pods and seeds per plant and seed size, and negatively correlated with plant height.

Several local varieties have been developed by mass selection. These varieties are variable in form, color, and size of the seed, and are of short stature. At Uzbek Grain Research Institute stature high-yielding varieties have been developed and released. They include Azerbaijansky 583, Milutinsky 4, Milutinsky 6, and Uzbekistansky 8. The last of these is high yielding and tall. In 1982 a new variety, Yulduz, was developed for Uzbekistan. It yields 1.2-1.5 t ha^{-1}, is 53-58 cm tall, and matures in 85-94 days. It also has a high protein content (31.6%). However, it is not resistant to ascochyta blight.

A new variety, Zornukhat, has been developed and is undergoing state varietal testing. This variety produces high yields (2–2.7 t ha^{-1}) under dryland and irrigated conditions.

Résumé

Progrès de la sélection du pois chiche dans les régions arides de l'URSS : *Le pois chiche, culture résistante à la sécheresse et à haute teneur en protéines, est connu en Moyenne-Asie depuis l'antiquité.*

Bien des aliments préparés en Uzbekistan comportent les grains de pois chiche comme élément. Dans les conditions pluviales où la culture des autres légumineuses est restreinte, le pois chiche est une culture de valeur après la jachère.

Des observations faites pendant de nombreuses années ont montré que l'opération simultanée de la castration et de la pollinisation augmente le pourcentage de formation des gousses, alors que la pollinisation sans la castration était plus efficace que la pollinisation après la castration. Par ailleurs, le pollen du pois chiche manifestait une viabilité relativement longue lorsqu'il était conservé à une humidité relative entre 20 et 40%.

Les études de générations ségrégantes montrent que le rendement en graines présentait une corrélation positive avec le nombre de gousses et de graines par plante et les dimensions des graines, mais une corrélation négative avec la hauteur de la plante.

---

1. Director, Research Institute of Grains and Pulses, Samarkand, Republic of Uzbekistan, USSR.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

Plusieurs variétés locales ont été développées par la sélection massale. Ces variétés sont courtes et sont variables en forme, en couleur et en dimensions de graines. A l'Institut d'Uzbek de recherches sur les grains, les variétés à haut rendement ont été développées et vulgarisées. Elles comprennent : Azerbaijansky 583, Milutinsky 4, Milutinsky 6 et Uzbekistansky 8. La dernière est une variété grande et à haut rendement. En 1982, une nouvelle variété, Yulduz, a été mise au point pour l'Uzbekistan. Elle donne un rendement de 1,2 à 1,5 t ha^{-1}; sa hauteur est de 53 à 58 cm, et elle parvient à maturité en 85 à 94 jours. Elle a aussi une forte teneur en protéines (31,6%). Toutefois, elle n'est pas résistante à la flétrissure ascochytique.

Une nouvelle variété, Zornukhat, a été mise au point et subit des essais variétaux d'état. Cette variété présente des rendements élevés (2 à 2,7 t ha^{-1}) dans des conditions pluviales et irriguées.

Chickpea is a drought-resistant and protein-rich crop, that has been known in the East including Middle Asia, since ancient times. Many foods prepared in the Middle East (including Uzbekistan) have chickpea grain as a component. Furthermore, under the dryland conditions of Middle Asia, where cultivation of other legumes is limited by high temperatures and drought, chickpea is a valuable crop grown after fallow.

Because statistics on chickpea area and production are incorporated with those of other legumes, there are no exact data available for this crop alone.

Since ancient times, several valuable local varieties of chickpea have been developed through mass selection in the Middle Asian Republics of Kazakhstan, Uzbekistan, Tadzhikistan, Turkmenia, and the Transcaucasian republics of Georgia, Armenia, and Azerbaidjan. These varieties are variable in seed form, color, and size, and other economic traits, but are short and adapted only to manual harvesting.

Early breeding programs carried out at the Uzbek Grain Research Institute, have resulted in the development of high-performing varieties, predominantly of relatively short stature. They are Azerbaijansky 583, Milutinsky 4 and Milutinsky 6. Over 3000 germplasm samples from the Vavilov Institute's collection in Leningrad were used as initial material. The research has shown that the most promising accessions suitable to the dryland conditions of Uzbekistan belong to the Iraqi, Spanish, Afghan, and South European ecological groups.

Flowering of chickpea in Uzbekistan coincides with the onset of low-moisture conditions in soil and atmosphere that limit the total flowering duration. Therefore, it was necessary to develop crossing techniques to make the maximum number of crosses in the relatively short flowering period.

To increase the pod-setting percentage in crosses among different ecological groups the following factors were studied; the time, emasculation and pollination methods, and storage life of the pollen.

Observations over many years have shown that high efficiency of crossing and seed setting is achieved when emasculation and pollination are carried out simultaneously. Moreover, seed setting percentage may increase (up to 52%) when the flowers are pollinated without emasculation.

Studies were conducted to determine the most appropriate time and methods for storage of chickpea pollen and its germination to prolong the crossing period. These factors are important especially when flowering in different parents does not coincide.

Chickpea pollen was found to have relatively long viability when stored at a relative humidity of 20-40%. This may be the reason why rains during the flowering period lead to low seed setting.

Analysis of chickpea hybrids and their segregating generations made it possible to determine the extent of variability and correlations between basic quantitative traits inherited in the first and second generations. The criterion of early maturity in chickpeas under dryland conditions is the number of days from seedling emergence to flowering. This trait correlates positively with the total vegetation period (r=0.39-0.65) and the length of the main stem (r=0.31 - 0.52). Chickpea yield is determined by the number of seeds per plant (r=0.36 - 0.45).

The length of the main stem is negatively correlated with productivity which makes it difficult to obtain tall, productive varieties.

Crossing of forms differing in the duration of seedling emergence to flowering showed the dominance of early flowering in F_1 plants. The degree of dominance, depending on the combination, was 0.4 - 2.0. Early generation selection for this trait appears efficient.

In the early 1950s, plant breeders at the Uzbek Grain Research Institute began practicing intervarietal single and multiple crosses with subsequent repeated selection in the segregating generations.

Parents were chosen with a view to improving separate traits. The variety Uzbekistansky 8, developed at the Uzbek Grain Research Institute, was released in Azerbaijan in SSR in 1972. This variety was obtained by pollinating the sample k-427 from Syria with a pollen mixture. It had a relatively high productivity, tall habit, and a tree-like form. However, in Uzbekistan its yields were unstable, it shattered easily when overripe, was crushed at combine harvesting because of seed roundness, and was inferior in quality to the released variety Milutinsky 6.

To eliminate these shortcomings, Uzbekistansky 8 was further crossed with the collection sample k-821 from Spain which was high yielding and had large wrinkled seeds with high protein content. From this complex hybrid population a new variety, Yulduz, was developed for dryland chickpea-producing areas in Uzbekistan in 1982. Under field conditions the yields were 1.2-1.5 t ha^{-1} and height ranged from 53–58 cm. Yulduz matures in 85-91 days and has a high protein content (31.6%). The new variety is tall, productive, relatively early maturing, drought- and heat-resistant, and is of good quality. However, in years of ascochyta epiphytotics, it is severely damaged by the disease.

A new variety, Zornukhat, has been developed through complex crossing and is now undergoing state varietal testing. This variety, possessing all the traits of Yulduz, shows high performance not only under dryland but also under irrigated conditions. It yields 2.0-2.7 t ha-1 under irrigation.

To produce material resistant to ascochyta blight, varieties are tested under artificial inoculation, and the method of back-crossing local varieties with resistant samples is used. Of 1900 samples, 6 resistant ones were isolated i.e., k-909, k-368 (Czechoslovakia), k-1226 (Moldavia), k-1403 (VIR-32), and two others. These were used in reciprocal crosses with the regional variety Yulduz. The F_2 populations of BC_3 (k-909 x Yulduz) that were similar to Yulduz in such morphological traits as tall stature, productivity, large seed, and white seed color, but possessing moderate resistance to ascochyta blight (with scores of 1 to 3), were tested in a controlled nursery in 1989.

Acknowledgment

This paper was presented in the presence of the author by Dr Kamakshi Balasubramanian, Senior Fellow, Distance Education (Russian), Central Institute of English and Foreign Languages, Hyderabad 500 007, India. Her assistance is appreciated.

Session 6

Main Items of Presentation and Discussion

- Repeated intercrossing and recurrent selection may produce more frequent recombinations of desirable characters.
- An increase of genetic variability by wide and diverse crossing, and by introgression of genes from wild species using embryo rescue and tissue culture techniques will be useful for breeding programs.
- An important aspect of chickpea breeding is the stabilization of yield. Major emphasis should therefore be placed on breeding for resistance to biotic and abiotic stress factors.
- There is a need for more basic studies on the genetics of resistance to ascochyta blight, botrytis gray mold, fusarium wilt, and the major insect pests.
- Research efforts should be strengthened to provide chickpea with characters suited to specific situations such as early and late sowing, high fertility, and different cropping systems.
- The large number of genes controlling economically important characters can be located using various types of genetic markers. Once genes are located, they can be transferred to otherwise acceptable backgrounds.
- Due to chromosomal imbalance, aneuploids have not played a significant role in the diploid food legumes. They are probably not needed for gene mapping, but would be useful for assigning linkage groups to chromosomes.
- Tall genotypes maintained their yield better when sowing was delayed, and therefore may have advantage over bushy types under late-sownconditons, even though at present the two types attain the same yield level when sown late.
- Jensen's Diallel Selective Mating System and Brim and Cooper's recurrent selection approach have been used in chickpea breeding programs, but have yielded no worthwhile results, possibly due to interference by diseases.
- Several characters have been described by chickpea physiologists as possibly useful for crop improvement; examples include, increased root volume for drought tolerance, variability in nodulation, and cold tolerance to hasten crop development for disease and pest escape. The increased root volume and cold tolerance are being considered for incorporation in breeding programs, but the variability in nodulation is not being used.
- Major emphasis should be placed on breeding for resistance to biotic and abiotic stresses in order to reduce the large gap between maximum experimental station yields and the world average.

Recommendations

- A major constraint to realization of yield potentials of improved varieties is susceptibility to a wide range of fungal diseases, including fusarium wilt, dry root rot, ascochyta blight, and botrytis gray mold, and to several viral diseases. Resistance breeding should include as one of its components a definite effort to identify the genes responsible for resistance.
- Estimates of genetic variances for gene expression in segregating populations should be made.
- Genetic variation for resistance to environmental stresses needs to be identified, especially the effects of: low temperature on pod formation and seed setting, drought on yield, and freezing cold and extreme heat on chickpea growth and development.
- Germplasm carrying known resistance genes needs to be better utilized.
- Appropriate inoculation should be applied to ensure adequate nodulation.
- Improved varieties should be appropriately tested to determine actual genetic gains under conditions typical of the agroecological zone for which the material is intended.
- Locations need to be identified where yield potential can be accurately determined and breeding for yield conducted.
- Where possible, dual-purpose selection should be practiced to obtain material that is suitable for cultivation in variable cropping systems, e.g., spring and winter sowing in the WANA region.
- A suitable breeding methodology needs to be adopted by breeders, and once this is done the program needs to ensure that the required characteristics can be combined by appropriate selection of parents.
- Population improvement can be facilitated by using male sterility, to allow a range of different breeding problems such as resistance to ascochyta blight and tolerance to cold, to be tackled.
- Comparison of chickpea breeding schemes with schemes developed and found successful in other crops will be useful. These may include techniques such as selective mating systems currently

used in soybeans, and intercrossing diverse elite material.

- Cooperation and exchanges between programs in defined agroecological zones should be fostered and encouraged. These exchanges would include segregating material, with the possibility of sequential screening at locations with comparative advantages for important disease, pest, or stress situations.
- Multilocational testing is a cornerstone of crop breeding. Improving the quality of such testing, and an understanding of the components that characterize an environment are important for progress. The collection of data on weather and soil at test sites, in addition to appropriate crop data, will help explain variety responses.

Session 6

Principaux thèmes de présentation et de discussion

- Le croisement répété et la sélection récurrente pourraient produire des recombinaisons plus fréquentes des caractères désirables.

- L'augmentation de la variabilité génétique par le croisement large et varié, ainsi que par l'introgression de gènes à partir d'espèces sauvages à l'aide des techniques de sauvetage d'embryons et de culture de tissus, sera utile pour des programmes de sélection.

- La stabilisation du rendement constitue un aspect important de la sélection du pois chiche. Par conséquent, un accent majeur doit être placé sur la sélection pour la résistance aux facteurs de stress biotique et abiotique.

- Des études plus fondamentales sont nécessaires sur la génétique de la résistance à la flétrissure ascochytique, à la pourriture grise due à botrytis, au flétrissement fusarien, et aux insectes ravageurs importants.

- Des travaux de recherche doivent être renforcés afin de pouvoir offrir, pour le pois chiche, des caractères adaptés aux situations spécifiques telles le semis précoce ou tardif, la fertilité élevée, et des systèmes de culture différents.

- Le grand nombre de gènes qui déterminent des caractères économiquement importants peuvent être localisés en utilisant les divers types de marqueurs génétiques. Une fois localisés, les gènes peuvent être transférés dans les milieux autrement acceptables.

- A cause du déséquilibre chromosomale, les aneuploïdes n'ont pas joué de rôle significatif dans les légumineuses vivrières diploïdes. Ils ne sont probablement pas nécessaires pour la réalisation de cartes de gènes, mais ils seront utiles pour l'affectation des groupes de linkage aux chromosomes.

- Les génotypes grands ont mieux conservé leur rendement lorsque le semis était retardé, et peuvent donc se révéler plus avantageux que les types buissonneux dans les conditions de semis tardifs, même si à présent les deux types atteignent le même niveau de rendement à semis tardif.

- Le Système de Jensen de croisement diallèle sélectif, ainsi que l'approche de sélection récurrente de Brim et Cooper, ont été utilisés dans les programmes de sélection de pois chiche, mais ils n'ont donné aucun résultat utile, dû peut-être à l'interférence par les maladies.

- Plusieurs caractères ont été décrits par les physiologistes de pois chiche comme éventuellement utiles à l'amélioration de la culture. Ils sont, entre autres, le volume racinaire plus élevé pour la tolérance à la sécheresse, la variabilité de la nodulation, et la tolérance au froid pour accélérer la croissance de la culture afin d'échapper aux maladies et aux ravageurs. On envisage actuellement l'incorporation dans les programmes de sélection, du volume racinaire élevé et de la tolérance au froid. La variabilité de la nodulation, par contre, n'est pas utilisée.

- Un accent majeur doit être mis sur la sélection pour la résistance aux stress biotiques et abiotiques afin de réduire l'écart important entre les rendements maximales en station d'expérimentation et la moyenne mondiale.

Recommandations

- Une des contraintes majeures à la réalisation des potentiels de rendement des variétés améliorées est la sensibilité à un éventail de maladies fongiques, y compris, le flétrissement fusarien, la pourriture sèche des racines, la flétrissure ascochytique, la pourriture grise due à botrytis, ainsi que plusieurs maladies virales. La sélection pour la résistance doit comprendre, comme une de ses composantes, un effort défini pour identifier les gènes responsables pour la résistance.

- Il faut établir des estimations des variances génétiques pour l'expression de gènes dans les populations ségrégantes.

- La variation génétique pour la résistance aux stress de l'environnement doit être identifiée, en particulier les effets de : la température basse sur la formation des gousses et des graines, de la sécheresse sur le rendement, et du froid glacial et de la chaleur extrême sur la croissance et le développement du pois chiche.

- Les ressources génétiques comportant les gènes de résistance connus doivent être mieux utilisées.

- L'inoculation appropriée doit être appliquée afin d'assurer une nodulation adéquate.

- Les variétés améliorées doivent être essayées d'une façon appropriée afin de déterminer les gains génétiques réels dans des conditions typiques à la zone agroécologique pour laquelle le matériel est destiné.

- Il faut identifier des emplacements où le potentiel de rendement peut être déterminé avec précision et où la sélection pour le rendement peut être effectuée.

- La sélection à double fin doit être pratiquée là où c'est possible afin d'obtenir du matériel qui est propice à la culture dans des systèmes de culture variables, par exemple, le semis du printemps et d'hiver dans la région WANA.

- Une méthodologie de sélection convenable doit être adoptée par les sélectionneurs, et une fois achevée, le programme doit assurer que les caractéristiques requises peuvent être combinées par la sélection appropriée des géniteurs.

- L'amélioration des populations peut être facilitée en utilisant la stérilité mâle, afin de permettre la solution d'un éventail de problèmes de sélection différents tels la résistance à la flétrissure ascochytique et la tolérance au froid.

- La comparaison des schémas de sélection du pois chiche avec les schémas mis au point et réussis pour d'autres cultures serait utile. Ceux-ci pourraient comprendre des techniques telles que les systèmes de croisement sélectif utilisés actuellement pour le soja, ainsi que le croisement du matériel élite varié.

- La coopération et les échanges entre les programmes dans des zones agroécologiques définies doivent être favorisés et encouragés. Ces échanges comporteraient du matériel ségrégant, avec la possibilité de criblage séquentiel à des emplacements avec des avantages comparatifs pour les situations importantes de maladies, de ravageurs ou de stress.

- Les essais multilocaux forment la pierre angulaire de la sélection des cultures. L'amélioration de la qualité de tels essais, ainsi que la connaissance des composantes qui caractérisent un environnement sont importantes pour le progrès. La collection des données sur le climat et le sol à des sites d'essais, outre les données de culture appropriées, permettra d'expliquer les réponses variétales.

Poster Presentations
Recent Advances in Chickpea Improvement and Prospects for the Nineties

Recent Advances in Chickpea Improvement and Prospects for the Nineties: South Asia

A.N. Asthana[1], M.P. Bharati[2], A.M. Haqqani[3], K. Moe[4], and M.M. Rahman[5]

Abstract

Breeding for disease resistance has received major attention, especially for wilt and ascochyta blight, followed by root rots, botrytis gray mold, and stunt. Stable resistance for pod borer (Helicoverpa armigera) *and botrytis is yet to be found, but relatively tolerant types have been selected.*

Work has been done on the development of early maturing cultivars for double cropping and for early or late sowing to suit cropping patterns. The importance of irrigated chickpea has been realized lately. Work is in progress for developing disease resistant, bold seeded desi and kabuli types, erect tall and compact types, and for incorporation of double-podded and multiseeded traits. These hold promise for the 1990s. Significant progress has been made as follows:

Bangladesh - Cultivar Nabin released. Screening undertaken for resistance to wilt, botrytis, root rot, and collar rot. Selections made for bold seed, late sowing, and high yield.

Myanmar - Cultivar Yezin 1 released. Chickpea grown in dry central part of Myanmar; kabuli type ICCV 2 is promising. Screening undertaken for wilt, dry root rot, and pod borer.

India - Eighteen cultivars released in 1980s (including three kabulis). Some were resistant to wilt, ascochyta, and stunt. Promising lines tolerant to botrytis, stunt, ascochyta, and pod borer were selected. Cultivars were identified for early maturity, bold seed, and for late sowing conditions. Better plant types are being developed.

Nepal - Cultivars Dhanush, Trishul, Radha, and Sita released. Lines resistant to wilt, and tolerant to botrytis and pod borer identified. Some high-yielding cultivars are in pre-release stage.

Pakistan - Cultivars C 44 and CM 72 released. Several lines resistant to ascochyta selected. Races of A. rabiei *being identified. Work on developing chickpea genotypes for rainfed, better managed, and rice-based cropping systems is in progress.*

Résumé

Récents progrès de l'amélioration du pois chiche et prévisions pour les années 90—Asie du Sud : *La sélection pour la résistance aux maladies a suscité une grande attention, particulièrement en ce qui concerne le flétrissement et la flétrissure ascochytique, suivis par les pourritures des racines, la pourriture grise due à botrytis et le nanisme. On n'a pas encore*

---

1. Principal Investigator (Plant Breeding), Directorate of Pulses Research, Kalyanpur, Kanpur 208 024, Uttar Pradesh, India.
2. Agronomist and Coordinator, National Grain Legume Improvement Program (NGLIP), Ministry of Agriculture, G.P.O. Box 404, Khumaltar, Kathmandu, Nepal.
3. Senior Scientific Officer, Pulses Program, National Agricultural Research Centre (NARC), P.O. National Institute of Health, National Park Road, Islamabad, Pakistan.
4. Plant Breeder, Food Legumes, Agricultural Research Institute, Yezin, Myanmar.
5. Principal Scientific Officer, Pulses Improvement Program, Regional Agricultural Research Station, Bangladesh Agricultural Research Institute (BARI), Ishurdi, Pabna, Bangladesh.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

*trouvé de résistance stable au foreur des gousses (*Helicoverpa armigera*) ni au botrytis, mais des types relativement tolérants ont été sélectionnés.*

Des travaux ont été effectués sur la mise au point de cultivars à maturité précoce destinés à la culture double et aux semis précoces ou tardifs selon les systèmes de culture. L'importance du pois chiche irrigué est mieux comprise aujourd'hui. Des travaux sont en cours pour développer des types 'desi' et 'kabuli' à gros grains et résistants aux maladies, des types grands érigés et compacts. Ils portent également sur l'incorporation de caractères de gousses doubles et grains multiples. Cela s'annonce bien pour les années 90. Des progrès significatifs ont été effectués comme suit :

Bangladesh—Cultivar Nabin vulgarisé. Criblage réalisé pour la résistance au flétrissement, au botrytis, à la pourriture des racines et à la pourriture du collet. Des sélections faites pour les gros grains, semis tardif et rendement élevé.

Myanmar—Cultivar Yezin 1 vulgarisé. Pois chiche cultivé dans la partie centrale sèche du Myanmar; le type kabuli ICCV 2 est prometteur. Criblage entrepris pour le flétrissement, la pourriture sèche des racines et le foreur des gousses.

Inde—Dix-huit cultivars vulgarisés au cours des années 80 (y compris trois kabulis). Certains résistaient au flétrissement, à la flétrissure ascochytique et au nanisme. Des lignées comportant une bonne tolérance au botrytis, au nanisme, à la flétrissure ascochytique et au foreur des gousses, ont été sélectionnées. Des cultivars ont été identifiés pour maturité précoce, gros grains et semis tardif. De meilleurs types de plantes sont en développement.

Népal—Cultivars Dhanush, Trishul, Radha et Sita vulgarisés. Des lignées résistantes au flétrissement et tolérantes au botrytis et au foreur des gousses ont été identifiées. Certains cultivars à haut rendement sont au stade de prévulgarisation.

Pakistan—Cultivars C 44 et CM 72 vulgarisés. Plusieurs lignées résistantes à la flétrissure ascochytique sélectionnées. Des races de A. rabiei *en voie d'identification. Des travaux sont en cours sur la mise au point de génotypes de pois chiche pour la culture pluviale, et pour systèmes de culture améliorés à base du riz.*

Recent Advances in Chickpea Improvement and Prospects for the Nineties: the Mediterranean Region of Europe

J.I. Cubero[1] and M.-T. Moreno Cubero[2]

Abstract

*The most significant advance in chickpea (*Cicer arietinum *L.) improvement so far registered in the Mediterranean region of Europe relates to winter chickpea technology. This technology has been made possible by obtaining cultivars showing resistance to low temperature (to -5°C) and to ascochyta blight. Chickpeas sown in autumn profit from winter rainfall; their growth is vigorous, and they develop a height and plant strength never reached by spring-sown crops. Roots, stems, and branches are strong, and thus able to support many pods. Winter chickpea is also free from wilt so prevalent in western Mediterranean countries.*

Resistance to ascochyta blight and winter conditions is being introduced in traditional cultivars. As in western Mediterranean countries cooking quality is important and related to seed size. An important objective in chickpea breeding is to develop large-seeded cultivars incorporating all other characteristics necessary for winter cultivation. As spring sowings will not be eliminated from Mediterranean agriculture, another objective in breeding is to transfer resistance to fusarium wilt to well-adapted, quality cultivars (usually landraces). Since most of the donor parent lines are small-seeded, complete recovery of the required seed size is slow.

Although there has been a significant decline in cultivated area and production in some Mediterranean countries there is scope for an increase in all of them. Factors causing decline are technical, such as low yield, lack of resistance to fusarium wilt and ascochyta blight, and absence of mechanization, as well as political ones, such as inadequate institutional help for existing research teams.

Research on new uses of chickpea is needed, as well as in traditional uses (for example, for animal feeding) which have been almost completely abandoned. The recovery to past importance also depends on a strong effort in extension to spread the new technology and the proper use of new cultivars. But perhaps the most important element for recovery is a change in the marketing system both for the commerical product and the seed of cultivars.

Résumé

Récents progrès de l'amélioration du pois chiche et prévisions pour les années 90—Région méditerranéenne de l'Europe : *Le progrès le plus significatif de l'amélioration du pois chiche (*Cicer arietinum *L.) qui ait été enregistré jusqu'ici dans la région méditerranéenne de l'Europe concerne la technologie du pois chiche d'hiver. Cette technologie est rendue possible par l'obtention de cultivars manifestant de la résistance aux basses températures (jusqu'à -5°C) et à la flétrissure ascochytique. Les pois chiches semés en automne bénéficient des pluies d'hiver; leur croissance est vigoureuse et les plantes atteignent une hauteur et une robustesse qui ne sont jamais réalisées par les cultures semées au printemps. Les racines, tiges et branches sont*

1. Professor of Genetics and Plant Breeding, Escuela Tecnica Superior de Ingenieros Agronomos, Departmento de Genetica, A.P. 3048, 14080 Cordoba, Spain.

2. Biologist, Centro de Investigacion y Desarrollo Agrarario, Departmento de Mejora y Agronomia, A.P. 240, 14080 Cordoba, Spain.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

fortes et peuvent ainsi supporter bien des gousses. Le pois chiche d'hiver est également exempt de flétrissement qui est très fréquent dans les pays de l'ouest de la Méditerranée.

La résistance à la flétrissure ascochytique et aux conditions d'hiver est en cours d'être introduite dans les cultivars traditionnels. Dans les pays de l'ouest de la Méditerranée, la qualité de cuisson est importante et fonction de la taille des grains. Un objectif important de la sélection du pois chiche consiste donc à mettre au point des cultivars à gros grains, incorporant toutes les autres caractéristiques nécessaires pour la culture d'hiver. Comme les semis de printemps ne seront pas éliminés de l'agriculture méditerranéenne, un deuxième objectif de la sélection consiste à transférer la résistance au flétrissement fusarien à des cultivars de qualité et bien adaptés (généralement des variétés locales). Etant donné que la majeure partie des parents donneurs sont à petits grains, la reprise complète des dimensions voulues des grains est lente.

Bien qu'un déclin significatif ait été enregistré quant à la superficie cultivée et à la production dans certains pays européens, il semble possible de les accroître dans tous. Les facteurs du déclin sont techniques, comme un faible rendement, le manque de résistance au flétrissement fusarien et à la flétrissure ascochytique et l'absence de mécanisation, ainsi que politiques, comme l'insuffisance de l'aide institutionnelle aux équipes de recherches existantes.

Des recherches sur de nouveaux usages du pois chiche sont nécessaires, ainsi que sur les usages traditionnels (par exemple, pour l'affouragement du bétail) qui ont été presque complètement abandonnés. Le retour à l'importance d'autrefois dépend aussi de la vigueur d'un effort de vulgarisation pour diffuser la nouvelle technologie et de l'usage correct de nouveaux cultivars. Mais peut-être l'élément le plus im"ortant de la reprise est un changement du système de commercialisation, tant pour le produit commercial que pour les semences de cultivars.

Recent Advances in Chickpea Improvement and Prospects for the Nineties: Eastern Africa

Geletu Bejiga[1]

Abstract

Both the area under production and the production of chickpea (Cicer arietinum *L.) have declined in recent years in eastern Africa. To reverse this trend, national agricultural research systems have initiated research programs.*

The most important diseases of chickpea in the eastern African countries (Ethiopia, Kenya, Tanzania, Uganda, and Sudan), are fusarium wilt, dry root-rot, collar rot, and stunt. Ascochyta blight has only been reported from Ethiopia and Tanzania. Pod borer, cut worm, and bruchids are among the most important insect pests.

Agronomic studies in Ethiopia have revealed that an advance in sowing date from mid-September to late August/early September could substantially increase the seed yield. Optimum seed rates have also been established. Scientists from Sudan have worked out irrigation schedules for chickpea. An optimum seeding rate in Sudan is ~60 kg ha^{-1} and the recommended sowing date lies between the end of October and November.

Early-maturing, desi-type chickpeas are required in Ethiopia, Kenya, Tanzania, and Uganda. Kabuli chickpea, with small to medium seed size and early maturity, has also good prospects in the region, particularly in Sudan and Ethiopia.

Sources of resistance to some important diseases have been identified for use in the breeding program. At least four improved cultivars have been released in Ethiopia, and one each in Kenya and Sudan. Generally, prospects for increased chickpea production in the region are bright. However, there is a need for an Eastern Africa Regional Program with backing from ICRISAT and ICARDA, supporting a strong research base by providing materials, training, and technical advice in order to help increase chickpea production in the region.

Résumé

Récents progrès de l'amélioration du pois chiche et prévisions pour les années 90—Afrique orientale : *La superficie exploitée ainsi que la production de pois chiche* (Cicer arietinum *L.) ont tous les deux baissé depuis quelques années en Afrique orientale. Pour redresser la situation, les systèmes nationaux de recherche agricole ont entrepris des programmes de recherches.*

Les maladies les plus graves du pois chiche dans les pays d'Afrique orientale (Ethiopie, Kenya, Tanzanie, Ouganda et Soudan) sont le flétrissement fusarien, la pourriture sèche des racines, la pourriture du collet et le nanisme. La flétrissure ascochytique n'a été signalée qu'en Ethiopie et en Tanzanie. Le foreur des gousses, le ver gris et les bruches sont parmi les insectes les plus dangereux.

Des études agronomiques faites en Ethiopie ont révélé que l'avancement des dates de semis, de la mi-septembre jusqu'à fin août/début septembre, pourrait nettement améliorer les rendements en grain. Les taux optimum de semis ont également été déterminés. Des chercheurs du Soudan ont élaboré des plans d'irrigation pour le pois chiche. Un taux optimum de

1. Postdoctoral Fellow, International Center for Agricultural Research in the Dry Areas (ICARDA), P.O. Box 5466, Aleppo, Syria.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

semis pour le Soudan est d'environ 60 kg ha^{-1} et la date de semis recommandée se situe entre fin octobre et novembre.

Des pois chiches du type 'desi', à maturation précoce, font défaut en Ethiopie, au Kenya, en Tanzanie et en Ouganda. Le pois chiche précoce 'kabuli', avec des grains petits ou moyens, a également de bons débouchés dans cette région, particulièrement au Soudan et en Ethiopie.

Les sources de résistance à certaines maladies importantes ont été identifiées pour l'usage dans le programme de sélection. Au moins quatre cultivars améliorés ont été vulgarisés en Ethiopie, et un au Kenya et au Soudan. D'une façon générale, les possibilités d'accroître la production de pois chiche dans cette région sont très favorables. Toutefois, il serait utile d'organiser un Programme régional pour l'Afrique orientale, avec l'appui de l'ICRISAT et de l'ICARDA, qui supporterait une base de recherche solide en fournissant du matériel, de la formation et des conseils techniques afin d'aider à accroître la production de pois chiche dans cette région.

Recent Advances in Chickpea Improvement and Prospects for the Nineties: Americas

J.A. Acosta-Gallegos[1], R.M. Gomez-Garza[2], J.A. Morales-Gomez[3], and E. Andrade-Arias[4]

Abstract

In this region Mexico is the main chickpea producer followed by Chile, Colombia, Bolivia, and Argentina. Peru and the USA also devote small areas to chickpeas.

In the USA, chickpea is a promising crop in eastern Washington and northern Idaho. But various diseases have been identified including ascochyta blight, rhizoctonia and fusarium root rots, botrytis, and viruses. In the breeding program in Washington, hybrid populations of chickpea are advanced by bulk progeny to F_5 before selection is done. In the F_5 or more advanced populations individual plants are selected for desirable phenotypic characteristics, which include earliness, plant height, podding habit and type, and an upright growth habit.

In Colombia, the chickpea crop almost disappeared in the 1970s due to fusarium root rot. Lately, the Instituto Colombiano Agropecuario (ICA), Brazil, Legume Breeding Program has been introducing segregating populations from ICARDA, as well as advanced material from Instituto de Investigaciones Agropecuarias (INIA) (Chile), Programa Colaborativo Andino (PROCANDINO) (Ecuador), and Instituto Nacional de Investigaciones Forestales Agricolas y Pecuarias (INIFAP) (Mexico). Non-adapted wilt resistant genotypes are being crossed to local susceptible cultivars. There is also a shortage of trained scientists working on the chickpea crop.

In Mexico, chickpeas are produced in two distinct regions: the central plateau, where desi cultivars are grown under residual moisture, and the coastal northwest region, where kabuli cultivars are grown under irrigation and residual moisture. A common problem in these two regions is wilt/root rot. Drought is also a strong constraint on the central plateau. The kabuli breeding program has been using desi lines as sources of resistance to wilt/root rot. The resistance is incorporated by the backcrossing of F_3- F_5 resistant F_2 derived families, selected in a wilt sick plot, to the large seeded parent (BC1) or to a different large seeded genotype (3-way cross).

The same procedure or a combination of pedigree-bulk are being used to introduce erect upright habit from Russian sources into local large-seeded cultivars.

Résumé

Récents progrès de l'amélioration du pois chiche et prévisions pour les années 90—Les Amériques : *Dans cette région, le Mexique est le principal producteur de pois chiche, suivi par le Chili, la Colombie, la Bolivie et l'Argentine. Le Pérou et les Etats-Unis consacrent aussi de petites superficies au pois chiche.*

1. Food Legume National Expert, Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP), A.P. 20, Pabellon, AGS. 20660, Mexico.
2. Research Assistant, Food Legume Program, A.P. 356, Culiacan, Sinaloa, Mexico.
3. Research Assistant, Food Legume Program, A.P. 1031, Hermosillo, Sonora, Mexico.
4. Research Assistant, Food Legume Program, A.P. 112, Celaya, GTO, Mexico.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

Aux Etats-Unis, le pois chiche est une culture qui promet dans l'est de l'Etat de Washington et le nord de l'Etat d'Idaho. Toutefois, diverses maladies ont été identifiées, y compris la flétrissure ascochytique, la rhizoctonie et la pourriture fusarienne des racines, le botrytis et les viroses. Dans le programme de sélection de Washington, les populations hybrides de pois chiche sont multipliées par descendances bulk pour donner la F_5 avant de faire la sélection. Dans la F_5 ou dans des populations successives, des plantes individuelles sont sélectionnées pour des caractéristiques phénotypiques désirables, dont la précocité, la hauteur de la plante, le port et le type de formation des gousses et un port dressé de la plante.

En Colombie, la culture de pois chiche a presque disparu au cours des années 70, en raison de la pourriture fusarienne des racines. Récemment, le Programme de sélection de légumineuses de l'Instituto Colombiano Agropecuario (ICA) du Brésil, a introduit des populations ségrégantes de l'ICARDA, ainsi que du matériel avancé provenant de l'Instituto de Investigaciones Agropecuarias (INIA) (Chili), du Programa Colaborativo Andino (PROCANDINO) (Ecuador) et de l'Instituto Nacional de Investigaciones Forestales Agricolas y Pecuarias (INIFAP) (Mexique). Des génotypes résistants au flétrissement et non adaptés sont en cours d'être croisés avec des cultivars sensibles locaux. Il y a aussi un manque de chercheurs qualifiés qui puissent travailler sur la culture du pois chiche.

Au Mexique, le pois chiche est produit dans deux régions distinctes : le plateau central, où l'on exploite des cultivars 'desi' sous humidité résiduelle, et la région côtière nord-ouest, où l'on exploite des cultivars 'kabuli' sous irrigation et humidité résiduelle. Un problème commun dans ces deux régions est le flétrissement/pourriture des racines. La sécheresse est également une sévère contrainte sur le plateau central. Le programme de sélection de kabuli utilise les lignées desi comme sources de résistance au flétrissement/pourriture des racines. La résistance est incorporée par rétrocroisement de familles F_3–F_5 dérivées de la F_2 résistante, sélectionnées dans une parcelle infectée de flétrissement, au parent à gros grains (BC1) ou à un génotype différent à gros grains (hybride trois voies).

La même procédure ou une combinaison de pedigree-bulk sert à introduire un port érigé dressé à partir des sources russes dans des cultivars locaux à gros grains.

Recent Advances in Chickpea Improvement and Prospects for the Nineties: Australia

E.J. Knights[1] and R.B. Brinsmead[2]

Abstract

Commercial chickpea production began in Australia in 1979 with the release of the Indian desi cultivar C 235 and a kabuli line introduced from the USSR Since then the industry has expanded to 87 000 ha with production being overwhelmingly of the desi type.

Hybridization programs and further introductions have subsequently produced improvements in yield potential and stability, agronomic attributes, and seed quality. An average yield increase of 5% over C 235 has been achieved with the desi crossbred 'Amethyst', concurrent with significant improvements in plant height and with lodging resistance. Other releases, involving both desi and kabuli introductions, have reflected the priority given to substantially increasing seed mass, consistent with maintaining, or increasing, seed yield.

In future breeding emphasis will largely be directed to augmenting resistance to Phytophthora megasperma *f. sp.* medicaginis, *the major factor limiting production in many chickpea areas. Crossbreds have been developed which incorporate moderate levels of resistance. Heightened resistance is likely to be achieved from recurrent selection, identification of new sources of resistances, and an interaction of resistance with enhanced waterlogging tolerance.*

Other important prospective gains from plant breeding include improved resistance to Helicoverpa (Heliothis) *spp. and the nematode* Pratylenchus thornei, *increased herbicide tolerance, low temperature seed-set, and lower seed levels of oligosaccharides and trypsin inhibitors.*

Résumé

Récents progrès de l'amélioration du pois chiche et prévisions pour les années 90—Australie : *La production commerciale du pois chiche a commencé en Australie en 1979, avec la vulgarisation du cultivar 'desi' indien C 235 et d'une lignée 'kabuli' introduite de l'URSS. Depuis lors, l'industrie s'est élargie pour atteindre 87 000 ha, la production étant presque toujours du type desi.*

Des programmes d'hybridation et de nouvelles vulgarisations ont par la suite fourni des améliorations du potentiel et de la stabilité du rendement, des attributs agronomiques et de la qualité des semences. Une augmentation moyenne de 5% du rendement par rapport à C 235 a été obtenue avec l'hybride desi Amethyst, simultanément avec une amélioration significative de la hauteur de la plante et de la résistance à la verse. D'autres vulgarisations, comprenant des introductions tant desi que kabuli, ont reflété la priorité accordée à la nécessité d'augmenter de manière importante la masse des grains, tout en maintenant ou en augmentant le rendement en semences.

A l'avenir, dans le cadre de la sélection, on insistera surtout sur l'augmentation de la résistance au Phytophthora megasperma *f. sp.* medicaginis, *principal facteur limitant de la production dans bien des zones de pois chiche. Des hybrides ont été mis au point, qui*

1. Chickpea Breeder, New South Wales Agriculture and Fisheries, Agricultural Research Centre, RMB 944, Tamworth, NSW 2340, Australia.
2. Supervising Agronomist, Hermitage Research Station, Via Warwick, Qld 4370, Australia.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

incorporent des niveaux modérés de résistance. Une résistance accrue serait probablement obtenue grâce à la sélection récurrente, à l'identification de nouvelles sources de résistance et à une interaction de la résistance avec une tolérance améliorée à l'inondation.

Les autres grands avantages prévus grâce à la sélection comprennent la résistance à Helicoverpa *(*Heliothis*) spp et au nématode* Pratylenchus thornei, *une tolérance accrue aux herbicides, une grenaison à basse température et des teneurs moins élevées d'inhibiteurs de trypsine et d'oligosaccharides.*

Recent Advances in Chickpea Improvement and Prospects for the Nineties: ICRISAT Center

Onkar Singh, N.P. Saxena, M.P. Haware, S.S. Lateef, and C.L.L. Gowda[1]

Abstract

ICRISAT Center, located at 18°N, 78°E near Hyderabad in India, is responsible for the development of short- and medium-duration desi and kabuli chickpea cultivars with stable and high yield and good consumer acceptance. Through multidisciplinary efforts, stable sources of single and/or multiple resistances to biotic (wilt, root rots, Helicoverpa *pod borer) and abiotic (drought, salinity) stresses have been identified and used in generating elite materials which combine high yield, resistance to wilt, and different levels of resistances to other stresses. Off-season nurseries under movable rainout shelters at ICRISAT Center are used to achieve faster progress in the breeding process. Extra-short duration, wilt-resistant desi and kabuli cultivars that mature in ≤80 days, escape terminal drought, and can profitably be used as a catch crop, and in double-cropping systems, have been developed recently. All materials included in the international trials/nurseries now essentially possess resistance to wilt and tolerance to other stresses. The provision of a large number of chickpea germplasm and segregating materials to, and our collaborative activities with, the national programs have resulted in release of cultivars in India, Bangladesh, Myanmar, Nepal, Ethiopia, and Kenya. The excellent performance of short- and medium-duration ICRISAT chickpea cultivars in recent on-farm trials in India has generated great interest among farmers. The likely impact of some of the current research activities, such as germplasm enhancement, ideotype breeding, diversified bulk population breeding, and screening for early growth vigor and heat tolerance, has been elucidated.*

Résumé

Récents progrès de l'amélioration du pois chiche et prévisions pour les années 90—Centre ICRISAT: *Le Centre ICRISAT, situé à 18°N, 78°E, près d'Hyderabad en Inde, est chargé de la mise au point de cultivars de pois chiche 'desi' et 'kabuli' à cycles court et moyen, avec un rendement stable élevé et une bonne préférence des consommateurs. Grâce aux efforts pluridisciplinaires, des sources stables de résistance simple et/ou multiple aux contraintes biotiques (flétrissement, pourritures des racines, le foreur des gousses* Helicoverpa*) et abiotiques (sécheresse, salinité) ont été identifiées et utilisées dans la génération de matériel élite qui réunit un rendement élevé, une résistance au flétrissement et différents niveaux de résistance à d'autres contraintes. Des pépinières hors-saison sous abris amovibles contre la pluie au Centre ICRISAT, permettent de réaliser des progrès plus rapides au cours de la sélection. On vient de mettre au point des cultivars desi et kabuli à cycle très court, résistants au flétrissement, qui parviennent à maturité en ≤80 jours, échappent à la sécheresse terminale et peuvent être exploités comme culture dérobée ou dans des systèmes de culture double. Tous les matériels qui figurent dans les essais/pépinières internationaux actuellement possèdent essentiellement une résistance au flétrissement et une tolérance à d'autres contraintes. La fourniture d'un grand nombre de lignées des ressources génétiques et de matériel ségrégant de pois chiche aux*

1. Plant Breeder, Senior Crop Physiologist, Plant Pathologist, Entomologist, and Senior Plant Breeder, Legumes Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

programmes nationaux, ainsi que nos activités en collaboration avec ces programmes, ont mené à la vulgarisation de cultivars en Inde, au Bangladesh, au Myanmar, au Népal, en Ethiopie et au Kenya. La performance excellente de cultivars de pois chiche de l'ICRISAT à cycles court et moyen dans des essais récents en milieu réel en Inde ont suscité un vif intérêt parmi les cultivateurs. L'impact probable de certaines des activités de recherche actuelles, comme l'enrichissement du pool génique, la sélection des idéotypes, la sélection de populations bulk diversifiées et le criblage pour la vigueur précoce de croissance et la tolérance à la chaleur, a été élucidé.

JNKVV–ICRISAT Cooperative Research Station, Gwalior: Recent Activities in Chickpea Improvement

O.P. Rupela[1], C. Johansen[2], N.P. Saxena[2], M.P. Srivastava[3], and Onkar Singh[2]

Abstract

The JNKVV–ICRISAT Cooperative Center was established in 1978 on the campus of the Jawaharlal Nehru Krishi Vishwa Vidhyalaya (JNKVV) College of Agriculture, Gwalior, Madhya Pradesh, India, at 26°13'N, 78°14' E and 212 m above sea level. The objectives of this Cooperative Center are:

1) *to improve long-duration pigeonpea, an important crop in the traditional system of cultivation in the region;*

2) *to offer a site for regional testing of promising chickpea genotypes in a major chickpea growing area of India; and*

3) *for exchange and dissemination of information in fulfilling ICRISAT's mandate in the region.*

It has significantly contributed to the development and identification of ICCV 1,6, and 10, promising medium-duration chickpea varieties adapted to the region. In addition, it has served as an important site for the evaluation of short- (ICCV 2), and long- (desi: ICCV 88101-104; kabuli: ICCV 13, 14) duration varieties during their development. Preliminary results on fitting chickpea into cropping systems relevant to the region, suggested that introduction of short-duration ICCV 2 could bring about greater stability for yield of chickpea and also offer scope for increasing cropping intensity. The increased cropping intensity can be achieved through possible double-cropping under rainfed conditions, and through triple-cropping under irrigated conditions.

Résumé

Station de recherche coopérative JNKVV-ICRISAT, Gwalior—Activités récentes de l'amélioration du pois chiche : *Le Centre coopératif JNKVV-ICRISAT a été fondé en 1978 sur le campus du collège d'agriculture Jawaharlal Nehru Krishi Vishwa Vidhyalaya (JNKVV) à Gwalior, Madhya Pradesh, en Inde, à 26°13'N, 78°14'E et à 212 m au-dessus du niveau de la mer. Les objectifs de ce centre coopératif sont :*

1) *l'amélioration du pois d'Angole à cycle long, une importante culture dans le système traditionnel de culture de cette région;*

1. Crop Physiologist, Legumes Program, ICRISAT Cooperative Research Station, College of Agriculture Farm, Jawaharlal Nehru Krishi Viswa Vidyalaya (JNKVV), Gwalior 474 002, Madhya Pradesh, India.

2. Principal Agronomist, Senior Crop Physiologist, and Plant Breeder, Legumes Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

3. Pigeonpea Breeder, College of Agriculture, Jawaharlal Nehru Krishi Viswa Vidyalaya (JNKVV), Gwalior 474 002, Madhya Pradesh, India.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

2) la disposition d'un site destiné aux essais régionaux de génotypes prometteurs de pois chiche dans une grande région de production de pois chiche de l'Inde; et

3) l'échange et la diffusion d'informations pour remplir le mandat de l'ICRISAT dans cette région.

Le Centre a contribué de manière significative à la mise au point et à l'identification de ICCV 1,6 et 10, variétés performantes de pois chiche à cycle moyen, adaptées à la région. En outre, il a été un site important pour l'évaluation de variétés à cycle court (ICCV 2), et à cycle long ('desi' : ICCV 88101-104; 'kabuli' : ICCV 13, 14) pendant leur développement. Les résultats préliminaires sur l'insertion du pois chiche dans des systèmes de culture appropriés à la région laissent entendre que l'introduction de ICCV 2 à cycle court pourrait apporter une plus grande stabilité au rendement du pois chiche et en même temps offrir de meilleures possibilités pour accroître l'intensité de la culture. L'intensité accrue de la culture peut être obtenue grâce à une culture double éventuelle dans des conditions pluviales, ainsi qu'avec une culture triple dans des conditions d'irrigation.

HAU–ICRISAT Cooperative Research Station, Hisar: Recent Advances in Long-duration Chickpea

S.C. Sethi[1], A.M. Ghanekar[1], and C.L.L. Gowda[2]

Abstract

Our objectives at Hisar (29°N, 75°E, 215 m) are to breed high-yielding long-duration desi and kabuli types, to identify early-maturing genotypes suited to late sowing, to fit in double cropping systems, and to breed varieties for high-input conditions.

The potentially serious diseases are fusarium wilt, root rots, stunt virus, ascochyta blight, and botrytis gray mold; whereas the most important insect pest is Heliocovera *pod borer. Cold, salinity, drought, and high temperatures are the important abiotic stresses that require attention.*

Single, three-way and double crosses are made to combine resistances into high-yielding backgrounds. Early segregating generations are screened against wilt and root rots, stunt virus, ascochyta blight (in collaboration with HAU, Hisar), and botrytis gray mold (in collaboration with GBPUA&T, Pantnagar). Later generations are grown in insecticide-free blocks to identify Heliocoverpa *tolerant lines. Elite lines with good agronomic performance and resistance/tolerance to one or more stress factors are identified and contributed to international trials/nurseries to test for wide adaptation and stability of performance.*

High-yielding lines so far bred at Hisar are desis: ICCV 1, ICCV 19, ICCV 88102, and ICCV 88104 and kabulis: ICCV 6, ICCV 13, ICCV 14; ICCC 14, ICCC 41, ICCV 15, ICCV 88106 and 88107 for late sowing conditions; ICCV 89851 and ICCV 89852 for high inputs; and ICCV 88506 and ICCV 88507 for cold tolerance. Seed samples of these lines are freely available to cooperators.

Résumé

Station de recherche HAU-ICRISAT, Hisar—Progrès récents de la sélection de pois chiche à cycle long : *Nos objectifs à Hisar (29°N, 75°E, 215 m) sont de sélectionner des types 'desi' et 'kabuli' à cycle long et à rendement élevé, d'identifier des génotypes à maturation précoce qui se prêtent à des semis tardifs, afin de permettre leur intégration dans des systèmes de culture double, ainsi que de sélectionner des variétés pour des conditions à intrants élevés.*

Les maladies potentiellement les plus graves sont le flétrissement fusarien, les pourritures des racines, le virus du nanisme, la flétrissure ascochytique et la pourriture grise due à botrytis; l'insecte le plus important est le foreur des gousses Helicoverpa. *Le froid, la salinité, la sécheresse et les fortes températures sont les principales contraintes abiotiques qui exigent l'attention.*

Des hybrides simples, des hybrides trois voies et des croisements doubles sont réalisés pour combiner les résistances dans du matériel à haut rendement. Des générations ségrégantes précoces sont criblées contre le flétrissement et la pourriture des racines, le virus du nanisme, la flétrissure ascochytique (en collaboration avec HAU, Hisar) et la pourriture grise due à

1. Plant Breeder and Plant Pathologist, Legumes Program, ICRISAT Cooperative Research Station, Haryana Agricultural University Campus, Hisar 125 004, Haryana, India.

2. Senior Plant Breeder, Legumes Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

botrytis (en collaboration avec GBPUA&T, Pantnagar). Des générations successives sont cultivées dans des parcelles exemptes d'insecticide, pour identifier les lignées tolérantes à Helicoverpa. *Les lignées élites qui ont de bonnes performances agronomiques et une résistance/tolérance à l'un ou plusieurs facteurs de contraintes sont identifiées et soumises à des essais/pépinières internationaux afin de tester pour l'adaptation et la stabilité de performances.*

Des lignées à haut rendement sélectionnées jusqu'à présent à Hisar sont des desi : ICCV 1, ICCV 19, ICCV 88102 et ICCV 88104 et des kabuli : ICCV 6, ICCV 13, ICCV 14; les lignées ICCC 14, ICCC 41, ICCV 15, ICCV 88106 et 88107 pour conditions de semis tardifs; les lignées ICCV 89851 et ICCV 89852 pour intrants élevés; et les lignées ICCV 88506 et ICCV 88507 pour tolérance au froid. Des échantillons de semences de ces lignées sont librement disponibles aux coopérants.

Desi–Kabuli Introgression Studies in Chickpeas

C.L.L. Gowda, B.V. Rao, and S. Chopra[1]

Abstract

Of the two distinct types of chickpeas (desi and kabuli), desi types are usually small seeded, with a colored seed coat and reticulated surface. Kabuli types are usually large seeded, with a white or pinkish seed coat, and a smooth seed surface. Desi types are considered primitive and the kabuli types to be of more recent origin. Both have been isolated geographically for many years. Apart from morphological differences, each type possesses unique and useful characteristics, and different gene blocks that can be transferred (introgressed) from one type into another to improve quality traits and yield.

A desi-kabuli introgression study was initiated in 1979 to determine the variability generated in desi x kabuli crosses and the frequency of recombinants with desired traits, and to introgress desirable characteristics from desi type into kabuli and vice-versa. Three desi and three kabuli varieties were included in a diallel cross. In the F_2 of desi x kabuli crosses a wide range of segregants for seed size, shape, and color were obtained. Desi type seeds were higher in proportion, followed by intermediate and kabuli types. The percentage of kabuli types was low, and varied with parental lines in a cross. The extent of variability for morphological characters in desi x kabuli crosses was similar to other crosses, and was more related to geographic divergence of parents than to seed type. In the second cycle of crossing, the extent of variability in the F_2 was less than in cycle 1, and the recovery of kabuli type segregants was higher when the third parent used was a kabuli. Qualitative characters can be transferred easily. Although there were vegetatively vigorous plants in the F_2, no segregants were yielding higher than the highest yielding parent.

Résumé

Etudes sur l'introgression 'desi'-'kabuli' chez le pois chiche : *Des deux types distincts de pois chiche ('desi' et 'kabuli'), les types desi sont généralement à petits grains, à tégument coloré et surface réticulée. Les types kabuli ont généralement de gros grains, à tégument blanc ou rose et surface de grain unie. Les types desi sont considérés comme primitifs et les types kabuli comme d'origine plus récente. Tous les deux ont été isolés géographiquement depuis bien des années. En dehors des différences morphologiques, chaque type possède des caractéristiques uniques et utiles ainsi que différents blocs de gènes qui peuvent être transférés (par introgression) d'un type à l'autre pour améliorer les caractères de qualité et le rendement.*

Une étude sur l'introgression desi-kabuli a été inaugurée en 1979 pour déterminer la variabilité engendrée dans les croisements desi × kabuli et la fréquence des recombinants à caractères désirables, et pour introgresser des caractéristiques désirables du type desi au type kabuli et vice versa. Trois variétés desi et trois variétés kabuli ont figuré dans un croisement diallèle. Dans la F_2 de croisements desi × kabuli, on a obtenu une grande variété de ségrégants pour la taille des grains, leur forme et leur couleur. Les grains du type desi étaient proportionnellement plus nombreux, suivis par des types intermédiaires et des types kabuli. Le pourcentage de types kabuli était faible et a varié en fonction des lignées parentales dans un croisement.

---

1. Senior Plant Breeder, and Research Associates, Legumes Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

L'étendue de la variabilité des caractéristiques morphologiques chez les croisements desi × kabuli était identique à celle des autres croisements, étant davantage fonction de divergences géographiques des parents que du type de grain. Dans le second cycle d'hybridation, l'étendue de la variabilité dans la F_2 était inférieure à celle du cycle 1, et la reprise de ségrégants du type kabuli était plus élevée lorsque le troisième parent utilisé était un kabuli. Des caractéristiques qualitatives peuvent être transférées facilement. Bien qu'il y avait des plantes végétativement vigoureuses dans la F_2, aucun ségrégant n'avait un rendement supérieur à celui du parent le plus performant.

Chickpeas in the Newly Reclaimed Areas in Egypt

A.M. Khattab[1]

Abstract

*Owing to limited cropped area in Egypt's Nile Valley and Delta, efforts are underway to increase new cultivated areas in Nubaria and South Tahrier districts and other places. Chickpea (*Cicer arietinum *L.) is receiving great attention because of its ability to grow in sandy soils. Five research seasons since 1983 have shown several promising results. First, high mean seed yield exceeding 2 t ha^{-1} has been obtained from the ICRISAT/ICARDA International Yield Trials (CIYT-large seeded and CIYT-sub-tropical region). Higher yields were obtained from the large-seeded trials than from the small-seeded trials. Second, seed yields were higher in Nubaria district than in Tahrier district. The reasons for higher seed yield in Nubaria are being investigated. Third, sowings in the new area will require inoculation with* Rhizobium *culture for biological nitrogen fixation. Seed inoculation with ICARDA strain No. 44 and application of 80 kg of P_2O_5 and 60 kg of K_2O ha^{-1} produced a record yield of 4.12 t ha^{-1} at Nubaria Research Station. Fourth, the chickpea crop grown with sprinkler irrigation will require protection from ascochyta blight disease. Two cultivars, ILC 200 and ILC 482, were found consistently resistant to ascochyta blight. Also, a combination of seed dressing with fungicide Rh 50-50 and fungicide spray with Bavistin ® provides good control of the disease. Fifth, chickpea with a selling price of 2400 Egyptian pounds t^{-1} is highly profitable (1 US$ = 2.6 Egyptian pounds).*

Résumé

***Les pois chiches dans les zones récemment mises en culture en Egypte :** En raison de la superficie cultivée restreinte dans la vallée du Nil et le delta de l'Egypte, des efforts sont entrepris pour accroître les nouvelles superficies cultivées dans les districts de Nubaria et de Sud Tahrier et d'autres lieux. Le pois chiche (*Cicer arietinum *L.) attire beaucoup d'attention en raison de son aptitude à croître dans des sols sableux.*

Des travaux de recherche effectués pendant cinq campagnes depuis 1983 ont montré plusieurs résultats prometteurs. Premièrement, un rendement moyen en grains élevé, dépassant 2 t ha^{-1}, a été obtenue au cours des essais internationaux de rendement ICRISAT-ICARDA (CIYT-gros grains et CIYT-région sub-tropicale). Des rendements plus élevés ont été obtenus dans les essais à gros grains que dans les essais à petits grains. Deuxièmement, les rendements en grains étaient plus élevés dans le district de Nubaria que dans le district de Tahrier. Les causes de ce rendement plus élevé à Nubaria font l'objet d'une enquête. Troisièmement, les semis dans la nouvelle région exigeront l'inoculation de la culture de Rhizobium *pour assurer une fixation biologique de l'azote. L'inoculation des semences avec la souche N° 44 de l'ICARDA et l'épandage de 80 kg de P_2O_5 et de 60 kg de K_2O ha^{-1} ont fourni un rendement record de 4,12 t ha^{-1} à la station de recherche de Nubaria. Quatrièmement, la culture de pois chiche avec irrigation par aspersion exige une protection contre la flétrissure ascochytique. Deux cultivars, ILC 200 et ILC 482, ont été régulièrement résistants à la flétrissure ascochytique. Par ailleurs, une combinaison de l'enrobage des semences avec le fongicide Rh 50-50 et une pulvérisation de fongicide avec Bavistin® permet une bonne maîtrise de la maladie. Dernièrement, le pois chiche qui a un prix de vente de 2400 livres égyptiennes t^{-1} est très rentable (1 US$ = 2,6 livres égyptiennes).*

1. Chickpea Breeder, Agricultural Research Center, Field Crops Institute, Food Legumes Section, El-Gamma St., Giza, Egypt.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

Current Status and Future Prospects of Chickpea Production in Sudan

A.I. Sheikh Mohamed[1]

Abstract

*Chickpea (*Cicer arietinum *L.) is traditionally grown during the winter in the northern region of Sudan. The crop is sown on soils of the Nile banks, islands, and basins after the flood recedes. The area and production fluctuate depending on the floods. Average yield is about 1.2 t ha*$^{-1}$*. At present, all chickpea production is consumed locally. Prospects for an increase in area and production are bright because improved production technology is being transferred to farmers, and because indigenous and foreign demand is increasing.*

Data collected from the varietal evaluation and agronomic studies from the 1982/83 to 1986/87 seasons at Hudeiba and Shendi Research Stations in the northern region formed the basis for release of a kabuli type (NEC 2491/ILC 1335) under the name Shendi. This, when sown during November with a seed rate of 60 kg ha^{-1}*, fertilizer rate of 86 kg N ha*$^{-1}$ *and frequent irrigation, gave high yields at research stations and farmers' fields. Its seed yield exceeded the local type by 43% at Hudeiba and 24% at Shendi. Some constraints of production, such as diseases and storage damage by insects, are discussed.*

Résumé

Bilan actuel et possibilités d'avenir de la production du pois chiche au Soudan : *Le pois chiche (*Cicer arietinum *L.) est traditionnellement cultivé pendant l'hiver dans la région nord du Soudan. Les semis se font sur les sols des rives, des îles et des bassins du Nil après la décrue. La superficie plantée et la production varie selon les inondations. Le rendement moyen est d'environ 1,2 t ha*$^{-1}$*. A l'heure actuelle, toute la production de pois chiche est consommée sur place. Des possibilités d'augmentation de la superficie et de la production sont excellentes, parce que la technologie améliorée de production est transférée aux cultivateurs et parce que la demande locale et étrangère s'accroît.*

Les données rassemblées à partir de l'évaluation variétale et des études agronomiques au cours des campagnes de 1982/83 à 1986/87 aux stations de recherches de Shendi et Hudeiba, dans la région nord, ont constitué la base de la vulgarisation d'un type 'kabuli' (NEC 2491/ILC 1335) sous le nom de Shendi. Lorsque cette variété était semée en novembre avec un taux de semis de 60 kg ha^{-1}*, une dose d'engrais de 86 kg N ha*$^{-1}$ *et une irrigation fréquente, elle fournissait des rendements très élevés aux stations de recherches et dans les champs paysans. Le rendement en grain dépassait celui du type local de 43% à Hudeiba et de 24% à Shendi. Certaines contraintes de production, comme les maladies et les dégâts de stockage par les insectes, sont examinées.*

---

1. Plant Breeder, Agricultural Research Corporation, Hudeiba Research Station, P.O. Box 31, Ed-Damer, Sudan.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

The Strategy to Arrest Decline in Chickpea Production in Ethiopia

Abebe Tullu[1]

Abstract

*Ethiopia is a center of diversity for cultivated chickpea (*Cicer arietinum *L.). A wild relative (*Cicer cuneatum*) is reported to occur in the northern part of the country. Of the two types of chickpea, the desi type is predominantly grown and production is concentrated in the central and northern highlands of Ethiopia. The crop is grown on Vertisols and soils of vertic properties mostly on residual moisture at elevations between 1400-3000 m (asl) where the annual rainfall ranges from 600 to 2000 mm. The growing season is characterized by cool, moist, warm winters and dry, hot summers lasting from 85-150 days.*

Chickpea production increased progressively up to 236 200 tons in 1973 over an area of 302 000 ha, but then tended to decrease and level off and has since failed to recover; yields are generally low, 0.6-0.8 t ha^{-1}. Major reasons include: diseases, insect pests, and management practices; technical, postharvest, and social constraints; edaphic problems and poor extension services, yield instability, and low yield potential of the landraces.

The research thrust at Debre-Zeit Agricultural Research Center, Alemaya University of Agriculture is multidisciplinary in nature and covers pathology, entomology, weed science, breeding, agronomy, soil science, microbiology, and on-farm and demonstration trials. To date, problem identification in some major chickspea areas, variety release with recommended packages, identification of sources of resistance to root-rot/wilt diseases, germplasm evaluation and utilization, work on gameticides and proper time of emasculation and pollination and genetic variation of some indigenous and exotic chickpeas, and identification of chemicals to control diseases, pests, and weeds constitute the multidisciplinary team approach to arrest decline in chickpea production.

In more specific terms,the national chickpea improvement program should lay emphasis on : breeding for disease and drought resistance in well adapted short- to medium-duration cultivars; evaluation and utilization of indigenous and introduced materials of wide geographic origins; study of genotype x environment interaction in traditional and non-traditional chickpea areas; development of effective field screening techniques for major diseases followed by laboratory work to confirm the results of field screening; developing integrated disease and pest control; survey of major diseases and field and storage pests and assessment of their distribution and intensity across years and locations; intensified testing of improved production techniques in different systems of cropping through on-farm trials with the appraisal of socio-economic aspects; pilot production-cum-demonstration and mass popularization of recommended packages; production of pamphlets and compilation of literature for use by extension workers and farmers; research under irrigated conditions; cropping sequence, double cropping, intercropping and fertilizer studies. To be successful in these activities, the development of improved multilocational testing programs with zonal responsibility but with one center coordinating the overall national program; training high-level research personnel and collaborative research proposals with ICRISAT and ICARDA are required. To create appropriate incentives towards boosting production, government policies favoring farmers should be developed.

1. Coordinator, Chickpea Research, Debre-Zeit Agricultural Research Center, Alemaya University of Agriculture, P.O. Box 32, Debre-Zeit, Shoa, Ethiopia.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

Résumé

Stratégie pour arrêter le déclin de la production de pois chiche en Ethiopie : *L'Ethiopie est un centre de diversité pour le pois chiche cultivé (*Cicer arietinum *L.). On a signalé, dans la partie nord du pays, une variété sauvage apparentée (*Cicer cuneatum*). Des deux types de pois chiche, le type 'desi' est le plus fréquemment cultivé et la production est concentrée dans les régions à haute altitude du centre et du nord de l'Ethiopie. La culture se fait sur des vertisols et des sols à propriétés vertiques surtout sur humidité résiduelle à des altitudes entre 1400 et 3000 m (au-dessus du niveau de la mer) où la pluviosité annuelle varie entre 600 et 2000 mm. La saison de culture est caractérisée par des hivers frais et humides, et des étés secs et très chauds, durant entre 85 et 150 jours.*

La production de pois chiche a augmenté progressivement pour parvenir à 236 200 tonnes en 1973 sur une superficie cultivée de 302 000 hectares, mais elle a ensuite tendu à baisser et n'a pas repris son avance précédente; les rendements sont généralement faibles : 0,6 à 0,8 t ha^{-1}. *Les principales raisons comprennent : maladies, insectes ravageurs et façons culturales; contraintes techniques, post-récoltes et sociales; problèmes édaphiques et services de vulgarisation inefficaces, instabilité du rendement et faible potentiel de rendement des variétés locales.*

L'effort de recherche du Centre de Recherche Agricole de Debre-Zeit, Université Alemaya d'agriculture, est pluridisciplinaire de par sa nature et porte sur la pathologie, l'entomologie, la malherbologie, la sélection, l'agronomie, la science des sols, la microbiologie, les essais en milieu réel et de démonstration. Aujourd'hui, l'approche de l'équipe pluridisciplinaire pour arrêter le déclin de la production de pois chiche se traduit par l'identification de problèmes dans certaines grandes régions de culture de pois chiche, la vulgarisation de variétés accompagnée d'un ensemble de recommandations, l'identification de sources de résistance aux maladies de pourriture des racines/flétrissement, l'évaluation et l'utilisation du matériel génétique, le travail sur les gaméticides et le meilleur moment pour la castration et la pollinisation, et la variation génétique de certains pois chiches indigènes et exotiques, ainsi que par l'identification de produits chimiques pour lutter contre les maladies, les ennemis et les adventices.

En termes plus spécifiques, le programme national d'amélioration du pois chiche devrait insister surtout sur : sélection pour la résistance aux maladies et à la sécheresse dans des cultivars bien adaptés, à cycle court et moyen; évaluation et utilisation de matériel indigène et introduit d'origines géographiques variées; étude de l'interaction génotype × environnement dans les zones de cultures traditionnelles et non traditionnelles du pois chiche ; développement de techniques efficaces de criblage au champ pour les principales maladies, suivi par un travail en laboratoire pour confirmer les résultats des criblages au champ; mise au point d'une lutte intégrée contre les maladies et les ennemis; étude des principales maladies et des ennemis des champs et de stocks et évaluation de leur distribution et de leur intensité en fonction des années et des emplacements; essais intensifiés de techniques de production améliorés dans différents systèmes de culture, par essais en milieu paysan avec l'évaluation des aspects socio-économiques; production et démonstration pilote et popularisation en masse de recommandations; production de brochures et compilation des informations pour usage par les vulgarisateurs et les cultivateurs; recherches dans des conditions d'irrigation; séquence de culture, culture double, cultures associées et études sur les engrais. Pour réussir dans ces activités, il est nécessaire de mettre au point des programmes améliorés d'essais multilocaux avec responsabilité zonale mais avec un seul centre coordonnant le programme national global; de former un personnel de recherche de haut niveau; et de mettre en place des propositions de recherches collaboratives avec l'ICRISAT et l'ICARDA. Afin de créer des primes appropriés pour augmenter la production, il faut mettre en place des politiques gouvernementales qui favorisent les cultivateurs.

Dual-season Chickpea

M. Kamal[1] and M.M.B. Solh[2]

Abstract

Chickpea (Cicer arietinum *L.) is normally sown in the Mediterranean basin during spring (February–April) and raised on residual moisture. In spite of the success of winter-sown chickpea, spring-sown chickpea will continue to have its place in the farming systems especially in hot spots of* Ascochyta rabiei. *Dual-season chickpea aims at the development of cultivars adapted to both winter and spring seasons. Such cultivars will (a) provide farmers with the flexibility to sow chickpea any time between winter and spring, (b) reduce the risk of building up ascochyta blight inoculum and disease spread, (c) facilitate crop management-e.g., weed control through pre-sowing cultivation after the first rains, and (d) facilitate breeding operations and seed multiplication. In a study conducted in Morocco, 36 advanced breeding lines were evaluated for their adaptation to winter- and spring-season sowing during the period 1987 to 1989 at three locations representing three distinct agroclimatic conditions. Nine lines showed dual-season adaptation: FLIP 82-150C, FLIP 83-47C, FLIP 83-48C, FLIP 84-8C, FLIP 84-72C, FLIP 84-92C, FLIP 84-144C, FLIP 84-182C, and ILC 195. Selection was based on high performance across the 12 environments, resistance to ascochyta, and early to medium maturity. The relationships between genotype mean yields and regression coefficients on location means, as well as ecovalence values confirmed the superiority of these genotypes as dual-season cultivars, particularly of FLIP 84-92C, ILC 195, and FLIP 84-182C. In winter sowing, yield advantages with these lines across locations were 44% over the best improved winter cultivar in 1987/88 and 24% in 1988/89. In spring sowing, the yield advantages were 34% in 1987/88 and 39% in 1988/89 over the best local spring cultivars. Under heavy ascochyta blight pressure in one location during 1988/89, these lines scored 4 or less on a 1 to 9 rating scale, where 1 = disease free and 9 = complete kill.*

Résumé

Pois chiche à double saison : *Le pois chiche* (Cicer arietinum *L.), est normalement semé dans le bassin méditerranéen pendant le printemps (février à avril) et la culture se fait sur humidité résiduelle. En dépit du succès du pois chiche à semis d'hiver, le pois chiche à semis de printemps continuera à jouer son rôle dans les systèmes d'exploitation, particulièrement dans les sites de forte infection par* Ascochyta rabiei. *Le pois chiche à double saison vise le développement des cultivars adaptés aux saisons d'hiver aussi bien que de printemps. De tels cultivars (a) permettront aux cultivateurs de semer du pois chiche à tout moment entre l'hiver et le printemps, (b) réduiront le risque d'accumulation de l'inoculum de la flétrissure ascochytique et du développement de la maladie, (c) faciliteront la gestion des cultures (par exemple, la maîtrise des adventices par culture présemis après les premières pluies), et (d) faciliteront les opérations de sélection et de multiplication de semences. Dans une étude entreprise au Maroc, 36 lignées de sélection avancée ont été évaluées pour l'adaptation aux semis d'hiver et de*

1. National Food Legume Coordinator, Arid Culture Project, Station Centrale des Legumineuses Alimentaires, Centre Régionale de Recherche Agronomique, B.P. 589, Settat, Morocco.

2. Regional Food Legume Breeder - North Africa (ICARDA), BP 6299, Rabat-Institutes, Rabat, Morocco.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

printemps pendant la période 1987 à 1989 à trois emplacements représentant trois conditions agroclimatiques distinctes. Neuf lignées ont manifesté une adaptation à double saison : FLIP 82-150C, FLIP 83-47C, FLIP 83-48C, FLIP 84-8C, FLIP 84-72C, FLIP 84-92C, FLIP 84-144C, FLIP 84-182C et ILC 195. La sélection était basée sur une forte performance dans les douze environnements; la résistance à la flétrissure ascochytique et une maturité précoce à moyenne. Les rapports entre les rendements moyens des génotypes et les coefficients de régression sur les moyennes des emplacements, ainsi que les valeurs d'écovalence ont confirmé la supériorité de ces génotypes comme cultivars de double saison, particulièrement celle de FLIP 84-92C, ILC 195 et FLIP 84-182C. Les avantages de rendement des semis d'hiver avec ces lignées dans divers emplacements étaient de 44% par rapport aux meilleurs cultivars d'hiver améliorés en 1987/1988 et de 24% en 1988/1989. Dans le cas des semis de printemps, l'avantage de rendement était de 34% en 1987/1988 et de 39% en 1988/1989 sur les meilleurs cultivars de printemps locaux. Sous une forte pression de la flétrissure ascochytique dans un emplacement en 1988/1989, ces lignées ont enregistré 4 ou moins sur une échelle de notation de 1 à 9, où 1 = exempt de maladie et 9 = destruction complète.

Prospects of Winter Chickpea in Algeria

M. Labdi[1], Z. Bousnad[2], M.M.B. Solh[3], and J. Wery[4]

Abstract

Experiments on winter chickpea (Cicer arietinum) *conducted in farmers' fields showed significant yield increases over spring chickpea in western Algeria. The main factors that contributed to seed yield increase are: (1) use of ascochyta blight-resistant cultivars; (2) lower drought stress during the grain filling period; and (3) better harvesting techniques.*

Yields in winter-sown chickpea using ILC 3279 and ILC 482 over 3 years ranged between 0.4 and 10.6 t ha^{-1} and between 0.5 and 14 t ha^{-1}, respectively, whereas yields of the spring-sown local landrace ranged from 0.1 to 0.85 t ha^{-1}. The increase in yield motivated farmers to extend the area under chickpea. Future research is directed towards the development of large-seeded, early-maturing, ascochyta blight-resistant, high-yielding cultivars, and improved production technologies for winter sowing.

Résumé

Possibilités du pois chiche d'hiver en Algérie : *Des essais effectués en milieu réel sur le pois chiche d'hiver (*Cicer arietinum*) ont montré des améliorations significatives de rendement sur le pois chiche de printemps en Algérie occidentale. Les principaux facteurs qui ont contribué à l'augmentation du rendement en grains étaient : (1) l'emploi des cultivars résistants à la flétrissure ascochytique; (2) le stress hydrique moins élevé pendant la période de remplissage des gousses; et (3) de meilleures techniques de récolte.*

Les rendements obtenus avec les pois chiches ILC 3279 et ILC 482 semés en hiver pendant 3 années ont varié entre 0,4 et 10,6 t ha^{-1} et entre 0,5 et 14 t ha^{-1}, respectivement, alors que les rendements de la variété locale semée au printemps ont varié de 0,1 à 0,85 t ha^{-1}. L'augmentation du rendement a encouragé les paysans à accroître la superficie cultivée en pois chiche. Les travaux de recherche futurs visent, d'une part, la mise au point de cultivars précoces et à gros grains, à haut rendement et résistants à la flétrissure ascochytique, et de l'autre part, la réalisation de technologies améliorées de production pour les semis d'hiver.

1. Food Legume Coordinator, Institut technique des grandes cultures (ITGC), BP No. 59, Sidi Bel Abbes, Algeria.
2. Assistant Professor, Department de botanique, INRA-Alger, Rue Pasteur, El-Harrach, Alger, Algeria.
3. Regional Food Legume Breeder - North Africa (ICARDA), BP 6299, Rabat-Institutes, Rabat, Morocco.
4. Assistant Professor of Crop Physiology, Ecole nationale superieure agronomique (ENSA)/Institut national de la recherche agronomique (INRA), 2, Place Viala, 34060 Montpellier, Cedex 1, France.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

Effect of Advancing Sowing Dates on Chickpea Production in Turkey

D. Sakar[1] and B. Yilmaz[2]

Abstract

Experiments were conducted with ascochyta-resistant and cold-tolerant cultivars to investigate the effect of advancing sowing time on productivity of chickpea in Diyarbakir, southeastern Anatolia, and in Ankara and Eskisehir, Central Anatolian Plateau.

The following cultivars were used: ILC 195, ILC 482, ILC 201, and ILC 3279 in Diyarbakir, ILC 195, Eser 87, and a local control in Ankara, and Canitez 87 in Eskisehir. Chickpea cultivars were sown at five different dates (20 December, 20 January, 20 February, 20 March,and 20 April) in Diyarbakir during 1986, 1987,and 1989. There were four sowing dates (30 March,15 April, 30 April, and 15 May) in Ankara in 1985, and also four sowing dates (25 March, 15 April, 5 May, and 25 May) in Eskisehir in 1986.

Advancing sowing time to December, January, or February resulted in 100% or more seed yield than the traditional sowing time in March and April under southeastern Anatolian conditions. However, the highest seed yield (1.77 t ha^{-1}) was obtained from the December sowing. Sowing in late March or April also produced 60% or more seed yield than traditional May sowing under central Anatolian conditions in Ankara and Eskisehir.

On-farm demonstrations with ILC 482 in southeastern Anatolia and with 86 AK 71114 in central Anatolia confirmed a significant increase in productivity when it was sown earlier than at the traditional sowing time. These two lines and nine other promising lines are being tested in on-farm trials. Some may be registered as cultivars in the near future.

Turkey has recorded a significant increase in chickpea production and has become the second highest chickpea producing country in the world, mainly due to fallow replacement in cereal-fallow rotation. It is expected that production will further increase with the introduction of winter sowing in southeastern Anatolia and early spring sowing in central Anatolia.

Résumé

***Influence de l'avancement des dates de semis sur la production du pois chiche en Turquie :** Des essais ont été effectués avec des cultivars résistants à la flétrissure ascochytique et tolérants au froid dans le but d'étudier l'effet de l'avancement du temps de semis sur la productivité de pois chiche à Diyarbakir, en Anatolie du sud-est, et à Ankara et Eskisehir, (Plateau d'Anatolie centrale).*

Les cultivars suivants étaient utilisés : ILC 195, ILC 482, ILC 201, et ILC 3279 à Diyarbakir, ILC 195, Eser 87, et un témoin local à Ankara, et Canitez 87 à Eskisehir. Les cultivars étaient semés à cinq dates différentes (20 décembre, 20 janvier, 20 février, 20 mars et avril) à Diyarbakir, en 1986, 1987 et 1989. Il y avait quatre dates de semis (30 mars, 15 avril, 30 avril et 15 mai) à Ankara en 1985, et quatre dates de semis également (25 mars, 15 avril, 5 mai, et 25 mai) à Eskisehir, en 1986.

L'avancement du temps de semis à décembre, janvier ou février a rendu possible une augmentation du rendement en grains de 100% ou plus par rapport au temps de semis

1. Director and Food Legume Coordinator, Tarimsal Arastirma, Enstitusu Mudurlugu, P.O. Box 72, Diyarbakir, Turkey.
2. Director, Field Crops Improvement Center, P.O. Box 226, Ulus, Ankara, Turkey.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

traditionnel en mars et avril dans des conditions d'Anatolie du sud-est. Cependant, le rendement en grains le plus élevé (1,77 t ha^{-1}) était obtenu du semis de décembre. Le semis en fin mars ou avril a également produit un rendement en grains de 60% ou plus par rapport au semis traditionnel en mai, dans les conditions d'Anatolie centrale à Ankara et à Eskisehir.

Les démonstrations au champ avec ILC 482 en Anatolie du sud-est, et avec 86 AK 71114 en Anatolie centrale, ont confirmé l'augmentation significative de la productivité lorsque le pois chiche est semé plus tôt que le temps traditionnel de semis. Ces deux lignées, ainsi que neuf autres lignées prometteuses sont en cours d'étude dans les essais au champ. Certaines lignées pourraient être enregistrées en tant que cultivars dans l'avenir proche.

La Turquie a enregistré une augmentation significative de la production du pois chiche et est devenue le deuxième pays producteur de pois chiche dans le monde, essentiellement dû au remplacement de la jachère dans la rotation céréale–jachère. La production devrait s'élever encore avec l'introduction du semis de début printemps en Anatolie centrale.

Winter Chickpea in Syria

M.W. Tawil[1]

Abstract

*Chickpea (*Cicer arietinum *L.) is an important food legume in Syria. It is sown at the beginning of the spring season (March-April) and harvested in the summer (June-July) in the rainfed areas with 300-500 mm of annual rainfall. Because of large variations in amount and distribution of rainfall the area sown with spring chickpea fluctuates between 25 000 and 90 000 ha. The local chickpea is of good quality and is adapted to drought conditions, but gives low yield. Therefore, to improve the utilization of winter rainfall for chickpea production, winter sowing was attempted. Since local chickpea cultivars are susceptible to ascochyta blight, genotypes obtained from ICARDA were evaluated for disease resistance to select those suitable for winter sowing.*

Work on winter chickpea since 1979 has resulted in the release of two genotypes during 1986: (1) ILC 482 (ex-Turkey) under the name of Ghab 1, and (2) ILC 3279 (ex-USSR) under the name of Ghab 2. These cultivars are suitable for areas with an annual rainfall of 300-550 mm, are more resistant to cold and ascochyta blight than the local chickpea, and can be mechanically harvested. Yields of Ghab 1 were 1.37 t ha^{-1} and Ghab 2 were 1.07 t ha^{-1}, when sown during the winter as compared to 0.84 t ha^{-1} for the local spring-sown cultivar. After 3 years of seed increase, the General Seed Multiplication Organization in Syria started distributing seed of these new cultivars to farmers as from the 1989/90 crop season.

Further research has resulted in the identification of FLIP 82-150C with a higher level of resistance to cold and ascochyta blight and better seed yield than Ghab 1 and Ghab 2, and is under consideration for release. Four years of yield testing numerous lines has helped in selection of FLIP 84-15C with a 100-seed mass of 46 g against 38 g for the local variety. This new line has produced higher yields than Ghab 1 and Ghab 2 and is now in on-farm trials. With these cultivars available it is expected that winter sowing of chickpea will spread and increase productivity and stabilize production in Syria.

Résumé

Pois chiche d'hiver en Syrie : *Le pois chiche (*Cicer arietinum *L.) est une importante légumineuse alimentaire en Syrie. Il est semé au début de la saison de printemps (mars-avril) et récolté en été (juin-juillet) dans les zones pluviales qui ont 300 à 500 mm de pluviosité annuelle. En raison de fortes variations de la quantité et de la répartition des pluies, les superficies semées en pois chiche de printemps fluctuent entre 25 000 et 90 000 ha. Le pois chiche local est de bonne qualité et est adapté aux conditions de sécheresse, mais a un faible rendement. Donc, pour améliorer l'utilisation des pluies d'hiver pour la production de pois chiche, les semis d'hiver ont été essayés. Les cultivars locaux de pois chiche étant sensibles à la flétrissure ascochytique, les génotypes obtenus de l'ICARDA ont été évalués pour la résistance aux maladies afin de sélectionner ceux qui conviennent aux semis d'hiver.*

Le travail sur le pois chiche d'hiver depuis 1979 a permis de vulgariser deux génotypes en 1986 : (1) ILC 482 (ex-Turquie) sous le nom de Ghab 1, et (2) ILC 3279 (ex-URSS) sous le nom de Ghab 2. Ces deux cultivars conviennent aux régions à pluviosité annuelle de 300 à 550 mm;

1. Head of Field Crops Division, Directorate of Scientific Agricultural Research, Ministry of Agriculture and Agrarian Reform, Douma, P.O. Box 113, Damascus, Syria.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

ils résistent mieux au froid et à la flétrissure ascochytique que le pois chiche local et peuvent être récoltés mécaniquement. Les rendements de Ghab 1 étaient de 1,37 t ha^{-1} et ceux de Ghab 2 étaient de 1,07 t ha^{-1}, avec le semis d'hiver, contre 0,84 t ha^{-1} pour le cultivar local semé au printemps. Après trois années d'augmentation des semences, l'Organisation Générale de Multiplication des Semences en Syrie a commencé à distribuer des semences de ces nouveaux cultivars aux paysans à partir de la campagne de culture de 1989/1990.

De nouvelles recherches ont permis d'identifier FLIP 82-150C à niveau plus élevé de résistance au froid et à la flétrissure ascochytique ainsi qu'un meilleur rendement en graines que Ghab 1 et Ghab 2. La vulgarisation de cette lignée est envisagée. Quatre années d'essais de rendement de nombreuses lignées ont permis de sélectionner le FLIP 84-15C avec une masse de 100 graines de 46 g contre 38 g pour la variété locale. Cette nouvelle lignée a fourni de meilleurs rendements que Ghab 1 et Ghab 2 et est actuellement aux essais en milieu paysan. Avec ces deux cultivars, on prévoit que les semis d'hiver du pois chiche se répandront et augmenteront la productivité et stabiliseront la production en Syrie.

Status of Chickpea Production in Iraq

A.I. Abbas[1]

Abstract

*Chickpea (*Cicer arietinum *L.) is the second most important food legume after faba bean in Iraq. Its cultivation is concentrated in the northern part of Iraq including Sulaymania, Dohok, Arbil, and Nainava provinces. It is mainly grown as a rainfed crop, but the possibility of growing it with supplemental irrigation is being explored. Chickpea is grown over an area of 14 000 ha. However, chickpea cultivation has continuously declined mainly due to the lack of improved cultivars and cultural practices, and difficulties encountered with crop mechanization. The average seed yield in the last 10 years has been 0.74 t ha^{-1}, but yields up to 1.7 t ha^{-1} have been obtained at experiment stations.*

Local chickpea production meets only 6.4% of the total consumption; the remaining 93.6% is met by import. The strategy to meet Iraq's chickpea demand is twofold: (a) through the development of improved cultivars and production practices; and (b) through the replacement of fallow in cereal–fallow rotation. The past research effort has helped to identify four chickpea cultivars, namely ILC 482, ILC 3279, FLIP 82-169C, and FLIP 81-293C that are suitable for winter sowing and are capable of producing high yields. Out of 500 000 ha rainfed area, 166 500 ha remains fallow. There is a possibility that 20% of the fallow land, or 33 300 ha, could be brought under chickpea cultivation provided seed of improved cultivars can be produced and that the crop can be properly mechanized. When this happens, two-thirds of Iraq's need will be met.

Résumé

***Bilan de la production de pois chiche en Irak :** Le pois chiche (*Cicer arietinum *L.) est la deuxième légumineuse alimentaire la plus importante après le haricot faba en Irak. Sa culture est concentrée dans la partie nord de l'Irak, y compris les provinces de Sulaymania, Dohok, Arbil et Nainava. Il est surtout exploité comme culture pluviale mais la possibilité de culture avec l'irrigation supplémentaire est à l'étude. Le pois chiche est cultivé sur une superficie de 14 000 hectares. Toutefois, la culture a baissé de manière continue, surtout en raison du manque de cultivars et de pratiques culturales améliorés et des difficultés rencontrées lors de la mécanisation de la culture. Le rendement moyen en grains des dix dernières années a été de 0,74 t ha^{-1}, mais des rendements allant jusqu'à 1,7 t ha^{-1} ont été obtenus aux stations expérimentales.*

La production locale de pois chiche ne couvre qu'environ 6,4% du total de la consommation; les 93,6% restant sont couverts par les importations. La stratégie pour répondre à la demande de pois chiche de l'Irak est double: (a) par la mise au point de cultivars et de pratiques de production améliorés; et (b) par le remplacement de la jachère dans la rotation céréale–jachère. Les derniers efforts de recherches ont aidé à identifier quatre cultivars de pois chiche, à savoir ILC 482, ILC 3279, FLIP 82-169C et FLIP 81-293C, qui conviennent aux semis d'hiver et peuvent produire des rendements élevés. Sur 500 000 ha de superficie pluviale, 166 500 ha

1. Head, Food and Forage Legumes, Ministry of Agriculture and Irrigation, State Board for Agricultural and Water Resources Research, Abu-Gharib, Baghdad, Iraq.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

demeurent en jachère. Il est possible que 20% de la terre sous jachère, soit 33 300 ha, pourraient servir à la culture du pois chiche, à condition de pouvoir produire des semences de cultivars améliorés et que la culture soit adéquatement mécanisée. Lorsque cela se produira, les deux-tiers des besoins de l'Irak seront satisfaits.

Problems and Solutions of Chickpea Production in Iran

B. Sadri[1] and A. Kahrobaian[2]

Abstract

Some 18 x 10^6 ha out of approximately 1610 x 10^6 ha in Iran are cultivated. Owing to insufficient moisture, one-third of the cultivated area, is left fallow each year. The area devoted to food legume production is 509 000 ha per annum.

*Chickpea (*Cicer arietinum *L.) is the most important food legume grown, occupying 316 000 ha. Chickpea is grown mostly as a rainfed crop (275 000 ha), although some 41 000 ha is raised under supplemental irrigation. The crop is sown at high elevations during March and April and harvested during July and August. The major limiting factors in chickpea production are lack of high-yielding cultivars, terminal drought stress, and the crop's unsuitability for mechanization.*

Research on chickpea is conducted at 18 experiment stations spread across the country. The main objective is to increase seed yield through the development of cultivars that are resistant to diseases, drought, cold, and seed shattering, mature early, are suitable for machine harvesting, and meet consumer acceptance. So far, four improved cultivars have been released; two kabuli types known as Jam and Koorosh, and two desi types Kaka and Perooz. Some suggestions for increasing chickpea production include interaction with the international agricultural research centers (especially for obtaining improved germplasm and training), popularization of improved cultivars and technologies through pilot farms, mass media and training of farmers, and the introduction of cereal-fallow rotation of chickpea on fallow land.

Résumé

***Problèmes et solutions de la production de pois chiche en Iran :** Environ 18 × 10^6 ha, sur environ 1610 × 10^6 ha à l'Iran sont cultivés. En raison de l'insuffisance d'humidité, un tiers de la superficie cultivée est laissée en friche chaque année. La superficie consacrée à la production de légumineuses alimentaires est de 509 000 hectares par an.*

*Le pois chiche (*Cicer arietinum *L.) est la légumineuse alimentaire la plus importante qui soit cultivée, occupant 316 000 hectares. Le pois chiche est cultivé surtout sous le régime pluvial (275 000 ha) bien qu'environ 41 000 ha soient cultivés avec l'irrigation supplémentaire. La culture est semée aux altitudes élevées en mars et avril et récoltée en juillet-août Les principaux facteurs limitants de la production du pois chiche sont le manque de cultivars à haut rendement, la contrainte de sécheresse terminale et le fait que cette culture ne convient pas à la mécanisation.*

Les recherches sur le pois chiche sont entreprises à 18 stations expérimentales réparties à travers le pays. Le principal objectif est d'accroître le rendement en grains par la mise au point de cultivars résistants aux maladies, à la sécheresse, au froid et à l'éclatement des semences, tout en ayant une maturation précoce, convenant à la récolte mécanisée et satisfaisant la préférence des consommateurs. Jusqu'à présent, quatre cultivars améliorés ont été vulgarisés :

1. Head, Food Legume Research Department, Seed and Plant Improvement Institute, Ministry of Agriculture, Mard - Abad Avenue, Karadj, Iran.

2. Chickpea Breeder, Agricultural Research Center, Meshhad, Iran.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

deux types 'kabuli', dénommés Jam et Koorosh, et deux types 'desi', Kaka et Perooz. Quelques suggestions pour l'augmentation de la production de pois chiche comprennent l'interaction avec les centres internationaux de recherches agricoles (surtout pour obtenir des ressources génétiques améliorées et la formation), la popularisation de cultivars et de technologies améliorés par le moyen d'exploitations-pilotes, l'usage des moyens de masse et la formation des cultivateurs, ainsi que l'introduction de la rotation céréale-jachère de pois chiche sur terre en friche.

Winter Sowing: A Major Breakthrough in Chickpea Production in Cyprus

A. Hadjichristodoulou[1]

Abstract

*Traditionally, chickpea (*Cicer arietinum *L.) has been sown in spring in Cyprus because the local cultivar is susceptible to* Ascochyta rabiei. *Winter-sown chickpea in the absence of ascochyta blight gives at least double the yield of spring-sown chickpea. During an epidemic year, the yield of the winter-sown local cultivar can be zero.*

During 1979, a program was initiated aiming at selection of tall, ascochyta blight resistant, high-yielding cultivars suitable for winter sowing and mechanical harvesting. It also aimed at selecting lines having large seeds (1000-seed mass >300 g) white to beige in color. The material screened was received from ICARDA. Two cultivars were released. One ILC 3279 (named Yialousa) has good cooking qualities, is tall (50-60cm under rainfed conditions), and is ascochyta blight resistant, but its seeds are relatively small (1000-seed mass 228 g compared to 262 g of the local). Another new cultivar, ILC 464 (named Kyrenia) was released in 1988. Compared with the local cultivar the grain yield is 23% higher, the grain size 42% greater, and the plant height 7 cm more. It is also more resistant to ascochyta blight. However, Kyrenia is more susceptible to ascochyta blight than Yialousa. In recent tests a new promising line, FLIP 85H 10C, obtained from ICARDA, out-yielded Yialousa by 20% and Kyrenia by 6%. It is tall (59 cm), has large seeds (1000-seed mass 338 g) and is resistant to ascochyta blight.

Studies on the association among traits under Mediterranean rainfed conditions revealed first, that yield was negatively correlated with days to flowering (r = -0.85). Second, yield was positively correlated with number of pods per plant (r = 0.90), with plant height (r = 0.72) and with 1000-seed mass (r = 0.35). Third, early flowering lines produced more pods (r = -0.8) and were taller than late lines (r = -0.6). Fourth, plant height was positively correlated with number of pods per plant (r = 0.73), and 1000-seed mass (r = 0.39). Finally, the number of pods per plant was positively correlated with 1000-seed mass (r = 0.32). It is concluded that selection for early, tall genotypes in dry Mediterranean conditions will positively affect yield components such as number of pods per plant, 1000-seed mass, and seed yield.

Résumé

Semis d'hiver—un grand pas pour la production du pois chiche à Chypre : *Traditionnellement, le pois chiche (*Cicer arietinum *L.) a été cultivé à Chypre comme culture à semis de printemps, parce que le cultivar local est sensible à l'*Ascochyta rabiei. *Le pois chiche semé en hiver en l'absence de la flétrissure ascochytique fournit un rendement au moins deux fois plus important que celui du pois chiche à semis de printemps. Pendant une année d'épidémie, le rendement du cultivar local à semis d'hiver peut être zéro.*

En 1979, un programme a été organisé, visant à la sélection de cultivars grands, résistant à la flétrissure ascochytique et à haut rendement, convenant aux semis d'hiver et à la récolte

1. Head, Field Crops Section, Agricultural Research Institute, Ministry of Agriculture and Natural Resources, Nicosia, Cyprus.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

mécanisée. Il s'agit aussi de sélectionner des lignées à gros grains (masse de 1000 grains >300 g) de couleur blanche ou beige. Le matériel criblé a été reçu de l'ICARDA. Deux cultivars ont été vulgarisés. Le ILC 3279 (appelé Yialousa) a une bonne qualité de cuisson; il est grand (50-60 cm sous culture pluviale), et résistant à la flétrissure ascochytique mais ses graines sont relativement petites (masse de 1000 graines = 228 g contre 262 g pour la variété locale). Un autre nouveau cultivar, ILC 464 (dénommé Kyrenia) a été vulgarisé en 1988. En comparaison avec le cultivar local, le rendement en grains est supérieur de 23%, la taille des grains est supérieure de 42%, et la hauteur de la plante, 7 cm de plus. Il est aussi plus résistant à la flétrissure ascochytique. Toutefois, Kyrenia est plus sensible à la flétrissure ascochytique que Yialousa. Dans des essais récents, une nouvelle ligne prometteuse FLIP 85H 10C, obtenue de l'ICARDA, a fourni un rendement supérieur de 20% à celui de Yialousa et de 6% à celui de Kyrenia. Cette variété est grande (59 cm), a de gros grains (masse de 1000 grains = 338 g) et résiste à la flétrissure ascochytique.

Des études sur l'association entre les caractères dans des conditions de culture pluviale dans la région de la Méditerranée ont révélé, premièrement, que le rendement a présenté une corrélation négative avec le nombre de jours jusqu'à la floraison (r = -0,85). Deuxièmement, le rendement présentait une corrélation positive avec le nombre de gousses par plante (r = 0,90), avec la hauteur de la plante (r = 0,72) et avec la masse de 1000 grains (r = 0,35). Troisièmement, les lignées à floraison précoce produisaient davantage de gousses (r = -0,8) et étaient plus grandes que les lignées tardives (r = -0,6). Quatrièmement, la hauteur de la plante présentait une corrélation positive avec le nombre de gousses par plante (r = 0,73), et avec la masse de 1000 grains (r = 0,39). Finalement, le nombre de gousses par plante présentait une corrélation positive avec la masse de 1000 grains (r = 0,32). La conclusion est que la sélection pour des génotypes précoces et grands dans des conditions sèches de la Méditerranée aura un effet positif sur les composants du rendement, comme le nombre de gousses par plante, la masse de 1000 grains et le rendement des grains.

Status of Chickpea (*Cicer arietinum*) in Afghanistan

A. Habibi[1]

Abstract

Food grain legumes are important in various parts of Afghanistan. They occupy 44 000 ha of land and produce about 38 000 t annually. The yields are relatively low at 0.86 t ha^{-1} due to lack of improved varieties and poor cultural practice.

Chickpea is grown mainly in Takhar, Bulkh, Herat, Kunduz, Badukhshan, Kandahar, and Miamuna provinces as a rainfed crop, occupying about 60% of the total area of food grain legume crops in the country.

There is scope for increasing the area under food grain legumes especially chickpea because of the high price of animal protein.

Various chickpea landraces grow isolated at different altitudes, ranging from 300-2410 m while wild species occur at 900-5600 m asl.

Chickpea research started in 1975. For 2 years we have been receiving useful seed material, especially cold-tolerant chickpea, from ICARDA and also some material from ICRISAT. Although our research activities are limited, varietal trials during 1986-1988 under dryland conditions enabled us to identify the variety ILC 260 from Turkey as a good producer. The average yield was 2.99 t ha^{-1} compared with 1.66 t ha^{-1} for the local chickpea. Our recent research efforts at Darul-Aman Agricultural Research Station resulted in the identification of two winter chickpea varieties: FLIP 86-33C and ILC 482 (used as a long-term control variety in Turkey); both these varieties were selections from CISN-W-1987. Winter sowing gives higher yields than spring sowing.

Résumé

Bilan du pois chiche (*Cicer arietinum*) en Afghanistan : *Les légumineuses alimentaires sont importantes dans différentes parties de l'Afghanistan. Elles occupent 44 000 hectares et produisent environ 38 000 tonnes par an. Les rendements sont relativement faibles, de l'ordre de 0,86 t ha^{-1}, en raison du manque de variétés améliorées et l'emploi de pratiques culturales inefficaces.*

Le pois chiche est surtout cultivé dans les provinces de Takhar, Bulkh, Herat, Kunduz, Badukhshan, Kandahar et Miamuna, comme culture pluviale, occupant environ 60% de la superficie totale de légumineuses alimentaires dans le pays. Il serait possible d'augmenter la superficie plantée en légumineuses alimentaires, surtout de pois chiche, en raison du prix élevé de la protéine animale.

Diverses variétés locales de pois chiche se trouvent de manière isolée à différentes altitudes, variant entre 300 et 2410 m, tandis que les espèces sauvages se trouvent entre 900 et 5600 m au-dessus du niveau de la mer.

La recherche sur le pois chiche a commencé en 1975. Depuis deux ans, nous recevons des semences utiles, particulièrement de pois chiche tolérant au froid, en provenance de l'ICARDA, ainsi que du matériel de l'ICRISAT. Bien que nos activités de recherches soient restreintes, les essais variétaux en 1986/88 dans des conditions pluviales nous ont permis

1. Junior Scientist, Agricultural Research Institute, Ministry of Agriculture and Land Reforms, Kabul, Afghanistan.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

d'identifier la variété ILC 260 de la Turquie comme étant un bon producteur. Le rendement moyen a été de 2,99 t ha^{-1}, contre 1,66 t ha^{-1} pour le pois chiche local. Nos efforts de recherches récents à la station de recherche agricole de Darul-Aman ont permis d'identifier deux variétés de pois chiche d'hiver : FLIP 86-33C et ILC 482 (employé comme une variété témoin à long terme en Turquie); toutes les deux variétés étaient des sélections obtenues de CISN-W-1987. Les semis d'hiver donnent des rendements supérieurs aux semis de printemps.

Session 7

Transfer and Exchange of Technology

Effective Networking in International Agricultural Research

N.J.H. Smith[1], D.L. Plucknett[2], and S. Ozgediz[2]

Abstract

Networking has penetrated virtually all fields of agricultural research, from farming systems research to the screening of crop germplasm. Networks can greatly facilitate research if certain principles are adhered to and pitfalls avoided. Fourteen principles for effective networking are provided as a backdrop to an analysis of some of the more common problems associated with networks. The main purpose of the paper is to help provide guidelines to make networks more efficient and to highlight remedial measures when problems occur.

Résumé

Des réseaux efficaces dans la recherche agricole : *Le système de réseaux a pénétré virtuellement dans tous les domaines de recherche agricole, depuis la recherche sur les systèmes d'exploitation jusqu'au criblage du pool génique des cultures. Les réseaux peuvent largement faciliter la recherche, si l'on respecte certains principes et si l'on évite certains pièges. Quatorze principes sont fournis en vue de l'établissement efficace de réseaux, servant de toile de fond à l'analyse de certains des problèmes les plus fréquents associés au réseaux. Le principal objectif de cette communication est d'offrir des lignes directrices permettant de réaliser des réseaux plus efficaces et de souligner des mesures de redressement pour faire face aux problèmes qui se posent.*

Networking appeals to scientists because they can share information, ideas, and technologies more readily than if they work in isolation. The idea of dividing research tasks, visiting each others' study sites, and participating in regular workshops is attractive to them. Networking in international agricultural research traces its origins to several disease screening nurseries for wheat in the early 1950s, and has recently burgeoned into a truly global phenomenon.

Hundreds of networks and sub-networks link agricultural scientists all over the world. Networks have formed to further research in many fields, ranging from screening crop germplasm to better understanding of livestock diseases. Four main types of network have evolved to meet the increased desire for cooperation among scientists: (i) information exchange networks; (ii) material exchange networks, mostly used for sharing crop germplasm and agricultural machinery; (iii) scientific consultation networks, in which minor adjustments to pre-existing research programs are made; and (iv) collaborative research networks which involve joint planning and a major reorientation of research (Plucknett et al. in press).

Although networks are benefiting agricultural research, their proliferation could overload already the understaffed and underfunded national agriculture research systems (NARS) and detract from the efficiency of research. Networking consumes time and resources, and scientists are likely to abandon collaborative research efforts if payoffs do not ensue. A review of principles for effective networking and some widely shared problems associated with international agricul-

1. Professor, Department of Geography, University of Florida, Gainesville, FL 32611, USA.
2. Scientific Advisor, and Management Advisor, Consultative Group on International Agricultural Research (CGIAR), World Bank, 1818 H St, NW, Washington, DC 20433, USA.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

tural research networks will help scientists and administrators avoid pitfalls and improve the efficiency of their research.

Principles for Success

Successful networking requires: (i) the identification of a widely shared problem; (ii) self-interest to motivate participants; (iii) involvement by participants in planning and management of the network; (iv) clear definition of the problem or focus of the network; (v) a base-line study to produce an authoritative founding document; (vi) a realistic research agenda; (vii) flexible research and management; (viii) constant infusion of new ideas and technologies; (ix) regular workshops or conferences to provide opportunities to assess progress and discuss issues; (x) collaborators to contribute resources; (xi) outside funding to facilitate travel, training, and meetings; (xii) collaborators with sufficient training and expertise to contribute effectively; (xiii) relatively stable network membership, and (xiv) efficient and enlightened leadership.

Not all of these principles have to be followed to ensure a successful network, but they are especially pertinent for material exchange, scientific consultation, and collaborative research networks.

Problems and Remedial Measures

Although networks are proliferating and evidently benefit research in agriculture and other scientific fields, even the most successful ones encounter problems. Indeed, the spectacular progress of some of the more dynamic networks may attract so many adherents and add on so many projects that research programs become unwieldy. Some of the problems explored here can be attributed to departures from basic networking principles outlined above.

Problems encountered in agricultural networks can be grouped roughly into three broad categories: (i) research quality, which relates to the conduct and quality of research, particularly methodological issues, uneven feedback of results from collaborators, data management, priorities and scope of the research agenda, planning, and proper characterization of study sites; (ii) personnel issues— such as rapid turnover of participants, the paying of collaborators, and language barriers; (iii) institutional problems, including such aspects as disbursing arrangements for funds, and associated accounting difficulties, the potential of networks to distort national programs, and inadequate credit and extension services to convey technology to farmers.

Research Quality

Quality of data or other products is a concern in some material exchange, scientific consultation, and collaborative research networks, particularly those dealing with international nurseries and agricultural machinery. Two components of research quality are analyzed here; acquiring and processing sufficient data to make research progress and reach reasonable decisions, and the quality of the information itself.

Communications Problems . Occasional dissatisfaction about the quality of communications has arisen in material exchange, scientific consultation, and collaborative research networks. Communication difficulties result from lack of motivation among participants and unreliable mail services. Many national programs in developing countries cannot make international telephone calls, or use courier and telex services due to budget constraints. Mail delivery in many countries is sporadic and untrustworthy. Courier firms are more reliable, but expensive. Some network sites have no telecommunication or mail services. International agencies can often facilitate communication by allowing network participants to channel communications through their offices.

Information Processing. Inefficient processing of information can retard the progress of a network. Information management is essential for effective networking. In the past, the Asian Rice Farming Systems Research Network (ARFSN) was plagued by the lack of an efficient computerized data management system. At the 18th meeting of the Working Group of ARFSN held in Pakistan in 1987, agreement was reached among collaborators to reduce differences in the way data emanating from networking trials are processed.

The falling price of computers and the increased use of satellites for telecommunication are improving data processing and opening up electronic mail services worldwide. Electronic mail allows instant communication between participants at a fraction of the cost of air couriers, telephone calls, or telexes.

Inadequate Responses. Some networks suffer from poor feedback, particularly during their early stages. In the 7th International Pearl Millet Adaptation Trial (IPMAT) in 1981, for example, seed packets were sent to 47 locations in 14 countries, but the coordinating body in India, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), received results from only 25 locations in 8 countries (ICRISAT 1984, p. 2). At one stage the International Maize and Wheat Improvement Center (CIMMYT), coordinator of the International Bread Wheat Screening Nursery (IBWSN), was obtaining feedback from only 36% of the sites participating in the global network (Dubin and Rajaram 1982). Low returns from international nurseries are due to a variety of resource and program difficulties.

On the human resource side, weak motivation of participants is particularly relevant. Excuses for not performing one's part range from lack of fertilizers to insufficient land for testing, but scientists will always find room, funds, or manpower for a project that interests them and is likely to bring them tangible benefits. Participants in international nurseries and other networks are keener when they see clear payoffs from collaboration.

Participation in international nurseries would be keener if fewer trials were burdened with lines that have not been properly checked out in advance. National scientists sometimes complain that too much "junk" germplasm is fed into international nurseries. More prescreening of materials would reduce the amount of poor-yielding or vulnerable lines incorporated into international nurseries. For example, the International Rice Research Institute (IRRI), coordinator for the International Rice Testing Program (IRTP), prescreens rice lines for rainfed conditions by orchestrating observational and yield nurseries in the Philippines, Northeast Thailand, and Bangladesh. From observational trials involving several hundred entries only the best performers qualify for IRTP yield trials.

It is also possible to improve the proportion of nursery sites reporting results to the coordinator by issuing preliminary reports of early returns. By alerting participants about outstanding performers before all results are tallied and analyzed, collaborators have time to request superior lines for the next test cycle. To speed up reporting of results and entice fuller cooperation, ICRISAT began using a computer in 1983 to issue preliminary results of IPMAT trials.

Data Quality . Even when collaborators in an international nursery report back results, the data may not always be reliable. The IRTP coordinator carefully checks all data returns from nursery sites. Several tests are performed on the returns, such as checking coefficients of variability, to detect impossible yield figures or unlikely scores on susceptibility to diseases and pests. In 1975, only 30% of IRTP returns were considered reliable; but by 1985, some three-quarters of the nursery results were found to be acceptable (D.V. Seshu, personal communication).

Variable Research Methodology. Quality does not only apply to networks dealing with germplasm screening. Networks whose primary product is research information can also suffer from uneven research output from participants. Farming systems research in eastern and southern Africa still leaves much to be desired in spite of sustained training efforts by CIMMYT staff. The indifferent quality of some farming systems research in the region has hampered progress of the CIMMYT Eastern and Southern Africa Economics Program. The Southeast Asian Universities Agroecosystem Network (SUAN), another scientific consultation network focusing on farming systems research, has also had problems with deficient data collection and sloppy analysis (Rambo and Sajise 1985).

Whenever possible, networks should adopt a common, or at least very similar, methodology. The methodological approach does not have to be a straitjacket however, and scientists should be allowed some leeway to adapt research to local conditions. But if participants stray too far from a commonly acceptable way of conducting the joint research effort, results may not be comparable.

Examples of research difficulties arising from using different methodologies can be drawn from a variety of networks. In the case of the International Network on Soil Fertility and Sustainable Rice Farming (INSURF), IRRI took on the responsibility of analyzing soil samples because several national programs used different techniques for assessing soil chemical and physical properties (Mamaril 1985).

Characterization of Study Sites . The proper characterization of study sites is often overlooked in research in networks. Unless the areas are properly described, results may not be comparable and extrapolations are risky. Accurate characterization of research locations is particularly vital to international nursery work and soil networks.

Improper identification of environmental parameters at research sites has been a problem in some soil fertility and germplasm testing networks (Greenland et al. 1987). Careless surveys of the chemical, physical, and climatic conditions of sites can lead to soil management recommendations that do not hold up in others that were thought to be 'similar' areas, or to crop yields that do not match results obtained from other sites in the nursery. One of the functions of the coordinator of the

International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) is to assist collaborating countries to properly identify soil sites within the network.

Soil identification is a problem for quite a few networks. Several soil classification systems are still in use worldwide, ranging from FAO/UNESCO's system to the United States Department of Agriculture (USDA) Soil Taxonomy. Rough equivalents can usually be found in each system, but precise analogs are difficult to establish. The USDA Soil Taxonomy is the finest-grained classification system and has the additional merit of using a scientific binomial nomenclature that follows clearly defined subdivisions. For these reasons, it has become the most widely used soil classification system since the early 1970s. But it has drawbacks for instance, it was devised for temperate climates and does not always work well in tropical environments (Whitmore 1985). Resistance to the complicated nomenclature of Soil Taxonomy, will decline as more scientists become familiar with the terminology.

Network Control . Networks must have clearly defined aims and be based upon realistic research agendas. The most successful networks run the greatest risk of departing from these principles because their high profile and achievements inevitably attract more followers and can lead to over ambitious research agendas. As a network grows, new collaborators often lobby to add more research projects. The balance between flexibility and disciplined adherence to an established research program is delicate. Networks are expected to evolve, take on new challenges, and follow fresh lines of inquiry. But if more and more tasks are taken on without others being completed or dropped, the enterprise can become overloaded and may stall. Not only are managerial problems more likely with larger networks, but the research thrust can become diffuse.

One solution is to create separate networks to tackle items that do not match, or at least complement, the original research agenda. Here we run into the dilemma of whether to lump or split networks. Packaging disparate topics into a single research enterprise is tidier for administrators, but may not make sense from the research viewpoint. Splitting the larger networks into smaller sub-networks, or creating new ones may be more sensible in some cases but, when carried too far, networks may multiply exponentially.

Personnel Issues

Staff Turnover . Rapid turnover of participants is high on the list of complaints of those involved in networks. The high turnover of potato scientists in Honduras, triggered by changes in political leadership at the national level, has hampered some projects within Programa Regional Cooperativo de Papa (PRECODEPA) a collaborative research network focusing on potato in Central America and the Caribbean. A similar problem has been noted with Papua New Guinea's participation in Southeast Asian Program for Potato Research and Development (SAPPRAD), a sister regional potato network operating in Southeast Asia. Frequent changes in staff in Ecuador's bean research program have hampered participation in the 14-country Bean/Cowpea Collaborative Research Support Program (CRSP).

Uncertainties and delays caused by excessive staff turnover is not confined to national agricultural research programs in developing countries. Scientists on temporary assignment to bilateral or larger networking activities must eventually return to their institutional duty, usually after only brief participation in the project.

When a collaborator leaves a network, a delay usually ensues until a new member comes on board, and becomes familiar with procedures. Rapid turnover of participants is especially critical during the early phases of networking. One or two individuals often provide the catalyst for establishing a network; if they leave too soon, the joint effort may stall.

In developing countries, the best scientists are often promoted to occupy administrative posts and so networks therefore often lose an appreciable number of members at a critical state. Once promoted to executive positions, scientists are usually cut off from the frontlines of research and rarely resume their scientific careers. However well organized, the ultimate success of a network rests largely on the quality of its members.

Training . Better training facilities and more rewarding careers in the agricultural sciences are crucial if the quality of participants in agricultural research networks in developing countries are to improve. Several developing countries have devoted considerable resources to improving the technical capabilities of their agricultural research staff. Mexico, for example, devotes US$ 2.6 million to postgraduate education for agricultural scientists; currently, some 10% of the Mexican agricultural research program's 2 200 staff have doctorate degrees and the proportion is growing. Brazil and India have also invested heavily in postgraduate training for their agricultural research scientists. This policy has enabled such countries to participate more fully in international networks.

Institutional and Bureaucratic Problems

Administration

Poor planning plagues some networks, particularly in their early stages. Difficulties may occur if a network is too informal and no government-level agreements have been made to expedite visas and the shipment of equipment and supplies. Whenever possible, networks should remain informal, but as more countries join international material exchange and collaborative research networks, the greater the need to formalize agreements between governments.

Coordination. Network coordinators and steering committees also need to pay closer attention to other planning matters, such as better coordination and timing of monitoring tours and training courses. The efficiency of some networks with multiple projects would be improved if there was better coordination among the sub-networks or facets of the main network (Greenland et al. 1987). Sufficient leadtime for all network activities is essential for a smooth operation.

Funding. Funding arrangements pose periodic problems in even the most successful and productive networks. Two major facets stand out: (i) insufficient funds to accomplish the task (a perennial complaint by scientists the world over); and (ii) the uneven flow of funds. The question of insufficient funds can usually be resolved with proper planning, a clear goal and realistic research agenda. And most importantly, some early successes will whet the appetite of donors. In an age of tightening funds for research, credibility becomes an ever more important asset.

The problem of inconsistent funding needs careful attention by network coordinators and their advisory boards. A research program can be inundated with funds at one stage, and then struggle through a prolonged period of financial drought. Demands on staff time and resources also follow a pattern of peaks and troughs, yet funding disbursements are not always in rhythm with the variable pace of scientific work. Insufficient funds forced the coordinator of the African Research Network on Agricultural Byproducts (ARNAB) to suspend publishing its newsletter in 1982. Fortunately, the funding picture brightened in 1983 enabling the International Livestock Center for Africa (ILCA) to resume publication of ARNAB's newsletter. Shifts in funding procedures, or outright withdrawal of support, by external donors can also undercut network efforts. In response to changes in funding policies of the United States Agency for International Development (USAID) in September 1985, for example, the IRRI Industrial Extension Network (IIEN) now restricts its activities to the Philippines.

The sporadic flow of funds for networks is partly due to the fact that most material exchange and research networks receive external funding from many sources, each with different schedules for releasing grants. The coordinator of the Trypanotolerant Livestock Network has worked out an informal agreement with the budget officer at ILCA, the network's coordinating institution, so that moneys are available to bridge funding gaps. Budget directors are essentially extending loans in such instances, and they are usually only prepared to do so when the network is performing well and external donors are reliable. International funding agencies, in turn, normally deliver on promises and commitments when the enterprise they are funding is viable. Flexibility in the accounting divisions of institutions coordinating networks and quality performances by network participants can ease the difficulties created by the fluctuating nature of scientific funding.

International agricultural research centers often coordinate international networks because they are usually fiscally more sound than national programs. ILCA, for example, with a 1985 budget of $15.7 million provided by 26 donors, had earned an unsecured $1 million credit line with a commercial bank. Many international agricultural research centers have similar flexibility to overdraw temporarily their accounts to prevent the disruption of research activities.

Funding flows from donors to networks could be evened out by creating some framework for coordinating support. At the moment, most donors, including multilateral and bilateral agencies, act independently. A liaison organization could be set up for each large international network, or group of networks, to pool funds from external donors and to release them according to need.

Although this idea has some merit, two difficulties surface immediately. First, donors may feel that they lack suitable control over their contributions. Glory for the success of a network may go to the scientists, research institutions, and the liaison organization, leaving external donors out of the limelight. Second, this additional level of bureaucracy between scientists and donors could be counterproductive. Bureaucracies absorb funds and have a tendency to grow ever larger and more complex. The administrative overhead of such an organization would inevitably siphon away some money earmarked for laboratories, libraries, and field work.

Member Participation. Prolonged and generous financial support without appreciable practical contributions from participants can be counterproductive. Inadequate support from national programs has been identified as the weakest link in most scientific consultation and collaborative research networks in Africa. The West Africa Rice Development Association (WARDA), an international agricultural research center based in Bouake, Côte d'Ivoire, has paid member countries in the region to supervise rice nurseries. Returns from such heavily subsidized nurseries have been extremely disappointing; not only have numerous sites not reported back data, but the information has often proved unreliable. Another problem with paying institutions to participate in networks is that collaboration usually ceases as soon as the flow of funds dries up. Agricultural research budgets in general have come under severe pressure with the global economic downturn in the early 1980s. Oil-exporting developing countries have been especially hard hit by the sharp dip in the world price of oil. Indonesia, for instance, slashed its operating budget for agricultural research by 50% in 1985. Such drastic cuts inevitably lead to the elimination of some projects and the scaling down of others. In 1986, the Bogor Research Institute for Food Crops (BORIF) was forced to withdraw from participation in INSURF even though fertilizers were supplied free. Budget shortfalls affect maintenance and purchase of vehicles, whilst gasoline and diesel oil shortages present obstacles to sustained field research in many developing countries.

National Priorities and Policies. Priorities for agricultural research, established by national governments and donor organizations, can help or hinder network development. Networks are part of, and subject to the vagaries and pressures of, the political, socioeconomic, and biophysical environment that surrounds them. One reason there are so few agricultural machinery networks, for example, is that many Third World governments are understandably uneasy about promoting any technology that might exacerbate already high underemployment levels.

While in some cases government policies may discourage, or at least not foster, certain networks, collaborative research ventures do have the potential to distort national priorities (Greenland et al. 1987). Unless sufficient care is taken, collaborative research networks can sweep national programs into their orbit and dominate the national program by drawing away resources from other important activities, especially if pressure to start the network is coming from an external donor and if the national programs are relatively weak. Before a national program becomes involved in an international network the relevance and impact of that network on the overall strategy and goals of the national program need to be assessed. If self-interest is allowed to motivate network participants collaborative research undertakings are less likely to distort national programs in developing countries.

Inadequate credit and extension facilities are sometimes a particularly weak link between research and products that farmers can use. Insufficient credit and extension agents are certainly not problems unique to networking; they apply to many agricultural research projects. These difficulties are most acute in much of subsaharan Africa, but they can also be found in parts of Latin America and Asia. In South Sulawesi, Indonesia, for example, lack of credit by local banks has proved a major stumbling block in the dissemination of IRRI-designed hand tractors (Reddy 1984). Such problems are beyond the purview of network participants and coordinators. Government decision makers need to be persuaded that improvements in credit and extension facilities will lead to a better return on the research dollar. Brazil is exemplary in this regard; there are some 15 000 extension agents as well as 30 000 salesmen for seed and fertilizer companies able to reach farmers with new technological advances (Abelson and Rowe 1987).

Conclusions

With the global proliferation of networks, concern is mounting that some networks are redundant and others are not very productive. Donors will be looking more critically at the networks they support as more midterm evaluations of networks are conducted. Two major trends to improve the efficiency of networking in international agricultural research are well underway: improving linkages between networks to promote cross-fertilization of ideas, and incorporation of proposed networks as subnetworks within existing large network structures. In this manner, redundancy will be reduced. By adhering to principles for successful networking and remaining alert to difficulties that can arise, scientists in developing countries and industrial nations will continue to benefit from joint research efforts.

References

Abelson, P.H., and Rowe, J.W. 1987. A new agricultural frontier. Science 235:1450-1451.

Dubin, H.J., and **Rajaram, S.** 1982. The CIMMYT's international approach to breeding disease-resistant wheat. Plant Disease 66:967-971.

Greenland, D.J., Craswell, E.T., and **Dagg, M.** 1987. International networks and their potential contribution to crop and soil management research. Outlook on Agriculture 16(1):42-50.

ICRISAT International Crops Research Institute for the Semi-Arid Tropics. 1984. The seventh International Pearl Millet Adaptation Trial (IPMAT 7), 1981. Patancheru, A.P. 502 324, India: ICRISAT. (Limited distribution.)

Mamaril, C.P. 1985. International and national cooperation in long-term coordinated schemes of experimentation on fertilizers. Pages 287-295 *in* Potassium in the Agricultural Systems of the Humid Tropics: 19th Colloquium of the International Potash Institute, 25-29 November 1985, Bangkok, Thailand. Berne, Switzerland: International Potash Institute.

Plucknett, D.L., Smith, N.J.H., and **Ozgediz, S.** (In press.) Networking in international agricultural research. Ithaca, New York, USA: Cornell University Press.

Rambo, A.T., and **Sajise, P.E.** 1985. Developing a regional network for interdisciplinary research on rural ecology: the Southeast Asian Universities Agroecosystem Network (SUAN) experience. Environmental Professional 7:289-298.

Whitmore, T.C. 1985. Tropical rain forests of the Far East. Oxford, UK: Clarendon Press.

The Future Role of Chickpea Information Management Systems

J.W. Estes[1]

Abstract

Modern computer technology will enable large amounts of data on different aspects of chickpea to be directly accessed by the end-user, instead of relying on catalogs of information produced by research centers. Large databases dealing with germplasm, breeding, and other related information will be made available on compact disks (CDs) along with the data retrieval systems required to search them. The Write-Once Read-Many compact disk technology, and improved communications services, will make it cost effective for international and regional research centers to update these frequently, and distribute the data to their client groups. Catalogs, where still required, will be produced regionally from the stored data. Expert systems will use these data along with the captured knowledge of chickpea researchers from several disciplines. These systems will help researchers to develop breeding strategies, identify diseases, and classify new germplasm.

Résumé

Rôle futur des systèmes de gestion de l'information sur le pois chiche : *La technologie informatique moderne permettra à l'utilisateur final d'avoir accès directement à des quantités importantes de données sur différents aspects du pois chiche, au lieu de se fier à des catalogues d'informations produits par les centres de recherche. De grandes bases de données portant sur les ressources génétiques, la sélection et d'autres informations relatives seront offertes sur les disques compacts, ainsi que les systèmes de saisie de données nécessaires pour y avoir accès. La technologie dite "Write-Once Read-Many" du disque compact et des services de communications améliorés permettront aux centres de recherches internationaux et régionaux de pouvoir, à un coût plus rentable, d'actualiser ces informations fréquemment et de distribuer les données aux groupes clients. Dans le cas échéant, les catalogues seront rédigés régionalement à partir des données mémorisées. Les systèmes experts utiliseront ces données ainsi que les connaissances enregistrées des chercheurs de pois chiche dans différentes disciplines. Ces systèmes aideront les chercheurs à mettre au point des stratégies de sélection, à identifier les maladies et à classer de nouvelles ressources génétiques.*

Over the past decade, information related to chickpea research such as germplasm data, pedigree data, and results of breeding trials have been kept in databases stored on computer systems managed by research centers. Access to this information has either been through the relevant research unit, or through printed materials such as germplasm catalogs generated from the stored information. Within research centers, some

1. Head, Computer Services, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

ICRISAT Conference Paper no. CP 567.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

online access has been made available to researchers, permitting them to directly search for desired information. Because of the associated learning difficulties for researchers the provider of the data has often been asked to conduct searches on behalf of the client. While data have been made available to International Agricultural Research Centers (IARCs) and those National Agricultural Research Systems (NARSs) with a central computing facility on magnetic tape, the majority of researchers in developing countries still rely on paper documents such as catalogs. Within the past 5 years, the use of microcomputers (PCs) in research departments has led to the development of microcomputer-based information retrieval systems that can put data directly within the reach of local/regional workers. However, two problems associated with this proliferation of microcomputers need to be considered, namely, efficient means of delivering the databases to the client, and development of systems for information retrieval that are simple enough for clients to use with minimal training. This paper proposes solutions to these problems in the short term, and looks at new technologies which will permit these data, and additional information, to be delivered to clients in different and stimulating forms.

Data Delivery

The standard way of interchanging data between microcomputer systems is by flexible (or floppy) diskette. However, replication costs, storage capacity, and problems with data reliability render diskettes unacceptable as a vehicle for sending large databases to clients spread over a wide geographical area. Compact Disc, Read Only Memory (CD–ROM) technology (van Hartevelt 1987) which first gained popularity in the audio recording world can also be used to store digital data, and overcome the problems of using diskettes. CD-ROMs hold 600 megabytes (MB) of data which cannot be altered, are insensitive to electromagnetic radiation, and can be reproduced cheaply. Further, the high capacity of CDs permits the necessary software and data to be stored on the same CD. Therefore, clients need only equip themselves with a PC and printer, along with a CD player to be able to take advantage of this packaging.

The cost of such systems would be of the order of $3000 and will be well within the reach of developing countries. The main disadvantage is the initial production cost, which could be about $5000. Reproduction, on the other hand, is a mechanical process and cheap. This cost would most likely be borne by IARCs. Within The Consultative Group on International Agricultural Research (CGIAR) system, Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) has demonstrated the viability of this approach by producing a CD-ROM containing both data on their complete maize germplasm collection, and the database software necessary to search it (CIMMYT 1988). Unfortunately, while the data stored on CD-ROMs are not expected to change, new annual data will have to be added to the distributed databases. However, the high intial cost of creating a new CD, coupled with budget constraints, precludes the possibility of producing updated databases each year. The falling prices of laser optical disk drives (Fujitani 1984) employing Write Once, Read Many (WORM) technology will permit both IARCs and NARSs to produce and update information on laser disks. While data distributed to clients would still be manufactured on standard optical disks, particularly where the number of clients is very large, master databases on WORM disks can be retained by IARCs and NARSs. These masters can be periodically updated, thus providing at least one copy of current data and improved software in a region during the period before a new master is manufactured for general distribution. WORM technology, coupled with improved communication in the form of emerging packet-switched networks in developing countries, will permit timely and cost-effective exchange of data between IARCs and NARSs.

The Changing Form of Information

The databases referred to above provide data and tools for generating information from that data. While the user interface will be easy to use and will assist the user in formulating queries, there is no guarantee that queries so formulated will be complete and take all factors into account. For example, a user searching for high-yielding varieties of chickpeas may or may not remember to include geographical factors when formulating his query. This type of check was previously done by centers of excellence providing information to a remote user; now the user must bear that responsibility himself. One approach to alleviating this problem is to develop user interfaces that make use of expert-system techniques to guide the user (Martorelli 1988). An expert system is a piece of software which contains imbedded knowledge about a particular problem area and has rules for simulating the reasoning process of an expert in that area (Smith 1988). In this case, the problem area would be factors in selecting chickpeas for desired characteristics, and would need to include all relevant "knowledge" from breeders, pathologists, entomologists, physiologists, and taxonomists. At the time the query is formulated, information relating to the query, but not specified by the user, will be requested (Bochenski 1989). The queries can be made more complete using the stored "knowledge" of the experts which would include general principles followed by these experts, plus their rules-of-thumb developed from years of experience in their respective fields. There are really two aspects to the process described above. First, the expert system could be used to help generate a strategy for searching for data with desired characteristics based on the "advice" of experts and, second, could automatically maintain the relationships between attributes during query formulation. Expert systems can also help in taxonomic classification and disease identification. It should be noted that expert systems developed for use on microcomputers are really acting as assistants to the user in finding a solution to his problem; they do not necessarily provide all the answers. However, a properly defined and validated expert system does provide assistance that can be rendered only by experts, and does it without the travel and communication costs. CD-ROM technology is now in widespread use in developed countries. The price of CD-WORM equipment is decreasing, and its use is increasing. Digital Video Interactive (DVI) (Glass 1989), a new technology, which will not be commercially available until the early 1990s, will further change the nature of information delivery. DVI combines computer graphics, still pictures, audio, and full-screen motion video in an integrated environment controlled by a microcomputer. This combined data can be stored on a CD-ROM, and computer software can integrate this information with the systems described earlier. For example, an expert system designed to assist in taxonomic classification and identification, could include references to photographs of similar plant material, plus a video of the areas in which those materials were collected.

Summary

A combination of microcomputer and compact disk technologies provides a cost-effective way of providing large databases to practicing crop scientists throughout the world. The large storage capacity of CDs permits the inclusion of software to search the databases, and can contain expert systems that include the collective knowledge of experts in the fields that produced the data. These expert systems are used to provide advice comparable to that received by direct contact. In the future Digital Video Interactive systems will permit data to be accompanied by video, pictures, and an audio commentary.

References

Bochenski, B. 1989. DBMS: Expert system integration – a budding relationship. Software Magazine 9(6):82-89.

CIMMYT (Centro Internacional de Mejoramiento de Maiz y Trigo). 1988. Maize Germplasm Bank Inquiry System. Mexico: CIMMYT.

Fujitani, L. 1984. Laser optical disk: the coming revolution in on-line storage. Communications of the ACM 27(6):546-554.

Glass, L.B. 1989. Digital video interactive. BYTE 14(5):283-289.

Martorelli, W.P. 1988. PC-based expert systems arrive. Datamation 34(7):56-66.

Smith, R.N. 1988. Applied expert systems. Pages 99-108 *in* Cutting edge technologies and microcomputer applications for developing countries. Boulder, Colorado, USA: Westview Press.

van Hartevelt, J.H.W. 1987. Advantages of CD-ROM for local access to computerized databases in developing countries, in comparison with traditional bibliographic services: suggested pilot projects. IAALD Quarterly Bulletin 32(3):161-168.

Chickpea Technology Exchange through Publication and Literature Exchange

L.J. Haravu and J.B. Wills[1]

Abstract

The nature of chickpea literature and problems of its accessibility are described. Attempts at ICRISAT and ICARDA in the past to provide a measure of bibliographical control to chickpea literature are briefly discussed. The provision of a forum for the exchange and communication of information on ongoing research in chickpea by scientists in national programs by establishing the International Chickpea Newsletter at ICRISAT is highlighted, and an analysis of the kind of information exchanged and users of the newsletters is presented. Work in establishing a database of ICRISAT's mandate crops as part of the Semi-Arid Tropical Crops Research Information Service (SATCRIS) and the establishment of the 'Chickpea and Pigeonpeas Prompts' as a sponsored abstracts service produced by CAB International is described. Other services of SATCRIS that promote awareness of and accessibility to chickpea literature are highlighted. Possible future directions at ICRISAT in utilizing newer information technologies for the benefit of chickpea workers is discussed.

Résumé

Echange de technologies de pois chiche par la publication et l'échange de documentation : La *nature de la documentation sur le pois chiche et les problèmes de son accessibilité sont décrits. Des efforts faits à l'ICRISAT et à l'ICARDA dans le passé pour fournir une certaine mesure de contrôle bibliographique sur la documentation sur le pois chiche sont brièvement examinés. La création, par la voie d'un bulletin international d'informations sur le pois chiche (International Chickpea Newsletter), d'une tribune pour l'échange et la communication d'informations sur les travaux actuels sur le pois chiche par des chercheurs des programmes nationaux, est présentée, suivie d'une analyse du genre d'informations échangées et des usagers des bulletins d'information. L'établissement d'une base de données pour les cultures du mandat de l'ICRISAT, au sein du Centre d'information sur les cultures des zones tropicales semi-arides (SATCRIS), ainsi que la mise en place du service de résumés d'articles Chickpea and Pigeonpea Prompts parrainé par CAB International sont décrits. D'autres services de SATCRIS qui favorisent la connaissance et l'accessibilité à la documentation sur le pois chiche sont soulignés. Des orientations futures à l'ICRISAT dans l'utilisation des technologies d'information plus évoluées à l'intention des travailleurs sur le pois chiche sont discutées.*

Improving and stabilizing yield and grain quality is the prime concern of chickpea researchers. Adaptability of chickpea to a wide range of soil and environmental conditions requires the research to be conducted in several different regions. Research results are reported through annual technical reports, technical manuals,

1. Manager, Library and Documentation Services, and Head, Information Services, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

ICRISAT Conference Paper no. CP 568.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

proceedings of workshops, etc. Access to such valuable information is often lost, because it rarely gets published in journals.

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the International Center for Agricultural Research in the Dry Areas (ICARDA) coordinate their efforts in improving the crop as well as in providing bibliographic control. Current literature originates mainly from these organizations, and from Indian and some other national programs. Three major bibliographies exist on this crop for retrospective literature.

1. Chickpea bibliography, 1930 to 1974, by K.B. Singh and L.J.G. van der Maesen, published by ICRISAT in 1977. This is a comprehensive bibliography, that includes all traceable literature prior to 1930. There are 3146 references, and approximately 35% of the literature covered is nonconventional. An update of the bibliography was originally planned to be included in the International Chickpea Newsletter, but this has proved to be not feasible due to financial and other constraints.
2. An annotated bibliography of chickpea diseases, 1915-1976, by Y.L. Nene and others, published by ICRISAT in 1978. Diseases and disease resistances are known to be the prime factors for yield stability of the crop. Hence this bibliography (containing 331 references) is of great value. Around 52% of the literature covered is from India and 25% is of a nonconventional nature.
3. An annotated bibliography of chickpea genetics and breeding, 1915-1983, by K.B. Singh and others, jointly published by ICARDA and ICRISAT in 1984. This is another major bibliography on the crop; it contains 1373 references.

Serial Publications

International Chickpea Newsletter

This has been issued by ICRISAT, twice a year since December 1979, as a means of rapid communication between research workers throughout the world. This current awareness newsletter contains contributions selected for their news interest as well as their scientific contents. Up to December 1986 selected abstracts on chickpea were included, but this service was discontinued when the CAB International (CABI) started its abstract service as "CAB Prompts Series: Chickpeas and Pigeonpeas". It was hoped to start this series in 1987. However, this was not possible and it commenced only in 1988, leaving a gap of one year in the provision of a current-awareness service to scientists working with chickpea and pigeonpea. Analysis of the contributions of the first 10 issues of the newsletter revealed that maximum contributions were from pathology, followed by breeding. The majority of the contributions was from ICRISAT, ICARDA, and Indian research organizations.

CAB Prompts Series: Chickpeas and Pigeonpeas

This quarterly current awareness publication was started in March 1988. It is produced from the CABI Abstracts bibliographic database, published by CABI in association with ICRISAT. It attempts to disseminate useful scientific and technical information for the benefit of researchers in countries of the semi-arid tropics (SAT). Copies are distributed free to key agricultural libraries and individual scientists in SAT countries.

SATCRIS

Description

The Semi-Arid Tropical Crops Information Service (SATCRIS) is an integral part of ICRISAT's Library and Documentation Services. The project is partly funded by International Development Research Centre (IDRC) and provides documentation and information retrieval services on the crops mandated to ICRISAT and other associated areas to users all over the SAT. The database at SATCRIS is developed by using machine-readable monthly subsets from CABI and AGRIS (the International Information System for the Agricultural Sciences and Technology) databases, and locally generated input including formal and semiformal publications of ICRISAT. The SATCRIS database covers the period from 1988 onwards and has the potential of becoming the most comprehensive database on chickpea, and other crops of interest to ICRISAT. About 30% of the chickpea literature in this database is of nonconventional nature, so enhancing its value. The versatile software package BASIS (Battelle's Automated Search Information System) is used for information storage, retrieval, and dissemination. It is planned in the future to make available subsets of the SATCRIS database for use on microcomputers.

Selective Dissemination of Information (SDI) Service

This automated SATCRIS service regularly alerts scientists to current literature that is likely to be useful to them. The service is based on the monthly data received from CABI and AGRIS. These data are matched against users' interest profiles, which are of two types. The first, standard or macroprofiles covering broad areas, e.g., chickpea breeding, are designed to serve a small group of scientists sharing similar interests. The second, special or individual profiles, are tailored to meet specific requirements of individual scientists. The service has built-in feedback, and outputs are backed up by a document delivery service.

Literature Search Service

This is a retrieval service to provide bibliographic references to meet a well-defined demand. SATCRIS staff search the SATCRIS database, the AGRICOLA database on CD-ROM, or external databases in an online mode using the DIALOG system in the USA. The availability of search results is made known widely to enable other users to utilize the search results obtained, and data on searches relevant to chickpea are available on request.

Information Analysis Service

SATCRIS collaborates with scientists in producing literature reviews, critical evaluations of the literature, and information consolidation products on specific topics, when funding is available for such work. So far no analysis of chickpea literature has been attempted.

Document Delivery Service

SATCRIS services generate requests for photocopies of original articles from all over the world. SATCRIS provides single copies of documents in its collection, on demand. In addition, it uses national and international libraries, depositories, and documentation and information centers in order to fulfil requests for copies of documents on all the five mandate crops.

Future Trends in Retrieval and Publication

Chickpea researchers can expect to benefit from advances in information technology now being implemented in a number of primary and secondary publishing organizations concerned with agricultural research. While conventional primary documents–research and information bulletins in particular–are likely to appeal strongly to researchers over the foreseeable future, because of the packaged data they contain, it is expected that more customized publications to client requirements will begin to make their appearance in the next 5 years. Such a shift will become possible because advances in technology–particularly those that exploit the storage capacities of compact disks–offer publishers the opportunity cheaply to create ad-hoc documents that are derived from previously published works and relate closely to clients' information requests. In other words, where previously researchers were expected to spend time in conducting searches for themselves by browsing in libraries, it has been accepted that (a) in SAT countries this is possible only for the fortunate few, and (b) that the majority of national researchers in the SAT can be kept fully informed of progress in their areas of interest only if low-cost information technologies are exploited cost-effectively. Chickpea researchers can therefore expect to be beneficiaries of these changes, along with other agricultural scientists throughout the world.

Specifically, as networking among legumes researchers becomes more widespread and better funded than at present, newsletters are likely to become regionalized, and SDI and search services more frequent and with narrower subject foci. Conversely, the publication of books on chickpea subjects is not expected to increase greatly, but those that are will be more quickly produced, more timely, and better indexed. The professional future for all chickpea scientists is therefore one in which any lack of information is probably not caused by deficiency in supply but by failure to inquire and to utilize.

The Role of Training

D.L. Oswalt and B. Diwakar[1]

Abstract

Individualized training programs have been established at ICRISAT Center to develop the technical skills and applied research experiences of national scientists. The contents of training programs are modified as the level of education and experience of the national staff nominees increases. ICRISAT's training programs aim to strengthen the work of national agricultural agencies by enabling more national employees to become confident and proficient in utilizing improved and sustainable technologies which are adaptable to their national research and development systems.

Résumé

Rôle de la formation *: Des programmes de formation individualisés ont été établis au Centre ICRISAT pour développer les compétences techniques et l'expérience des chercheurs nationaux en matière de recherches appliquées. Le contenu des programmes de formation est modifiée en fonction du niveau d'éducation et d'expérience des personnes désignées par les programmes nationaux. Les programmes de formation de l'ICRISAT visent à renforcer le travail des organismes agricoles nationaux en permettant à un nombre plus élevé d'employés nationaux d'être confiants et compétents quant à l'utilisation de technologies améliorées et durables qui sont adaptables à leurs systèmes nationaux de recherche et de développement.*

The training activities at ICRISAT are designed to enhance the transfer of technology to National Agricultural Research Programs. Participants are provided opportunities to develop their applied skills and to gain experiences in a systems approach to agricultural research. Individuals trained in chickpea improvement have increased substantially since 1980 (Table 1).

Types of Training and Objectives

ICRISAT's training programs meet the diverse needs of national research programs by establishing the following broad categories of training:

Postdoctoral Fellows. This program is intended for scientists who have recently completed a PhD degree. Objective: To provide an opportunity to study and to obtain hands-on experience by working with a team of senior research scientists in the semi-arid tropics.

Research Fellows. This program is for scientists, with a MSc, PhD, or equivalent, who are employed in leadership positions in a national program.

Objective: To provide national scientists with an opportunity to work with international research scientists and to become proficient in recent research and development technologies.

Research Scholars. This is for MSc or PhD degree

1. Principal Training Officer and Senior Training Officer II, Training Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

ICRISAT Conference Paper no. CP 569.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

Table 1. Participants in chickpea training programs at ICRISAT Center from 1974 to 1989.

Country	1974-79	1980-84	1985-89
Botswana	1		
Egypt		1	
Ethiopia	3	2	4
Kenya	1		1
Malawi			1
Morocco			2
Niger			1
Sudan	2	5	1
Uganda			2
Zambia			1
Afghanistan	2		2
Bangladesh		1	7
India	22	38	23
Indonesia		1	3
Iran			1
Iraq	1		
Jordan		2	
Malaysia			1
Nepal		1	6
Pakistan		4	11
Peoples Republic of China			1
Philippines			6
Sri Lanka		7	4
Thailand	1	3	5
Tunisia			1
Turkey		3	
Vietnam			3
Chile	1	1	1
Czechoslovakia		1	
Federal Republic of Germany		1	1
Japan	1		2
Mexico			1
Netherlands			3
UK		2	
USA		1	
Total	35	74	95

candidates from the semi-arid tropics or those interested in working there. Candidates complete course work at selected agricultural universities and conduct research for MSc or PhD theses supervised by ICRISAT's senior scientists.

Objective: To give promising students the opportunity to develop competence in technical and managerial skills related to increased and stabilized food production in the semi-arid tropics.

In-service Trainees. These full-season (6 months) training programs are designed to meet the specialized needs of individuals and cooperating institutions. The approaches and depths of training are designed for scientists, agriculturalists, managers, or others engaged in specialized agricultural activities. Academic qualifications vary from a school certificate to PhD degrees. Preference is for applicants under 40 years of age. Programs cover the following topics:

i) Cereals and legumes improvement programs provide opportunities to develop skills in plant breeding, pathology, physiology, microbiology, entomology, biochemistry, and systems management.

ii) Production agronomy gives trainees opportunities to gain practical skills for increasing crop production through an integrated approach to utilizing social, cultural, and economic factors in improving agricultural production.

iii) Resource management provides opportunities to develop research skills in catchment-area development for improved land, water, and systems research management.

Special Courses. Special courses for 1 to 9 months are conducted in genetic resources, pathology, entomology, physiology, food quality, soil sciences, socioeconomics, watershed management, or research station management, and use of scientific English .

Admission Requirements

Nominees for an ICRISAT Training Program must be recommended by an agency or institution working in the semi-arid tropics and be willing to study, conduct research, or do field trials in areas compatible with ICRISAT's mission and the sponsoring agency's programs.

Nomination and Sponsoring Agency

Candidates are nominated by the agency or organization which employs them, or guarantees to employ them.

The candidates are provided funds to cover travel, transit allowances, incidental allowance, room, food, medical insurance, and other training expenses.

ICRISAT has a limited number of partial or complete scholarships. Agencies may provide full sponsorship or may apply for ICRISAT assistance on behalf of their candidates.

Accommodation

Recreation facilities, a large library, single dormitory rooms for 140 persons, and 16 furnished flatlets are located on the research center campus.

Follow-up

The Training Program staff contacts former participants to follow their national research and technology transfer activities. Participants are informed of research developments and achievements through ICRISAT's publications, newsletters, supply of genetic materials, and personal visits or communications.

The Chickpea Trials Network Model

H.A. van Rheenen[1], R.S. Malhotra[2], J.H. Miranda[1],
C.M. Pattanayak[1], and D.V. Seshu[3]

Abstract

The initiation and development of ICRISAT's and ICARDA's chickpea trials network is described, and special attention is given to the adjustments made over the years, the problems faced, and the successes achieved. Possibilities for improvement are considered, and the chickpea trials network is compared with networks of two other institutions.

Résumé

Modèle de réseau des essais sur le pois chiche : *L'initiation et le développement du réseau d'essais sur le pois chiche de l'ICRISAT et de l'ICARDA sont décrits, en portant une attention particulière sur les ajustements effectués au cours des années, les problèmes rencontrés et les succès obtenus. Des possibilités d'amélioration sont envisagées et le réseau des essais sur le pois chiche est comparé avec les réseaux de deux autres institutions.*

For crop improvement in general it is necessary to have a sound variety testing program as is emphasized in plant breeding handbooks. The area such a testing program is to cover depends on the mandate of the institution that conducts the improvement program.

The organization of multilocational testing requires an understanding of common interests and an agreement between participants about entries to be tested; it also needs dispatch of experimental books and seed for sowing. The trial data have to be analyzed, and the results coordinated and communicated to all parties in order for conclusions to be arrived at on how to proceed with the testing program, and eventually to reach a decision regarding cultivar recommendation and release.

International institutes often have been given the mandate for coordinating crop improvement worldwide, and this has resulted in more interaction, more collaboration, and a more frequent and free exchange of ideas and material than in earlier days, for instance, for crops such as faba bean and common bean (Summerfield and Roberts 1985).

Here we shall describe how the international chickpea trial network developed over the years, what major changes took place, what problems were faced, what successes were achieved, and what improvements can be suggested. A general reference is made here to International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Progress Reports on International Trials and Nurseries (1976-88) and International Center for Agricultural Research in the Dry Areas (ICARDA) Food Legume Improvement Program's International Nurseries Reports 1978-88.

1. Principal Plant Breeder (Chickpea), Senior Research Associate, Legumes Program, and Principal Coordinator Cooperative Cereals Research Network (CCRN), Cereals Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.
2. International Trials Scientist, International Center for Agricultural Research in the Dry Areas (ICARDA), P.O. Box 5466, Aleppo, Syria.
3. Coordinator, International Network for Genetic Enhancement of Rice, International Rice Research Institute (IRRI), P.O. Box 933, Manila, Philippines.

ICRISAT Conference Paper no. CP 571.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

How Chickpea International Testing Started

ICRISAT was established in 1972 and ICARDA in 1977. It was fortunate that they could rapidly build up their genetic resources with the help of Regional Pulse Improvement Programs, a joint research effort by the Indian Agricultural Research Institute (IARI), New Delhi, India; United States Agency for International Development (USAID); United States Department of Agriculture (USDA); Karaj Agricultural University, Iran; and Arid Land Agricultural Development Program (ALAD), Beirut, Lebanon. In 1975 they were able to help construct an international chickpea trials network. For winter and summer sowings, three types of trials and nurseries were formed and sent to cooperators.

How the International Chickpea Trials Network Developed Further

After the chickpea trials network was established, methodologies were developed to make it function well. Its main components were: a good distribution system; sound statistical design and analysis; rapid communication of results; and follow up on usage of the results.

The Genetic Resources Units played a key role in supplying germplasm suitable for multilocational testing and for use as parents in crossing programs. The improvement programs at ICRISAT and ICARDA soon supplemented the germplasm with elite breeding material. The material made available to participants varied from F_1 seed, made on request, to early generation material and more widely tested varieties from Advanced Yield Trials (AYT). The Pathology, Entomology, and Crop Physiology Units identified sources of resistance to diseases, pests, and abiotic stresses, respectively, and made these available for international testing and for use in breeding programs.

Lists of available trials and nurseries were sent every year to interested institutions and researchers, who in turn could send in their requirements. Trial books prepared through the Crop Research Integrated Statistical Package (CRISP) computer program and seed packages were sent to collaborators, and suitable computer programs were used to keep track of all dispatches. The trial data when received were analyzed by the GENSTAT or CRISP program, and the results were tabulated in Progress Reports and communicated to collaborators.

The system as such remained almost unchanged over the past 12 years, but the trial sets underwent several changes and diversifications.

Major Changes in International Trials

In the course of years, as experience was gained and new ideas were conceived through visits, data feedback, and workshops, the nurseries and trials were diversified, and experiments were added. Tables 1 and 2 list all the nurseries and trials and the number of sets sent. The tables show interesting features and changes which merit some discussion.

The information on agronomic practices such as date of sowing, plant population, weed control, need for *Rhizobium* inoculation, role of iron deficiency in calcareous soils, was almost lacking in the mandated countries of ICARDA in the West Asia and North Africa (WANA) region. Thus the agronomic experiments were initiated to encourage the network scientists to conduct such experiments and at the same time to help them in developing packages of production for their areas.

In 1979/80 the system of early generation bulk yield testing was introduced and F_2 and F_3 trials were made available. The system was in use for a period of 7 years. It appeared that the F_2, F_3, and later generations yield data showed low correlation values, not justifying the discard of early generation bulks (van Rheenen and Gowda, unpublished data). These observations were confirmed by studies of Geletu et al. (submitted for publication).

In 1985/86 a somewhat new design called the duplicated augmented design (DAD) was introduced. It now appears that the Randomized Complete Block Design generally gives more satisfactory results.

Problems Faced in the International Trials Network

We mention here three problems: one is the discrepancy between the number of trial sets sent and data sets returned. Table 3 lists those in percentages for the major collaborating regions during the period 1975-87. The mean discrepancy is 38%.

A second problem is that of trial quality. A number of factors can adversely affect the quality of a trial as reflected in the coefficients of variation (CV). Table 4 shows mean CV values over 3-year periods for the major collaborating regions. These are high, which is an alarming phenomenon.

Table 1. Distribution of chickpea international trials and nurseries by ICRISAT 1975-87.

Name of trial[1]	1975/76	1976/77	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	Total
ICCT	26	-	-	-	-	-	-	-	-	-	-	-	-	26
ICCT-D	5	34	-	-	-	-	-	-	-	-	-	-	-	39
ICCT-DS	-	-	11	9	12	15	14	24	27	20	21	17	25	195
ICCT-DM	-	-	-	-	-	-	-	-	-	-	15	14	17	46
ICCT-DL	-	-	24	13	15	8	18	21	16	14	15	14	17	175
ICCT-K	16	36	33	5	-	-	-	-	-	-	-	8	8	106
ICSN	29	35	-	-	-	-	-	-	-	-	-	-	-	64
ICSN-DS	-	16	14	11	15	19	25	19	21	17	24	12	25	218
ICSN-DM	-	-	-	-	-	-	-	21	17	14	17	14	13	96
ICSN-DL	-	19	26	17	19	18	19	21	16	13	13	11	17	209
ICSN-K	-	5	18	5	-	-	-	-	-	-	-	-	-	28
F_2-MLT	-	-	-	-	11	13	-	-	-	-	-	-	-	24
F_2-MLT-DS	-	-	-	-	-	-	8	5	10	10	20	-	-	53
F_2-MLT-DM	-	-	-	-	-	-	-	5	10	10	12	-	-	37
F_2-MLT-DL	-	-	-	-	-	-	9	-	16	10	13	-	-	48
F_3-MLT	-	-	-	7	10	16	-	-	-	-	-	-	-	33
F_3-MLT-DS	-	-	-	-	-	-	11	9	13	11	-	-	-	44
F_3-MLT-DM	-	-	-	-	-	-	-	12	11	15	-	-	-	38
F_3-MLT-DL	-	-	-	-	-	-	15	-	14	10	-	-	-	39
PT-MLT	-	-	-	-	-	-	8	-	9	7	-	-	-	24
ICAT	-	-	5	2	-	10	11	19	13	6	3	-	5	74
ICHRN	-	-	-	-	-	-	-	-	-	-	44	45	32	121
CPE-MLT (DS/DM, D/K, M-L)	-	-	-	-	-	41	38	18	9	11	22	10	-	149
ICRRWN	-	12	22	37	33	35	25	25	22	25	25	24	28	313
IIUCRRWN	-	-	-	-	-	-	11	15	18	22	25	26	20	137
ICSDN	-	-	-	-	-	-	-	10	10	10	10	11	10	61
CABN	-	-	9	13	-	-	-	-	-	-	-	4	3	29
Total	76	157	162	119	115	175	212	224	252	225	279	210	220	2426

1. ICCT = International Chickpea Cooperative Trial; ICSN = International Chickpea Screening Nursery; MLT = Multilocational Trial; PT = Plant Type; ICAT = International Chickpea Adaptation Trial; D = Desi; K = Kabuli; S = Short-duration, M = Medium-duration, L = Long-duration; ICHRN = International Chickpea *Helicoverpa* Resistance Nursery; CPE = Chickpea Entomology; ICRRWN = International Chickpea Root Rots Wilt Nursery; IIUCRRWN = ICRISAT/ICAR Uniform Chickpea Root Rot and Wilt Nursery; ICSDN = International Chickpea Stunt Disease Nursery; CABN = Chickpea Ascochyta Blight Nursery.

Table 2. Distribution of chickpea international trials and nurseries by ICARDA 1977/78 to 1988/89.

Name of trial/nursery[1]	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	Total
CRN	23	-	-	-	-	-	-	-	-	-	-	-	23
CRYT	11	-	-	-	-	-	-	-	-	-	-	-	11
CAT	-	22	39	44	50	49	57	-	-	-	-	-	261
CIYT	-	20	40	38	37	46	49	50	56	44	48	44	472
CISN	-	20	38	33	39	47	50	-	-	-	-	-	227
CIF_3/F_4	-	9	28	26	32	31	34	56	53	54	39	20	382
CIABN	-	13	27	32	40	41	41	49	64	63	57	48	475
CFPPT	-	21	-	-	-	-	-	-	-	-	-	-	21
CIYT-W	-	-	15	42	70	66	65	61	58	62	56	51	546
CDPPT	-	-	15	23	26	22	15	18	9	-	-	-	128
CFIT	-	-	14	24	27	29	16	20	7	18	22	17	194
CIYT-L	-	-	-	30	32	47	51	62	71	66	69	74	502
CWCT	-	-	-	27	31	41	33	36	22	28	31	18	267
CIET	-	-	-	-	-	10	11	-	-	-	-	-	21
CIYT-W-STR	-	-	-	-	-	-	19	35	30	32	29	32	177
CISN-W	-	-	-	-	-	-	-	51	61	64	57	55	288
CISN-S	-	-	-	-	-	-	-	41	42	54	54	46	237
CIIMN	-	-	-	-	-	-	-	16	29	13	12	8	78
CIYT-T	-	-	-	-	-	-	-	-	-	47	58	60	165
CICTN	-	-	-	-	-	-	-	-	-	8	34	30	72
CIRT	-	-	-	-	-	-	-	-	-	-	18	21	39
Total	34	105	216	319	384	429	441	495	502	553	584	524	4586

1. CRN = Chickpea Regional Nursery; CRYT = Chickpea Regional Yield Trial; CAT = Chickpea Adaptation Trial; CI = Chickpea International; YT = Yield Trial; SN = Screening Nursery; ABN = Ascochyta Blight Nursery; FPPT = Fertility-cum Plant Population Trial; W = Winter; DPPT = Date of Planting-cum Plant Population Trial; FIT = Fertility-cum Inoculation Trial; L = Large Seeded; WCT = Weed Control Trial; IET = Iron Efficiency Trial; STR = Sub-Tropical Region; S = Spring; LMN = Leaf Miner Nursery; T = Tall Type; CTN = Cold Tolerance Nursery; IRT = Inoculation Response Trial.

Table 3. **Returns from ICRISAT's international chickpea trials and nurseries 1976-87.**

Region	Data books returned (%)
SE Asia	75
W. Asia	24
Africa	30
S. America	44
N. America	21
Europe	7
Total average	62

A third problem is that of representativeness. Regression analyses for varieties grown at different locations within zones of adaptation show a remarkably low stability of performance (Table 5).

Successes Achieved Through the International Chickpea Trials Network

Possibly the major contribution of the trials network to chickpea improvement is the spread of plant material with different desirable characters at different stages of development and suitable for different production technologies.

Table 6 is an updated list of released varieties that were identified or developed through the international chickpea testing network.

The trial network has helped to increase the international interaction of chickpea researchers.

Potential Improvements in the International Chickpea Testing Network

The material, entered in international trials and nurseries, used to come mainly from the gene banks and improvement programs of the International Agricultural Research Centers (IARC). The situation can be improved by soliciting also entries from other programs in the world.

The more open system as proposed in the above paragraph will have an important additional advantage. It will help to decentralize the network, and transform collaborators into more directly involved participants. For instance, Ethiopia could, within the world network, be a sub-center for eastern African chickpea producing areas. So could Turkey be a sub-center for the West Asian and Mediterranean region.

The low correlation observed between the performance of different varieties at different but similar loca-

Table 4. Mean coefficients of variation in international chickpea trials from 1976-78 to 1985-87.

Region	1976-78	1979-81	1982-84	1985-87	Mean
Asia	28.5 (54)[1]	25.6 (60)	35.0 (188)	26.5 (153)	28.9
Africa	29.3 (5)	60.5 (3)	49.2 (5)	-	46.3
Americas	43.4 (5)	13.3 (1)	27.7 (6)	-	28.1

1. Figures in parentheses are numbers of trials.

Table 5. Mean correlation between locations in international chickpea trials from 1976-78 to 1985-87.

	Mean correlation values for periods				
Latitude (°)	1976-78	1979-81	1982-84	1985-87	All years
0-19	0.24 (26)[1]	0.07 (7)	0.13 (50)	0.03 (14)	0.12 (97)
20-24	0.24 (10)	-0.03 (11)	0.13 (104)	0.06 (53)	0.10 (178)
25-29	0.20 (46)	0.11 (24)	0.18 (229)	0.08 (185)	0.14 (484)
30-34	0.01 (6)	-	0.54 (7)	-0.13 (1)	0.14 (14)
>35	0.08 (1)	-	0.11 (1)	-	0.10 (2)

1. Figures in parentheses are numbers of computations.

Table 6. Release of varieties promoted by the international chickpea testing network.

Country	Released variety	Year of release
Algeria	ILC 482	1988
Bangladesh	Nabeen (ICCL 81248)	1986
Cyprus	Yialousa (ILC 3279)	1984
	Kyrenia (ILC 464)	1987
Ethiopia	850-3/27 × F 378	1988
France	TS 1009 (ILC 482)	1988
	TS 1502 (FLIP-81-293)	1988
India	ICCV 1	1982
	ICCV 6	1984
	GNG 149	1985
	Swetha (ICCV 2)	1989
	Kranthi (ICCC 37)	1989
Italy	Califfo (ILC 72)	1987
	Sultano (ILC 3279)	1987
Kenya	ICCL 83110	1986
Morocco	ILC 195	1987
	ILC 482	1987
Myanmar	Yezin 1 (P 436)	1986
	Schwe Kyehmon (K 850 × F 378)	1986
Nepal	Sita (ICCV 1)	1987
	Radha (JG 74)	1987
Oman	ILC 237	1988
Portugal	Elmo (ILC 5566)	1989
	Elvar (FLIP 85-17C)	1989
Spain	Fardan (ILC 72)	1985
	Zegri (ILC 200)	1985
	Almena (ILC 2548)	1985
	Alcazaba (ILC 2555)	1985
	Atalaya (ILC 200)	1985
Sudan	Shendi (NEC 2491/ILC 1335)	1987
Syria	Ghab 1 (ILC 482)	1986
	Ghab 2 (ILC 3279)	1986
Tunisia	Chetoui (ILC 3279)	1986
	Kassab (FLIP 83-46C)	1986
	Amdoun 1 (Be-sel-81-48)	1986
	Amdoun 1 (Be-sel-81-48)	1986
Turkey	ILC 195	1986
	Gunej Sarisi 482 (ILC 482)	1986
	ILC 3279	1988

tions mentioned earlier urges us to learn more about plant responses to environmental factors. It is suggested that the network can enhance studies in this field.

The network could further be improved by more frequent interaction, for instance, through regional travelling workshops and seminars.

Comparisons with Other International Testing Networks

Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT)

The international testing program at CIMMYT is divided into two parts, one for maize, and the other for wheat, triticale, and barley. The wheat program is the largest and sent out for cycle 1988/89 some 2843 sets of 39 different nurseries to 272 cooperators in 87 different countries (CIMMYT 1979 and 1985).

International Rice Research Institute (IRRI)

About 30 types of nurseries are formed every year. More than 50% of the test entries originate from national programs. More than one thousand sets of nurseries are dispatched every year. The International Rice Testing Program (IRTP) collaborates not only with national programs but also with other international institutes like Centro Internacional de Agricultura Tropical (CIAT), International Institute of Tropical Agriculture (IITA), and West Africa Rice Development Association (WARDA) for successful functioning of its network. The IRTP network is funded by the United Nations Development Programme (UNDP).

References

CIMMYT (Centro Internacional de Mejoramiento de Maiz y Trigo). 1979. International testing program in wheat, triticale and barley. CIMMYT Today no. 10.

CIMMYT (Centro Internacional de Mejoramiento de Maiz y Trigo). 1985. Managing trials and reporting data for CIMMYT's international maize testing program. Mexico: CIMMYT. 20 pp.

Bejiga, G., van Rheenen, H.A., Jagdish, C.A., and Singh, O. (In press.) Relationships among the F_2 to F_6 generations in chickpea (*Cicer arietinum* L). Indian Journal of Genetics and Plant Breeding.

ICARDA (International Center for Agricultural Research in the Dry Areas). 1978-88. Food Legume Improvement Program, international nurseries reports. Aleppo, Syria: ICARDA.

Summerfield, R.J., and Roberts, E.H. (eds.). 1985. Grain legume crops. London, UK: Collins.

On-farm Research on Chickpeas and Transfer of Technology in India

P.W. Amin, K.C. Jain, J.V.D.K. Kumar Rao, C.S. Pawar, Jagdish Kumar, H.A. van Rheenen, and D.G. Faris[1]

Abstract

Dissemination of plant material and information (transfer of technology) is an important component of ICRISAT's strategy to assist National Programs (NPs). In response to the request from the Government of India, a planning meeting was held at ICRISAT from 25 to 26 April 1988, and 43 irrigated and 33 non-irrigated trials were planned in 10 states of the Indian Union. An intensive training for the extension staff was held from 9-13 May 1988 to prepare for the trials. A total of 19 irrigated and 10 non-irrigated trials were jointly monitored by ICRISAT and NP staff. Several farmers' days were held and on-the-job training was conducted to acquaint the extension staff and farmers with new varieties and improved management.

In irrigated trials, an average dry-grain yield of 1.875 t ha^{-1} was obtained with a range of 0.44-3.7 t ha^{-1}. Improved and commonly cultivated varieties performed equally well in the absence of wilt disease. The improved wilt-resistant varieties showed a clear advantage over the commonly cultivated varieties in wilt-infested plots.

Under residual moisture conditions, the improved short-duration (75-80 days) wilt-resistant variety, ICCV 2 gave 30% better yield than varieties of longer duration such as Annigeri, and performed well in diverse climatic situations. With irrigation and fertilizer inputs this variety yielded up to 3.3 t ha^{-1} indicating its responsiveness to good management. It has good potential for use in double cropping.

The trials had the desired impact at the farmers level in the first year itself. Many trials will continue through 1991.

Résumé

***Recherche en milieu réel sur les pois chiches et le transfert de technologie en Inde :** Diffusion du matériel végétal et de l'information (transfert de technologie) est une composante importante de la stratégie de l'ICRISAT pour l'assistance aux programmes nationaux. Suite à une demande du Gouvernement de l'Inde, une réunion de planification était tenue à l'ICRISAT du 25 au 26 avril 1988, et 43 essais irrigués ainsi que 33 essais non irrigués ont été envisagés dans 10 Etats de l'Inde. Afin de préparer pour les essais, une formation intensive pour le personnel de vulgarisation était tenue du 9 au 13 mai 1988. Un total de 19 essais irrigués et 10 essais non irrigués étaient conjointement suivis par les chercheurs de l'ICRISAT et des programmes nationaux. Plusieurs journées ouvertes aux paysans ont été organisées. La formation sur le tas*

1. Senior Entomologist, Plant Breeder, Crop Physiologist, Entomologist, Plant Breeder, Principal Plant Breeder, and Principal Coordinator Asian Grain Legume Network (AGLN), Legumes Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

ICRISAT Conference Paper no. CP 570.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

a permis de renseigner le personnel de vulgarisation et les paysans sur de nouvelles variétés et la gestion améliorée.

Dans le cadre des essais irrigués, un rendement moyen en grains secs de 1,875 t ha^{-1} a été obtenu avec une plage de 0,44–3,7 t ha^{-1}. Les variétés améliorées ainsi que les variétés courantes ont donné de bonnes performances en l'absence du flétrissement. Dans les parcelles infestées, les variétés améliorées résistantes au flétrissement ont révélé un avantage nette sur les variétés courantes.

En conditions d'humidité résiduelle, la variété améliorée à cycle court (75 à 80 jours) et résistante au flétrissement, ICCV 2, a donné un rendement 30% supérieur à celui des variétés à cycles plus long tel Annigeri. La variété s'est également révélée performante dans diverses situations climatiques. Avec l'apport d'irrigation et des engrais cette variété a donné des rendements jusqu'à 3,3 t ha^{-1}, ce qui indique ses réponses à une bonne gestion. Elle a un bon potentiel pour l'exploitation dans la culture double.

Les essais ont eu l'impact souhaité au niveau des paysans dès la première année, et certains essais continueront en 1991.

India is the world's largest producer of chickpea (area : 7.131 x 10^6 ha; production : 4.084 x 10^6 t); however, the productivity is low and averages about 0.57 t ha^{-1} (Jodha and Subba Rao 1987). Improper tillage, lack of short-duration varieties, sub-optimum plant density, severe drought stress under residual moisture, water-logging in irrigated crops, and insect pests and diseases, all lead to low yields. When these constraints are overcome, yields may improve. Preliminary trials in the 1987/88 season in Maharashtra have indicated high potential yields ranging from 1.5 -3.4 t ha^{-1} under irrigation.

A Request for Technical Assistance

The Government of India (GOI) has been concerned about the low production of chickpea and has instituted special thrust programs to stimulate chickpea production. In 1988, the GOI asked ICRISAT to assist in demonstrating the potential for higher yields in chickpea.

A meeting of the officials of GOI, State Departments of Agriculture from Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Rajasthan, and Uttar Pradesh, and ICRISAT was held at ICRISAT Center 24 - 25 April 1988 to formulate long-term plans for assistance from ICRISAT. The objectives were to demonstrate high yield potentials under improved management practices, to identify key constraints for high yields, and develop methods to overcome these constraints. The GOI provided funds for these demonstrations. ICRISAT provided improved technology, seed of improved wilt-resistant varieties, and funds for monitoring the trials. The project was implemented by ICRISAT's newly created Legumes On-farm Testing and Nurseries (LEGOFTEN) Unit, which has a multidisciplinary staff, comprising a breeder, an agronomist, a plant protection specialist, and nine trained field staff.

Training

ICRISAT organized a training workshop for collaborators from 9-13 May 1988 for 35 collaborators from eight States. At this workshop trial locations were chosen, soil samples collected, pest and disease problems discussed, and treatments finalized.

Setting up Demonstrations and Monitoring

There were four treatments as follows: (1) ICRISAT-recommended variety and package of practices, (2) State-recommended variety and ICRISAT package, (3) ICRISAT-recommended variety and State-recommended package, and (4) State-recommended variety and package. A plot size of 0.2 ha per treatment was agreed upon.

Two sets of trials were formulated: one irrigated and the other nonirrigated. Accordingly, ICRISAT suggested two sets of varieties : ICCV 6, ICCC 37, ICCV 5 or ICCC 42 for irrigated trials, and ICCV 2, an extra-short-duration (ESD) variety, for nonirrigated trials. All ICRISAT varieties have resistance to fusarium wilt. The state officials identified improved varieties for their states, Annigeri in Karnataka and Andhra Pradesh, JG 315 and Ujjain 21 in Madhya Pradesh, G 5, Chafa, and BDN 9-3 in Maharashtra, H 208 in Orissa, K 850 in Uttar Pradesh, and a local variety in Tamil Nadu. A package of practices for the trials was formulated (Table 1).

A total of 43 irrigated and 33 nonirrigated trials was planned. Of these 19 irrigated and 8 nonirrigated trials were chosen for joint monitoring by LEGOFTEN staff and officials of the state Departments of Agriculture. The remaining 14 irrigated and 24 nonirrigated trials were monitored by state officials. The trials were laid out on research farms and in farmer's fields, and were visited three or four times in a season. Detailed observations on field operations and their costs were recorded.

Results

A combination of improved varieties and good management gave high yields. In irrigated trials (Table 2) they ranged from 0.44 to 3.7 t ha^{-1} with an average of 1.88 t ha^{-1}. The increase in yields of irrigated chickpea was due more to improved management (16.6 to 22.1%) than to varieties (3.2 to 8.1%), indicating that under good managements, the commonly grown varieties also performed well. However, improved varieties produced better yields because of their fusarium wilt resistance in places such as Ridaj (Table 2).

In nonirrigated trials the ESD variety ICCV 2, outyielded common long-duration varieties at 6 out of 8 locations (Table 3). On average it gave a 29% higher yield than long-duration varieties, which was further improved to 53% by improved management (Treatment 1 over Treatment 4). Because its duration is about 30 days shorter than local varieties, it has performed better in residual moisture situations. Further, it also responds to high inputs. In two farmers' fields, it produced a grain yield of 3.3 t ha^{-1} and 2.8 t ha^{-1} in 95 days after three irrigations. In market surveys, it fetched 25% more money than small-seeded desi varieties.

Chickpea Economics

Cultivation costs ranged from Rs 2444 to 9323 ha^{-1} for irrigated trials (Table 2) and from Rs 2261 to 5548 ha^{-1} for nonirrigated trials (Table 3).

The ICRISAT package gave higher profits than the State-recommended one for irrigated and nonirrigated trials (Table 4). On residual moisture ICCV 2 produced substantially higher profits with both packages.

Technology Transfer: Farmers' Days and On-the-job Training

As trials progressed, several farmers from nearby areas visited the fields where they were shown the varieties

Table 1. ICRISAT and State-recommended package of practices for irrigated chickpea[1].

Input/operation	ICRISAT-recommended package	State-recommended package
Land preparation	Fine tilth	Fine tilth
Farm yard manure (t ha^{-1})	10	5
Seedbed	Raised beds and furrows	Flat
Fertilizers (kg ha^{-1})	Ammonium sulphate, 100	DAP 100
	SSP, 250	Urea 0-10
	$ZnSO_4$, 10	MOP 0-15
Variety	Wilt resistant ICRISAT	State
Spacing (cm)	30 × 10	30 × 10
Weed control	Herbicide	Manual
Seed dressing	Benlate® + Thiram	Thiram
Plant protection	Dust formulation	Sprays
Ferrous sulphate (kg ha^{-1})	2.5, one spray	Nil
Irrigations	At sowing, pod set and pod filling. By furrow irrigation	At sowing, pod set and pod filling. By flooding.

1. For production under residual moisture, sowing on the flat was recommended, and ESD variety ICCV 2 was used.

Table 2. Grain yield (t ha^{-1}) of the ICRISAT/Department of Agriculture monitored, irrigated chickpea trials at different Indian locations, postrainy season, 1988/89.

	ICRISAT package				State package			
State/locations	ICRISAT variety		State variety		ICRISAT variety		State variety	
Andhra Pradesh								
Tangadencha	1.55	(7246)[1]	1.28	(7546)	1.09	(6224)	1.09	(5956)
Gujarat								
Hathrol	1.43	(3835)	1.70	(3705)	1.22	(3480)	1.44	(3345)
Karnataka								
Gangavati	0.92	(4235)	1.28	(4235)	1.28	(4350)	1.47	(4350)
Madhya Pradesh								
Bhikangaon	0.81	(6032)	0.86	(5095)	0.79	(4077)	0.80	(3797)
Narsingpur	1.61	(4623)	1.72	(4718)	1.34	(3755)	1.28	(3855)
Maharashtra								
Chakur	1.36	(4687)	1.77	(4687)	1.45	(3557)	2.33	(3557)
Parbhani	1.75	(9323)	1.70	(9323)	1.68	(7714)	1.66	(7714)
Pokharni	1.62	(4390)	1.25	(4390)	1.20	(3938)	1.08	(3938)
Bori	2.95	(4727)	2.82	(4727)	2.20	(4175)	2.95	(4175)
Niwali	0.85	(4029)	0.78	(4029)	0.76	(3648)	0.70	(3648)
Niwali	3.70	(4718)	3.61	(4718)	2.96	(3595)	3.11	(3595)
Jintur	2.95	(4082)	2.46	(4082)	2.37	(3517)	1.86	(3517)
Ridaj	3.50	(5962)	2.80	(5962)	2.24	(4362)	1.40	(4362)
Niwali	2.50	(4722)	2.41	(4722)	2.32	(4241)	2.04	(4241)
Gangakhed	2.85	(4467)	2.50	(4467)	2.50	(3525)	2.42	(3525)
Hingoli	1.50	(6957)	1.21	(6957)	1.10	(5235)	0.74	(5235)
Orissa								
Keonjhar	1.73	(5939)	1.11	(5939)	1.00	(5099)	0.45	(5099)
Rajasthan								
Ajmer	0.44	NR[2]	0.23	NR	0.11	NR	0.12	NR
Uttar Pradesh								
Amarokh	1.59	(3860)	1.51	(3685)	1.60	(2619)	1.37	(2444)
Average	1.88	(5213)	1.74	(5166)	1.54	(4284)	1.49	(4242)

Two-way comparison of mean yields.

	Cultivation package			
Variety	ICRISAT	State	Mean	Increase (%)
ICRISAT	1.88	1.54	1.70	5.8
State	1.74	1.49	1.61	
Mean	1.80	1.51		
Increase (%)	19.4	-		

1. Figures in parentheses are cost of cultivation in Rs ha^{-1}.
2. NR data not received.

and the improved cultivation practices. For irrigated trials, the adverse effect of flood irrigation on plant growth and survival was demonstrated. The plant mortality was much less in crops grown on raised beds. On-the-job training also included the identification of eggs of *Helicoverpa armigera* and the foliar damage caused by larvae. The differences between wilt caused by *Fusarium oxysporum* and caused by *Sclerotium rolfsii* were also explained. Although we have not kept a record the number of farmers visiting these trials, it could be as high as 10 000. In addition, about 2000 farmers attended the farmers' days conducted by the extension staff.

Table 3. Grain yield (t ha^{-1}) in the ICRISAT/Department of Agriculture monitored nonirrigated chickpea trials at different Indian locations, postrainy season, 1988/89.

State/locations	ICRISAT package				State package			
	ICRISAT variety		State variety		ICRISAT variety		State variety	
Andhra Pradesh								
Tangadencha	0.82	(5102)[1]	0.20	(4868)	1.62	(5072)	0.76	(4349)
Karnataka								
Gangavati	1.31	(3685)	1.36	(3685)	1.26	(3730)	0.63	(3730)
Madhya Pradesh								
Bhikangaon	1.39	(3866)	0.96	(3674)	1.19	(3197)	0.85	(3225)
Narsingpur	1.62	(3503)	1.53	(3523)	1.02	(3450)	1.19	(3470)
Maharashtra								
Chakur	0.91	(4875)	1.04	(4875)	0.49	(3457)	0.75	(3457)
Sawarkhed	1.04	(3560)	0.95	(3560)	0.73	(3250)	0.86	(3250)
Orissa								
Keonjhar	1.01	(5548)	0.73	(5548)	0.82	(4815)	0.58	(4815)
Uttar Pradesh								
Amarokh	1.75	(2261)	0.88	(2555)	1.38	(2505)	0.83	(2325)
Average	1.23	(4050)	0.95	(4036)	1.06	(3684)	0.80	(3578)

Two-way comparison of mean yields.

Variety	Cultivation package		Mean	Increase (%)
	ICRISAT	State		
ICRISAT	1.23	1.06	1.15	30.5
State	0.95	0.80	0.88	
Mean	1.09	0.93		
Increase (%)	17.1	-		

1. Figures in parentheses are the cost of cultivation in Rs ha^{-1}.

Table 4. Yield, income, cost of cultivation, and profits from chickpeas, postrainy season, 1988/89.

Treatment	Yield (t ha^{-1})	Income (Rs ha^{-1})[1]	cost of cultivation (Rs ha^{-1})	Profits (Rs ha^{-1})
Irrigated (n = 19)[2]				
ICRISAT variety and method	1.88	11250	5213	6037
State variety and ICRISAT method	1.74	10410	5166	5244
ICRISAT variety and State method	1.54	9210	4284	4926
State variety and State method	1.49	8928	4242	4686
Nonirrigated (n = 8)				
ICRISAT variety and method	1.23[3]	8624	4050	4574
State variety and ICRISAT method	0.95	5724	4036	1688
ICRISAT variety and State method	1.06[3]	7441	3684	3757
State variety and State method	0.80	4824	3578	1246

1. Sales price Rs 6000 t^{-1}.
2. n = number of trials.
3. ICCV 2 variety used in this trial fetches about Rs 1000 t^{-1} more than other varieties. Income is calculated at the then existing market price of Rs 7000 t^{-1} for this variety.

Seedbed Preparation

Farmers experienced difficulty in making raised beds and furrows. Some developed their own local implements for this purpose. However, these implements were unable to make beds more than 10-12 cm high. One local engineer prepared a bullock-drawn implement that gave a bed height of 20-25 cm with a furrow width of 25-30 cm. It has attachments for the simultaneous application of fertilizer and seeds and thus reduces the overall costs. It has become popular with farmers not only for chickpeas but also for other crops that are liable to waterlogging.

Sowing Method

Sowing by placement as recommended in the ICRISAT package was not practicable owing to labor shortages and high labor costs. Sowing by local seed drill as practised by farmers was found to be cost-effective.

SowingTime

Although farmers are aware of the importance of early sowing to take advantage of residual moisture, sowing time must depend on the duration of the rainy-season crops. Most farmers sow chickpea during November. October sowing is only possible after harvesting short-duration crops such as mung bean. To accommodate early sowing we are experimenting with ESD pigeonpea (of 100 days duration) as a rainy-season crop.

Crop Establishment

With the existing level of land preparation and method of sowing, it is difficult to obtain optimum interplant spacing. With delay in sowing, the moisture recedes and the germination is affected. Deep sowing improves emergence. Early sowing may further reduce the risk of poor germination. For irrigated chickpea crop establishment does not pose a great problem.

Fertilizers

Although fertilizers are available, farmers normally apply them at low rates, particularly for nonirrigated chickpeas. Further, most farmers are not aware of nutritional deficiencies and so do not use micronutrients. This reduces yields. However, farmers can easily apply micronutrients if properly advised to do so.

Weeds

Most farmers resort to hand weeding. However, increasing labor costs will favor the use of herbicides particularly for irrigated chickpea. Where grown on residual moisture, hand weeding of chickpeas will continue.

Diseases

Wilt caused by *Fusarium oxysporum* commonly reduces yield. Wilt resistant cultivars with good agronomic characters are now available. Plant mortality resulting from *Sclerotium rolfsii* is another important problem, particularly in waterlogged crops. ICCV 2 is particularly susceptible to *Sclerotium rolfsii*. No resistant varieties are available. In some fields phyllody was also observed.

Pests

Helicoverpa armigera is a problem in central and southern India. It is however, not so severe in chickpeas as in other crops, and could be managed with two applications of insecticides. ESD chickpea may need just one application at the podding stage. Dusting gave better control than spraying.

End-season Drought Stress

Long-duration varieties suffer from drought stress particularly in light soils. ESD variety ICCV 2, which matures in 75–80 days, can circumvent this problem. It has become very popular.

Seed Quality

Chickpea seed does not rapidly lose its viability. However, because of severe damage by bruchids in storage most farmers do not keep seed. At sowing they purchase seed from local merchants at cost. Seed of improved varieties is in short supply. Government seed multiplication programs fail to keep up with the demand. Therefore, most farmers still have to depend on local merchants and seed quality and purity cannot be assured. Farmers should be trained to store their seed in a safe manner.

Conclusions

Chickpea is a low risk and profitable crop when compared with others such as wheat, safflower, and sorghum. It suffers less from pest problems. Diseases, particularly fusarium wilt, can be overcome by the use of resistant cultivars. ESD chickpeas can reduce the risk from terminal drought stress. The first year's trials have shown high a yield potential and have identified the constraints in farmers' fields.

Acknowledgment

We sincerely thank Dr Y.L. Nene for his strong support and guidance of the technology transfer program.

Reference

Jodha, N.S., and **K.V. Subba Rao.** 1987. Chickpea: World importance and distribution. Pages 1-10 *in* The Chickpea. Saxena, M.C., and Singh, K.B. (eds.). Wallingford, Oxon, UK: CAB International.

The Asian Grain Legumes Network (AGLN) Model

D.G. Faris, C.L.L. Gowda, and D. McDonald[1]

Abstract

The Asian Grain Legumes Network (AGLN) deals with chickpea and provides an example for forming other chickpea networks. The AGLN was established in 1986 to strengthen research in Asian countries on chickpea, pigeonpea, and groundnut, to generate appropriate technology by more effectively using existing staff and facilities, and to coordinate and facilitate collaborative research activities on these crops to help farmers increase their legume production. The structure and operation of the network is founded on five components: membership, research, coordination, communication, and assets. The network has two elements: bilateral and multilateral links. The bilateral element is based on memoranda of understanding between ICRISAT and each of 11 AGLN countries, and on work plans detailing specific activities. The national AGLN coordinator is the administrative link between each national program and the AGLN Coordination Unit (supported by ICRISAT). The multilateral element provides links between AGLN members in all network groups including those in national programs, several regional and international institutes, donors, and mentor institutions. The linking activities include meetings, workshops, monitoring tours, regular and special training at ICRISAT and in-country, special projects and working groups, an information bank, and literature services. Overall the AGLN provides a structure to facilitate interchange and cooperation among grain legume scientists in Asia, provides scientific backstopping, acts as a clearing house for information and material, and helps strengthen national programs.

Résumé

Modèle du Réseau asiatique sur les légumineuses à grains : *Le Réseau asiatique sur les légumineuses à grains (AGLN) traite du pois chiche et présente un exemple pour la réalisation d'autres réseaux sur le pois chiche. L'AGLN a été établi en 1986 pour renforcer les recherches dans les pays d'Asie sur le pois chiche, le pois d'Angole et l'arachide, pour mettre au point une technologie appropriée en utilisant plus efficacement le personnel et les moyens d'action existants et pour coordonner et faciliter des activités de recherche collaborative sur ces cultures afin d'aider les cultivateurs à accroître leur production de légumineuses. La structure et l'opération du réseau se base sur cinq composants : les membres, la recherche, la coordination, la communication et les biens. Le réseau a deux éléments : des liens bilatéraux et multilatéraux. L'élément bilatéral est basé sur des protocoles d'accord entre l'ICRISAT et chacun des onze pays de l'AGLN, ainsi que sur des plans de travail détaillant des activités spécifiques. Le coordinateur national de l'AGLN est le lien administratif entre chaque programme national et l'Unité de coordination d'AGLN (appuyée par l'ICRISAT). L'élément multilatéral assure des liens entre les membres de l'AGLN dans tous les groupes de réseaux, y*

1. Principal Coordinator, and Senior Plant Breeder, Asian Grain Legumes Network (AGLN), and Program Leader (Acting), Legumes Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

ICRISAT Conference Paper no. CP 572.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

compris ceux des programmes nationaux, de plusieurs instituts régionaux et internationaux, des bailleurs de fonds et des institutions-guides. Les activités de liens comprennent des réunions, des ateliers, des tournées d'observation, des formations régulières et spéciales à l'ICRISAT et dans le pays concerné, des projets spéciaux, des groupes de travail, une banque d'informations et des services de documentation. Dans l'ensemble, l'AGLN fournit une structure pour faciliter les échanges et la coopération entre les chercheurs des légumineuses à grains en Asie, assure la surveillance scientifique, joue le rôle de bureau central pour des informations et des matériels et contribue à aider à renforcer les programmes nationaux.

In their presentation at this workshop on effective research networking Drs Smith, Plucknett, and Ozgediz described the value of agricultural research networks (ARNETs) and reviewed fourteen principles for effective networks. They also outlined several types of networks each set up to meet a certain need. Our purpose is to describe one example of an ARNET model, the Asian Grain Legumes Network (AGLN), which has been set up in part to meet the research needs of chickpea scientists in Asia. Although most of the AGLN activities described do not refer directly to chickpea by name, many of them do include chickpea as it is one of the crops covered by the network. The AGLN model may also give ideas of how other chickpea networks might be organized.

Founding

In 1983 a consultative group meeting at ICRISAT, attended by legume scientists from several Asian countries, and representatives from regional donor agencies, identified the major constraints to the production of groundnut, chickpea, and pigeonpea in Asia, and the priority research needed to overcome those constraints (ICRISAT 1984). With these needs in mind the group endorsed ICRISAT's concept of an Asian Regional Legume Program. At the follow-up review and planning meeting in 1985, ICRISAT's Director General announced the appointment of a coordinator for what since late 1986 has been called the Asian Grain Legumes Network. ICRISAT agreed to supply a network coordinator and the AGLN Coordination Unit was located at ICRISAT Center. This meeting also recommended a general plan of action and a list of specific activities to be undertaken by the Coordinator (ICRISAT 1987). The AGLN has been structured and has developed activities based on the recommendations of the above two meetings.

Objectives

The general objectives of AGLN were similar to those spelled out by network coordinators who met in Nairobi in May 1988 (Faris and Ker 1988). These are to:

- strengthen the applied research capability of National Agricultural Research Systems (NARS) to identify, address, and solve farmers' problems;
- generate appropriate technology by more effectively utilizing existing research personnel, facilities, and other resources;
- ensure stability of agricultural production through a responsive research capability; and
- provide the support, both technical and financial, required to facilitate the coordination of activities on a regional basis.

The specific objectives of the AGLN when it was set up were to:

- produce a directory of AGLN cooperators;
- operate an information bank for the cooperators;
- identify adapted grain legume lines and the appropriate agronomy for their cultivation in each AGLN country;
- promote training of legume scientists from AGLN countries; and
- foster special research support projects.

As pointed out in the Smith et al. presentation in this workshop a clear objective is essential for a network to succeed. These objectives are now being refined as recommended by the recent legumes network coordinators' meeting (ICRISAT 1989b).

Structure and Operation

The structure and operation of the AGLN is founded on the five components incorporated in most ARNETs: membership, research, coordination, communication, and assets (Faris and Gowda 1989). The structure and operation of the AGLN can also be divided into bilateral and multilateral elements.

Bilateral Element

The bilateral element is founded on strong links between ICRISAT and national program scientists based on a formal memorandum of understanding (MOU) with each AGLN country. These MOUs lay out the areas of research collaboration on ICRISAT's mandate crops and such matters as the movement of scientists and seed material, the import of equipment, and the release of information and varieties. By the end of 1989 there will be a signed MOU with 11 major AGLN countries: Bangladesh, India, Myanmar, Nepal, Pakistan, and Sri Lanka in South Asia; and the People's Republic of China, Indonesia, the Philippines, Thailand, and Vietnam in East and Southeast Asia. The AGLN also works with other countries of Asia when its assistance is requested.

Collaborative work plans for each country have been developed as part of each memorandum of understanding. Usually, these are developed at a review and planning meeting or at other related meetings held in the country concerned. They set out the specific commitments of AGLN/ICRISAT and the country.

The country-AGLN coordinators are the administrative contact persons in each member country with the AGLN Coordination Unit based at ICRISAT Center. Decentralizing the responsibility for network operations within each country increases the overall effectiveness of the coordination in the network.

An integral part of the AGLN's bilateral element is its interaction with donors, and international, regional, and mentor institutes, which was a major recommendation of the 1985 meeting (ICRISAT 1987). The Coordination Unit has found contacts and joint activities with this group to be very fruitful. We shall describe some of these later.

Multilateral Element

The multilateral element of the AGLN comes from the many network activities that link network members with each other. These activities include the network coordinators' meetings (ICRISAT 1989b), workshops, monitoring tours, working groups (ICRISAT 1988a), scientists' meets (ICRISAT 1989a), and training to name but a few. Donor, regional, and international institute groups are also very much part of the multilateral element of the AGLN. The multilateral activities will be discussed in more detail in the progress section below.

The Coordination Unit consists of a network coordinator, a breeder, and a secretary. The Unit receives guidance from an Advisory Committee at ICRISAT, scientists and administrators at the review and work plan meetings in each country, country-AGLN coordinators, workshop recommendations (ICRISAT 1984, 1987), network coordinators' meetings (ICRISAT 1989b), and from other sources.

The main mode of action of the Coordination Unit is to facilitate contacts between legume scientists in AGLN countries and those at ICRISAT Center. The scientifically productive contact is directly between scientists, and after the initial contact the involvement of the Coordination Unit becomes secondary. New initiatives are now relatively easy to launch because the contacts and agreements with each country have already been made.

Funding

ICRISAT supports the Coordination Unit and provides funds for ICRISAT scientists to visit AGLN countries, and for the training of scientists from AGLN countries. The value of a small external funding is demonstrated by the large number of activities and additional research that have been made possible in South Asian countries by a grant from the Asian Development Bank (ADB). This grant was for the strengthening of legume research programs in Bangladesh, Myanmar, Nepal, and Sri Lanka. Similarly, money made available by the Australian International Development Assistance Bureau (AIDAB) has resulted in several important research activities in Indonesia on peanut stripe virus (PStV), and in Thailand on pigeonpea. More recently donors have shown interest in supporting projects in association with the AGLN. This aspect is expected to expand.

Progress

The AGLN's objectives are a good basis on which to evaluate the network's progress. The degree to which the recommendations of the 1983 and 1985 meetings have been met also forms a good measure of progress. This present progress report provides in addition a good framework for a description of the networks activities.

AGLN Directory

Almost 500 scientists have responded to the invitation to become a cooperator in the AGLN. Their names have been entered in a database, and the first edition of the directory, giving names and addresses, should be available soon. Later editions will list the crop(s) and discipine(s) of each cooperator.

Information Bank

Information from ICRISAT is available to network cooperators through the Information Services, Legumes Program and the library, which operates the Semi-Arid Tropical Crops Information Service (SATCRIS) (ICRISAT 1988b). Of direct interest to the group is the International Chickpea Newsletter, and the joint CABI/ICRISAT CAB Prompts Series on Chickpea.

The AGLN Coordination Unit has collected pamphlets, books, reports, and maps from each country and these are being cataloged. In addition, unpublished information about each country is collected by the Coordination Unit staff when traveling. A management information system called AGLNIS is currently being developed by ICRISAT's Computer Services to allow easy access to this information. Apart from handling information from trip reports, AGLNIS will help in correspondence, as it is linked with the AGLN Directory, and in the production of progress reports for distribution to AGLN cooperators.

ICRISAT Material

Trials containing advanced generation material have been made available to network cooperators directly through scientists in ICRISAT's Legumes Program, who are also AGLN cooperators. Special attempts are made to visit all trials, and to review all results at annual planning meetings. The results are published in the various reports distributed by ICRISAT. Details of these trials and results on chickpea in Asia are reported elsewhere in this workshop. The network can also act to facilitate movement of material among AGLN countries.

Training

Training has both a linking and improvement component. The Coordination Unit has facilitated and helped to support:

- Trainees in regular ICRISAT courses.
- Special courses such as virus identification, integrated pest management, and legume utilization. Many of these have been made possible by special grants from donors such as the Food and Agriculture Organization (FAO), International Development Research Centre (IDRC), Peanut Collaborative Research Support Program (Peanut-CRSP), and ADB.
- In-country training courses on chickpea, pigeonpea, groundnut, mung bean, and lentil given by local national and scientists from other national programs and scientists from ICRISAT, Asian Vegetable Research and Development Center (AVRDC), and International Centre for Agricultural Research in the Dry Areas (ICARDA) and financed by the ADB through the AGLN.
- In-country courses on integrated pest management, given in Thailand and Indonesia by local, Australian Centre for International Agricultural Research (ACIAR), and ICRISAT staff.
- The agroclimatology workshop with inputs from all AGLN countries, FAO, the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT), IRRI, the Resource Management Program (RMP) at ICRISAT, the AGLN itself, and local geography and cartography consultants (Virmani et al. 1990). This and similar workshops provide a training component but also enable scientists to use and analyze their own data to put forward a joint publication.

Special Research Projects

Most of the AGLN's special projects arise from specific recommendations of the 1985 meeting. An example is the Peanut Stripe Virus Working Group (ICRISAT 1988a), which shows how inputs from many groups can be used to tackle a common problem. Others have developed more recently for example the Sri Lanka Pigeonpea Production Project given below.

Pigeonpea Production Project

The Pigeonpea Production Project was started because Sri Lanka needed to produce pigeonpea to replace the US$ 45 million dhal import. It deals with the whole sequence of pigeonpea production and utilization. This project will provide the production technology needed to make pigeonpea available at an economic price to consumers in Sri Lanka and to strengthen the research structure to support this technology. Previous attempts to extend pigeonpea production apparently failed because of insect devastation, and lack of a dhal-making infrastructure. The steps in this project involve interaction between Sri Lanka and ICRISAT AGLN scientists to provide:

- an agroeconomic intelligence survey to guide the project;
- establishment of best approach to develop a dhal-making infrastructure;
- demonstration of existing pigeonpea production technology in conjunction with dhal production; and
- collaboration between an ICRISAT and a Sri Lankan pigeonpea scientist to upgrade pigeonpea research in Sri Lanka to identify and answer pressing production problems.

Other Activities

Other activities that illustrate the AGLN's collaboration with national programs and other organizations include:

- A groundnut scientists' meeting held in 1988 in Indonesia (ICRISAT 1989a) and a chickpea scientists' meeting held in 1986 in Pakistan.
- Nepal/IRRI/ICRISAT monitoring tour and workshop on the improvement of chickpea, pigeonpea, and other pulses, held in 1989.
- Transfer of an ICRISAT chickpea scientist to Nepal for one year and transfer of Nepal chickpea scientists to ICRISAT to analyze and interpret trial results.
- Collaboration with the ACIAR pigeonpea projects in Thailand and Indonesia, and with the groundnut project in Indonesia.
- The analysis of pigeonpea production data and the development of a pigeonpea growth model by ACIAR staff working partly at ICRISAT.
- Participation of AGLN Coordination Unit in planning for the Southeast Asia Regional Food Legume Steering Committee, Asian Rice Farming Systems Network (ARFSN) Working Group, and FAO's RAS 82/002 Coordination Committee.

These are only some examples of the initiatives with which the AGLN has been associated.

Conclusion

The AGLN has been presented as a model partly because it includes networking activities on chickpeas in Asia but also because its structure, operation, and philosophy may serve as an example for participants at this workshop wishing to start a chickpea research network. Basically the AGLN model is designed to facilitate links among grain legume scientists in Asia by determining the problems and needs of these scientists, encouraging collaborative research and sharing of material to meet these problems, supporting activities to bring the scientists together to share ideas and information, and to backstop research needs of the members.

References

Faris, D.G., and **Gowda, C.L.L.** 1989. Networking and the AGLN. Pages 3-11 *in* Linking grain legumes research in Asia: summary proceedings of the Regional Legumes Network Coordinators' Meeting, 15-17 Dec 1988, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Faris, D.G., and **Ker, A.D.R.** 1988. Eastern and southern Africa network coordinators' review: proceedings of a Workshop, 9-12 May 1988, Nairobi, Kenya. Ottawa, Canada: International Development Research Centre.

ICRISAT International Crops Research Institute for the Semi-Arid Tropics. 1984. Grain legumes in Asia: summary proceedings of the Consultative Group Meeting for Asian Regional Research on Grain Legumes (Groundnut, Chickpea, Pigeonpea), 11-15 Dec 1983, ICRISAT Center, India. Patancheru, A.P.502 324, India: ICRISAT. 102 pp.

ICRISAT International Crops Research Institute for the Semi-Arid Tropics. 1987. Coordination of grain legumes research in Asia: summary proceedings of the Review and Planning Meeting for Asian Regional Research on Grain Legumes (Groundnut, Chickpea, and Pigeonpea), 16-18 Dec 1985, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT. 96 pp.

ICRISAT International Crops Research Institute for the Semi-Arid Tropics. 1988a. Coordination of research on peanut stripe virus: summary proceedings of the First Meeting to Coordinate Research on Peanut Stripe Virus Disease of Groundnut, 9-12 Jun 1987, Malang, Indonesia. Patancheru, A.P. 502 324, India: ICRISAT. 32 pp.

ICRISAT International Crops Research Institute for the Semi-Arid Tropics. 1988b. Semi-Arid Tropical Crops Information Service (SATCRIS). Patancheru, A.P. 502 324, India: ICRISAT.

ICRISAT International Crops Research Institute for the Semi-Arid Tropics. 1989a. Summary and recommendations of the Asian Region Groundnut Scientists' Meeting, 14-17 Nov 1988, MARIF, Malang, Indonesia. Patancheru, A.P. 502 324, India: ICRISAT. 24 pp.

ICRISAT International Crops Research Institute for the Semi-Arid Tropics. 1989b. Linking grain legumes research in Asia: summary proceedings of the Regional Legumes Network Coordinators' Meeting, 15-17 Dec 1988,ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT. 110 pp.

Smith, N.J.H., Plucknett, D.L. and **Ozgediz, S.** 1990. Effective networking in International Agricultural Research. Pages 303-309 *in* Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Virmani, S.M., Faris, D.G., and **Johansen, C.,** (eds). 1990. Agroclimatological constraints to the production of chickpea, pigeonpea, and groundnut in Asia. Research Bulletin no. 14. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Diversity and Convergence in On-farm Research Methodology

R.K. Pandey[1], D.P. Garrity[2], and N.F.C. Ranaweera[2]

Abstract

It is becoming widely accepted that research to accelerate crop productivity growth in less-favorable environments requires unique methods to be effective. Several different approaches to on-farm and farming systems research have now been developed and deployed. This paper reviews some of the central concepts, and notes the convergence of procedures that appears to be evolving. A model of technology generation, adaptation, and adoption is discussed with emphasis on the linkages in the research continuum. We review some aspects of IRRI's experience in the development of on-farm cropping systems research methods. Application of the concepts to chickpea research is discussed.

Résumé

Diversité et convergence de la méthodologie de recherche en milieu paysan : *L'on admet de plus en plus que la recherche pour accélérer la croissance de la productivité des cultures dans les environnements peu favorables exige des méthodes uniques pour être efficace. Plusieurs approches différentes à la recherche sur les systèmes d'exploitation et à la recherche en milieu paysan sont maintenant mises au point et ont été mises en oeuvre. Ce rapport passe en revue certains des concepts centraux et note la convergence de procédures qui semble se manifester. Un modèle de génération de technologie, d'adaptation et d'adoption est exposé, en insistant sur les liens dans le processus de recherche. Nous examinons certains aspects de l'expérience de l'IRRI quant au développement de méthodes de recherche sur les systèmes de culture en milieu paysan. L'application des concepts à la recherche sur le pois chiche est examinée.*

Large environmental and socio-economic variability is characteristic of most agroecosystems in the tropics and subtropics. The imperative for more effective research methods to derive and fit technology to specific ecosystems is therefore necessary.

Many institutions have devoted attention to on-farm and farming systems research, and not unexpectedly, different methods and styles of research have evolved. This paper attempts a brief overview of some of the widely accepted principles of on-farm research that employ a farming systems perspective (OFR/FSP), against a background of International Rice Research Institute (IRRI) experience during the past 15 years. Emphasis will be placed on the convergence of concepts and procedures that appear to be evolving (Harrington et al. 1989), and where there is divergence in the approach of different institutions, the underlying factors that explain the differences. Application of these concepts and procedures to the particular problems of chickpea technology generation and diffusion will be

1. Director, Directorate for Cropping System Research, Indian Council of Agricultural Research (ICAR), Modipuram, Meerut 250 110, Uttar Pradesh, India.
2. Agronomist/Crop Ecologist, Multiple Cropping Department, and Visiting Economist, Agricultural Economics Department, International Rice Research Institute, Los Baños, P.O. Box 933, Manila, Philippines.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India:

discussed. As with other commodities predominantly produced by resource-poor farmers, there is a sense of openness among researchers involved that new approaches are needed (Biggs 1985; Chambers and Jiggins 1987).

Model of the Technology Development Continuum

On-farm research approaches that use a farming system perspective may offer distinct opportunities as tools in the complex process of developing client- and location-specific technology; technology that farmers perceive as maximizing returns to the limited resources that they control. OFR/FSP and experiment station research share common goals for the generation and transfer of relevant technology, which constitute complementary and interdependent functions within the research process. OFR/FSP employs specific methods to define relevant client groups and their research priorities. It emphasizes technology adaptation for suitable niches, and is usually best conducted on-farm in order to capture the full range and variability of those conditions (Collinson 1987). Development and spread of farming systems research methodologies have been pioneered at a number of international agricultural research centers (IARCs) including IRRI (Byerlee et al. 1982; Horton and Sawyer 1988; Monteith et al. 1988; Zandstra et al. 1981).

Technology generation, adaptation, and adoption activities may be seen as part of a research and development process (Denning 1988) composed of six activities (Fig. 1). Activity A is technology generation at international and national research centers, primarily in laboratories and on-station. It tends to be more commodity- than systems-oriented. Activity B is on-station technology generation and adaptation for specific regions and agroclimatic environments. The main participants at this stage are researchers from national research systems working at regional stations. Certain aspects of IARC research are also conducted at this level in collaboration with national scientists, for example, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) chickpea materials for evaluation in specific agroclimatic environments. Activity C involves on-farm technology generation and adaptation for specific regions and agroclimatic environments. The main participants are researchers, although contributions from extension workers and farmers are also crucial. IRRI on-farm cropping systems research falls in this category. A cropping systems research site of this type may operate as a semi-permanent field location for generating and testing new technologies, including those at an early stage of development. Activities B and C are very closely linked. Activity D is shown as the focal point of the research and development model. This is farmer-participant research. The farmer and adaptive researcher, who may be an extension worker, are the key participants in this testing and evaluation process. This integrative activity seeks to fit technology generated through Activities A, B, and C to individual farming practices and production systems.

Farmers' own observations and tests compose Activity E –an aspect of farmer innovation independent of the formal research and extension system. The importance of this process is evident in the unique farming practices evolved by farmers in agroecosystems without any impact of formal research and development efforts. Activity F is the acceptance of innovations by farmers.

The above sets the context for the array of interlocking activities that constitute an effective system of generation, adaptation, and adoption. But how are these activities best carried out? And what is the proper balance among them? These practical questions must be addressed by every research institution.

Integration of On-farm and On-station Research

On-farm research with a farming systems perspective is designed to increase the capacity of technology generation and transfer systems to respond effectively to the need of specific client groups, most commonly resource-poor farmers. It complements and depends upon research carried out on experiment stations. It involves a client-orientated philosophy, a specific approach to research that goes beyond merely placing a conventional trial in a farmer's field. It also includes the formal diagnosis and ranking of problems, and the design and development of appropriate technologies to solve them. Farmers are actively involved at various stages in the research process.

On-farm research helps on-station research by providing:

- a complementary role in the generation of technology;
- a feedback and support function; and
- opportunities for research managers to refocus their research priorities.

An integrative model of on-station and on-farm

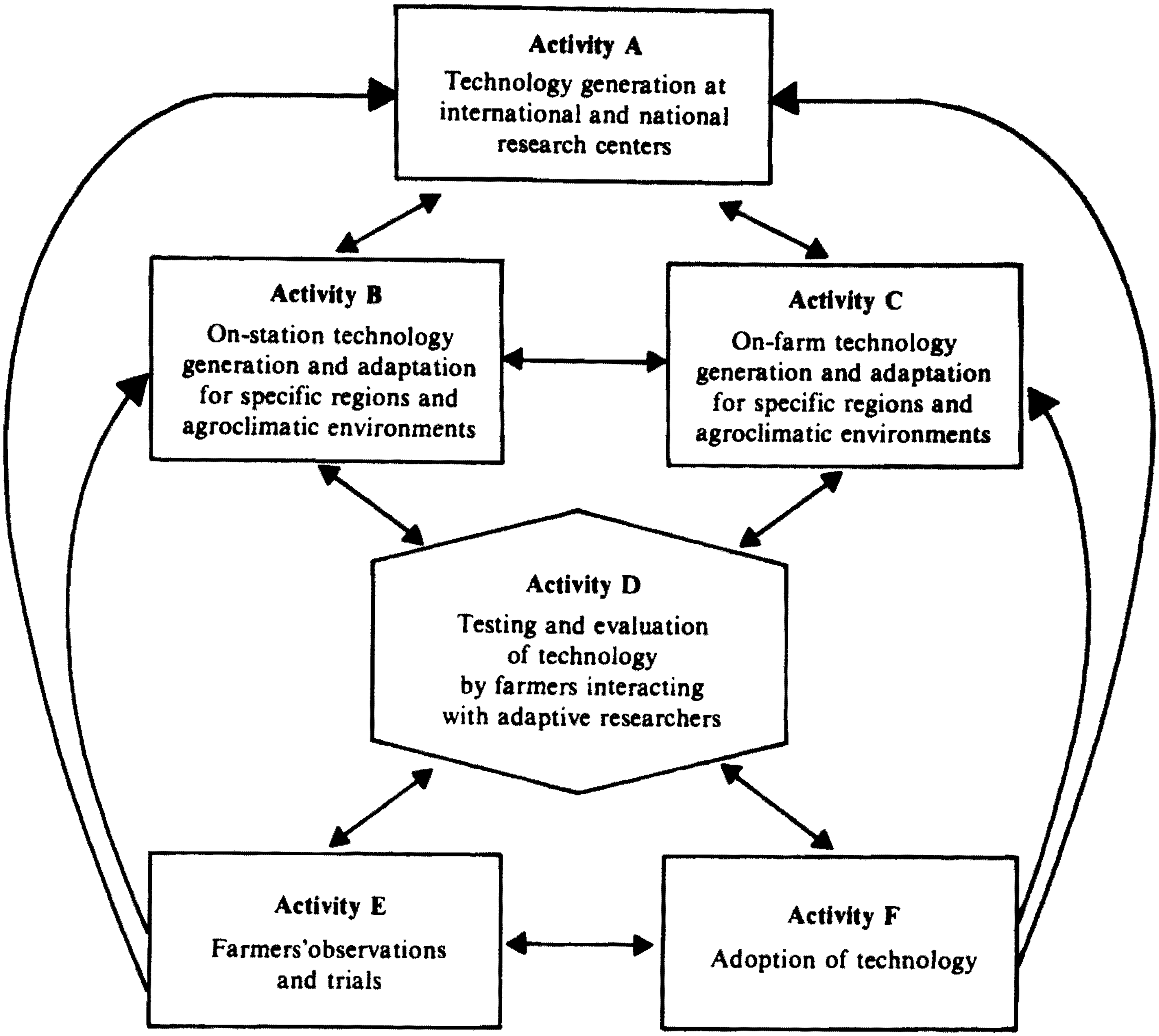


Figure 1. Conceptual model for technology generation, adaptation, and adoption. Source: Denning 1988.

research is probably best suited for technology generation and transfer, since it tends to avoid the development of conflicts of interest between the more reductionist station-based scientists and the on-farm action-orientated scientists.

Strategies for On-farm Research

Most IARCs have been actively involved in the development of on-farm research methodologies suited to their mandated ecosystems and commodities. Their approaches may be divergent, but their goals and philosophy for on-farm methodology are similar. The concept they consider basic to all approaches include:

- a diagnostic function which influences the selection of research priorities;
- the conduct of much of the research and development on-farm; and
- farmer participation in assessing new technology.

Harrington et al. (1989) reviewed a number of these approaches, and concluded that, although each seemed quite unlike the others, hidden behind the wide variation in terms and research tools were strong similarities in underlying concepts and procedures.

The strategies for agricultural research can be broadly distinguished as either commodity-based or ecosystem-based farming system research. Among the CG Centers commodity-based systems research is practiced by IRRI, Centro Internacional de Agricultura Tropical (CIAT), Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) and Centro Internacional de la Papa (CIP). Ecosystem-based systems research is practiced by ICRISAT in the semi-arid zones, International Center for Agricultural Research in the Dry Areas (ICARDA) in the arid zones, and International Institute of Tropical Agriculture (IITA) in the humid tropics.

IRRI has been associated with the development of two major types of on-farm research methodology: Cropping Systems Research and Yield Constraints Analysis. These methods evolved to address two hypotheses that had assumed dominant importance in Asian rice research by the mid-1970s:

1. there was unrealized potential to further intensify rice-based cropping systems; and
2. there was a substantial gap between irrigated rice yields obtained by farmers, and those possible using the available technology.

The methodologies are founded on principles that are generalizable across different crops and systems, but the form that they assumed, and their application, was directed to the unique environment in which rice is grown, and in particular the promising opportunities presented by major technical changes in tropical rice cultivars.

The Working Group of the Asian Rice Farming Systems Network (ARFSN) developed a seven-stage research process that has been widely employed (Zandstra et al. 1981). The stages are site selection, site description, cropping pattern design, cropping pattern testing, multilocational testing, and production programs (Fig. 2). The stage of impact analysis was more recently added (Morris 1986). As the ARFSN began the development of methods for crop–animal research and other systems, the cropping pattern design stage was broadened to multi-enterprise technology design in order to encompass the broader perspective of farming systems which included non-crop enterprises. The on-farm research connected with the methodology involves both researcher-managed and farmer-managed trials. Farmer participation in the research is dominant in the farm-scale evaluation of alternative cropping patterns.

The distinguishing feature of this methodology is the emphasis on the cropping pattern; intensifying it, diversifying it, or increasing the productivity of the crops in existing patterns. Component technology development and evaluation is a critical element of this research process, as it is directed at increasing and stabilizing the production of the crops (or other enterprises) within the pattern (or farming system). Therefore the research focuses on identifying and overcoming the factors that constrain the yield of the component crops. The overall focus, however, is on the performance of the entire cropping pattern. This explicitly recognizes that although a technical innovation may improve a system's performance, the incorporation of that innovation invariably affects other cropping activites.

The acid test of the research team's understanding of the component technology occurs in the annual cropping pattern design activity, when all management practices are specified for the component crops. Knowledge gaps are clarified by this exercise, which feeds into the next cycle of research.

There are limitations associated with the methodology. These are related to applicability and cost-effectiveness in different agricultural environments and different research teams. An important hypothesis underlying the methodology is that the number of crops (or number of enterprises) in a given agroecosystem can be increased. Thus, the choice of a target environment, and research site selection within it, is a fundamental aspect of the process. Underlying this process is the hypothesis that new multi–enterprise technologies will be successful. The methodology is less suitable in areas where there are few, if any, significant interactions between crops in a pattern. In this case it may be more cost-efficient to concentrate on solving productivity problems within the dominant component crop or crops.

On-farm research requires managerial skills to: select representative and accessible sites, win farmers' confidence, organize field teams, provide adequate supervision and transpsort, and motivate and reward scientists to work in remote areas, in apparently non-prestigious positions. Multi-commodity research involves the interaction of larger numbers of researchers, which creates greater logistical support requirements. The cropping systems research may be complex when compared to single commodity research creating greater difficulty in prioritizing the research activities. Agroecosystems analysis has been used in the cropping systems research process as an appropriate tool to focus a diverse team's attention on problem identification and prioritization (Magbanua and Garrity 1989).

Complexities in Rainfed Farming and in Technology Transfer

Technologies that fostered the dramatic 'green revolution' in irrigated wheat and rice do not apply under the

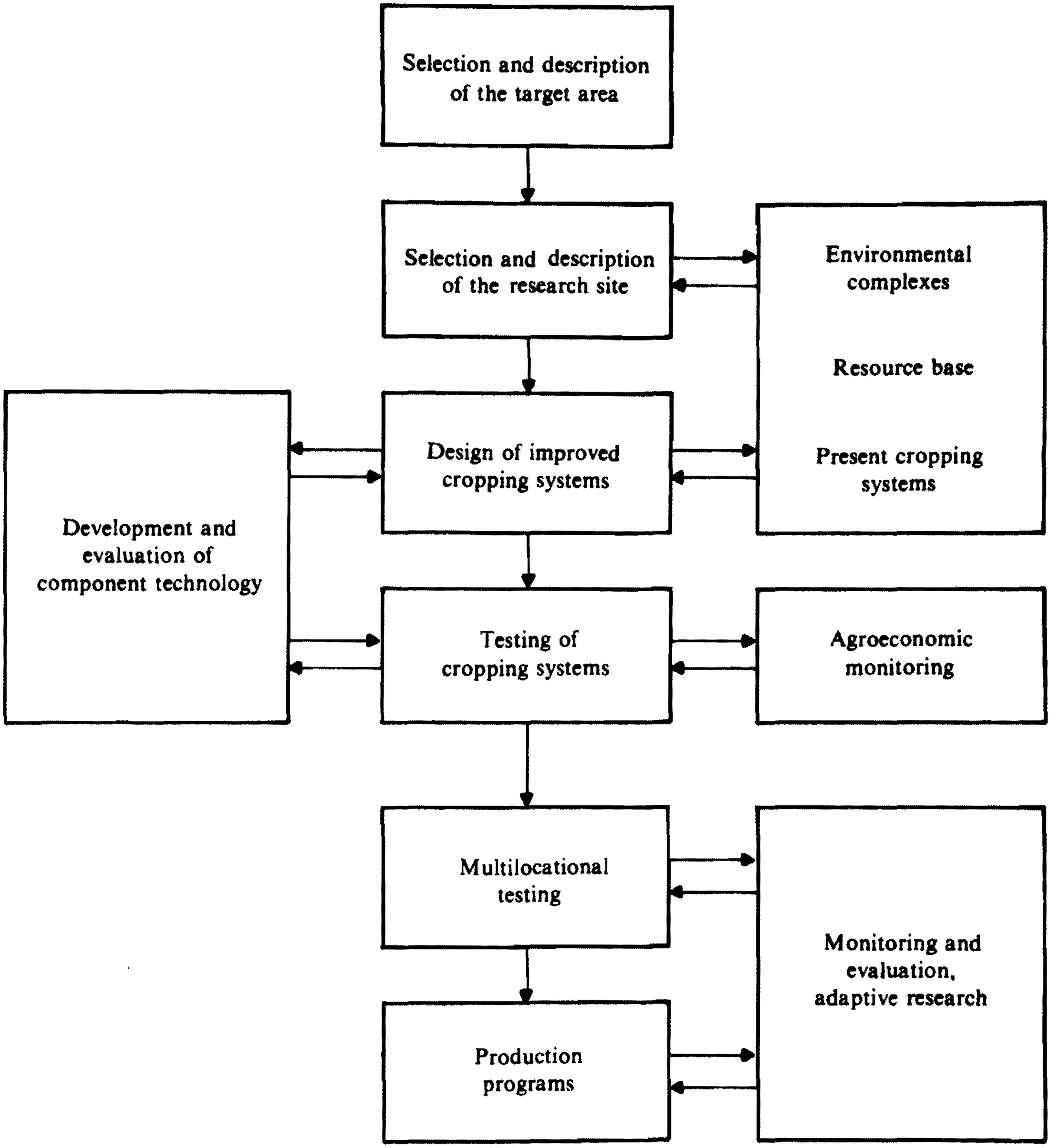


Figure 2. Components of site-related cropping systems research methodology. Source: Adapted from Zandstra et al. 1981.

highly variable and complex conditions of rainfed farming which require more site-specific identification of constraints. Given the vast areas under rainfed farming, and the increasisng number of small farmers forced to cultivate marginal and degraded lands, national and international centers might best focus their research by limiting on-farm research to a few contrasting agro-ecological situations while closely collaborating with national networks of on-farm test sites, emphasizing not only yield and biological potential, but also other production criteria that influence technology adoption, and complementing efforts to increase productivity with research to increase sustainability at low input levels.

Technology transfer in most national programs is a top-down process of research-to-extension-to-farmer, largely ignoring the immense need for constant feedback from the farmers. Experience has shown that when the subsistence farmer is presented with a package of technology presumably superior to his current practices, he tends to react either by adopting only one or two components at a time, or by experimenting to adapt the given technology to his particular situation. Neither research nor extension agencies have as yet fully appreciated the impact of environmental variability on rainfed farming in the semi-arid and arid lands. In striking contrast to agriculture in irrigated or assured rainfall areas, where decisions can be taken before the start of the cropping season, rainfed farming requires making day-to-day decisions during the season, in response to weather conditions.

On-farm Research in the Chickpea Context

The constraints enhancing the productivity of chickpea in India are biological, physical, socio-economic, and institutional. There are serious yield gaps in transfer of available technologies shown by the gaps between potential yield and actual farmer yields. For example experimental yields of 3.5 t ha^{-1} have been reported for chickpea, while a farm-level yield of 0.9 t ha^{-1} is common in north India. Similarly, seed yields of 3 t ha^{-1} have been reported at ICRISAT Center, while farm yields in Andhra Pradesh are only 0.26 t ha^{-1}. The major reasons for the yield differences are drought stress, and inadequate crop management and pest control.

To narrow the yield gap, on-farm research on the following aspects need attention:

- germplasm enhancement through on-farm evaluation and adaptation;
- integrated pest management through on-farm research and management strategy; and
- integrated crop management through on-farm research and evaluation of relevant technology.

Improving the productivity of rainfed chickpea in areas where the majority of the farmers are resource-poor, is going to be a relatively slow process. The stability of production will also continue to be low. Doubling productivity will take considerable effort and resources, but experience with soybeans suggests that substantial increases in productivity at the farm level can be accomplished in food legumes. Average yields of soybeans in the USA in 1924 were 0.76 t ha^{-1}, lower than the current average chickpea yield in northern India (Luedders 1977). Productivity in the USA now averages around 2.0–2.2 t ha^{-1} which represents a threefold increase in 60 years. The improvement in seed yields in soybean in the USA has ranged from 0.7 to 0.9% per year since the 1930s (Luedders 1977; Boerma 1979). These increases are only a little lower than those recorded for cereals (Evans 1983). However, as in cereals, the increases have been stepwise, and the result of both improved cultural practices and increased genetic potential (Jensen 1978; Boerma, 1979).

Chickpea researchers face particularly challenging problems in evolving an optimum on-farm research thrust to complement fundamental station-based work. The very nature of the crop's constraints suggests that attention should be given to spatial and systems variability, and enterprise interactions that determine the niche in which this crop will thrive.

References

Biggs, S. 1985. A farming systems approach: some unanswered questions. Agricultural Administration 18:1-12.

Boerma, H.R. 1979. Comparison of past and recently developed soybean cultivars in maturity groups VI, VII, and VIII. Crop Science 19:611-613.

Byerlee, D., Harrington, L., and **Winklemann, D.L.** 1982. Farming systems research: issues in research strategy and technology design. American Journal of Agricultural Economics 64:897-904.

Chambers, R., and **Jiggins, J.** 1987. Agricultural research for resource-poor farmers. Part II: A parsimonious paradigm. Agricultural Administration and Extension 27:109-128.

Collinson, M. 1987. Farming systems research: procedures for technology development. Experimental Agriculture 23:365-386.

Denning, G.L. 1988. On-farm research to generate technology for rainfed rice farmers. Entwicklung und Laendlicher Raum 22(3):13-15.

Evans, L.T. 1983. Raising the yield potential: by selection or by design. Pages 371-389 *in* Genetic engineering of plants (Kosuge, T., Meredith, C.P., and Hollaender, A., eds.). New York, USA: Plenum Publishing Co.

Harrington, L.W., Read, M.D., Garrity, D.P., Wooley, J., and Tripp, R. 1989. Approaches to on-farm client-oriented research: Similarities, differences, and future directions. Presented at the International Workshop on Developments in Procedures for FSR/OFR, 13-17 Mar 1989, Bogor, Indonesia. El Batan, Mexico: CIMMYT.

Horton, D., and Sawyer, R. 1988. On-farm research experiences with potatoes. Entwicklung und Laendlicher Raum 22(3):19-21.

Jensen, N.F. 1978. Limits to growth in world food production. Science 201:317.

Luedders, V.D. 1977. Genetic improvement in yield of soybeans. Crop Science 17:971-972.

Magbanua, R.D., and Garrity, D.P. 1989. Agroecosystems analysis of a key acid upland farming systems research site. Presented at the 5th Annual Scientific Meeting of the Crop Science Society of the Philippines, 26-28 Apr 1989, Iloilo City, Philippines.

Monteith, J.L., Matlon, P.J., Sachan, R.C., Virmani, S.M., and Walker, T.S. 1988. The evolution of on-farm research at ICRISAT. Entwicklung und Laendlicher Raum 22(3):7-9.

Morris, R.A. 1986. Farming systems research at IRRI: an overview. Pages 36-40 *in* Proceedings of the Workshop on Farming Systems Research, 17-21 Feb 1986, ICRISAT Center, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Zandstra, H.G., Price, E.C., Litsinger, J.A., and Morris, R.A. 1981. A methodology for on-farm cropping systems research. Los Baños, Laguna, Philippines: International Rice Research Institute.

Ten years of International Trials and their Lessons for the Future

Jagdish Kumar[1], C.L.L. Gowda[1], S.C. Sethi[2], Onkar Singh[2], and Murari Singh[3]

Abstract

The international chickpea trials have made available to cooperators segregating and advanced breeding materials with high yields, increased seed size, and disease resistance. A steady demand for high-yield nurseries indicates the usefulness of these materials. A few cultivars from these have already been released in Bangladesh, Ethiopia, India, Myanmar, and Nepal, and many more have been identified. Cooperation and material exchange among cooperators have increased, and this activity has also increased the size of crop improvement programs. Data return has been between, 60-70%. Subgrouping of trials into short, medium, and long durations has proved useful. Further reduction in duration within short and long-duration maturity may enhance stability of performance. Relatively high coefficients of variation indicate a considerable scope for improvement in quality of the experiments. An increase in the general level of resistance to foliar diseases will be useful in medium- and long-duration environments. Selection among crosses based on early generation bulk yield tests did not appear to be promising. Comparison of cultivars and lines from India and from west Asia indicated that the former outyielded the latter in lower latitudes. Differences in higher latitudes were marginal. This suggests wider adaptability of lines from India. Inclusion of more materials from cooperators, and some changes in the design of nurseries are suggested.

Résumé

Dix années d'essais internationaux et leurs leçons pour l'avenir : *Les essais internationaux de pois chiche ont mis à la disposition des coopérateurs un matériel ségrégant et de sélection avancée, ayant un rendement élevé, une taille des grains accrue et la résistance aux maladies. Une demande soutenue de pépinières à haut rendement indique l'utilité de ces matériels. Quelques cultivars provenant de ce matériel ont déjà été vulgarisés au Bangladesh, en Ethiopie, en Inde, à Myanmar et au Népal. Bien d'autres ont été identifiés. La coopération et l'échange de matériel entre coopérateurs ont augmenté et cette activité a également accru l'importance des programmes d'amélioration des cultures. La rentrée des données est de l'ordre de 60 à 70%. Le groupement des essais en cycle court, moyen et long, s'est avéré utile. Une réduction supplémentaire de la durée au sein des cycles court et longs pourrait améliorer la stabilité de la performance. Des coefficients de variation relativement élevés indiquent une possibilité considérable d'amélioration qualitative des essais. Une augmentation du niveau général de résistance aux maladies foliaires pourra être utile dans les milieux à durée moyenne et longue. La sélection parmi les hybrides, basée sur les essais de rendement des premières générations bulk ne semble pas être prometteur. La comparaison entre cultivars et lignées de*

1. Senior Plant Breeders, and 2. Plant Breeders, Legumes Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh 502 324, India.

3. Biometrician, International Center for Agricultural Research in the Dry Areas (ICARDA), P.O. Box 5466, Aleppo, Syria.

ICRISAT Conference Paper no. CP 573.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

l'Inde et d'Asie occidentale a indiqué que les premiers donnent des rendements bien plus élevés en basses latitudes que ceux de l'Asie occidentale. Les différences aux latitudes élevées sont marginales. Cela laisse entendre une meilleure adaptabilité des lignées de l'Inde. L'inclusion de davantage de matériel en provenance des coopérateurs, ainsi que certains changements de la conception des pépinières sont suggérés.

Chickpea international trials and nurseries have been coordinated with the objectives of increasing productivity and adaptation of the crop, by disseminating seed materials, encouraging contacts, and fostering information exchange among chickpea scientists. As suggested in the International Chickpea Improvement Workshop held in 1979, multilocational trials of F_2 and F_3 populations were initiated in the 1978/79 season. In view of the large variation in the length of growing season in chickpea-producing areas, medium-duration trials and nurseries were added to the existing short- and long-duration ones in 1985. To support the development of medium-duration materials, a suitable testing site was selected at Gwalior. An International Chickpea Adaptation Trial (ICAT) was conducted to determine the global adaptation of the crop 1981/82 to 1983/84.

To increase the stability of the crop, lines with resistance to diseases and from diverse parentage were included in the nurseries. The detailed results of these appear in the International Trials and Nurseries reports each year, and are distributed to cooperators and other interested individuals. Important conclusions drawn over the past 10 years are briefly discussed here.

Trials and Nurseries

Chickpea materials made available to cooperators have been classified into: (1) F_2 and F_3 bulk population trials (F_2 and F_3 MLTs), (2) International Chickpea Screening Nurseries (ICSNs) comprising of advanced generation bulked lines, and (3) International Chickpea Cooperative Trials (ICCTs) of germplasm lines and promising breeding lines developed at ICRISAT and cooperating centers. The trials were replicated, generally with 4-6 rows in plots each 4 m long. The nurseries were unreplicated with 2-row plots, using controls in an augmented design. Later these were also replicated (in a duplicated augmented design) with 4-row plots. Each of these trials involved three maturity durations, short, medium, and long. They were requested by cooperators at different locations in various chickpea-growing countries as reported earlier (van Rheenen et al. 1990). A demand for 120-130 sets per year has been recorded. About 65% of the cooperators returned the data, which is a good response.

Analysis of data over the years indicated generally high coefficients of variation, making it difficult to interpret them in a meaningful way. Generally low correlations between the performance of entries across locations, and over years at a location have been observed. These result from the large genotype x environment (G x E) interactions encountered in chickpea.

Genotype x Environment Interaction

Large G x E interactions observed in chickpeas have been discussed earlier (Byth et al. 1980; Singh et al. 1980; Smithson et al. 1985). These result from biotic and abiotic stresses encountered at different locations and years. While efforts to develop resistance to these stresses are being made, we have studied the adaptation of chickpea by conducting a global adaptation trial for 3 years.

The ICAT, mentioned earlier, comprised seven desi and one kabuli entry from India and eight kabulis from seven West Asian countries. It was conducted in important chickpea growing countries in latitudes between 10° and 52°. Seed yield data were returned from 70 environments (location–year combinations). It was observed that locations accounted for 50-60% of the variation for seed yield (Kumar et al. unpublished) and the contribution of the cultivars was about 2 to 8%. There were large G x E interactions. However, the over–all mean yield was well over 1 t ha^{-1} in these latitudes, indicating good adaptation of the crop (Table 1). The lowest yields occurred between latitude 10°-20°. As expected, the Indian cultivars produced high yields at 20°-30° latitudes, but they also did well at higher latitudes, where the crop is sown during the spring. The West Asian cultivars only performed well at higher latitudes. This possibly reflects, in part, their response to longer photoperiods. Indian germplasm may therefore be useful to augment variation in breeding materials for West Asian and other locations.

Of the 70 environments of ICAT, 11 produced a

Table 1. Mean seed yield of 16 chickpea cultivars at worldwide locations during 1981/82 to 1983/84.

Latitudes	Number of locations	Mean seed yield (t ha^{-1}) All (16)[1]	Indian (8)	West Asian (8)
10°-20°	10	1.02	1.23	0.80
20°-30°	30	1.34	1.59	1.08
30°-40°	22	1.17	1.03	1.29
40°-52°	8	1.42	1.46	1.37

1. Figures in parentheses are numbers of cultivars.

mean seed yield of more than 2 t ha^{-1}. These occurred at latitudes between 20° and 30° except in Rapid City, USA (44°N) and winter sowing at Aleppo, Syria (37°N). Among cultivars from India and West Asia, the former produced more than 2 t ha^{-1} in 16, and the latter in 7 environments. Again these high yields were mostly in latitudes of 20°-30° where the growing season is relatively cool and there is less demand for soil moisture. Analysis of data for common locations over years showed not only large variations in yield performance over locations but also substantial interactions between genotypes and locations, and between genotypes, locations and years, suggesting that different cultivars may be needed for different regions.

Multilocational Trials of F_2 and F_3 Bulks

As with other multilocational trials and nurseries, correlations between the performance of F_2 and F_3 trials across locations were generally low and inconsistent. We computed correlation coefficients for performance in F_2 (Table 2) and F_3 (Table 3) generations at ICRISAT Center and other locations in short-duration environments on one hand, and performance in F_3 to F_5 generations at ICRISAT Center on the other. It was apparent that selection of crosses on the basis of mean yield at one or more locations may not necessarily determine the performance of their segregants in later generations. Therefore, replicated early generation bulk testing was discontinued as from 1985/86 season. F_2 to F_4 bulks are however made available to cooperators on request and have been found useful for selection purposes.

Reasons for Failure of Trials and Nurseries

The exact reasons for failure of trials and nurseries were not always given by cooperators. However, the information from medium- to long-duration locations indicated that here the crop was mostly damaged by foliar

Table 2. Correlation coefficients between F_2 and F_3 yields and selections in F_4-F_5 generations of chickpeas at ICRISAT Center and other locations with short-duration environments.

Season	F_2 trial yield location	ICRISAT Center F_3 yield	Number of selected plants F_4	Mean yield F_5 lines	Number of F_5 bulked lines
1980/81	ICRISAT Center	-0.29	-0.72**	0.13	-0.84**
1981/82	ICRISAT Center	0.73**	-0.25	-0.25	-0.22
1980/81	Rahuri	0.62*	0.74**	-0.53	0.46
1981/82	Rahuri	-0.19	0.15	-0.58*	0.16
1980/81	Mean MLT[1]	-0.29	0.24	-0.63*	0.32
1981/82	Mean MLT	0.52	-0.21	-0.53	0.26

*, ** significant at 0.05 and 0.01 levels.
1. MLT = multilocational trials.

Table 3. Correlation coefficients for seed yields of F_3 Multilocational Trials (MLT) in 1981/82 and 1982/83 and seed yields and selections made at ICRISAT Center.

		ICRISAT Center			
Season	F_3 trial yield location	Number of plants selected in F_4	Number of lines bulked in F_5	Mean yield of selected F_5 lines	Percentage increase of F_5 lines over moving means of Annigeri
1981/82	Akola	-0.52	-0.63*	-0.32	0.41
	Gulbarga	-0.66*	-0.66*	0.30	0.33
	Rahuri	0.87**	0.64*	-0.14	0.13
	ICRISAT Center	0.24	0.40	0.38	0.07
	Mean MLT	-0.03	-0.01	0.29	0.11
1982/83	Akola	0.05	0.10	0.43	-0.21
	Gulbarga	-0.30	-0.23	-0.09	-0.14
	Rahuri	0.24	0.16	-0.04	0.21
	ICRISAT Center	-0.41	-0.31	-0.08	0.15
	Mean MLT	0.12	0.10	-0.65*	-0.28

*, ** significant at 0.05 and 0.01 levels.

diseases, and excessive vegetative growth resulting in poor podding. At the short-duration locations, poor plant establishment and damage by wilt, root rots, and pod borer have been cited as the most common reasons for crop failure. These stresses, even when not severe, would add to high coefficients of variation at particular sites.

Susceptibility of chickpeas to various diseases has been considered a major reason for lack of yield stability (Smithson et al. 1985). Therefore, incorporation of disease resistance is likely to stabilize production. Resistance to fusarium wilt has been emphasized at ICRISAT and this is apparent in ICCT-DS and ICSN-DS entries over the years (Table 4). Similar efforts for other trials and diseases are underway. Multiple stress tolerance/ resistance of breeding materials, identified as important for different regions will be emphasized in the coming years (van Rheenen et al. 1989).

Contributions by Cooperators

International centers can act as catalysts in strengthening cooperation among national and regional programs, for instance, in the exchange of elite materials. Over the years, cooperators have contributed to international

Table 4. Mean mortality (%) due to wilt of entries included in International Chickpea Cooperative Trials (ICCTs) and International Chickpea Screening Nurseries (ICSNs) in wilt-sick plots at ICRISAT Center, 1981/82 to 1986/87.

	ICCT			ICSN		
Season	DS[1]	DM	DL	DS	DM	DL
1981/82	56	NT[2]	72	66	NT	48
1982/83	46	NT	86	58	62	70
1983/84	46	NT	78	73	75	85
1984/85	42	NT	ND[3]	48	56	ND
1985/86	26	49	74	37	44	68
1986/87	18	18	42	13	44	69

1. DS = Desi short-, DM = Desi medium-, and DL = Desi long-duration.
2. NT = No trial.
3. ND = Trial conducted, but no data available.

trials, in particular to the various ICCTs, where high-yielding entries were included. Notable examples are; Annigeri, JG 62, Pant G 114, K 850, JG 74, P 436, BDN 9-3, Phule G-4, L 550, G 130, H 208, P 324, BG 203 and T 3. In ICSNs advanced breeding lines from ICRISAT are generally included. Cooperators hesitate to contribute to ICSNs due to a shortage of seed and also to the relative uncertainty of the performance of their material. Many programs can only contribute released materials, but it would be useful to include material from cooperators in these nurseries as well.

Selection of Materials by Cooperators

Over the years the highest-yielding five entries in ICSNs have outyielded the best controls, indicating the usefulness of the trial material (Table 5). As mentioned earlier these entries have increased resistance to fusarium wilt. Short-duration entries also have larger seeds than the controls. Selections from the trials and nurseries have been released in several countries and many more useful lines have been identified (van Rheenen et al. 1990).

Future Direction of Trials

Large G x E interactions encountered in chickpea require breeding lines to be tested at many locations and the suitable ones to be identified for particular regions.

Table 5. Mean seed yield of the five best entries in International Chickpea Screening Nurseries expressed as percentages of the best control cultivar from 1978/79 to 1987/88.

Season	DS[1]	DM	DL
1978/79	109	NT[2]	115
1979/80	115	NT	120
1980/81	111	NT	110
1981/82	109	NT	139
1982/83	117	111	126
1983/84	101	106	112
1984/85	120	117	134
1985/86	108	106	118
1986/87	118	125	121
1987/88	110	122	125

1. DS = Desi short-, DM = Desi medium-, and DL = Desi long-duration.
2. NT = No trial.

It would be helpful if the genetic base of the breeding material could be widened. This is a challenging task as many of the elite lines used as parents trace their pedigree to a few landraces and cultivars (Smithson et al. 1985). The use of lines from the large germplasm collection and their derivatives at ICRISAT Center is helpful. Improvement of resistance to root rots and wilt in the short- and medium-duration materials, and important foliar diseases in long-duration materials, is likely to confer more stability in chickpea productivity. A reduction in the maturity period of the longer-duration materials may also add to the stability of production in their areas of adaptation (Kumar et al., unpublished).

The maturity duration subgrouping used in desi types should be extended to kabuli types as well. There is a need for extra-short-duration materials for cultivation between latitudes 0°-10° or in drought-prone areas represented by peninsular and central Indian conditions.

Changes in design of nurseries may reduce coefficients of variation (van Rheenen et al. 1990). Contributions from cooperators to trials and nurseries will help broaden the genetic base and strengthen regional and international cooperation in identifying cultivars adapted to larger chickpea producing regions.

Acknowledgments

The cooperation of chickpea scientists in conducting trials and nurseries is gratefully acknowledged. Thanks are also due to Drs H.A. van Rheenen, T. Dasgupta, and D. Neeley, and Messrs. J.H. Miranda and B.V. Rao for their help.

References

Byth, D.E., Green, J.M., and **Hawtin, G.C.** 1980. ICRISAT/ICARDA chickpea breeding strategies. Pages 11-27 *in* Proceedings of the International Workshop on Chickpea Improvement, 28 Feb-2 Mar 1979, ICRISAT, Hyderabad, India. Patancheru, A.P. 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Singh, K.B., Kumar, J., Sethi, S.C., Gowda, C.L.L., Jain, K.C., and **Hawtin, G.C.** 1980. International chickpea trials and nurseries. Pages 33-42 *in* Proceedings of the International Workshop on Chickpea Improvement, 28 Feb-2 Mar 1979, Hyderabad, India. Patancheru, A.P., 502 324, India: International Crops Research Institute for the Semi-Arid Tropics.

Smithson, J.B., Thompson, J.A., and **Summerfield, R.J.** 1985. Chickpea (*Cicer arietinum* L.). Pages 312-390 *in* Grain legume crops (Summerfield, R.J., and Roberts, E.H., eds.). London, UK: Collins.

van Rheenen, H.A., Malhotra, R.S., Miranda, J.H., Pattanayak, C.M., and **Seshu, D.V.** 1990. The chickpea trials network model. Pages 323-328 *in* Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

van Rheenen, H.A., Reddy, M.V., Kumar, J., and **Haware, M.P.** 1989. Breeding for resistance to soil-borne diseases in chickpea. Presented at the Consultancy Meeting on Breeding for Disease Resistance in Kabuli Chickpeas, 6-8 Mar 1989, International Center for Agricultural Research in the Dry Areas, Aleppo, Syria.

Zoning Chickpea Environments

R.S. Malhotra and H. Harris[1]

Abstract

Cluster analysis was used as a tool to classify chickpea growing environments into zones. Data on days-to-flowering and seed yield for two chickpea international yield trials developed by ICARDA and conducted by cooperating scientists worldwide during 1985/86 and 1986/87 were used for the present study. The GENSTAT hierarchical, agglomerative clustering program was employed with correlation coefficient as the distance measure and single linkage as the clustering strategy. Results revealed that by characterization of the genotype by location, interaction within a cluster/zone was minimized. Further, key sites should be selected from each cluster for initial evaluation of a large number of breeding materials. These selected materials from each zone should then provide an opportunity for selection of material for specific adaptation.

Résumé

Zonage des environnements de pois chiche : *L'analyse en grappes a servi d'outil pour classer en zones les environnements de culture de pois chiche. Les données sur le nombre de jours à la floraison et le rendement en grains pour deux essais internationaux de rendement du pois chiche mis au point par l'ICARDA et effectués par des chercheurs coopérants dans le monde entier en 1985/86 et 1986/87 ont été exploitées. Le programme GENSTAT de groupement hiérarchique et agglomératif de données a été employé avec le coefficient de corrélation comme mesure de distance et le linkage simple comme stratégie de mise en grappes. Les résultats ont révélé que la caractérisation du génotype en fonction de l'emplacement permet de réduire au minimum l'interaction au sein d'une grappe/zone. En outre, des emplacements-clés devraient être sélectionnés dans chaque grappe en vue d'une évaluation initiale d'un grand nombre de matériels de sélection. Ces matériels sélectionnés dans chaque zone devraient alors permettre la sélection de matériels pour une adaptation spécifique.*

Kabuli Chickpea (*Cicer arietinum* L.) is primarily grown under varied moisture, temperature, soil type, crop management, and biotic stress conditions in different parts of West Asia, North Africa, Mediterranean Europe, and Latin America. It is mainly cultivated in rainfed areas that receive 350 - 600 mm average annual rainfall. International Center for Agricultural Research in the Dry Areas (ICARDA) and International Crops Research Institute for Semi-Arid Tropics (ICRISAT), have worldwide responsibilities to work on the improvement of kabuli chickpea. One way to improve the efficacy of a breeding program for such diverse environmental conditions would be to divide areas into relatively homogeneous regions, and then to satisfy the specific requirements of each region. Until now no objective sub-division of chickpea-growing areas has been carried out, although Malhotra et al. (1985) pinpointed major divisions on the basis of feedback of

1. International Trials Scientist (Food Legume Improvement Program), and Soil Water Conservation Scientist (Farm Resource Management Program), International Center for Agricultural Research in the Dry Areas (ICARDA), P.O. Box 5466, Aleppo, Syria.

Citation: ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1990. Chickpea in the Nineties: proceedings of the Second International Workshop on Chickpea Improvement, 4-8 Dec 1989, ICRISAT Center, India. Patancheru, A.P. 502 324, India: ICRISAT.

results from various cooperators in different parts of the world. Mulitze et al. (1987) reviewed several approaches suggested by various workers to stratify environments into sub-regions. Cluster analysisbased on the differential grain yield responses of a set of genotypes has been the most widely used technique. Abou-El Fittouh et al. (1969) were among the first to apply cluster analysis. They classified cotton variety trail sites in the USA and advocated the use of the technique to stratify environments into sub-regions. Later, this technique was also used by Byth et al. (1976); Ghaderi et al. (1980); Fox et al. (1985); Imrie et al. (1981); and Imrie and Shanmugasundaram (1987). Because similar information is not available for chickpea, an attempt has been made to classify the chickpea-growing areas of West Asia, North Africa, Mediterranean Europe, and Latin America into regions based on differential yield responses, and to select key sites that provide an opportunity to select materials for specific adaptation.

Materials and Methods

The results of the Chickpea International Yield Trials-Winter for the Mediterranean Region (CIYT-W-MR), assembled at ICARDA by the ICARDA/ICRISAT chickpea breeding program, and distributed from Aleppo, Syria to cooperators from West Asia, North Africa, Mediterranean Europe, and Latin America during 1985/86 and 1986/87, provided data for the present study. The CIYT-W-MR was grown by national programs in a randomized complete block design with four replications, usually with a plot size of 4.8 m^2 (4 4-m rows, spaced 30 cm apart). There were 24 entries, including a local control provided by each cooperator. The entries had performed well in at least 2 years of yield testing at Aleppo, Syria, and also in unreplicated screening nurseries in many countries. Data on seed yield and time to 50% flowering from 37 sites in 1985/86 and 39 sites in 1986/87, reported by the cooperators of each entry at each site, excluding the national or local control, were used for the analyses (Table 1). Eleven of the test entries and 22 of the growing sites were common in the two seasons. A detailed description of the trial sites, entries, and data is given in the International Nursery Reports (ICARDA 1988, 1989). The code numbers assigned to each location (Table 1) have been used instead of location names.

The GENSTAT hierarchical, agglomerative clustering program (Genstat 5 Committee 1988) was applied with correlation coefficient as the distance measure and single linkage as the clustering strategy. A large difference in successive clustering steps was used as an indicator of cluster truncation.

Results and Discussion

The combined ANOVA for seed yield for 23 genotypes at 37 locations in 1985/86 and 39 locations in 1986/87, is given in Table 2. The mean squares due to genotypes (G), locations (L), and genotype x location (G x L) interaction were highly significant for both the years. Further, the combined ANOVA for 11 common genotypes across 22 common and 30 non-common locations across 2 years (Table 3) also confirmed the presence of highly significant differences due to locations, and G x L and genotype x location x year (G x L x Y) interactions. The objective in further analysis is thus to minimize the effect of location, and to maximize the recovery of information on the performance of genotypes within environments.

Cluster Analysis

The dendrogram (Fig. 1a) illustrating the outcome of cluster analysis based on yield correlations as a similarity index for the 1985/86 trials shows that two locations, Jindiress (Syria) and Heimo (Syria), were the first to form a cluster at the 85% similarity value; at the 75% similarity value, two more locations, Menzel Temmime (Tunisia) and Tel Hadya (Syria) were added into this cluster. There were large differences between mean seed yields at these four locations (Table 1) indicating that location mean yield did not play any strong role in grouping the environments into a cluster. With reduction in similarity values, more and more environments were amalgamated into this cluster and some new clusters were formed. Four clusters were formed at the 55% similarity value: Cluster I with 13 locations (10, 26, 29, 35, 24, 34, 23, 17, 6, 18, 9, 16, and 20); Cluster II with 3 locations (13, 25, and 33); Cluster III with 2 locations (36 and 8); and Cluster IV with 2 locations (21 and 5). The remaining ungrouped locations were assigned to two clusters those amalgamating at 40% similarity index to Cluster V (28, 3, 4, 27, 14, 32, and 11) and the remainder to Cluster VI (12, 2, 7, 15, 1, 30, 31, 19, and 37).

The dendrogram based on days to 50% flowering (Fig. 1b) revealed that a large number of locations amalgamated in a similar way to that for seed yield. A few locations (such as Toshevo, Bulgaria and Montpellier, France) amalgamated at earlier stages on days to 50% flowering (Fig. 1b) than on seed yield

Table 1. Latitude, elevation and average rainfall, chickpea seed yield and time to flowering, 1985/86 and 1986/87.

Code no.	Country	Location	Latitude (°N)	Elevation (m)	Rainfall (mm)	Yield (t ha⁻¹)	Days to 50% flower
1	Bulgaria	Toshevo	43.40	236	561	1.07	194
2	France	Montpellier	43.37	49	487	1.84	177
3	Greece	Larissa	39.07	70	320	2.72	151
4	Iraq	Sulaimaniya	36.05	700	NA[1]	1.12	179
5	Italy	Metaponto	40.24	18	317	3.85	124
6	Jordan	Marow	32.33	580	414	1.30	126
7	Lebanon	Beqaa	33.55	995	657	1.55	150
8	Morocco	Marchouch	33.33	450	416	2.05	139
9	Pakistan	Islamabad	33.29	683	373	1.31	172
10	Portugal	Elvas	38.53	208	484	1.65	145
11	Portugal	Oerias	38.41	50	484	1.52	97
12	Spain	Badajoz	38.49	219	178	2.02	124
13	Spain	Madrid	40.30	599	340	2.17	155
14	Syria	Idleb	36.56	446	614	2.59	126
15	Syria	Al-Ghab	35.30	170	872	3.02	126
16	Syria	Homs	34.45	485	333	2.49	130
17	Syria	Gellin	32.80	NA	NA	1.65	124
18	Turkey	Diyarkabir	37.55	660	475	2.11	132
19	Turkey	Izmir	38.05	100	452	1.59	131
20	Lebanon	Terbol	33.49	890	529	2.32	144
21	Spain	Cordoba	37.51	110	481	2.06	NA
22	Spain	Sevilla	37.30	20	410	1.16	NA
23	Syria	Hama	35.08	316	324	2.58	113
24	Syria	Heimo	37.03	426	341	2.25	145
25	Syria	Jable	35.40	7	970	5.96	NA
26	Tunisia	Beja	36.52	NA	NA	2.66	NA
27	Tunisia	El-Kef	36.10	NA	NA	1.62	NA
28	Tunisia	Mateur	37.03	NA	377	0.21	NA
29	Tunisia	Menzel Temime	36.45	NA	386	1.95	NA
30	Tunisia	Oued Melize	37.55	NA	NA	2.63	NA
31	Tunisia	Ras Rajel	37.21	NA	NA	0.20	NA
32	Turkey	Adana	37.00	35	537	1.96	124
33	Algeria	Setif	36.09	1023	301	0.84	129
34	Syria	Tel Hadya	36.01	284	337	1.94	112
35	Syria	Jindiress	36.24	210	505	3.29	134
36	Algeria	Kharoub	36.25	640	475	1.37	137
37	Colombia	Surabata	05.49	2540	527[2]	0.65	87
38	Cyprus	Laxia	35.06	150	254	0.36	112
39	Algeria	Quadah	NA	NA	NA	0.87	83
40	Algeria	Sidi Bel Abbes	35.11	488	300	2.05	111
41	Algeria	Guelma	36.29	300	301	1.53	84
42	France	Montboucher	44.34	136	340	0.87	167
43	Italy	Tarquinea	42.15	50	157	4.66	131
44	Italy	Catania	37.28	700	341	2.33	149
45	Italy	Capalbio	NA	NA	NA	2.17	190
46	Jordan	Irbid	32.33	620	510	0.24	124
47	Turkey	Balikhesin	40.19	NA	NA	1.03	NA
48	Libya	El- Safsaf	32.49	580	NA	1.09	NA
49	Morocco	ZemMemra	NA	450	196[2]	0.89	105
50	Spain	Granada	37.20	950	NA	0.62	154
51	Syria	Izra'a	32.51	575	405	1.98	132
52	Syria	Deir-ez-Zor	32.50	NA	43[2]	1.66	127

1. NA = data not available.
2. Additional irrigation was provided but amount not reported.

(Fig. 1a). The strongest grouping for both characters, but especially for time to 50% flowering, mainly included locations in West Asia (Jordan, Syria, and Lebanon) and southern Europe (the Iberian Peninsula and Greece). In the grouping on yield, three locations; Surabata (Colombia), Ras Rajel (Tunisia), and Izmir

Table 2. Analysis of variance for seed yield and estimated components of variance for 23 chickpea genotypes in 37 locations in 1985/86 and 39 locations in 1986/87.

Source of variance	1985/86 df	1985/86 SS (×10⁴)	1985/86 MS (×10⁴)	1986/87 df	1986/87 SS (×10⁴)	1986/87 MS (×10⁴)
Genotypes (G)	22	1039.6	47.25**	22	794.4	36.11**
Location (L)	36	119090.0	3308.00**	38	65417.0	1721.50**
G × L	791	6048.8	7.65**	836	5084.4	6.08**
G × L between cluster	131	1298.0 (21.4)[1]		132	1389.0 (27.3)	
G × L within cluster 1	264	1106.3 (18.2)		308	1044.8 (20.5)	
G × L within cluster 2	44	520.4 (8.6)		66	557.0 (10.9)	
G × L within cluster 3	22	60.0 (1.0)		44	321.1 (6.3)	
G × L within cluster 4	22	24.3 (0.4)		22	75.2 (1.5)	
G × L within cluster 5	44	187.6 (3.1)		22	76.5 (1.5)	
G × L within cluster 6	264	2852.5 (47.1)		66	21.3 (4.2)	
G × L within cluster 7	-	-		176	140.7 (27.7)	
Pooled error	2346	7502.2	3.20	2499	8194.3	3.28

1985/86	1986/87
$\hat{\sigma}_g^2 = 1.0704 \times 10^4$	$\hat{\sigma}_g^2 = 0.8515 \times 10^4$
$\hat{\sigma}_{gl}^2 = 4.4492 \times 10^4$	$\hat{\sigma}_{gl}^2 = 2.8028 \times 10^4$
$\hat{\sigma}_e^2 = 12.7915 \times 10^4$	$\hat{\sigma}_e^2 = 13.1161 \times 10^4$
$\hat{\sigma}_g^2 : \hat{\sigma}_{gl}^2 = 1:4.2$	$\hat{\sigma}_g^2 : \hat{\sigma}_{gl}^2 = 1:3.45$

1. Values in parentheses are the contribution to SS as per cent of SS due to G × L.
** Significant at $P = 0.01$.

Table 3. Analysis of variance for seed yield for 11 common chickpea genotypes in different locations combined over 1985/86 and 1986/87 seasons.

Source of variation	df	SS (×10⁴)	MS (×10⁴)
Genotype (G)	10	744.80	74.48
Location (L)	51	74060.00	1452.00**
G × L	510	3933.00	7.71**
G × L between cluster	40	583.10 (14.8)	
G × L within cluster 1	210	1601.00 (40.7)	
G × L within cluster 2	10	38.73 (1.0)	
G × L within cluster 3	10	28.58 (0.7)	
G × L within cluster 4	50	504.2 (12.8)	
G × L within cluster 5 (ungrouped)	190	1176.00 (29.9)	
Year (Y)	1	11030.80	11030.80**
Y × L	21	20710.00	986.19**
G × Y/Loc[1]	241[1]	1210.00	5.02**
Pooled error	2210	7228.58	3.27

1. One d.f. less due to a missing combination of genotype and environment (242-1).
** Significant at $P = 0.01$.

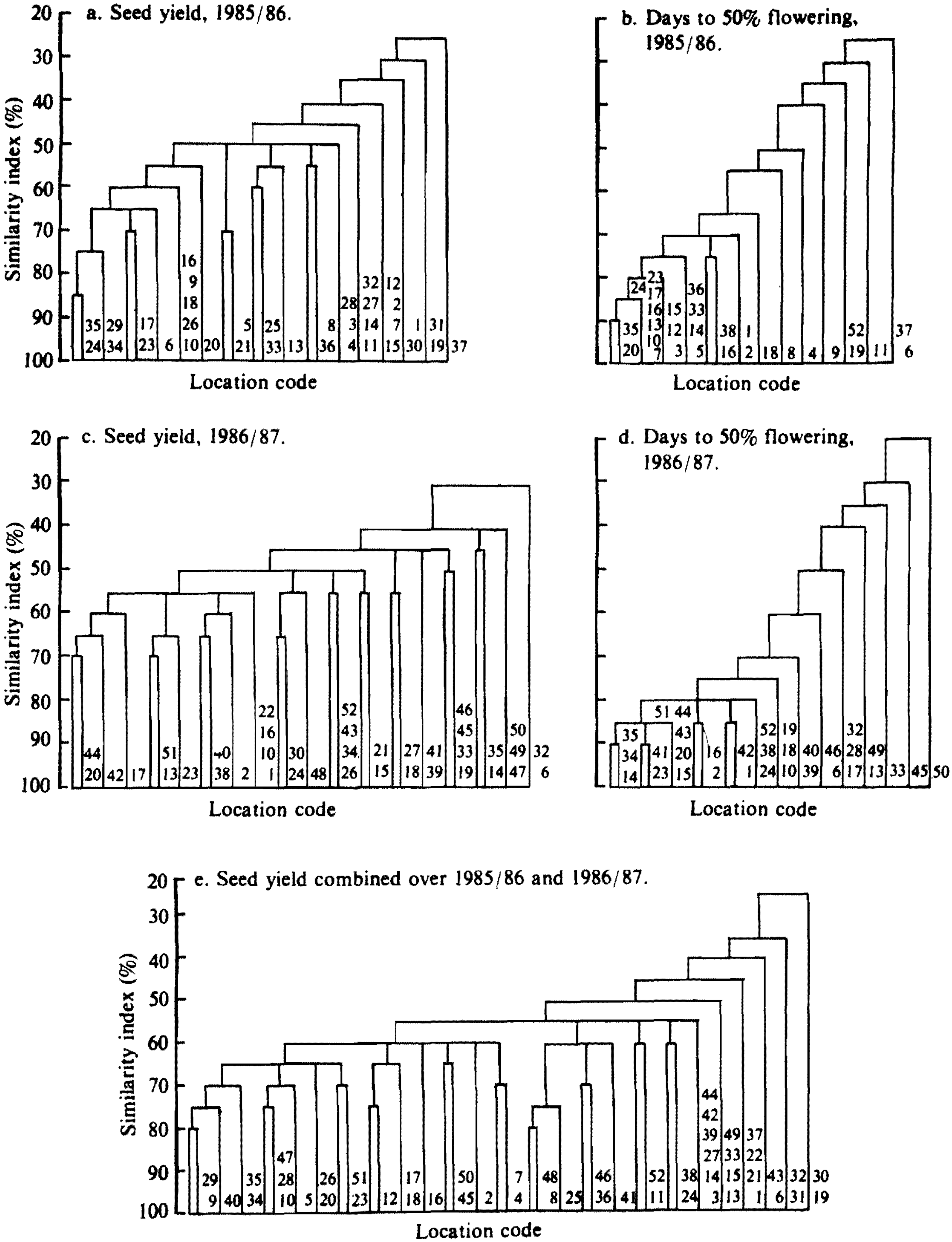


Figure 1. Dendrograms showing amalgamation of locations based on: a. seed yield, 1985/86; b. days to 50% flowering, 1985/86; c. seed yield, 1986/87; d. days to 50% flowering, 1986/87; and e. seed yield combined over 1985/86 and 1986/87.

(Turkey), were quite distinct and were amalgamated at low similarity index values. Surabata also was an outlier in days to 50% flowering.

In the seed yield data for 1986/87, clustering of locations was initiated earliest at 70% similarity values (Fig. 1c) when two clusters were formed each with two locations, Terbal (Lebanon), and Catania (Italy), in the first case, and Madrid (Spain), and Izra'a (Syria), in the second. All four locations represented medium elevations sites. At the 55% similarity value, a large number of locations were grouped giving rise to five clusters: Cluster I (20, 44, 42, 17, 51, 13, 23, 38, 40, 2, 10, 22, 1, and 16); Cluster II (30, 24, and 48); Cluster III (43, 34, 26, and 52); Cluster IV (15 and 21); and, Cluster V (27 and 18), which later merged at the 50% similarity value. Based on the amalgamation process at similarity values lower than 55%, the ungrouped locations were put into two clusters, Cluster VI (33, 19, 45, and 46) and Cluster VII (41, 39, 14, 35, 49, 50, 47, 32, and 6).

The dendrogram based on time to 50% flowering revealed that a large number of locations amalgamated in a way similar to that for seed yield (Fig. 1d). As in the previous year, locations such as 35 and 14 amalgamated much earlier on days of 50% flowering (Fig. 1d) than on seed yield (Fig. 1c).

In general, the grouping was weaker in 1986/87 than in 1985/86, especially for days to 50% flowering. Nonetheless, a similar pattern emerged, in that the closest associations occurred amongst locations in West Asia and southern Europe. Of the 22 locations that were common to both analyses, half grouped in the same way in both years. Locations in North Africa appear distinct from those in the above regions, but showed no consistent grouping amongst themselves.

The seed yield data for the entries common to both years were pooled and a further analysis was carried out with data from all 52 locations that were used in one or both years. The four clusters formed at the 60% similarity index level (Fig. 1e) basically confirmed the groupings of the more diverse set of genotypes of the individual years. These clusters, encompassing 32 of the 52 locations, amalgamated at the 55% level of similarity index.

Analysis of Variance

When the clusters for yield were incorporated into an ANOVA, 21% of the total SS due to G x L interaction could be separated into a between cluster G x L interaction for the first year's data, 27% for the second year's data, and 15% for the combined data set (Tables 2 and 3). The corresponding figures for the proportion of the total sum of squares (SS) remaining within the major cluster were 18, 21, and 41%. These values were disappointingly small in the first case and large in the second. They reflect the relatively low level of the similarity index at which clusters formed in the cluster analyses, and illustrate that while the grouping was relatively consistent, a good deal of diversity remains within the clusters.

The inclusion of clusters in the analysis of variance allowed the ratio of the component of genotypic variance ($\hat{\sigma}_g^2$) to the G x L interaction component ($\hat{\sigma}_{gl}^2$) to be reduced within the clusters to 1 : 1. It is worth mentioning that in the clusters formed by grouping the ungrouped locations at much lower similarity indices this ratio increased, showing that the environments within these clusters were quite diverse. This suggested that environmental effects which were associated with locations in determining differential genotypic responses were reduced when relatively homogeneous locations were put together in clusters. Thus, by clustering, the predictability of performance of different genotypes within clusters should increase, and the identification of specific types of genotypes suitable for specific clusters, zones of environments would be possible.

General Discussion

From the results we can begin to propose tentative guidelines for selection of material with specific adaptation for inclusion in international nurseries. It appears that selection for performance at Terbol, the ICARDA sub-station in Lebanon, should be relevant to much of Syria, the drier areas of Algeria represented by Sidi Bel Abbes, and parts of the Iberian Peninsula. This is our first attempt to carry out a spatial analysis of the data from these trials. Further work, and probably further information, is needed to make full use of the information in the data sets. No association was found between latitude and days to flowering of the genotypes. The latitudinal range was too small, and the temperature effect too large. Temperature data are not available for most of the sites, but we have taken initial steps to remedy that in 1989 by providing automatic weather stations at selected locations.

The size of the present data set, and in particular its continuity, is limited. Inclusion of data from other years in a much larger analysis is planned. Sufficient data over a longer time may help to interpret the effects of season-to-season variability in weather patterns which is a problem for yield data interpretation in semi-arid environments.

References

Abou-El-Fittouh, H.A., Rawlings, J.O., and **Miller, P.A.** 1969. Classification of environments to control genotype by environment interaction with an application to cotton. Crop Science 9:135-140.

Byth, D.E., Eisemann, R.L., and **De Lacy, I.H.** 1976. Two-way pattern analysis of large data set to evaluate genotypic adaptation. Heredity 37:215-230.

Fox, P.N., Rosielle, A.A., ***and*** **Boyd, W.J.R.** 1985. The nature of genotype x environment interactions for wheat yield in Western Australia. Field Crops Research 11:387-398.

Genstat Committee. 1988. Genstat 5 Reference Manual. Oxford, UK: Clarendon Press.

Ghaderi, A., Everson, E.H., and **Gress, C.E.** 1980. Classification of environments and genotypes in wheat. Crop Science 20:707-710.

ICARDA (International Center for Agricultural Research in the Dry Areas). 1988. Food legume nurseries 1985-86. International nursery report no. 10. Aleppo, Syria: ICARDA.

ICARDA (International Center for Agricultural Research in the Dry Areas). 1989. Food legume nurseries 1986-87. International nursery report no. 11. Aleppo, Syria: ICARDA.

Imrie, B.C., Drake, D.W., De Lacy, I.H., and **Byth, D.E.** 1981. Analysis of genotypic and environmental variation in international mungbean trials. Euphytica 30:301-311.

Imrie, B.C., and **Shanmugasundaram, S.** 1987. Source of variation in yield in international mungbean trials. Field Crops Research 16:197-208.

Malhotra, R.S., Robertson, L., Singh, K.B., Erskine, W. and **Saxena, M.C.** 1985. Cooperative international testing program on faba beans, kabuli chickpeas and lentils. Pages 297-313 *in* Proceedings of the International Workshop on Faba Beans, Kabuli Chickpeas and Lentils in the 1980s (Saxena, M.C. and Varma, S. eds.). Aleppo, Syria: International Center for Agricultural Research in the Dry Areas.

Mulitze, D., Malhotra, R.S., and **Goldsworthy, P.** 1987. Relating production and environment: the international nursery networks. Pages 85-96 *in* Agricultural environments: characterization, classification and mapping: proceedings of the Rome Workshop on Agro-ecological characterization, classification and mapping, 14-18 Apr 1986, Rome, Italy (Bunting, A.H., ed.). Wallingford, Oxon, UK: CAB International.

Session 7

Main Items of Presentation and Discussion

- In networks two points are important, namely, complementarity of research work and leadership in management. For example in North Africa through ICARDA sponsorship, the three national coordinators, and scientists met to classify their problems into common, bilateral, and unilateral. They then decided to strengthen cooperation in the very few common problems to which all three national programs could contribute. Leadership was given by the program having the most expertise to deal with each particular problem.
- The difficulties of interpreting the results of international nurseries and trials will continue unless there is information on the environment and soils at test locations to assist in the interpretation of results.
- In northern India, growing early-maturing cultivars can reduce the risks of foliar diseases including ascochyta blight. Since most chickpea cultivation in that region is rainfed, the productivity will also be stabilized by the short duration of such cultivars per se.
- International trials are important, but need to be specific in purpose. There is a North Central Soybean Uniform Trial in the USA for advanced breeding lines, submitted by breeder cooperators from university and state groups. This trial advances breeding objectives, because breeder-cooperators gain access to each others' materials for testing and use as parents. International chickpea trials also include entries developed by cooperators. For instance, JG 74 and P 436 from India have been released in Nepal and Myanmar and the use of such cultivars as parents is extensive.
- Whether NARSs prefer to receive replicated trials or observation nurseries depends on the capability of the individual NARS. Programs in which one scientist looks after several legume crops usually request advanced lines, whereas at the other extreme some NARSs request segregating populations, or even ask for specific crosses to be made.
- The practice of grazing or 'nipping' of chickpea is followed in parts of India to restrict excessive vegetative growth. No research data appear to be available to measure the value of this practice.
- The accepted coefficient of variation for replicated chickpea trials should be 20% or less.
- The outreach research activities for a particular technology transfer should continue as long as the host country requests assistance. Three to five years' outreach research for chickpea may be a minimum to identify constraints in farmers' fields and to generate effective technologies to overcome these constraints.
- The rate of technology transfer will vary. If the technology is effective, it spreads fast. Although the production technology for chickpea is economically viable, and properly demonstrated, its rate of adoption is low. This slow adoption is because chickpea is not being supported by favorable public policies (remunerative prices). The difference between what a producer gets and a consumer pays is 20% for cereals but more than 100% for chickpeas.
- For irrigated conditions, wilt-resistant long-duration genotypes, and for residual moisture conditions the early variety ICCV 2 have been found best in Madhya Pradesh, India. In the last 2 years the chickpea varieties ICCV 2, and ICCC 37 have been introduced through joint action of JNKVV, ICRISAT, and the Department of Agriculture.
- The merits of specific genotypes and management practices differ under irrigated and rainfed conditions. Under irrigated conditions most varieties respond well to management. Recently bred chickpea varieties have the advantage of wilt resistance. Under residual moisture, varieties which are about a month earlier than previously available varieties complete their life-cycle before end of season drought develops. Thus the crop can make effective use of available moisture.
- Three practices can be used to conserve moisture under rainfed conditions and ensure good plant stands. These are, sowing as early as possible after the harvest of the rainy-season crop, deep sowing, and sowing early-maturing varieties.
- In multilocational trials the best variety for a location is identified by its performance. However, there is no critical analysis of the reasons for this performance and this is required if better breeding strategies are to be developed.
- It is imperative that full data sets be collected on plant and on environment.

Recommendations

Networks

- ICRISAT and ICARDA should maintain their research networks to transfer germplasm and crop management practices, and to disseminate information (e.g., ICRISAT's SDI service). Since one of the most valuable payoffs in networking is the improved communication among NARSs, International Agricultural Research Centers (IARCs) should pay particular attention to promoting such interaction.

- NARSs should be more involved in planning and running network activities. This will ensure their contribution to joint efforts, e.g., by entering germplasm into international nurseries.
- Generations of segregating populations requested by NARSs should be provided by IARCs.
- Selection should take place when possible in the environments where the crop is to be grown. One effective way to provide genetic variability to NARSs for selection in their specific ecological conditions is to develop homozygous, heterogeneous populations by means of single-seed descent. Early generation populations can be subjected to negative screening for critical characteristics, for instance wilt resistance, at IARCs. Non-segregating variable F_6 populations can be sent to NARSs for selection for adaptation and agronomic merit.
- Environmental data including that for soils should be routinely provided by NARSs to network centers.
- Mechanisms need to be introduced to ensure quality control of network products, and participants need to be accountable for the quality of their research results. One way to ensure such accountability is to empower the network's steering committee to modify or terminate network projects.
- The purpose and value of a network must be fully explained to research directors so that participants receive adequate support for collaborative efforts from their parent institutions.
- IARCs should strive to establish effective links with all participants in the global enterprise of agricultural research and development, e.g., NARSs, United Nations organizations, universities, Non-Governmental Organizations, bilateral aid agencies, and the private sector.

Training

- Training activities should be tailored to the needs of individual NARSs.
- Traveling workshops should be more widely held. The 'traveling workshop' is a particularly useful mechanism for training, and helps to build cohesion among all network members.
- It is recommended that IARCs and NARSs conduct training courses for research technicians on trial management to improve the experimental precision of network trials.

Technology Development and Verification at Farm Level

- The IARCs should assist NARSs in the development of on-farm research methodology development, with emphasis on a multidisciplinary approach. A spinoff from such an approach would be improved links between research and extension.

Session 7

Principaux thèmes de présentation et de discussion

- Deux points sont importants dans les réseaux, notamment la complémentarité des travaux de recherche et la direction dans la gestion. Par exemple, en Afrique du Nord, à travers le parrainage de l'ICARDA, les trois coordonnateurs nationaux et des chercheurs se sont réunis pour classer leurs problèmes en problèmes communs, bilatéraux, et unilatéraux. Ensuite, ils se sont décidés de renforcer la coopération dans les problèmes communs très peu nombreux auxquels tous les trois programmes nationaux pourraient contribuer. La direction était assurée par le programme ayant le maximum de compétences pour entamer chaque problème particulier.

- Les difficultés d'interprétation des résultats obtenus à partir des pépinières et des essais internationaux continueront tant qu'on ne dispose pas d'informations sur l'environnement et les sols à des emplacements d'essais qui aideraient l'interprétation des résultats.

- En Inde du Nord, l'exploitation des cultivars à maturation précoce peut réduire les risques de maladies foliaires y compris la flétrissure ascochytique. Puisque la plupart de la culture du pois chiche dans cette région est pluviale, la productivité sera également stabilisée par le cycle court de tels cultivars per se.

- Des essais internationaux sont importants, mais doivent avoir un objectif précis. Il existe un Essai uniforme de soja pour le Centre nord (North Central Soybean Uniform Trial) aux Etats-Unis pour les lignées de sélection avancées, soumises par les sélectionneurs coopérants provenant des groupes universitaires et de l'Etat: Cet essai permet d'avancer les objectifs de sélection, car les sélectionneurs coopérants gagnent l'accès aux matériels de l'un et de l'autre pour des essais et pour l'utilisation en tant que géniteurs. Des essais internationaux de pois chiche comportent aussi des entrées mises au point par les coopérants. Par exemple, JG 74 et P 436 en provenance de l'Inde ont été vulgarisés au Népal et au Myanmar. L'utilisation de tels cultivars en tant que géniteurs est extensive.

- La préférence des Systèmes nationaux de recherche agricole à recevoir des essais avec répétitions ou des pépinières d'observation dépend des compétences des Systèmes individuels. Les programmes dans lesquels un seul chercheur prend en charge plusieurs cultures légumineuses, demandent normalement des lignées avancées. A l'autre extrême, quelques Systèmes nationaux demandent des populations ségrégantes, ou parfois demandent même la réalisation des croisements spécifiques.

- La pratique de pâturage ou "pinçage" (nipping) du pois chiche est adopte dans quelques régions de l'Inde pour restreindre la croissance végétative excessive. Peu de données de recherche semblent être disponibles pour mesurer la valeur de cette pratique.

- Le coefficient de variation accepté pour des essais avec répétitions du pois chiche doivent être de l'ordre de 20% ou moins.

- Les activités de recherche hors-station pour un transfert de technologie particulier doivent continuer tant que le pays hôte demande l'assistance. Trois à cinq années de recherche hors-station pour le pois chiche peut être un minimum pour identifier les contraintes dans le milieu réel et pour engendrer des technologies efficaces permettant de surmonter ces contraintes.

- Le taux de transfert de technologie varierait. Si la technologie est efficace, elle serait rapidement adoptée. Bien que la technologie de la production du pois chiche est viable économiquement, et démontrée d'une manière convenable, son taux d'adoption est bas. Cette adoption lente est parce que le pois chiche n'est pas soutenu actuellement par des politiques publiques favorables (prix rémunératifs). La différence entre ce que le producteur reçoit et ce que le consommateur paye est de 20% pour les céréales mais de plus de 100% pour le pois chiche.

- Pour des conditions irriguées, des génotypes résistants au flétrissement et à cycle long, et pour des conditions de humidité résiduelle la variété précoce ICCV 2 ont été répérées comme meilleures à l'Etat de Madhya Pradesh en Inde. Dans les deux dernières années, les variétés de pois chiche ICCV 2 et ICCC 37 ont été introduites par l'action conjointe du JNKVV, de l'ICRISAT, et du Département de l'Agriculture.

- Les mérites de génotypes spécifiques et des pratiques de gestion sont différentes dans des conditions irriguées et pluviales. Dans les conditions irriguées, la plupart des variétés répondent bien à la gestion. Des variétés de pois chiche sélectionnées récemment ont l'avantage de résistance au flétrissement. Sous l'humidité résiduelle, les variétés qui sont environ un mois plus précoces que les variétés disponibles auparavant achèvent leur cycle de développement avant le début de la sécheresse fin-de-saison. La culture peut donc exploiter effectivement l'humidité disponible.

- Trois pratiques peuvent être utilisées pour conserver l'humidité dans des conditions pluviales et pour assurer un bon établissement. Ce sont, le semis aussitôt que possible après la récolte de la culture de la saison pluviale, le semis en profondeur, et le semis des variétés à maturation précoce.

- Dans des essais multilocaux, la meilleure variété pour un emplacement est identifiée par sa performance. Cependant, il n'y a pas d'analyse critique des raisons de cette performance. Cette analyse est nécessaire si l'on envisage la mise au point de meilleures stratégies de sélection.

- Il est impératif que les ensembles de données complets soient collectés sur la plante et sur l'environnement.

Recommandations

Réseaux

- L'ICRISAT et l'ICARDA doivent conserver leurs réseaux de recherche afin de transférer les ressources génétiques et les pratiques de gestion des cultures, et de diffuser les informations (par exemple, le Service de diffusion sélective de l'information (DSI) de l'ICRISAT). Puisque l'une des bénéfices les plus utiles de la création des réseaux est la communication améliorée entre les Systèmes nationaux de recherche agricole, les Centres internationaux de recherche agricole doivent accorder une attention particulière à la promotion de telles interactions.

- Les Systèmes nationaux doivent participer davantage dans la planification et l'opération des activités de réseau. Cela assurera leur contribution aux efforts conjoints, par exemple, par l'introduction de ressources génétiques dans les pépinières internationales.

- Les générations de populations ségrégantes demandées par les Systèmes nationaux doivent être fournies par les Centres internationaux.

- Dans la mesure du possible, la sélection doit s'effectuer dans les environnements où la culture serait exploitée. Une méthode efficace de fournir la variabilité génétique aux Systèmes nationaux pour la sélection dans leurs conditions écologiques spécifiques est de développer des populations hétérogènes homozygeuses à l'aide de la méthode de filiation unique. Des populations des premières générations peuvent être soumises au criblage négatif pour les caractéristiques critiques, par exemple, la résistance au flétrissement, aux Centres internationaux. Les populations F_6 variables non-ségrégantes peuvent être envoyées aux Systèmes nationaux pour la sélection pour l'adaptation et la mérite agronomique.

- Les données de l'environnement y compris celles des sols doivent être régulièrement fournies par les Systèmes nationaux aux centres des réseaux.

- Des mécanismes doivent être introduits pour assurer le contrôle de la qualité des produits du réseau, et les participants doivent être responsables pour la qualité des résultats de leur recherche. Une façon d'assurer une telle responsabilité est d'autoriser le comité de direction du réseau à modifier ou à mettre fin aux projets de réseau.

- L'objectif et la valeur d'un réseau doit être expliqué en détail aux directeurs de recherche afin que les participants puissent recevoir, de leurs institutions mères, un soutien adéquat pour les efforts collaboratifs.

- Les Centres internationaux doivent s'efforcer à établir des liens efficaces avec tous les participants dans l'entreprise globale de la recherche et le développement agricole, par exemple, les Systèmes nationaux, les organisations des Nations-Unies, les universités, les organisations non-gouvernementales, les agences d'aide bilatérale, ainsi que le secteur privé.

Formation

- Les activités de formation doivent être adaptées aux besoins des Systèmes nationaux individuels.

- Les "ateliers itinérants" doivent être tenus plus largement. L'atelier itinérant est un mécanisme particulièrement utile pour la formation et permet de développer la cohésion entre tous les membres du réseau.

- Il est recommandé que les Centres internationaux et les Systèmes nationaux mettent en place des cours de formation pour les techniciens de recherche sur la gestion des essais afin d'améliorer la précision expérimentale des essais du réseau.

La mise au point de technologie et la vérification au niveau paysan

- Les Centres internationaux doivent aider les Systèmes nationaux dans le développement de la méthodologie de recherche en milieu réel, avec l'accent sur une approche pluridisciplinaire. Un résultat d'une telle approche serait l'amélioration des liens entre la recherche et la vulgarisation.

Appendix

Overcoming Constraints to Chickpea Production

A Questionnaire for

"Chickpea in the Nineties"

Second International Workshop on Chickpea Improvement

4-8 December 1989
ICRISAT Center, Patancheru, A.P. 502 324, India.

Purpose

To identify major biotic, abiotic, socioeconomic, and research constraints that need to be overcome to ensure high and stable chickpea production and utilization, and to determine possible future chickpea production trends.

Your response to this questionnaire along with others received will be analyzed by the Workshop Organizers. The results will be published in the Proceedings and widely circulated to planners and administrators in chickpea-growing countries. It is hoped that this provide guidance for them scientists and for help national and international institutions to develop relevant plans to overcome the constraints to chickpea production. Without your answers important aspects could be missed; it is therefore ultimately in your own interest and that of the chickpea producers in your country to complete this little task.

Please bring your completed questionnaire to the Workshop

Instructions

- Please consider the effect that each item listed within a section presently has on chickpea yield, production, and utilization in your country or district.
- Mark (x) the relative importance of each constraint:

Example	VI	I	SI	N
VI - Very Important	x			
I - Important		x		
SI - Somewhat Important			x	
N - Not Important				x

- Rank the 3 most serious constraints within each section in order of importance (1 = most important).
- Please follow special instructions in Sections 4.2, 5.2 and B.

Before you start please answer:

Name ______________________________
Address ______________________________
____
____
____
____
Designation ______________________________

My answers are for my whole country (name country) ______________________________
or
only for my own region (District, State, Province etc) (name) ______________________________

Your field (mark one) ☐ Research ☐ Extension ☐ Education

For the country or district that you are reporting, please indicate approximate:

Latitude ______________ Longitude ______________ Altitude ______________

A. Constraint Identification

1. Importance of each subject in overcoming constraints to chickpea production.

Subject area:	Mark (x) relative importance of each VI	I	SI	N	Rank top 3 1-3
Genetic resources					
Breeding					
Entomology					
Pathology					
Agronomy					
Physiology					
Economics					
Food technology					
Technology transfer to farmer					
Technical information for scientists					
Others (list)					

2. Genetic Resources

Lack of:	Mark (x) relative importance of each VI	I	SI	N	Rank top 3 1-S
Collections					
Descriptions					
Evaluations					
Maintenance					
Availability					
Catalogs					
Variability					
Enhanced material					
Others (list)					

3. Breeding

Lack of:	Mark (x) relative importance of each VI	I	SI	N	Rank top 3 1-3
Germplasm variability					
Breeding methodology					
Screening techniques					
Adaptation to farmers' conditions					
Crop stability					
Adequate research					
Availability of improved seed					
Others (list)					

4. Entomology

4.1 Insect pests

Presence of:	Mark (x) relative importance of each VI	I	SI	N	Rank top 3 1-3
Helicoverpa (Heliothis) pod borer					
Semiloopers					
Spodoptera sp					
Cutworms					
Leaf miner					
Aphids					
White grubs					
Secona weevil					
Bruchids					
Metapina sp (nodule-damaging fly)					
Others (list)					

4.2 Pest Management
For the 3 most important insects in 4.1

	Mark (x) relative importance of each											
	Rank 1				Rank 2				Rank 3			
Inadequate:	VI	I	SI	N	VI	I	SI	N	VI	I	SI	N
Chemical control												
Chemical availability												
Knowledge on resistance to insecticide												
Genetic resistance to insects												
Integrated control methods												
Screening techniques												
Research efforts												
Others (list)												

5. Pathology

5.1 Diseases

Presence of:	Mark (x) relative importance of each VI	I	SI	N	Rank top 3 1-3
Ascochyta blight					
Black root rot					
Botrytis gray mold					
Alternaria blight					
Collar rot					
Colletotrichum blight					
Phoma blight					
Stemphylium blight					
Rust					
Powdery mildew					
Sclerotinia stem rot					
Fusarium wilt					
Verticillium wilt					
Dry root rot					
Wet root rot					
Phytophthora root rot					
Foot rot					
Bacterial blight					
Stunt virus					
Alfalfa mosaic virus					
Cucumber mosaic virus					
Bean yellow mosaic virus					
Lettuce necrotic yellows virus					
Pea enation mosaic virus					
Pea streak virus					
Nematodes					
Others (list)					

5.2 Disease Management
For the 3 most important diseases in 5.1

	Mark (x) relative importance of each											
	Rank 1				Rank 2				Rank 3			
Inadequate:	VI	I	SI	N	VI	I	SI	N	VI	I	SI	N
Seed dressing												
Chemical control												
Genetic resistance												
Stability of resistance												
Integrated control												
Screening techniques												
Research efforts												
Others (list)												

6. Agronomy

Stresses:	Mark (x) relative importance of each VI	I	SI	N	Rank top 3 1-3
Poor soil structure					
Poor soil fertility					
Deficiencies					
Toxicities					
Poor seedbed preparation					
Poor seedling emergence					
Poor nodulation					
Poor plant population					
Weed infestation					
Poor cultivation during growth					
Poor crop growth					
Waterlogging					
Lack of rain					
Excessive vegetative growth					
Short season length					
Harvest losses					
Inadequate research					
Others (list)					

7. Physiology

Stresses:	Mark (x) relative importance of each VI	I	SI	N	Rank top 3 1-3
Nutrition					
Water uptake					
Drought					
Humidity					
Salinity					
Acidity					
High temperature					
Low temperature					
High radiation (excess sunshine)					
Low radiation (cloudiness)					
Growth rate					
Root development					
Plant architecture					
Flowering/podding					
Partitioning					
Pod drop					
Others (list)					

8. Food Technology

Stresses:	Mark (x) relative importance of each VI	I	SI	N	Rank top 3 1-3
Postharvest losses					
Poor quality					
Lack of consumer acceptance					
Inadequate processing facilities					
Long cooking time					
Poor product storability					
Others (list)					

9. Economics

Inadequate:	Mark (x) relative importance of each VI	I	SI	N	Rank top 3 1-3
Farmer financing					
Production stability					
Transport					
Storability					
Market size					
Prices					
Price stability					
Marketing infrastructure					
Export trade					
Others (list)					
Yield-loss studies					
Cost-benefit studies					

10. Technology Transfer to Farmers

Factors:	Mark (x) relative importance of each VI	I	SI	N	Rank top 3 1-3
Farmers disinterested					
Farmers lack resources					
Too few extension workers					
Poor linkages with farmer					
Researchers too remote					
Insufficient on-farm research					
Lack of technology					
Technology not relevant					
Acceptability of technology					
Practicability of technology					
Others (list)					

11. Technical Information for Scientists and/or Extension Agents

Lack of access to:	Mark (x) relative importance of each				Rank top 3 1-3
	VI	I	SI	N	
Scientific journals					
Data bases					
Literature searches					
Extension pamphlets/ audio-visual aids					
Workshops					
Training opportunities					
Others (list)					

B. Estimated Future Productivity and Cropping Area of Chickpea

1. Chickpea productivity (yield in kg ha^{-1})

Please put a mark (x) to indicate the expected increase or decrease in present chickpea productivity (kg ha^{-1}) in your country (or district) in 5 and 10 years' time.

Change (%)	-80	-60	-40	-20	0	+20	+40	+60	+80	+100
By 1995										
By 2000										

This for your country ☐ or district ☐

2. Chickpea cropping area ('000 ha)

Please indicate present and expected chickpea cropping area in your country (or district) in 5 and 10 years' time

	Area ('000 ha)		
	Desi	Kabuli	Total
Present			
By 1995			
By 2000			

This for your country ☐ or district ☐

Thank you for your help - please remember to bring this completed copy to 'Chickpea in the Nineties'.

Responses to Questionnaire on Overcoming Constraints to Chickpea Production

D.G. Faris and C.L.L. Gowda

Purpose

A questionnaire first suggested and originally designed by H.A. van Rheenen was provided to participants of the Workshop so they could identify major biotic, abiotic, socio-economic, and research constraints that need to be overcome to ensure high and stable chickpea production and utilization, and to determine possible future chickpea production trends. The results of this survey should provide guidance to planners and administrators in chickpea growing countries, and to scientists in national and international institutions involved in chickpea research.

The Questionnaire

The questionnaire is in two parts — A. Constraints identification and, B. Estimated future productivity and cropping area of chickpea.

A. Constraints Identification

The constraints were grouped into ten categories dealing with various crop research disciplines, economics, postharvest, and technology transfer activities (Table 1).

The sections on entomology and pathology listed the major insect pests or diseases, and a subsection on management of the three pests or diseases indicated as top ranking by each respondent.

Respondents were asked to rate each constraint in the questionnaire into four classes: very important (VI), important (I), somewhat important (SI), and not important (N). They were also asked to rank the three most important in each category.

B. Estimated Future Productivity and Cropping Area of Chickpea

Here the respondents were asked to provide for their own regions estimates area of chickpea productivity (yield kg ha^{-1}) by the year 1995 and 2000, and chickpea area in 1995 and 2000.

Results and Discussion

The questionnaire was sent to the 90 external participants to the Second International Workshop on Chickpea Improvement, held at ICRISAT Center, 4–8 December 1989. Of these 63 questionnaires were returned that could be analyzed. Respondents were from South Asia (Bangladesh-1, India-25, Myanmar-2, Nepal-4, Pakistan-5, and Sri Lanka-1); West Asia (Cyprus-1, Iraq-1, Syria-4, and Turkey-1); Europe (Italy-1, and Spain-3); North Africa (Algeria-1, Egypt-1, Morocco-1, and Tunisia-1); eastern African countries (Ethiopia-2, Kenya-1, and Sudan-1), Americas (Mexico-1, and USA-3) and Australia-2. For analysis items rated very important were scored 4, important 3, somewhat important 2, and not important 1. The scores for each item were totaled for each country; and the sum of scores across country gave the overall scores. The detailed countrywise scores are in Table 1 and the scores across all countries in Table 2. In the following paragraphs the results are discussed by section within the questionnaire.

Out of 63 respondents from 22 countries, 25 were from India. Therefore, there was concern that the overall results might be overshadowed by India. As it turned out the Indian responses did not significantly alter the overall rating (in the top-five bracket) of the constraints in each section. Whenever the Indian responses did affect the overall score these have been identified showing the change.

Table 1. Total scores for different subjects/disciplines as reported by respondents from different countries

		South Asia							WANA Region								Eastern Africa			Europe		Americas	
Code	Description	Bangladesh	India	Myanmar	Nepal	Pakistan	Sri Lanka	Australia	Algeria	Cyprus	Egypt	Iraq	Morocco	Syria	Tunisia	Turkey	Ethiopia	Kenya	Sudan	Italy	Spain	Mexico	USA
A1.	**Importance of each subject in overcoming constraints to production**																						
A1.1	Genetic resources	4	82	8	8	12	3	6	4	4	3	4	3	12	3	3	8	3	2	1	6	4	7
A1.2	Breeding	3	91	7	14	16	1	8	4	4	4	4	4	14	3	2	8	4	4	3	12	4	12
A1.3	Entomology	3	70	6	9	9	3	5	3	2	1	3	3	11	2	3	6	3	3	2	4	4	2
A1.4	Pathology	3	74	6	15	13	3	6	4	3	3	4	4	14	4	3	8	3	3	4	12	2	11
A1.5	Agronomy	4	74	5	14	12	3	6	4	3	2	2	4	15	4	3	8	3	4	3	11	3	6
A1.6	Physiology	3	58	6	7	13	2	5	3	3	2	2	2	12	0	4	6	2	4	3	7	2	5
A1.7	Economics	3	48	7	4	10	3	3	4	4	4	2	4	9	4	2	5	2	2	4	7	1	6
A1.8	Food technology	2	42	5	4	6	1	3	2	4	3	2	3	6	1	3	3	2	2	1	7	3	5
A1.9	Technology transfer to farmers	4	77	6	12	13	4	4	4	3	4	2	4	14	2	3	8	2	4	3	11	2	4
A1.10	Technical information for scientists	3	59	8	10	13	4	4	4	4	3	2	4	11	1	3	7	2	4	1	5	2	5
A1.11	Others (list)	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0
A2.	**Genetic resources, lack of:**																						
A2.1	Collections	4	77	8	7	10	4	6	4	2	3	4	4	11	3	3	8	3	3	1	6	3	7
A2.2	Descriptions	4	65	8	7	11	4	5	4	3	4	3	4	5	3	3	6	3	2	1	9	3	6
A2.3	Evaluations	3	87	7	7	14	4	5	4	4	3	3	4	10	3	4	8	4	4	3	9	4	7
A2.4	Maintenance	3	74	6	11	11	3	3	4	2	3	3	4	8	3	3	8	3	3	1	6	3	7
A2.5	Availability	4	72	3	9	11	3	7	4	3	3	4	3	10	3	4	8	3	4	1	6	4	10
A2.6	Catalogs	3	68	3	7	9	1	5	4	3	2	2	3	6	3	3	6	3	4	2	11	3	6
A2.7	Variability	3	80	0	11	14	2	6	4	4	4	3	4	8	3	4	8	3	4	1	7	4	7
A2.8	Enhanced material	2	66	4	15	11	3	3	3	0	4	3	4	12	3	4	8	3	3	4	12	3	8
A2.9	Others (list)	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Continued

Table 1. Continued.

Code	Description	Bangladesh	India	Myanmar	Nepal	Pakistan	Sri Lanka	Australia	Algeria	Cyprus	Egypt	Iraq	Morocco	Syria	Tunisia	Turkey	Ethiopia	Kenya	Sudan	Italy	Spain	Mexico	USA
		South Asia							WANA Region								Eastern Africa			Europe		Americas	
A3 Breeding, lack of:																							
A3.1	Germplasm variability	4	80	7	11	13	3	7	4	3	3	4	4	10	3	4	8	4	4	1	6	4	6
A3.2	Breeding methodology	3	73	7	8	14	1	4	4	4	3	4	4	6	3	2	7	4	3	1	5	4	7
A3.3	Screening techniques	4	74	6	11	11	3	7	3	4	2	4	4	8	3	2	8	4	4	1	5	4	8
A3.4	Adaptation to farmers' conditions	4	85	6	11	14	3	4	4	2	4	3	3	10	2	3	8	3	4	3	7	4	7
A3.5	Crop stability	3	90	3	15	15	4	7	4	3	4	4	4	10	4	3	8	4	4	1	7	4	8
A3.6	Adequate research	3	73	6	14	15	4	5	4	3	2	2	3	6	2	3	8	4	4	4	9	4	6
A3.7	Availability of improved seed	3	82	7	15	12	4	5	4	2	4	4	4	12	2	3	7	3	3	4	12	4	10
A4.1 Entomology, insect pests:																							
A4.1.1	*Helicoverpa* pod borer	4	100	8	12	20	4	7	3	2	2	4	3	13	3	4	7	3	4	0	3	4	2
A4.1.2	Semiloopers	0	40	2	2	8	1	2	1	0	2	4	1	4	0	0	0	0	1	0	3	1	
A4.1.3	*Spodoptera* sp.	0	29	3	2	7	3	2	2	0	2	3	1	4	0	0	0	0	3	0	3	4	1
A4.1.4	Cutworms	2	43	2	6	7	3	2	2	0	2	0	1	5	0	0	5	0	2	0	3	1	3
A4.1.5	Leaf miner	0	27	5	2	3	2	2	4	3	2	4	4	14	3	4	1	3	3	4	9	2	1
A4.1.6	Aphids	0	34	4	2	10	3	3	1	2	4	4	1	8	0	0	4	3	4	1	4	2	4
A4.1.7	White grubs	0	27	1	6	4	1	2	1	0	2	0	1	4	0	0	1	0	1	0	3	1	1
A4.1.8	*Sitona* weevil	0	22	1	3	5	1	2	1	2	2	0	0	5	2	0	1	0	1	0	3	1	1
A4.1.9	Bruchids	4	72	5	8	13	1	2	3	3	2	4	4	9	2	3	8	0	4	0	8	1	1
A4.1.10	*Metopina* spp.	0	20	2	2	3	1	2	1	0	1	0	1	4	0	0	0	0	1	0	3	1	1
A4.1.11	Others (list)	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A4.2 Pest management for the three most important insect pests in A4.1, inadequate:																							
A4.2.1	Chemical control	0	72	7	5	9	3	8	4	0	4	4	0	9	0	0	6	0	3	2	8	2	5
A4.2.2	Chemical availability	0	57	7	4	8	2	7	4	0	4	3	0	8	0	0	4	3	4	1	5	2	6
A4.2.3	Knowledge on resistance to insecticides	2	56	7	8	11	3	7	4	0	4	2	0	5	0	0	8	3	4	1	4	3	5
A4.2.4	Genetic resistance to insects	4	80	8	12	15	3	6	3	0	3	4	0	8	0	4	8	4	3	4	4	4	4
A4.2.5	Integrated control methods	4	81	6	11	14	4	7	3	0	3	3	0	6	0	4	8	3	4	4	10	4	7
A4.2.6	Screening techniques	2	68	7	8	10	1	6	3	0	3	3	0	6	0	0	8	4	3	1	5	4	6
A4.2.7	Research efforts	3	76	7	7	12	4	6	3	0	3	3	0	8	0	0	8	3	4	4	7	2	6

Continued

Table 1. Continued.

		South Asia							WANA Region									Eastern Africa			Europe		Americas	
Code	Description	Bangladesh	India	Myanmar	Nepal	Pakistan	Sri Lanka	Australia	Algeria	Cyprus	Egypt	Iraq	Morocco	Syria	Tunisia	Turkey	Ethiopia	Kenya	Sudan	Italy	Spain	Mexico	USA
A5.1 Pathology, diseases:																							
A5.1.1	Ascochyta blight	0	68	0	2	16	2	2	4	4	3	4	4	16	4	4	3	4	1	4	9	0	12
A5.1.2	Black root rot	0	35	3	3	7	1	2	1	1	3	4	0	7	1	0	5	0	4	1	3	0	2
A5.1.3	Botrytis gray mold	4	55	0	12	5	1	4	1	1	2	4	1	7	1	0	2	0	1	1	2	0	6
A5.1.4	Alternaria blight	0	35	0	2	8	1	2	1	1	2	4	1	7	1	1	2	0	1	2	2	0	2
A5.1.5	Collar rot	4	40	3	4	8	3	2	2	1	3	0	2	4	2	0	6	3	2	1	2	0	2
A5.1.6	Colletotrichum blight	0	28	0	2	5	1	2	2	1	1	0	1	3	1	0	4	0	1	1	2	0	2
A5.1.7	Phoma blight	0	23	0	2	5	1	3	3	1	1	0	0	3	1	0	1	0	1	1	2	0	2
A5.1.8	Stemphylium blight	0	24	0	2	4	1	2	2	1	1	0	3	3	1	0	0	0	1	1	2	0	2
A5.1.9	Rust	0	28	0	2	6	2	2	2	1	2	3	1	4	1	0	4	0	2	1	2	3	2
A5.1.10	Powdery mildew	0	28	0	1	5	3	2	1	2	2	0	0	6	1	0	2	2	2	1	2	0	2
A5.1.11	Sclerotinia stem rot	0	46	3	3	7	2	3	2	1	2	0	1	6	2	0	6	0	2	1	2	0	4
A5.1.12	Fusarium wilt	4	94	4	12	11	4	2	4	1	4	4	4	14	4	3	8	3	4	2	12	4	8
A5.1.13	Verticillium wilt	0	27	0	2	4	1	2	3	1	3	4	1	6	4	0	2	0	3	2	2	0	6
A5.1.14	Dry root rot	0	67	3	9	13	1	3	3	1	4	4	3	5	2	0	8	3	4	1	3	4	8
A5.1.15	Wet root rot	0	43	0	2	7	1	2	1	1	4	4	0	5	0	0	8	0	4	1	2	4	4
A5.1.16	Phytophthora root rot	0	34	0	3	8	2	5	1	1	2	0	1	5	1	0	2	0	2	1	3	0	2
A5.1.17	Foot rot	0	38	3	2	5	1	2	2	1	2	4	1	5	1	0	2	3	2	1	2	0	4
A5.1.18	Bacterial blight	0	30	0	2	7	1	2	1	1	2	0	1	3	1	0	2	0	1	1	2	0	2
A5.1.19	Stunt virus	0	58	0	2	7	1	3	3	1	2	4	3	5	3	1	7	4	4	1	7	0	5
A5.1.20	Alfalfa mosaic virus	0	20	0	2	6	1	3	2	1	2	4	0	2	0	0	1	0	3	1	0	0	4
A5.1.21	Cucumber mosaic virus	0	22	0	4	4	1	3	2	1	2	0	0	2	0	0	0	0	3	1	0	0	2
A5.1.22	Bean yellow mosaic virus	0	22	0	2	4	2	2	2	1	3	0	0	2	0	0	0	0	3	1	0	2	4
A5.1.23	Lettuce necrotic yellow virus	0	20	0	2	4	1	2	2	1	2	0	0	2	0	0	0	0	2	1	0	0	1
A5.1.24	Pea enation mosaic virus	0	22	0	2	4	1	2	3	1	2	0	0	2	0	0	0	0	2	1	0	0	5
A5.1.25	Pea streak virus	0	22	0	2	4	1	2	2	1	1	0	0	2	0	0	0	0	2	1	0	0	4
A5.1.26	Nematodes	0	33	0	3	7	2	3	4	1	2	0	3	10	3	0	0	0	3	2	1	0	1
A5.1.27	Others(list)	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Continued

Table 1. Continued.

Code	Description	Bangla- desh	In- dia	Myan- mar	Ne- pal	Paki- stan	Sri Lanka	Aust- ralia	Alger- ia	Cy- prus	Eg- ypt	Iraq	Moro- cco	Sy- ria	Tuni- sia	Tur- key	Ethi- opia	Ken- ya	Su- dan	It- aly	Sp- ain	Mex- ico	USA
		South Asia							WANA Region								Eastern Africa			Europe		Americas	
A5.2 Disease management for the three most important diseases in A5.1:																							
A5.2.1	Seed dressing	4	64	2	2	10	3	4	3	1	3	4	4	10	4	3	8	0	4	4	9	2	9
A5.2.2	Chemical control	1	58	1	4	8	3	3	2	1	3	4	0	10	0	4	2	0	3	4	9	1	5
A5.2.3	Genetic resistance	0	90	4	12	12	4	5	4	4	4	4	4	11	4	3	8	0	4	4	12	2	12
A5.2.4	Stability of resistance	0	77	4	7	10	4	5	4	4	4	3	4	10	4	3	8	0	4	4	11	4	12
A5.2.5	Integrated control	4	68	3	7	7	4	5	3	1	4	3	3	10	3	4	8	0	4	0	12	3	11
A5.2.6	Screening techniques	0	68	4	8	9	1	5	3	4	3	4	3	6	1	2	8	0	3	4	10	2	11
A5.2.7	Research efforts	2	73	4	7	9	4	6	4	4	4	4	4	9	3	0	8	0	4	4	10	3	10
A6 Agromony stresses:																							
A6.1	Poor soil structure	1	52	2	8	14	2	6	3	1	2	0	0	7	0	0	3	3	3	2	5	0	6
A6.2	Poor soil fertility	3	61	5	6	13	3	2	4	2	2	0	0	8	0	0	4	0	3	2	5	0	5
A6.3	Deficiencies	3	45	2	4	10	1	4	1	2	2	0	0	8	0	0	4	0	3	1	3	0	5
A6.4	Toxicities	1	35	2	3	6	1	2	1	1	2	0	0	5	0	0	4	0	3	1	3	0	3
A6.5	Poor seedbed preparation	2	47	7	11	12	1	3	4	2	2	4	4	11	3	3	8	0	4	1	7	2	6
A6.6	Poor seedling emergence	3	58	6	10	11	0	4	3	2	3	0	3	10	3	3	8	0	4	3	4	2	9
A6.7	Poor nodulation	2	54	6	6	9	4	3	1	4	4	0	0	8	1	3	4	3	4	1	6	0	9
A6.8	Poor plant population	4	85	6	8	13	2	4	3	3	2	4	4	11	3	4	7	3	3	2	8	3	9
A6.9	Weed infestation	1	77	6	6	13	2	8	4	4	2	4	4	16	4	1	5	0	4	4	6	3	11
A6.10	Poor cultivation during growth	1	59	6	5	11	0	2	4	4	2	4	3	5	3	0	8	0	3	2	8	0	4
A6.11	Poor crop growth	1	62	3	6	12	4	4	3	3	2	0	2	8	2	0	8	0	3	0	7	0	5
A6.12	Waterlogging	1	33	3	3	7	0	5	1	1	2	0	0	6	1	0	8	4	2	3	3	0	4
A6.13	Lack of rain	2	67	3	9	15	1	6	4	1	1	4	4	15	3	3	5	3	4	3	10	4	7
A6.14	Excess vegetative growth	1	51	0	6	7	1	4	1	1	3	0	0	5	1	0	2	0	2	1	3	0	4
A6.15	Short season length	3	49	4	2	5	1	6	1	3	1	4	0	9	3	0	7	3	4	1	3	0	6
A6.16	Harvest losses	2	39	7	6	8	1	5	2	3	2	4	0	12	2	3	4	0	3	1	5	0	4
A6.17	Inadequate research	4	62	7	7	11	4	5	4	3	3	0	2	15	1	0	8	4	2	4	11	3	9
A6.18	Others (list)	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Continued

Table 1. Continued.

Code	Description	Bangladesh	India	Myanmar	Nepal	Pakistan	Sri Lanka	Australia	Algeria	Cyprus	Egypt	Iraq	Morocco	Syria	Tunisia	Turkey	Ethiopia	Kenya	Sudan	Italy	Spain	Mexico	USA
		South Asia							WANA Region								Eastern Africa			Europe		Americas	
A7 Physiology stresses:																							
A7.1	Nutrition	0	57	6	10	9	4	5	3	2	2	3	3	8	3	0	4	0	4	2	8	2	7
A7.2	Water uptake	0	50	3	3	9	1	6	4	3	4	3	1	8	1	0	6	4	2	3	10	2	8
A7.3	Drought	4	82	4	11	16	1	6	4	4	4	4	4	16	4	4	8	4	4	3	11	4	8
A7.4	Humidity	0	38	0	5	7	2	3	1	1	1	2	1	9	1	0	1	3	1	4	4	1	5
A7.5	Salinity	2	47	3	4	7	1	2	1	1	4	2	1	5	1	0	2	3	3	1	3	3	4
A7.6	Acidity	0	35	3	8	5	2	3	1	1	2	2	1	4	1	0	0	3	3	1	3	1	5
A7.7	High temperature	4	46	6	4	9	0	3	3	3	2	3	3	13	4	0	6	3	4	2	10	2	8
A7.8	Low temperature	0	45	2	6	10	3	7	3	3	1	4	3	13	1	4	4	1	1	4	5	3	8
A7.9	High radiation	3	25	3	3	6	1	3	1	1	1	1	1	10	1	0	2	1	3	1	9	1	5
A7.10	Low radiation	0	29	3	3	7	2	2	1	1	1	1	1	5	1	0	5	1	1	1	3	1	5
A7.11	Growth rate	0	51	3	4	12	4	6	3	3	2	1	1	5	1	0	8	2	3	1	6	0	8
A7.12	Root development	4	53	3	4	11	3	3	0	3	1	1	1	9	1	0	8	3	3	1	6	0	8
A7.13	Plant architecture	3	61	2	5	10	1	7	4	3	1	0	1	10	1	3	6	3	0	1	6	3	9
A7.14	Flowering/podding	3	63	6	5	13	4	7	4	3	4	3	3	8	3	0	8	3	4	1	8	2	8
A7.15	Partitioning	0	65	0	4	10	2	7	4	3	1	0	1	11	1	0	8	3	4	1	5	4	7
A7.16	Pod drop	4	41	4	5	9	2	1	3	2	1	3	1	9	1	0	5	4	3	1	3	2	7
A7.17	Others (list)	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A8 Food technology stresses:																							
A8.1	Postharvest losses	4	70	6	9	11	2	4	1	3	1	2	0	7	1	2	8	4	4	1	4	4	6
A8.2	Poor quality	0	38	6	9	7	2	7	2	3	4	4	0	5	1	1	4	3	2	3	3	2	8
A8.3	Lack of consumer acceptance	0	38	4	4	9	1	5	1	3	4	1	3	12	0	1	3	4	1	1	3	2	10
A8.4	Inadequate processing facilities	3	56	3	7	10	1	4	1	3	3	2	0	5	3	1	8	4	4	1	3	3	5
A8.5	Long cooking time	0	38	3	2	6	2	4	2	3	2	3	0	8	1	4	6	3	1	3	3	2	6
A8.6	Poor product storability	4	51	3	7	8	3	3	2	3	4	3	0	6	1	2	8	3	4	1	3	2	6
A8.7	Others (list)	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

Continued

Table 1. Continued.

Code	Description	South Asia							WANA Region								Eastern Africa			Europe		Americas	
		Bangladesh	India	Myanmar	Nepal	Pakistan	Sri Lanka	Australia	Algeria	Cyprus	Egypt	Iraq	Morocco	Syria	Tunisia	Turkey	Ethiopia	Kenya	Sudan	Italy	Spain	Mexico	USA
A9 Economics, inadequate:																							
A9.1	Farmer financing	3	61	3	4	13	3	4	3	2	3	2	3	10	3	3	6	3	3	2	5	2	6
A9.2	Production stability	0	80	4	5	13	4	6	4	3	2	4	4	12	3	3	8	2	4	4	10	4	11
A9.3	Transport	0	37	3	5	8	1	2	1	1	1	2	0	5	1	0	5	2	3	1	4	2	6
A9.4	Storability	4	69	0	8	9	3	2	2	2	4	3	0	7	1	3	8	3	4	1	4	2	7
A9.5	Market size	0	44	4	4	9	3	7	1	3	4	3	0	9	3	0	6	2	1	1	6	4	7
A9.6	Prices	0	74	4	7	14	3	7	1	3	4	3	4	15	3	3	7	3	4	4	6	3	12
A9.7	Price stability	3	78	2	7	14	2	6	1	4	4	3	4	13	3	4	7	3	4	3	7	4	12
A9.8	Marketing infrastructure	0	60	1	7	14	1	6	1	3	2	3	3	8	1	3	8	3	1	1	11	0	7
A9.9	Export trade	0	45	6	3	9	1	8	1	1	4	1	3	10	2	0	8	3	4	2	11	4	5
A9.10	Others (list)	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	8	0	0
A9.11	Yield-loss studies	3	56	7	6	8	1	4	0	2	4	2	0	11	3	0	7	4	3	3	9	3	5
A9.12	Cost-benefit studies	0	53	3	6	10	3	3	0	3	0	2	0	11	3	0	7	3	4	3	8	3	5
A10 Technology transfer to farmers:																							
A10.1	Farmers disinterested	0	39	5	5	8	3	6	2	1	2	2	0	5	1	0	3	4	1	3	6	3	6
A10.2	Farmers lack resources	0	79	6	11	13	3	2	3	1	2	2	3	9	3	2	7	4	3	3	4	3	7
A10.3	Too few extension workers	4	57	3	6	7	4	3	4	1	2	4	0	12	3	3	6	1	3	4	11	4	8
A10.4	Poor linkages with farmers	4	75	2	8	13	4	3	4	1	3	2	4	13	3	3	7	1	3	4	12	3	5
A10.5	Researchers too remote	3	52	1	9	11	4	3	3	1	3	2	0	11	1	0	6	1	4	1	9	1	7
A10.6	Insufficient on-farm research	3	77	6	9	13	4	4	4	1	2	4	1	13	2	2	8	2	4	2	9	4	5
A10.7	Lack of technology	3	45	3	8	14	4	4	3	2	2	3	1	10	1	0	4	0	2	1	4	2	7
A10.8	Technology not relevant	0	38	2	5	8	0	2	2	1	2	0	1	7	1	0	4	0	1	1	3	2	4
A10.9	Acceptability of technology	3	62	3	9	9	1	3	4	1	4	3	3	11	2	0	6	2	4	1	6	2	8
A10.10	Practicability of technology	0	62	3	6	14	3	2	4	1	4	3	1	9	2	0	6	2	4	1	7	2	8

Continued

Table 1. Continued.

Code	Description	South Asia: Bangladesh	India	Myanmar	Nepal	Pakistan	Sri Lanka	WANA Region: Australia	Algeria	Cyprus	Egypt	Iraq	Morocco	Syria	Tunisia	Turkey	Eastern Africa: Ethiopia	Kenya	Sudan	Europe: Italy	Spain	Americas: Mexico	USA
A11	**Technical information for scientists and/or extension agents:**																						
A11.1	Scientific journals	3	67	8	12	13	3	3	4	3	4	4	3	11	3	3	7	3	4	1	3	4	10
A11.2	Data bases	4	63	3	11	12	2	5	4	3	2	2	0	13	3	1	8	3	2	1	3	4	6
A11.3	Literature searches	3	61	7	10	13	4	4	0	3	3	4	3	11	3	1	8	3	3	1	3	4	9
A11.4	Extension pamphlets/ AV aids	4	71	6	15	13	3	2	4	2	2	3	3	16	1	1	6	3	4	2	8	1	8
A11.5	Workshops	3	69	7	12	11	3	3	4	3	4	4	0	10	1	1	6	3	3	1	11	3	11
A11.6	Training opportunities	3	85	4	14	12	4	2	4	3	2	4	0	13	1	1	8	4	4	1	11	4	9
A11.7	Others (list)	0	3	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0

A.1 Importance of Each Subject in Overcoming Constraints to Chickpea Production

Among the subjects, breeding received the highest overall score indicating its importance worldwide (Table 2). Out of 22 countries, breeding was among the top-5 subjects in 20 countries (Table 1). In the remaining two countries (Sri Lanka and Turkey) it ranked low. Pathology ranked second overall as a subject for emphasis, with 16 countries placing it among the top five. Agronomy research and Technology transfer to farmers were placed third and fourth overall. Countries such as Australia, Italy, Spain, and USA, as well as India, Kenya, Mexico, Syria, and Tunisia did not rate technology transfer among the top 5.

A.2 Genetic Resources

In genetic resources, lack of evaluation was rated high overall, and it was ranked high in all countries, except Nepal. Lack of variability was ranked second overall. Other overall rankings were inadequacy of collections third, availability of germplasm fourth, and enhanced germplasm fifth. However, when the responses from South Asia and India were excluded from the list the need for enhanced germplasm material was ranked second overall.

A.3 Breeding

Among the topics in breeding, lack of crop (yield) stability was rated high, closely followed by lack of availability of improved seeds. However, when responses from India (and South Asia) were excluded, lack of availability of improved seeds became the top-rated limiting factor. Lack of adaptation (of varieties) to farmers conditions, and lack of adequate research were also highlighted. Lack of appropriate breeding methodology was not considered a constraint, receiving the lowest rating overall.

A.4.1 Presence of Insect Pests

As expected, *Helicoverpa armigera* pod borer was the most important pest of chickpea throughout the world. It was ranked as the most important pest in 13, and important in 7 countries. Only Algeria

Table 2. Total score of all countries ranked within subject groups.

Code	Description	Total score		
		All countries	Minus India	Minus rest of S. Asia
A1 Importance of each subject in overcoming constraints to production:				
A1.2	Breeding	234	143	102
A1.4	Pathology	208	134	94
A1.5	Agronomy	199	125	87
A1.9	Technology transfer to farmers	198	121	82
A1.1	Genetic resources	193	111	76
A1.10	Technical information for scientists	165	106	68
A1.3	Entomology	162	92	62
A1.6	Physiology	158	100	69
A1.7	Economics	144	96	69
A1.8	Food technology	114	72	54
A1.11	Others (list)	3	3	3
A2 Genetic resources, lack of:				
A2.3	Evaluations	209	122	87
A2.7	Variability	191	111	81
A2.1	Collections	188	111	78
A2.5	Availability	185	113	83
A2.8	Enhanced material	185	119	84
A2.4	Maintenance	178	104	70
A2.2	Descriptions	170	105	71
A2.6	Catalogs	163	95	72
A2.9	Others (list)	0	0	0
A3 Breeding, lack of:				
A3.5	Crop stability	215	125	85
A3.7	Availability of improved seed	214	132	91
A3.4	Adaptation to farmers' conditions	201	116	78
A3.1	Germplasm variability	200	120	82
A3.6	Adequate research	191	118	76
A3.3	Screening techniques	187	113	78
A3.2	Breeding methodology	178	105	72
A4 Entomology, insect pests:				
A4.1.1	*Helicoverpa* pod borer	219	119	71
A4.1.9	Bruchids	161	89	58
A4.1.5	Leaf miner	105	78	66
A4.1.6	Aphids	100	66	47
A4.1.4	Cutworms	91	48	28
A4.1.2	Semiloopers	75	35	22
A4.1.3	*Spodoptera* spp.	71	42	27
A4.1.7	White grubs	58	31	19
A4.1.8	Secona weevil	55	33	23
A4.1.10	*Metapina* spp.	46	26	18
A4.1.11	Others (list)	5	5	5

Continued

Table 2. Continued.

Code	Description	Total score		
		All countries	Minus India	Minus rest of S. Asia
A4.2 Pest management for the three most important insect pests in A4.1, inadequate:				
A4.2.5	Integrated control methods	183	102	63
A4.2.4	Genetic resistance to insects	175	101	63
A4.2.7	Research efforts	164	92	59
A4.2.1	Chemical control	142	70	49
A4.2.6	Screening techniques	139	79	55
A4.2.3	Knowledge on resistance to insecticides	131	83	53
A4.2.2	Chemical availability	110	69	50
A5 Pathology, diseases:				
A5.1.12	Fusarium wilt	217	123	88
A5.1.1	Ascochyta blight	172	105	85
A5.1.14	Dry root rot	152	85	59
A5.1.19	Stunt virus	124	66	56
A5.1.3	Botrytis gray mold	114	60	38
A5.1.5	Collar rot	97	57	35
A5.1.11	Sclerotinia stem rot	95	49	34
A5.1.15	Wet root rot	95	52	42
A5.1.2	Black root rot	84	50	36
A5.1.17	Foot rot	83	45	34
A5.1.26	Nematodes	80	47	35
A5.1.13	Verticillium wilt	76	49	42
A5.1.16	Phytophthora root rot	76	42	29
A5.1.4	Alternaria blight	75	41	30
A5.1.9	Rust	69	41	31
A5.1.10	Powdery mildew	64	36	27
A5.1.18	Bacterial blight	61	31	21
A5.1.6	Colletotrichum blight	59	31	23
A5.1.20	Alfalfa mosaic virus	54	34	25
A5.1.22	Bean yellow mosaic virus	54	32	24
A5.1.7	Phoma blight	51	28	20
A5.1.8	Stemphylium blight	51	27	20
A5.1.21	Cucumber mosaic virus	49	27	18
A5.1.24	Pea enation mosaic virus	49	27	20
A5.1.25	Pea streak virus	46	24	17
A5.1.23	Lettuce necrotic yellow virus	43	23	16
A5.1.27	Others (list)	1	1	1
A5.2 Disease management for the three most important diseases in A5.1:				
A5.2.3	Genetic resistance	201	111	83
A5.2.4	Stability of resistance	178	101	80
A5.2.7	Research efforts	166	96	76
A5.2.1	Seed dressing	146	86	70
A5.2.5	Integrated control	145	80	69
A5.2.6	Screening techniques	142	85	68
A5.2.2	Chemical control	101	59	46

Continued

Table 2. Continued.

Code	Description	Total score		
		All countries	Minus India	Minus rest of S. Asia
A6 Agronomy stresses:				
A6.8	Poor plant population	199	114	81
A6.9	Weed infestation	192	115	87
A6.13	Lack of rain	181	114	84
A6.17	Inadequate research	175	113	80
A6.6	Poor seedling emergence	157	99	69
A6.5	Poor seedbed preparation	149	102	69
A6.11	Poor crop growth	142	80	54
A6.10	Poor cultivation during growth	140	81	58
A6.7	Poor nodulation	136	82	55
A6.2	Poor soil fertility	134	73	43
A6.1	Poor soil structure	124	72	45
A6.15	Short season length	120	71	56
A6.16	Harvest losses	117	78	54
A6.3	Deficiencies	103	58	38
A6.14	Excess vegetative growth	94	43	28
A6.12	Waterlogging	90	57	43
A6.4	Toxicities	77	42	29
A6.18	Others (list)	4	4	4
A7 Physiology stresses:				
A7.3	Drought	217	135	99
A7.14	Flowering/podding	169	106	75
A7.1	Nutrition	148	91	62
A7.15	Partitioning	146	81	65
A7.13	Plant architecture	145	84	63
A7.7	High temperature	143	97	74
A7.2	Water uptake	137	87	71
A7.8	Low temperature	135	90	69
A7.12	Root development	132	79	54
A7.11	Growth rate	129	78	55
A7.16	Pod drop	116	75	51
A7.5	Salinity	104	57	40
A7.4	Humidity	93	55	41
A7.6	Acidity	87	52	34
A7.9	High radiation	84	59	43
A7.10	Low radiation	77	48	33
A7.17	Others (list)	3	3	3
A8 Food technology stresses:				
A8.1	Postharvest losses	156	86	54
A8.4	Inadequate processing facilities	133	77	53
A8.6	Poor product storability	129	78	53
A8.2	Poor quality	117	79	55
A8.3	Lack of consumer acceptance	111	73	55
A8.5	Long cooking time	104	66	53
A8.7	Others (list)	2	2	2

Continued

Table 2. Continued.

Code	Description	Total score: All countries	Minus India	Minus rest of S. Asia
A9 Economics, inadequate:				
A9.2	Production stability	196	116	90
A9.7	Price stability	196	118	90
A9.6	Prices	191	117	89
A9.1	Farmer financing	154	93	67
A9.4	Storability	152	83	59
A9.8	Marketing infrastructure	152	92	69
A9.11	Yield-loss studies	146	90	65
A9.12	Cost-benefit studies	136	83	61
A9.5	Market size	126	82	62
A9.3	Transport	95	58	41
A9.10	Others (list)	13	12	11
A10 Technology transfer to farmers:				
A10.6	Insufficient on-farm research	185	110	75
A10.4	Poor linkages with farmer	184	109	78
A10.2	Farmers lack resources	178	99	66
A10.3	Too few extension workers	157	100	76
A10.9	Acceptability of technology	154	92	67
A10.10	Practicability of technology	151	89	63
A10.5	Researchers too remote	138	87	59
A10.7	Lack of technology	130	85	53
A10.1	Farmers disinterested	109	70	49
A10.8	Technology not relevant	91	53	38
A11 Technical information for scientists and/or extension agents:				
A11.6	Training opportunities	200	115	78
A11.4	Extension pamphlets/AV aids	185	114	73
A11.1	Scientific journals	183	116	77
A11.5	Workshops	179	110	74
A11.3	Literature searches	168	107	70
A11.2	Data bases	162	99	67
A11.7	Others (list)	0	0	0

and Italy did not rate it as an important pest. Leaf miner was an important pest in the West Asia and North Africa (WANA) region, East Africa, Europe, Mexico, and USA. Bruchids were the most important storage pests in most countries of the world. Aphids were also important. Other pests such as cutworms, semiloopers, *Spodoptera*, and white grubs were important locally in a few countries.

A.4.2 Pest Management

Integrated control measures and use of genetic resistance were the preferred pest management methods in most countries. Chemical control was rated third overall. Lack of research efforts, screening techniques, and knowledge on resistance to insecticides were other areas rated as important.

A.5.1 Diseases

Among the 26 chickpea diseases listed, five were important overall: fusarium wilt, ascochyta blight, dry root rot, stunt virus, and botrytis gray mold, in that order. Fusarium wilt was rated in the top-5 in all countries, except Australia. It is important in South Asia, North and eastern Africa, Mexico, Syria, Turkey, and USA. Ascochyta blight is important in western India, Europe, Pakistan, the WANA region, and USA. Dry root rot is important in most countries. Stunt virus is important in Australia, India, North Africa, Spain, and Turkey. Other major diseases that were in the top-10 listing are: collar rot, sclerotinia stem rot, wet root rot, black root rot, and foot rot. Nematodes were important in Italy and the WANA region. It is possible that nematodes are present in other countries but not recognized as economically important. The parasitic weed, *Orobanche,* was also listed by many scientists from the WANA region as being very important.

A.5.2 Disease Management

Among various components of disease management, inadequate genetic resistance and stability of resistance were rated as major constraints. Need for improved research efforts, seed dressing, and integrated control was emphasized. Chemical control has been rated lowest among disease management options.

A.6 Agronomy

Poor plant population, weed infestation, and lack of rain were rated the three top agronomic constraints. Outside of South Asia, weed infestation and lack of rain were more important than plant population. Lack of adequate research was also important in many countries. Poor seedbed preparation and harvest losses were less important in India, compared to all other countries. Other agronomic constraints were (in order of rating): poor seedling emergence, poor seedbed preparation, poor crop growth, poor cultivation during growth, poor nodulation, poor soil fertility, poor soil structure, shorter growing season, and nutritional defiencies. Waterlogging, excessive vegetative growth, and toxicities were local problems in some countries (Australia, Egypt, Ethiopia, and Italy.

A.7 Physiology

Drought was the most important physiological factor limiting chickpea production. Problems in flowering and podding, nutrition, partitioning, and plant architecture were also major constraints in different countries. High temperature was a limiting factor in Bangladesh, India, Morocco, Tunisia, Sudan, Syria, and Spain; while low temperature was a constraint in Australia, Cyprus, Ethiopia, Morocco, Syria, and USA. Other constraints reported important were root development, water uptake, pod drop, and salinity.

A.8 Food Technology

Postharvest losses, inadequate processing facilities, and poor product storability were the major constraints in food technology. Almost all countries have rated postharvest losses as a major constraint, followed by lack of processing facilities. Surprisingly, lack of consumer acceptance has been reported as a constraint even in the major traditional chickpea areas. Long cooking time was rated lowest.

A.9 Economics

Production stability, price stability, and prices have been rated high as economic constraints to chickpea production. These three factors have been rated as important constraints in more than a dozen countries. Other constraints of secondary importance are farmer financing, storability, and market infra-structure. Answers indicated the need for yield-loss and cost-benefit studies, and a larger market size.

A.10 Technology Transfer to Farmers

Insufficient on-farm research, poor links with farmers, and lack of farmer resources have been reported as major constraints for technology transfer. All countries have said that farmers lack resources. Shortages of extension workers, practicability of technology and acceptability of technology, are constraints of secondary importance. Many countries indicate that practicability of technology was more important than acceptability of technologies. Only seven countries (Australia, Cyprus, Egypt, Italy, Kenya, Mexico, and Myanmar) indicated that farmers are not interested in adopting the new technology, while four countries (Australia, Bangladesh, Cyprus,and Pakistan) suggested that technology suitable to farmers is lacking.

A.11 Technical Information for Scientists and Extension Agents

Lack of training opportunities, non-availability of scientific journals, and lack of access to pamphlets and audio-visual aids were cited as bottlenecks for information exchange among scientists and extension agents. Lack of scientific journals is amongst the five most important constraints for all countries. Scientists in India had greater accessibility to scientific journals than other countries. Other constraints are lack of access to workshops and literature searches.

B.1. Estimated Future Productivity and Cropping Area

Only 55 respondents filled in this part of the questionnaire. Respondents were asked to project the percentage change in chickpea productivity (yield kg ha^{-1}) in 1995 and 2000 over present yield levels (Fig. 1). Overall, they predicted 30% average increase by the year 1995, and 51% by 2000. The major chickpea growing countries (India, Myanmar, Nepal, Pakistan and Turkey) predicted increases ranging from 20–40% (Mean:28%) by 1995, and 40–60% (Mean:51%) by 2000. The North African chickpea producing countries (Algeria, Morocco, Tunisia) and Iraq expect a 100% increase in productivity by 1995. Both Ethiopia and Mexico predicted no improvement in productivity by 1995, but a 20% increase by 2000. The countries on the northern side of Mediterranean sea (Italy, Spain, and Syria), Cyprus, and Kenya expect a 20% increase by 1995, and 40% by 2000 while Sudan

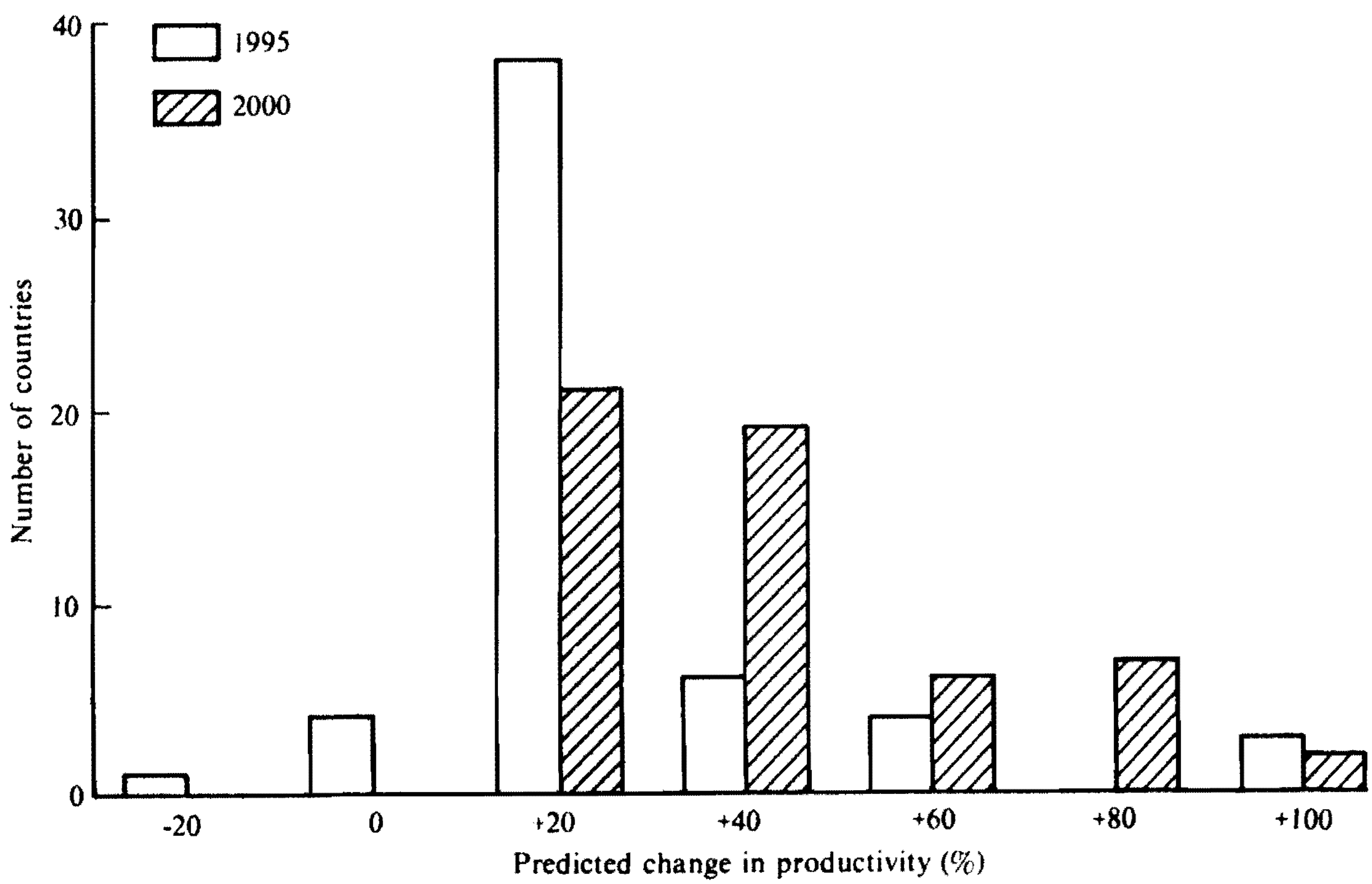


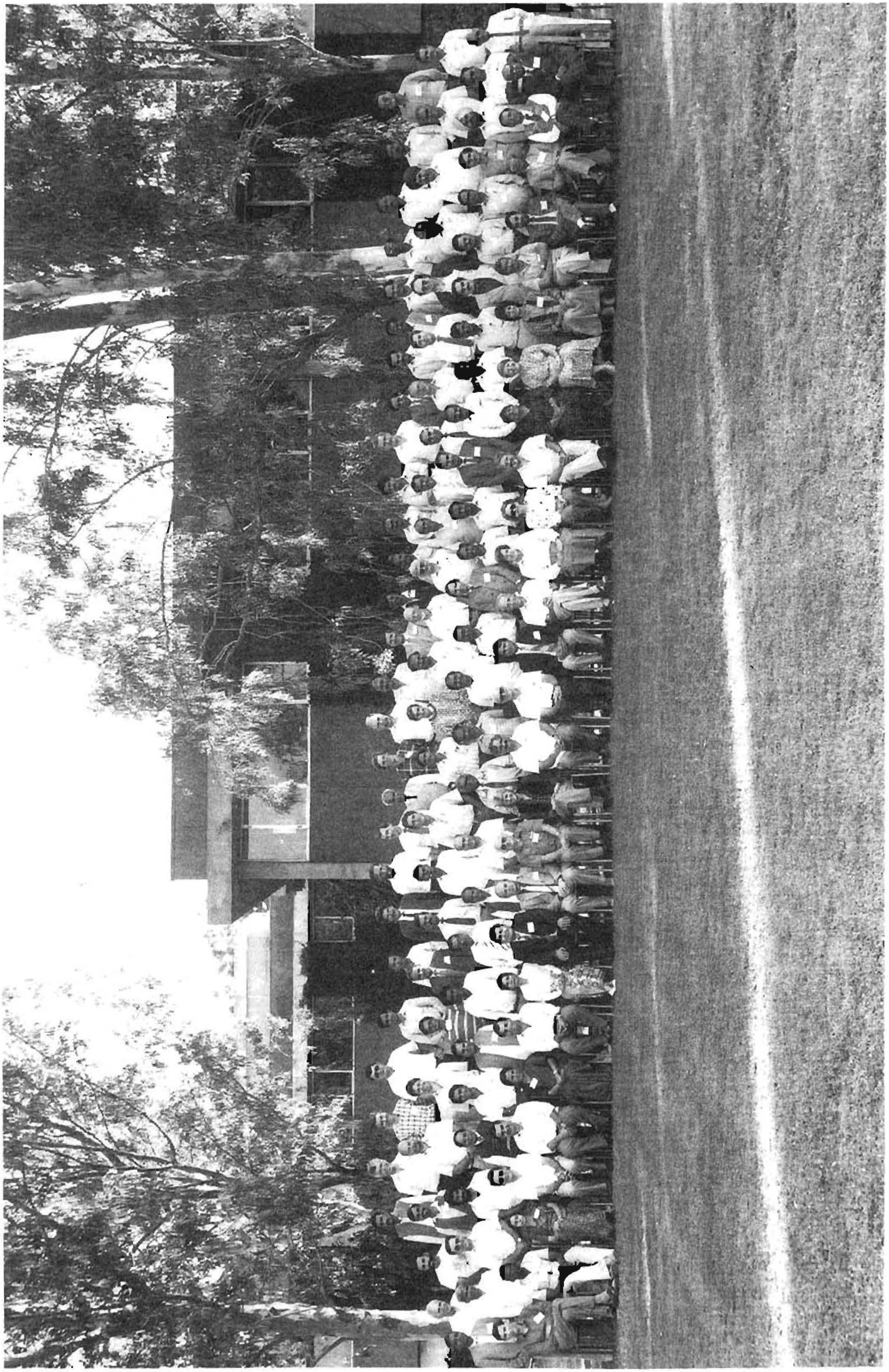
Figure 1. Predicted change (%) in chickpea productivity in different countries by the years 1995 and 2000.

expects 40% by 1995 and 60% by 2000. Developed countries (Australia and USA) expect a modest increase of 20% in productivity by 1995 and 2000, although some scientists in Australia expect a 40% increase by 2000. Sri Lanka, which is trying to introduce chickpea, expects a 40% increase in 1995, and 80% in 2000.

B.2. Chickpea Area in 1995 and 2000

Only a few respondents answered this part, so we are not reporting on this section.

Participants



Participants

AFGHANISTAN

A. Habibi
Junior Scientist
Agricultural Research Institute
Ministry of Agriculture and Land Reforms
Kabul

ALGERIA

M. Labdi
Food Legume Coordinator
Institut technique des grandes cultures (ITGC)
BP No. 59
Sidi Bel Abbes

AUSTRALIA

E.J. Knights
Chickpea Breeder
New South Wales Department of Agriculture and Fisheries
Agricultural Research Centre
RMB 944
Tamworth, NSW 2340

H.S. Saini
Special Chemist
North Coast Agricultural Institute
New South Wales Department of Agriculture and Fisheries
Bruxner Highway
Wollongbar, NSW 2480

R.H. Sedgley
Senior Lecturer
Agronomy Department
School of Agriculture
University of Western Australia
Nedlands, WA 6009

J.H. Silsbury
Senior Lecturer in Agronomy
Department of Agronomy
Waite Agricultural Research Institute
Glen Osmond
South Australia 5064

B.J. Walby
Proceedings Editor
9 The Nook
Balwyn North
Victoria, 3104

CYPRUS

A. Hadjichristodoulou
Head, Field Crops Section
Agricultural Research Institute
Ministry of Agriculture and Natural Resources
Nicosia

EGYPT

A.M. Khattab
Chickpea Breeder
Agricultural Research Center
Field Crops Institute
Food Legumes Section
El-Gamma St.
Giza

ETHIOPIA

Bashir Tesfayse
Research Officer
Scientific Phytopathological Laboratory
P.O. Box 152
Ambo
Shoa

Abebe Tullu
Coordinator, Chickpea Research
Debre-Zeit Agricultural Research Center
Alemaya University of Agriculture
P.O. Box 32
Debre-Zeit
Shoa

FEDERAL REPUBLIC OF GERMANY

H. Rembold
Professor, University of Munich, and
Head, Research Unit for Insect Biochemistry
Max-Planck Institute for Biochemistry
D-8033 Martinsried
München

M. von Oppen
Professor
Institute of Agricultural Economics and
Social Sciences in the Tropics
Universitat Hohenheim
Institut 490
Postfach 700 562
7000 Stuttgart 70

INDIA

Sabra Abbas
Principal Scientist
Division of Plant Physiology
Indian Agricultural Research Institute (IARI)
New Delhi 110 012

I.P.S. Ahlawat
Senior Scientist (Legumes)
Division of Agronomy
Indian Agricultural Research Institute (IARI)
New Delhi 110 012

M. Ali
Principal Investigator and Head (Agronomy)
Directorate of Pulses Research
Kalyanpur
Kanpur 208 024
Uttar Pradesh

K.S. Amin
Principal Investigator and Head, Pathology
Directorate of Pulses Research
Kalyanpur
Kanpur 208 024
Uttar Pradesh

A.N. Asthana
Principal Investigator (Plant Breeding)
Directorate of Pulses Research
Kalyanpur
Kanpur 208 024
Uttar Pradesh

P.N. Bahl
Assistant Director General (Food Crops)
Indian Council of Agricultural Research (ICAR)
Krishi Bhavan
New Delhi 110 001

B. Baldev
Principal Scientist
Division of Plant Physiology
Indian Agricultural Research Institute (IARI)
New Delhi 110 012

J.K. Chavan
Associate Professor
Department of Biochemistry
Mahatma Phule Agricultural University
Rahuri 413 722
Maharashtra

B.S. Dahiya
Senior Chickpea Breeder
Department of Plant Breeding
Haryana Agricultural University
Hisar 125 004
Haryana

R.B. Deshmukh
Plant Breeder (Pulses)
Pulses Improvement Project
Mahatma Phule Agricultural University
Rahuri 413 722
Maharashtra

K.S. Dhindsa
Professor and Head
Department of Chemistry and Biochemistry
Haryana Agricultural University
Hisar 125 004
Haryana

S. Lal
Project Director
Directorate of Pulses Research
Kalyanpur
Kanpur 208 024
Uttar Pradesh

S.S. Lal
Senior Entomologist
Directorate of Pulses Research
Kalyanpur
Kanpur 208 024
Uttar Pradesh

R.V. Maheshwari
Plant Breeder (Pulses)
Agriculture Research Station
Karni Road
Sri Ganganagar 333 501
Rajasthan

K.K. Paliwal
Asst. Breeder (Pulses)
Main Pulses Research Centre
RAK College of Agriculture
Sehore 466 001
Madhya Pradesh

R.S. Rana
Director
National Bureau of Plant Genetic Resources (NBPGR)
Pusa Campus
New Delhi 110 012

P. Rangasamy
Professor (Pulses)
School of Genetics
Tamil Nadu Agricultural University
Coimbatore 641 003
Tamil Nadu

S.R. Sree Rangasamy
Director
School of Genetics
Tamil Nadu Agricultural University
Coimbatore 641 003
Tamil Nadu

T. Swamy Rao
Senior Scientist (Pulses)
Agricultural Research Station
University of Agricultural Sciences
Gulbarga 585 101
Karnataka

J.N. Sachan
Principal Scientist (Entomology)
Directorate of Pulses Research
Kalyanpur
Kanpur 208 024
Uttar Pradesh

P.M. Salimath
Scientist in charge
Indian Agricultural Research Institute (IARI)
Centre for Improvement of Pulses in South
Dharwad 580 002
Karnataka

C.S. Saraf
Principal Scientist (Legumes)
Division of Agronomy
Indian Agricultural Research Institute (IARI)
New Delhi 110 012

A. Satyanarayana
Senior Scientist (Pulses)
Regional Agricultural Research Station (APAU)
Lam ARS P.O.
Guntur 522 034
Andhra Pradesh

V.K. Sehgal
Senior Entomologist (Pulses)
Department of Entomology
College of Agriculture
G.B. Pant University of Agriculture and Technology
Pantnagar 263 145
Uttar Pradesh

V.K. Shinde
Senior Scientist (Pulses)
Marathwada Agricultural University
Agricultural Research Station
Badnapur 431 302
Maharashtra

Gurdip Singh
Senior Plant Pathologist (Pulses)
Department of Plant Breeding
Punjab Agricultural Univeristy
Ludhiana 141 004
Punjab

I.S. Singh
Pulses Breeder
Department of Plant Breeding
College of Agriculture
G.B. Pant University of Agriculture and Technology
Pantnagar 263 145
Uttar Pradesh

T.A. Thomas
Head
Germplasm Evaluation Division
National Bureau of Plant Genetic Resources (NBPGR)
Pusa Campus
New Delhi 110 012

M.M. Verma
Senior Pulse Breeder
Department of Plant Breeding
Punjab Agricultural University
Ludhiana 141 004
Punjab

K.B. Wanjari
Pulses Breeder
Pulses Research Unit
Punjabrao Krishi Vidyapeeth
Akola 444 104
Maharashtra

IRAN

A. Kahrobaian
Chickpea Breeder
Ministry of Agriculture and Rural Development
Agricultural Research Center
Meshhad

B. Sadri
Head
Food Legume Research Department
Seed and Plant Improvement Institute
Ministry of Agriculture
Mard - Abad Avenue
Karadj

IRAQ

A.I. Abbas
Head, Food and Forage Legumes
Ministry of Agriculture and Irrigation
State Board of Agricultural and Water Resources Research
Abu-Ghraib
Baghdad

ITALY

N. Greco
Nematologist
Consiglio Nazionale delle Ricerche
Instituto di Nematologia Agraria
Applicata ai Vegetali
via Amendola, 165/A - 70126 Bari

E.A. Kueneman
Senior Officer
Field Food Crops Group
Plant Production and Protection Division (AGPP)
Food and Agriculture Organization of the United Nations
via delle Terme di Caracalla
00100 Rome

KENYA

W.N. Muasya
Pulses Breeder
National Dryland Farming Research Centre-Katumani
P.O. Box 340
Machakos

MEXICO

J.A. Acosta-Gallegos
Food Legume National Expert
Instituto Nacional de Investigaciones
Forestales y Agropecuarias (INIFAP)
A.P. 20
Pabellon, AGS 20660

MOROCCO

H. Fatiha
Centre Regional de Settat
B.P. 290
Settat

MYANMAR

T. Nwe
Deputy Assistant General Manager, Food Legumes
Agricultural Research Institute
Yezin

H. Morris
Entomologist, Food Legumes
Agricultural Research Institute
Yezin

NEPAL

M.P. Bharati
Agronomist and Coordinator
National Grain Legume Improvement Program (NGLIP)
Ministry of Agriculture
G.P.O. Box 404
Khumaltar
Kathmandu

Sharada Joshi
Assistant Plant Pathologist
Division of Plant Pathology
P.O. Box 1126
Kumaltar
Kathmandu

NETHERLANDS

M. van Eijk
Plant Breeding Department
Wageningen Agricultural University
Wageningen

PAKISTAN

K. Ahmed
Entomologist (Pulses)
National Agricultural Research Centre (NARC)
P.O. National Institute of Health
National Park Road
Islamabad

A.M. Haqqani
Senior Scientific Officer
Pulses Program
National Agricultural Research Centre (NARC)
P.O. National Institute of Health
National Park Road
Islamabad

H.R. Khan
Scientific Officer
National Agricultural Research Center (NARC)
P.O. National Institute of Health
National Park Road
Islamabad

I.A. Khan
Scientific Officer
National Agricultural Research Centre (NARC)
P.O. National Institute of Health
National Park Road
Islamabad

M.I. Khan
Extension Agronomist
Barani Agricultural Development Project
P.O. Box 1004
P.O. Peshawar University
Peshawar, NWFP

B.A. Malik
Coordinator (Pulses)
National Agricultural Research Centre (NARC)
P.O. National Institute of Health
National Park Road
Islamabad

M. Tufail
Director of Pulses
Ayub Agricultural Research Institute (AARI)
Jhang Road, Faisalabad

A. Wadud Khan
Gram Botanist
Gram Research Sub-station
Ahmad-wala
Karak, NWFP

SPAIN

J.I. Cubero
Professor of Genetics and Plant Breeding
Escuela Tecnica Superior de Ingenieros Agronomos
Departmento de Genetics
A.P. 3048
14080 Cordoba

M.-T. Moreno Cubero
Biologist
Centro de Investigacion y Desarrollo Agrarario
Departmento de Mejora y Agronomia
A.P. 240
14080 Cordoba

R.M. Jimenez-Diaz
Professor of Plant Pathology
Departado de Agronomia
Escuela Tecnica Superior de
Ingenieros Agronomos (ETSIA)
Universidad de Cordoba
CSIC
A.P. 3048
14080 Cordoba

SRI LANKA

U.W. Nilmalgoda
Research Officer
Regional Agricultural Research Centre
Diyatalawa Road
Bandarawela

SUDAN

A.I. Sheikh Mohamed
Plant Breeder
Agricultural Research Corporation
Hudeiba Research Station
P.O. Box 31
Ed-Damer

SYRIA

M.W. Tawil
Head of Field Crops Division
Directorate of Scientific Agricultural Research
Ministry of Agriculture and Agrarian Reform
Douma
P.O. Box 113
Damascus

TUNISIA

H. Halila
Food Legume Coordinator
Institut National de la
Recherche Agronomique de Tunisie (INRAT)
2080 Ariana

TURKEY

D. Ozbay
Province Director of Agriculture
Tarim 11 Muduru
Diyarbakir

D. Sakar
Director and Food Legume Coordinator
Tarimsal Arastirma
Enstitusu Mudurlugu
P.O. Box 72
Diyarbakir

B. Yilmaz
Director
Field Crops Improvement Center
P.O. Box 226
Ulus, Ankara

UNITED KINGDOM

A.B.S. King
Principal Entomologist
Natural Resources Institute (NRI)
Central Avenue, Chatham Maritime
Chatham, Kent ME4 4TB

R.J. Summerfield
Reader in Crop Physiology and
Deputy Director, Plant Environment Laboratory
University of Reading
Department of Agriculture
Cutbush Lane, Shinfield
Reading, Berkshire RG2 9AD

UNITED STATES OF AMERICA

I. Buddenhagen
Professor
Department of Agronomy
University of California
Davis
California 95616

W.J. Kaiser
Research Plant Pathologist
United States Department of Agriculture
Agricultural Research Service (USDA-ARS)
Regional Plant Introduction Station
59 Johnson Hall
Washington State University
Pullman, WA 99164-6402

F.J. Muehlbauer
Research Geneticist
United States Department of Agriculture
Agricultural Research Service (USDA-ARS)
215 Johnson Hall
Washington State University
Pullman, WA 99164-6421

N.J.H. Smith
Professor
Department of Geography
University of Florida
Gainesville, FL 32611

J.E. Specht
Professor
Department of Agronomy
University of Nebraska
Lincoln, NE 68583-0915

UNION OF SOVIET SOCIALIST REPUBLICS

K. Eshmirzaev
Director
Research Institute of Grains and Pulses
Samarkand
Republic of Uzbekistan

V. Zoubel
Assistant Agricultural Counsellor (USSR Embassy)
Shanti Path
Chanakyapuri
New Delhi 110 021

ICARDA
International Center for Agricultural Research in the Dry Areas
P.O. Box 5466
Aleppo
Syria

Geletu Bejiga
Postdoctoral Fellow

H. Harris
Soil Water Conservation Scientist
Farm Resource Management Program

R.S. Malhotra
International Trials Scientist
Food Legume Improvement Program

M. Pala
Wheat-based Systems Agronomist
Farm Resource Management Program

M.C. Saxena
Program Leader/Agronomist-Physiologist
Food Legume Improvement Program

M.M.B. Solh
Regional Food Legume Breeder-North Africa (ICARDA)
B.P. 6299
Rabat-Institutes
Rabat
Morocco

S. Weigand
Entomologist
Food Legume Improvement Program

ICRISAT

P.W. Amin
Coordinator and Senior Entomologist
LEGOFTEN, Legumes Program

J.M.J. de Wet
Program Director, Cereals

B. Diwakar
Senior Training Officer
Fellowships and Training

J.W. Estes
Head, Computer Services

D.G. Faris
Principal Coordinator
Asian Grain Legumes Network
Legumes Program

A.M. Ghanekar
Plant Pathologist
Legumes Program
ICRISAT Cooperative Research Station
Haryana Agricultural University Campus
Hisar 125 004
Haryana

M. Goon
Assistant Director General
(Administration)

C.L.L. Gowda
Senior Legumes Breeder
Asian Grain Legumes Network
Legumes Program

S.D. Hall
Research Editor
Information Services

L.J. Haravu
Manager
Library and Documentation Services

M.P. Haware
Plant Pathologist
Legumes Program

N. Horn
Assistant Virologist
Legumes Program

A.K.S. Huda
Agroclimatologist
Resource Management Program

K.C. Jain
Plant Breeder, Pigeonpea
Legumes Program

R. Jambunathan
Principal Biochemist and Program Leader
Biochemistry Unit

C. Johansen
Principal Crop Physiologist
Legumes Program

Jagdish Kumar
Plant Breeder, Chickpea
Legumes Program

S.S. Lateef
Entomologist
Legumes Program

D. McDonald
Program Director (Acting),
and Principal Plant Pathologist
Legumes Program

M.H. Mengesha
Principal Germplasm Botanist and Program Leader
Genetic Resources Unit

J.L. Monteith
Program Director
Resource Management Program

J.P. Moss
Principal Cell Biologist
Legumes Program

Y.L. Nene
Deputy Director General

K. Okada
Assistant Principal Microbiologist
Legumes Program

C.K. Ong
Principal Agronomist
Resource Management Program

D.L. Oswalt
Principal Training Officer
and Program Leader
Fellowships and Training

B.K. Patel
Special Assistant to Director General for Planning

C.M. Pattanayak
Principal Coordinator
Cooperative Cereals Research Network
Cereals Program

C.S. Pawar
Entomologist
LEGOFTEN, Legumes Program

M.P. Pimbert
Principal Entomologist
Legumes Program

R.P.S. Pundir
Botanist II
Genetic Resources Unit

A. Ramakrishna
Agronomist
Resource Management Program

J.V.D.K. Kumar Rao
Crop Physiologist
LEGOFTEN, Legumes Program

R.C. Nageswara Rao
Crop Physiologist
Legumes Program

G.V. Ranga Rao
Entomologist
Legumes Program

B. Srinivasa Rao
Research Associate
Legumes Program

B.V. Rao
Research Associate
Legumes Program

D.V.R. Reddy
Principal Plant Virologist
Legumes Program

M.V. Reddy
Senior Plant Pathologist
Legumes Program

O.P. Rupela
Crop Physiologist
Legumes Program
ICRISAT Cooperative Research Station
College of Agriculture Farm
Jawaharlal Nehru Krishi Viswa Vidyalaya (JNKVV)
Gwalior 474 002
Madhya Pradesh

N.P. Saxena
Senior Crop Physiologist
Legumes Program

S.C. Sethi
Plant Breeder, Chickpea
Legumes Program
ICRISAT Cooperative Research Station
Haryana Agricultural University Campus
Hisar 125 004
Haryana

S.B. Sharma
Plant Nematologist
Legumes Program

Faujdar Singh
Training Officer
Fellowships and Training

K.B. Singh
Principal Chickpea Breeder
(Food Legume Improvement Program, ICARDA)

Onkar Singh
Plant Breeder, Chickpea
Legumes Program

Piara Singh
Soil Scientist
Resource Management Program

Umaid Singh
Biochemist
Biochemistry Unit

A. Srinivasan
Postdoctoral Fellow
Legumes Program

L.D. Swindale
Director General

H.A. van Rheenen
Principal Plant Breeder, Chickpea
Legumes Program

S.M. Virmani
Principal Agroclimatologist
Resource Management Program

J.A. Wightman
Principal Entomologist
Legumes Program

J.B. Wills
Head
Information Services

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics

Patancheru, Andhra Pradesh 502 324, India

ISBN 92-9066-181-X Printed at ICRISAT Center ICR 90-0006