INTERNATIONAL WORKSHOP ON GRAIN LEGUMES

ICRISAT

International Crops Research Institute
for the Semi-Arid Tropics

INTERNATIONAL WORKSHOP ON GRAIN LEGUMES

JANUARY 13-16, 1975

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics
1-11-256, Begumpet
Hyderabad 500016 (A.P.), India

CONTENTS

FIRST SESSION

SECOND SESSION

THIRD SESSION

FOURTH SESSION

FIFTH SESSION

SIXTH SESSION

SEVENTH SESSION

EIGHTH SESSION

PLENARY SESSION

Foreword

In my welcoming message printed in the program for this workshop, I made reference to the important role grain legumes play in human nutrition in the semi-arid tropics and the disturbing consequences of the trend of diminishing production of these vital protein sources as the laws of economics force farmers to switch to high-yielding cereals and other alternate crops.

I mentioned that awareness of these factors was one of the basic motivations that led the participants to accept our invitation to join this workshop and to share their ideas and experience. I thanked them in advance for their high degree of enthusiasm and dedication to the tasks ahead of them.

I am pleased to report that the quality of presentations, depth of discussion and review and particularly the work reflected in the reports of the various discussion groups was outstanding and went beyond our expectations in providing motivation and guidance to our pulse improvement program.

It is our hope that this publication will stimulate continued dialog and bring about further collaboration between grain legume researchers throughout the world.

R.W. Cummings, director
International Crops Research Institute
for the Semi-Arid Tropics

Preface

INTRODUCTORY REMARKS

J. S. Kanwar[1]

I consider it a great privilege to have this opportunity of welcoming you to the first International Workshop on Grain Legumes organized by ICRISAT. ICRISAT has a worldwide responsibility for research on the two grain legumes–pigeonpeas and chickpeas–which occupy the most important position in the diet of the people living in the semi-arid tropics. We are limiting the scope of the workshop to these two crops because they are mostly consumed with sorghum, millet and other cereals, and serve as the main source of protein for balancing diets of the people living in the semi-arid tropics.

I am sure most of you have experienced in the last two years the effect of high prices of meat and are familiar with the unfavorable grain-to-meat conversion ratio. You can now appreciate that the grain legumes offer greater hope for balancing diets of human beings, particularly in developing countries. Thus, any efforts made in improving these crops will be a help to the largest number of the people struggling with malnutrition and starvation.

I need hardly emphasize how important both of these grain legumes are for all the semi-arid tropical countries, particularly India. Ninety-two percent of the world's production of pigeonpeas and eighty-two percent of chickpeas is grown in India. The decrease in production and shrinkage in acreage of these crops in the last decade as a consequence of the green revolution is a cause for great concern. Because of their low yield potential, even under irrigation, pigeonpeas and chickpeas are in an unfavorable position to compete with higher paying cereals. The pulse crops have been pushed to marginal soils with no irrigation which are the main areas of their production. The main problems of these crops are:

1. Low yield potential and instability of yield;
2. Lack of adequate research on breeding, agronomy, entomology, pathology, grain quality, consumer acceptance and cooking quality;
3. Inadequate collection of genetic resources.

I hope I will not be misunderstood if I say that these crops have been neglected and need a massive injection of technological inputs to give quantum jumps in production per unit of area and per unit of time in the semi-arid tropics. Most of these crops will continue to be grown under unirrigated conditions, but if a breakthrough in yield is obtained, they can replace, compete successfully or fit into crop rotations even under irrigated conditions to maximize returns to farmers and bridge the protein gap.

Pigeonpea is mostly cultivated as an intercrop, or a mixed crop, and forms an integral part of diets based on rice or sorghum. It has such a plasticity that even in drought years when other crops fail, it is capable of producing some yields.

---

[1] Associate Director, International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, India

Physiologists realize that because of this plasticity, pigeonpea can fit into intercropping systems with a large number of crops commonly grown in the semi-arid tropics. We have yet to learn more about the growth habits of this plant in relation to moisture stress, wind direction, nutrient stress and other soil environmental stresses including salinity, alkalinity and poor soil structure.

Scientists feel that the varieties we have are not very responsive to fertilizers. Can we expect large yield increases without introducing high responsiveness to fertilizers? Are we looking for nitrogen responsiveness or phosphate responsiveness? Is the analogy of wheat and rice to pigeonpea meaningful? Can we develop varieties which, with low inputs of fertilizers and manures, give fairly high yields?

While in India pigeonpea is exclusively used as a dhal, in many countries it is eaten as green pods or has other culinary uses. What breeding strategy will be suitable for taking alternate uses into account?

Diseases like wilt and pests like pod borers pose another difficult problem in production of pigeonpea as well as chickpea. For obvious reasons, pesticide-based technology may be difficult to popularize in the semi-arid tropics. What are the alternatives? Is integrated pest management or breeding for pest resistance the answer? Has research in this direction succeeded with other crops? What is the best strategy for ICRISAT?

Our scientists feel that medium duration varieties should receive major attention, very early varieties, which will create a new equation with diseases and pests, call for a pesticide umbrella and cause some serious problems. Whether ideotype is a curiosity or a necessity is still an open question. Our scientists feel that increasing the yield level and immunization against diseases, pest and aberrant weather are our major goals. Can we evolve varieties which are suitable for intercropping with sorghum and millet and which are capable of giving maximum total production per acre per year?

Chickpea is called the bean of the ancient world. It produces a maximum return of nourishment for minimum expenditure of money or effort. It produces an average of 126 kg protein from one hectare. It is probably the highest yielding of any legume grain except groundnuts and soybeans. One hundred grams of chickpea provides 358 calories, more than any other legume except groundnut and lupine seeds.

The high nutritional yield makes chickpea a particularly important food in famine areas. If one draws a map of the world's most dense areas of chickpea consumption or production, one would also obtain a map of the world's poverty-prone areas. Give a man chickpea and water and he can survive even under the most difficult conditions. Armies have fought with the main ration of parched chickpea and achieved unbelievable results.

Chickpea is also credited with medicinal properties. Many recipes in the Middle East and in India are based on chickpea because of its nutritional and other qualities. In Indian villages, germinating chickpeas and jaggery are distributed to the families at the time of celebration of the birth of a child.

Chickpea is mostly grown as a pure crop although some is grown as a mixed and intercrop. Wilt is a serious problem in chickpea production. Whether wilt is physiological or pathological and related to soil environments or fungi is still an open question.

The ICRISAT chickpea Improvement program has accelerated the breeding work by taking two successful crops in a year in different seasons at two different sites. However, the crossing work is tedious and labor-intensive. Let us critically examine the strategy which K.B. Singh and A.K. Auckland are proposing. This crop has suffered competition from the green revolution in wheat, but its pivotal position in the human diet and its multifarious uses makes it a very promising, rather an indispensable, crop in the economy of the semi-arid tropics with slightly cooler temperatures.

Our first goals are high yield and stable yield. Research on quality of the grain and amino acid profile of the proteins will also be given a high priority. We believe that yield should be consistent with quality, but we realize that unless we have spectacular quantum jumps in yield of these crops, we cannot achieve a breakthrough in their production. Thus, our first goal is yield at a constant quality. Our main target is to increase production of protein of high quality per unit of area per unit of time. We would be interested if the workshop participants could give us leads on improving levels of methionine, cystine and tryptophan. Can we achieve this goal without sacrificing yield?

Has research paid too little attention to the cooking quality, milling quality and consumer acceptance of grain legumes? Can we decide on a suitable strategy in this case?

Keen interest exists in grain legume research. The number of symposia, colloquia, seminars, and conferences held or being held in different institutes and organizations in recent years demonstrates this interest. But this workshop will not be another meeting merely swelling the list of such gatherings. We have set before you a few objectives which explain fully the purpose of the workshop. These are:

1. To identify breeding priorities related to the problems limiting potential and stability of yield in pigeonpeas and chickpeas.
2. To review the concepts and techniques of crop improvement suited to grain legumes, particularly pigeonpeas and chickpeas.
3. To consider preservation, evaluation and utilization of world's genetic resources of pigeonpeas and chickpeas.
4. To identify areas of cooperative effort among breeders of pigeonpeas and chickpeas.

I wish to emphasize that our scientists seek your critical comments on their approach with respect to pigeonpea and chickpea breeding. We also wish to establish links for cooperative work throughout the semi-arid tropics. We know that by joint efforts we can achieve our goals more quickly.

I hope that these deliberations will give us clear-cut ideas about the strategy for crop improvement in pigeonpea and chickpea and establish a cooperative research program for a breakthrough in production of these grain legumes which are highest on our priority list.

PARTICIPANTS

1. Dr. Ewert Aberg
Professor and Head
Department of Plant Husbandry
Agricultural College of Sweden
Uppsala 7, Sweden S-75007

2. Dr. Raul Abrams
Head, Agronomy Department
Faculty of Agriculture
University of Puerto Rico
Mayaguez, Puerto Rico 00708

3. Dr. R.P. Ariyanayagam
Plant Breeder
Pigeonpea Program
University of West Indies
St. Augustine, Trinidad
West Indies

4. Dr. Taye Bezuneh
Director
Debre-Zeit Agr. Exp. Station
College of Agriculture
Haile Sellassie I University
P.O. Box 32
Debre-Zeit, Ethiopia

5. Dr. Satish Chandra
Senior Plant Breeder
Div. of Genetics & Plant Physiology
Central Soil Salinity Res. Inst.
Karnal - 132001, Haryana, India

6. Dr. Eric J. Corbin
Regional Research Officer
Agricultural Research Institute
Department of Agriculture
Wagga Wagga, 2650 New South Wales
Australia

7. Dr. Jose Ignacio Cubero
Instituto Nacional de Investigaciones
Agrarias
Centro Regional de Andalucia
Apartado 240
Cordoba, Spain

8. Dr. Peter J. Dart
Soil Microbiology Department
Rothamsted Exp. Station
Harpenden, Herts
England

9. Doc. Dr. Didar Eser
Plant Growing and Breeding Department
Faculty of Agriculture
University of Ankara
Ankara,
Turkey

10. Dr. K.J. Frey
Professor of Plant Breeding
Department of Agronomy
Iowa State University of Science and
Technology
Ames, Iowa 50010
U.S.A.

11. Dr. E.E. Hartwig
Research Agronomist
Soybean Production Research
Delta Branch Exp. Station
Agr. Res. Service, USDA
Stoneville, Mississippi 38776
U.S.A.

12. Dr. G.C. Hawtin
Arid Lands Agr. Dev. Program
The Ford Foundation
P.O. Box 2379
Beirut, Lebanon

13. Dr. L.R. House
Arid Lands Agr. Dev. Program
The Ford Foundation
P.O. Box 2379
Beirut, Lebanon

14. Dr. J.H. Hulse
Program Director
Agr., Food & Nutrition Sciences
International Dev. Res. Centre
Box 8500
Ottawa, Canada K1G 3H9

15. Dr. J. Jaffari
Plant Breeder
Faculty of Agriculture
University of Tehran
Karaj, Iran

16. Dr. H.K. Jain
Jawaharlal Nehru Fellow
Division of Genetics
Indian Agr. Res. Institute
New Delhi - 110012, India

17. Dr. Walter J. Kaiser
Head, Div. of Plant Quarantine Services
East African Agr. & Forestry Res. Org.
P.O. Box 30148
Nairobi, Kenya

18. Dr. B.R. Murty
Project Coordinator {Millets) and
International Coordinator Biology of
Adaptation, IBP (Cicer)
Indian Agr. Res. Institute
New Delhi - 110012, India

19. Dr. B.P. Pandya
Pulse Geneticist
G.B. Pant Univ. of Agr. & Tech.
Pantnagar, Dist. Nainttal
Uttar Pradesh, India

20. Dr. P. Pushpamma
Professor of Food and Nutrition &
Principal, College of Home Science
A.P. Agricultural University
Khaliratabad
Hyderabad - 500004, A.P., India

21. Dr. K.O. Rachie
Assistant Director
Grain Legume Imp. Program
International Institute of Tropical
Agriculture
Oyo Road, P.M.B. 5320
Ibadan, Nigeria

22. Dr. S. Ramanujam
Coordinator, Pulse Imp. Project
Division of Genetics
Indian Agr. Res. Institute
New Delhi - 110012, India

23. Prof. Dr. S. Rehm
Institut fur Tropischen und
Subtropischen Pflanzenbau
der Universitat Gottingen
34 Gottingen
GrisebachstraBe 6
West Germany

24. Dr. W. Vernon Royes
Ministry of Agriculture
Hope Gardens
P.O. Box 113
Kingston-7, Jamaica
West Indies

25. Dr. M.C. Saxena
Professor of Agronomy and Coordinator
(Soybean)
G.B. Pant Univ. of Agr. & Tech.
Pantnagar, Dist. Nainital
Uttar Pradesh, India

26. Dr. S.G. Sr1kant1a
Director
National Institute of Nutrition
Jamai-Osmania
Hyderabad - 500007, A.P., India

27. Dr. D. Wynne Thorne
Director
Agricultural Experiment Station
Utah State University
Logan, Utah 84322
U.S.A.

28. Dr. E.S. Wallis
Department of Agriculture
University of Queensland
St. Lucia, Brisbane 4067
Australia

ICRISAT Personnel

1. Dr. R.W. Cummings, Director
2. Dr. J.S. Kanwar, Associate Director
(Chairman of Workshop)
3. Dr. J.M. Green, Pigeonpea Breeder
4. Dr. A.K. Auckland, Chickpea Breeder
5. Dr. H. Doggett, Sorghum Breeder
6. Dr. K.B. Singh, Associate Chickpea Breeder
7. Dr. D. Sharma, Associate Pigeonpea Breeder
8. Dr. J.C. Davies, Entomologist
9. Dr. Y.L. Nene, Plant Pathologist
10. Dr. R. Jambunathan, Biochemist
11. Dr. A.R. Sheldrake, Pulse Physiologist
12. Dr. L.J.G. van der Maesen, Germplasm
Botanist

FIRST

SESSION

CHICKPEA BREEDING AT ICRISAT

K. B. Singh and A. K. Auckland[1]

INTRODUCTION

Origin and Distribution

Cicer arietinum L (2n=16, n=8) known by the common names chickpea, garbanzo beans, gram, hommes, is not known in a wild state, but is found as an escape in Mesopotamia and Palestine. It appears to have originated in western Asia and to have spread at an early date to India and Europe. The crop was known to the ancient Egyptians, Hebrews and Greeks. It has been introduced in recent times to tropical Africa, Central and South America, South East Asia and Australia. Detailed information on chickpea can be found in Pulse Crops of India (Argiker 1970) and a monograph on the genus Cicer by van der Maesen (1972).

Production

Chickpea is the world's third pulse crop, fifth food legume and fifteenth grain crop of the world (FAO Production Year book 1972). The total world area under the crop is estimated as 10.54 million hectares (Figure 1) and it is grown in 31 countries in Asia, Africa, Central America and Europe (Tables 1 and 2). India has nearly 74% of the world acreage and total production. Other countries where the crop is important are, in descending order, Pakistan, Ethiopia, Mexico, Burma, Spain, Morocco, Turkey, Iran and Tanzania. Most of the crop is consumed locally and the export trade is minimal.

Uses and Chemical Composition of Seed

Chickpea is the most important pulse of India. The whole dried seeds are cooked or boiled in the form of dhal, which is prepared by splitting the seeds in a mill and separating the husk. Chickpea flour is popular throughout the Indian subcontinent, and is one of the chief ingredients of many forms of Indian confectionery. Green seeds are eaten raw or cooked, as are the leaves, as a vegetable. Dry stems and husks are fed to livestock. An acrid liquid from the glandular hairs is collected by spreading a cloth over the crop at night, which absorbs the exudation with the dew: it contains malic and oxalic acid and is used medicinally and as vinegar. In Spain and North Africa, seeds are soaked overnight, boiled for an hour, and sold in the markets. In the Western Hemisphere, chickpeas are canned commercially.

The protein and amino acid content of chickpeas and other grain legumes and cereals are given in Table 3. Harvey (1970) compiled data on the protein composition of chickpeas and compared it with human milk. Human milk has a lower content of most of the amino acids except for proline, tryptophane and valine. However, methionine and tryptophane content of chickpea seems to be low. The P.E.R. value of chickpea seems to be one of the highest among the grain legumes.

Husbandry

Chickpea is cultivated as a "winter" crop in the tropics and as a spring or summer crop in temperate climates. It is primarily a crop of low rainfall areas but gives good yields under irrigated conditions. Excessive rains soon after sowing, or at flowering, can harm the crop. The advent of early "summer" in the tropics reduces the growing period, hastens maturity and reduces yield. It is grown on soils ranging from light sandy to heavy loam. It is sensitive to saline and alkaline soils, and high pH inhibits nodule formation. Chickpea is grown in India as a cold weather crop, either in admixture with cereals and other crops or in pure stand, when the seed is either broadcast or planted in rows about 60 cm apart. The highest per hectare production is in Egypt (1667 kg under

---

[1] **International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, India**

Figure 1. World Area, Production and Productivity of Pulses, 1972

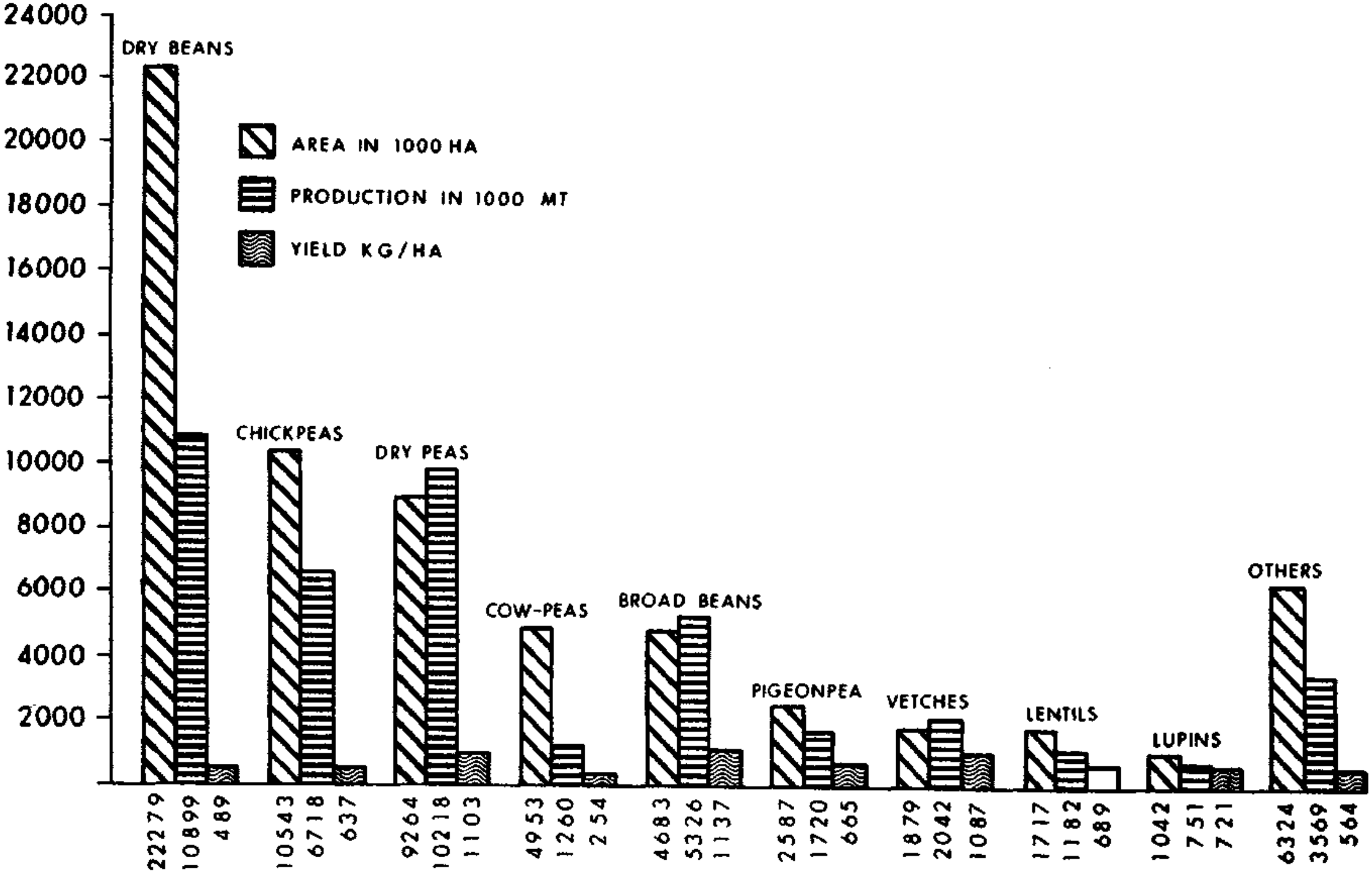


Table 1. Area, Yield and Production of Chickpea in the World

	Area Harvested 1000 Ha				Yield Kg/Ha				Production 1000 Mt			
	1961-65	1970	1971	1972	1961-65	1970	1971	1972	1961-65	1970	1971	1972
WORLD	11863	10089	10236	10543	594	699	644	637	7042	7051	6594	6718
Africa	469	581	542	572	555	628	442	621	260	365	239	355
Algeria	19	24	27F	28F	463	454	444	464	9	11	12F	13F
Egypt	5	3	4	4	1649	1984	1797	1667	8	5	7	7
Ethiopia	272	294	298F	302F	604	630	634	642	165	185	189F	194F
Libyan A. Rep.		1		IF	486	200	537	520				
Morocco	136	158	108	130F	479	868	18	846	65	137	2	110F
Sudan	2	2F	2F	2F	707	1067	1028	1056	2	2F	2F	2F
Tanzania	10	71	73F	75F	295	138	164	187	3	10	12F	14F
Tunisia	20	26F	26F	26F	388	500	500	496	8	13*	13*	13F
Uganda	4	4F	4F	4F	340	500	500	500	1	2F	2F	2F
C. America	134	197	210	215	895	798	809	837	120	157	170	180
Dominican Rep.					711	708	708	721				
Mexico	134	197	210F	215F	895	798	810	837	120	157	170F	180F
S. America	19	24	24	30	681	664	564	569	13	16	13	17
Argentina	6	4	3	4	909	1034	1046	995	5	5	3	4
Chile	8	11	16	20	495	479	445	460	4	5	7	9
Peru	6	8	5	6F	701	721	636	667	4	6	3	4F
Asia	10843	9016	9203	9490	594	705	655	635	6444	6352	6029	6025
Bangladesh	55	70	65	70F	650	843	788	857	36	59*	51F	60F
Burma	117	100F	134	168	502	580	531	542	59	58	71	91
India	9257	7752	7839	8027	598	715	663	636	5537	5546	5199	5106
Iran	104	95F	95F	100F	469	505	474	500	49	48F	45F	50F
Iraq	5	6	5	5F	623	640	600	700	3	4	3	4F
Israel	2	2	1	2F	729	1094	1770	1000	1	2	2	2F
Jordan	6	1	IF	IF	674	297	845	857	4		IF	IF
Lebanon	1	2F	2F	2F	884	499	500	500	1	1*	IF	IF
Pakistan	1170	864	923	970	546	590	542	532	639	510*	500	516
Syrian A. Rep.	41	25	29	30F	637	612	812	833	26	15	24	25F
Turkey	86	100	110	115F	1034	1090	1209	1478	89	109	133	170
Europe	399	271	256	236	516	596	552	593	206	162	142	140
Bulgaria	1	1	1	2	1022	1407	1325	1000	1	1	2	2
Greece	20	15	17	17F	720	940	988	1000	15	14	17	17F
Italy	66	41	29	24	620	867	1025	1042	41	35	30	25
Portugal Con.	71	55	46	45	316	359	350	267	23	20	16	12
Spain	237	157	159	145	523	569	469	566	124	89	75	82
Yugoslavia	3	3F	3F	3F	749	677	667	667	2	2F	2F	2F
Developed	399	272	256	236	515	597	554	594	205	163	142	140
W. Europe	397	270	255	234	514	593	548	590	204	160	140	138
Oth. Oevlpd.	2	2	1	2	729	1094	1770	1000	1	2	2	2
Developing	11463	9816	9979	10304	596	702	646	638	6835	6887	6450	6575
Africa	461	577	536	565	543	621	429	612	251	358	230	346
Latin America	153	221	234	245	868	783	784	804	133	173	184	197
Near East	250	233	248	259	724	789	869	1000	181	184	216	259
Far East	10599	8786	8960	9235	592	703	650	625	6270	6173	5821	5773
Centr. Planned	1	1	1	2	1022	1407	1325	1000	1	1	2	2
Europe USSR	1	1	1	2	1022	1407	1325	1000	1	1	2	2

Source : "F.A.O. PRODUCTION YEAR BOOK"
Volume 26 1972

* = Unofficial Figure
F = FAO estimate

Table 2. Area, Yield and Production of Important Areas of Chickpea During 1972

Important area	Country	Area (1000 Ha)	Production (1000 Mt)	Yield (Kg/Ha)	Contribution towards total production *(%)*
Indian Subcontinent:	Bangladesh Burma India Pakistan	9235	5773	625	86-9
North Africa:	Algeria Egypt Ethiopia Morocco Sudan Tunisia Libya	493	339	687	5.0
Middle East:	Iran Iraq Jordan Lebanon Syria Turkey Israel	255	253	992	3.7
Europe:	Bulgaria Greece Italy Portugal Spain Yugoslavia	236	140	593	2.1
Central America:	Mexico	215	180	837	2.7
South America:	Argentina Chile Peru	30	17	566	0.2

Table 3. The Protein Content of Pulses and Some Cereals

Group	Protein %	Lysine %	Tripto-phane %	Methio-nine %
Gram chickpea	17.1	0.49	0.04	0.11
Pigeon-pea	22.3	0.43	0.04	0.12
Urd bean	24.0	0.43	0.07	0.09
Mung bean	24.0	0.43	0.04	0.10
Lentil	25.1	0.38	0.05	0.04
Reas	19.7	0.98	0.08	0.07
Cow-pea	24.6	0.39	0.04	0.09
Dry bean	24.9	0.43	0.03	0.11
Horse gram	22.0	0.58	0.07	0.07
Chikling vetch	28.2	0.47	0.05	0.05
Soybean	43.2	-	-	0.07
Wheat	11.8	0.14	0.07	0.12
R1ce	8.5	0.23	0.06	0.18

Source : Health Bulletin No.23 (1946)
Nutrition Res. Laboratories,
Coonoor (S. India).

irrigation) and the lowest in Tanzania (187 kg). In India average yields are about 700 kg/ha.

Two types of chickpea are cultivated; small seeded Deshi type with generally brown to bright yellow testa color and large seeded Kabuli type with salmon white testa color. Large seeded types are characteristic of the Mediterranean and Western Hemisphere areas of production and small seeded types of the Indian subcontinent. White or light colored, large seeds command the highest price in India

Major Diseases and Pests

Wilt caused by <u>Rhizoctonia</u> and Fusarium spp. blight (<u>Ascochyta</u> sp.) and rust (<u>Uromyces</u> sp.) cause major losses. Chemical control may be effective but development of resistant varieties seems to be the proper answer.

The most serious and widely reported pest is the pod borer (<u>Heliothis armigera</u>) in the field and beetles (<u>Callosobruchus</u> spp.) in the store. Chemical control will be utilized at ICRISAT but simultaneous efforts will be made to develop resistant varieties where possible.

REVIEW OF GENETIC INVESTIGATIONS

Genetic investigations on chickpeas were started in 1911, at the Imperial Agricultural Research Institute Pusa, India. A large number of simply inherited characters have been reported since 1930, and these have been compiled by van der Maesen (1972). Information on quantitative characters is less extensive.

Path coefficient analysis on chickpeas suggest that the number of pods and number of primary branches were the most important plant characteristics positively associated with seed yield (Singh, Malhotra and Singh unpublished), whereas seed size was negatively associated with yield. Other workers have reported that the number of seeds per pod, the number of days to flowering and plant height are positively correlated with grain yield. Athwal and Sandha (1967) found negative correlations between seed size and the number of seeds per pod and suggested that selection for high numbers of seeds per pod may counteract selection for large seed as a means of increasing yield.

Moderate heritability for yield, 100-seed.

weight, branch length, number of seeds per pod and pod size have been reported (Athwal and Gill 1964), Chandra (1968) reported broad sense heritabilities for setting percentage (80%-85%), days to flowering (73%-75%), duration of flowering (79%-81%), plant height (68%-73%) and primary branches (68%-75%), Sandhu and Chandra (1969) reported narrow sense heritability as only 20% for yield. Niknejad et al. (1971) reported that large seeds were partially dominant to small seeds with at least eight pairs of genes controlling seed size and estimated broad sense heritability for seed size as 81%.

Lal (1972) reported that general combining ability effects were more important than specific combining ability effects for grain yield, grain weight, pods per plant, number of branches, days to flowering, pod maturity and plant height. His study through graphical and component analysis further confirmed the importance of additive gene effects for all those characters except pod maturity. On the other hand, Gupta and Ramanujam (1973) found nonadditive gene action to be more important than additive gene action for yield and yield components except seed size.

Heterosis has been reported for yield and yield components by Pal (1945), Argikar (1950), Ramanujam et al. (1964) and Singh et al.(1973). Singh (1973) has suggested the use of hybrid vigor for isolating pure lines as high in yield as the F_1 hybrids and supported this proposal with data on Vigna radiatus.

Sterility has been reported to be caused in Cicer by both environmental and genetic factors. The common form of sterility is known to be caused by fasciation of essential organs of the flowers, the sterility being partial or complete. To date, male sterility, which could be of value for population improvement methods of breeding, has not been reported.

Hybridization techniques have been reviewed by Argikar (1970) and van der Maesen (1972). At ICRISAT, we have collected Information (Tables 4 and 5) which suggest that under our conditions, pollination can be done at any time of the day between 0800 and 1700 hours, and simultaneous emasculation and pollination gave a higher percentage of seed set than consecutive day operations.

Information on interspecific hybridization, inheritance of resistances, quality characters and ideotype (Donald 1968) characteristics 1s minimal for chickpeas. We have a few small studies at ICRISAT to investigate genetic variability, yield components, heritabilities, combining abilities, harvest Index

Table 4. Seedset Percentages According to Time of Day that Flower was Pollinated

Time of day	Percentage of seed set
0800 to 1000 hours	19.7
1001 to 1200 hours	21.4
1300 to 1500 hours	21.2
1501 to 1700 hours	23.1

Average temperature : 20.6° C

Average Relative humidity: 59.8%

Average hours of sunshine: 10.4

Table 5. Seedset Percentages According to Simultaneous or Consecutive-day Emasculation and Pollination

Method	Percentage of seed set
Simultaneous (n = 576 flowers)	23.61
Consecutive days (n = 713 flowers)	15.04

and varietal response to fertility.

CURRENT STATUS OF CHICKPEA BREEDING IN THE WORLD

Breeding work appears to have been initiated by Government institutions in India in the 1920's. A large number of varieties were developed and released for cultivation by the Indian Agricultural Research Institute, State Departments of Agriculture and agricultural universities. These varieties showed no spectacular yield improvement over the local landraces and were never popular with farmers. One of the reasons for not achieving any real breakthrough in developing high yielding varieties may have been the inadequate use of diverse germplasm. It was estimated by van der Maesen (1972) that about 75% of chickpeas grown in the main producing areas are grown from unselected local types.

The Regional Pulse Improvement Project (RPIP) under the aegis of the U.S. Department of Agriculture, which operated in Iran and India between 1962 and 1972, collected a wide range of chickpea germplasm. The project distributed germplasm to many institutions, but, owing to its untimely termination, tangible results in breeding were not achieved.

Ivanov et al. (1969) have described the results of pulse research in the U.S.S.R. and report the release of some 70 improved varieties from the 22,000 or so pulse varieties collected by Vavilov and his colleagues.

The current status of chickpea breeding in Australia, Ethiopia, India, Iran, Lebanon, Mexico, Morocco, Spain and Turkey will be reported by other delegates to this conference.

THE CHICKPEA BREEDING PROGRAM At ICRISAT

Germplasm Evaluation and Utilization

To date we have assembled 8916 germplasm lines from various parts of the world. The expansion, maintenance and assessment of this collection will eventually be the responsibility of Dr. van der Maesen. As plant breeders, our immediate requirement is the evaluation of this germplasm for agronomic, physiologic and yield characters, reaction to pests and diseases, harvest Index, response to fertilizers, tolerance to drought, plant architecture, etc. It is possible that some of this material may be of immediate value as potential varieties in other countries, and it is proposed to make some tests in International nurseries during 1975. The main value, however, is envisaged as parental material for our breeding program.

Preliminary evaluation of the germplasm indicates that we have already available a wide range of characters which can be exploited in our breeding program (Table 6). One hundred varieties were tested in yield trials in the Lahaul Valley (n. India) during 1974, and the performance of the 10 best varieties is given in Table 7. Yields in this trial ranged from 1140 kg/ha to 3148 kg/ha.

The Immediate Problems of Genetic Improvement

The world's average productivity of chickpea is now very low—about 710 kg/ha. For comparison, when soybeans were first grown in the U.S.A. in 1924, yields averaged 740 kg/ha; but rose to 1320 kg/ha during the 1924 to 1938 period. This rise was attributed mainly to the development of high yielding varieties suitable for different local conditions.

Low Yield of Chickpea

The low yield of chickpeas may be due to the following factors:

(1) Losses caused by pests and diseases.

(2) Inherently low yielding capacity of the indigenous land races.

(3) Lack of stability.

(4) The growing of the crop under conditions of low fertility and the apparent unresponsiveness of present day varieties to high fertility conditions. (It is noteworthy that the breeding of dwarf, lodging resistant and fertilizer responsive wheats were instrumental in bringing about the green revolution, but it would be premature at this stage to state that similar factors will increase the productivity of chickpeas).

Other factors which deserve consideration are:

(1) While chickpea is grown for its protein rich seed, the protein content

Table 6. Variability for Some Chickpea Characters	
Character	Range
Pods/plant (no.)	9 - 618
100 seed wight (g)	5.65 - 67.90
Seeds/pod (no.)	1.14 - 2.90
Canopy width (cm)	14 - 128
Plant height (cm)	16 - 71

Table 7. Performance of 10 Highest Yielding Chickpea Varieties on Gondia Farm, (Lahaul Valley, N.India) 1974

Cultivar	Origin	Yield Kg/Ha	Pods/pi.	Seeds/pod	100 seed weight (gm)	Primary Branches/plant
F - 187	India	3148	130	1.18	15.76	2.6
P - 3052	Iran	3148	171	1.02	18.19	3.0
P - 946	Iran	2824	111	1.46	14.10	2.4
Bengal gram	India	2824	146	1.08	18.11	2.9
P - 2823	Iran	2685	148	1.18	16.22	2.8
Pb - 7	India	2592	151	1.13	14.41	2.6
L - 550	India	2580	144	1.07	23.76	2.8
P - 2974	Iran	2546	112	1.09	19.82	2.6
P - 300	India	2537	120	1.52	12.84	2.5
P - 618	India	2527	152	1.17	16.12	2.7

is in fact fairly low (17-18%). Soybeans, in comparison, range from 40-50% protein. The protein content, of chickpea must be maintained at its present level or increased.

(2) Wherever chickpea is consumed as dhal, there is a need to maintain or improve mill recovery which at present ranges from 68-74%.

(3) Palatability and seed size preferences for the crop must be taken into account and we are relying on the economics division at ICRISAT to provide us with data on these matters.

Aims and Objectives in Breeding

ICRISAT aims at the development of high yielding varieties for farmers and a high quality product for the consumer.

Our objectives, in order of priority are:

(1) High yield and good acceptance (palatability, seed color, seed size, etc.)

(2) Stability of yield.

(3) Resistance to diseases and pests.

(4) Higher protein content and good amino acid profiles.

There is no reason why, eventually, a near perfect chickpea (or range of chickpea varieties) should not be produced. However, we believe that the present aims of our program at ICRISAT should be primarily high yield and stability. In "going all out for yield" it is most probable that we shall "unwittingly" select for polygenic resistance to pests and diseases. We can if necessary quite easily add single gene resistance at a later stage. It may be difficult to breed a high yielding variety which gives stable production in all environments, but we shall judiciously assess this problem throughout the course of the breeding program. It is our Intention to select from segregating populations grown under optimum conditions with high levels of fertilizer application in order that the expression of genetic variation will be maximized and our ability to select enhanced. This may also result in the selection of strains responsive to high fertilizer applications. Adaptability to low and high fertilizer conditions will be assessed in later generations.

Breeding Procedures

In considering the breeding procedures to adopt for chickpea breeding at ICRISAT, the following points are worthy of note:

(1) Chickpea is a strictly self-pollinated crop.

(2) A large scale breeding program in chickpea has not yet been carried out in any part of the world.

(3) There is limited information available to date on the performance of the germplasm introduced from abroad or on that originating in India; nor do we have prior knowledge of performance as parental material for hybridization programs.

(4) Comparisons of breeding procedures for this crop have not been investigated.

(6) The crop is grown at present under conditions of low fertility.

(6) The ICRISAT site at Hyderabad, where the main breeding program will take place, is outside the main chickpea growing areas of the Indian subcontinent. Chickpeas are more widely grown in northern India and give higher yields there. High yields appear to be associated with length of maturity period. Approximate maturity periods for varieties commonly grown in Coimbatore, Hyderabad, Uttar Pradesh and the Punjab are 90, 110, 155 and 165 days respectively. It is imperative that we obtain land in northern India in which to carry out concurrent selection with the Hyderabad site, within segregating populations.

(7) The land races growing at present may have considerable adaptability to local conditions and we may wish to retain their good gene complexes.

(8) The germplasm we are collecting is of greater diversity than has as yet been assembled. We expect to make large Initial gains and "eye selection" is considered important in the breeding program.

(9) The more sophisticated breeding procedures now being used to "create variability" and "detect small increases or improvements" in crops

of the more developed nations of the world may not necessarily be applicable at this stage to chickpea improvement in the semiarid tropics.

(10) We can obtain two generations a year by growing an off-season crop in either the Lahaul Valley or in the Lebanon.

(11) Hand crossing is tedious and laborious and the percentage success is low, but we can employ a large labor force for crossing. It is our intention to make a large number of crosses and to grow large segregating populations of promising crosses.

CONCLUSIONS ON BREEDING PROCEDURES

With the above points in mind we propose to approach breeding procedures from two standpoints:

(1) The "classical" approach.

(2) The "recurrent selection" approach.

"Classical" Approach (Single, Double, 3-way, Multiple Crossing and Backcrossing)

Each cross will be assessed on its F_1 performance and the more obvious poor performers may be discarded. The merits of elimination of crosses on the basis of F_1 performance in self-pollinated crops are debatable and there is little evidence to suggest that it is a valid procedure. Non-additive genetic variance is the primary basis for heterosis and specific combining ability; dominance variance dissipates as homozygosity increases; the F_1 performance is no indication of the transgressive segregants which may appear in later selfing generations. The joint authors of this paper are uncertain about this elimination procedure. However, Borlaug apparently eliminates wheat crosses at CIMMYT on F_1 performance, and it would be of considerable merit to us in reducing the number of crosses, if that elimination were to be effective. The delegates' view on this matter would be appreciated.

Large spaced F_2 populations will be grown from most crosses at two sites initially and under conditions of high fertility. Phenotypic evaluation of yielding ability, especially number of pods, will be made and stringent elimination of crosses made at this stage.

The crosses retained for further selection will be graded into (a) Very promising, (b) promising and (c) difficult to ascertain. These three grades of crosses, assessed on F_2 performance, will undergo the following breeding procedures:

(a) "Very Promising" will undergo a modified pedigree method of breeding: selection of F_2 plants; family selection after the F_2 and plant selection within some families until homozygosity is achieved. This will enable us to "get to know the crop".

(b) "Promising" will undergo a modified bulk method of breeding: selection of F_2 plants: bulking to F_4 or F5, and thereafter line selection and testing.

(c) "Difficult to ascertain" will undergo a bulk method of breeding: retaining all the F_2 progeny and bulking to the F4 or F5 when individual plant selection will be practiced.

The "Very Promising" and "Promising" crosses will be advanced in off-season nurseries in either the Lahaul Valley or the Lebanon. Elimination of genotypes susceptible to diseases will be practiced in the off-season if and when epiphytotic conditions are present. As we gain knowledge of the performance of our segregating populations we may carry out selection for other characters under the rainfed conditions of the Lahaul Valley, where genetic differentiation appears to be well expressed. In this way it is possible we may select for photo- and thermoinsensitivity, giving general adaptability of genotypes.

The new strains produced from our breeding program will be assessed for yield, stability and fertilizer response at a number of sites. Chemical analysis of seed and palatabllity of these strains will also be assessed.

"Recurrent Selection" Approach

Hanson (1959) highlighted linkage as a tremendous conservative force inhibiting the frequency of genetic recombination. The classical approach to plant breeding offers limited means of achieving genetic recombination in quantitatively inherited characters. Various authors have since recommended population improvement using recurrent selection as a means of increasing the frequency of genetic recombination and maximizing the exploitation of genetic variability. Recurrent selection has been used successfully in cross-pollinated crops. Jensen (1970) suggested a "diailel selective mating system" for self-pollinated species and later (Redden and Jensen 1974) reported on the use of this method and showed that mass selection with concurrent random mating could be a useful breeding procedure for wheat and oats.

Wallace (1963), however, has pointed out that the lack of introgression in self-pollinated plants may reflect a breakdown of coadapted gene combinations too great for these plants to tolerate. Backcrossing techniques and/or recurrent selection methods could destroy coadapted gene combinations which may be essential for that species to survive. Continued crossing and recurrent selection methods may increase genetic recombination–but it could also cause "genetic disintegration" of coadapted gene combinations which may have developed over the centuries in land races of chickpeas.

Notwithstanding the arguments of Wallace, we feel that Jensen's diailel selective mating procedure is a method of recurrent selection which may be of considerable value for chickpea breeding. The system uses multiple parent input into a central gene pool (population), which through selective mating of individuals is advanced through successive generations. It leads to the formation of a series of gene pools from which plants can be selected and on which thereafter the conventional breeding systems can be practiced: in fact, there is a continued state of open options. We have already started this scheme, but may have to modify it on gaining more information on the parental material we desire to use for different gene pool formations.

Progress to Date

During the "winter" season of 1973/74 at Hyderabad and the 1974 off-season nursery at Kferdane (Lebanon) and Lahaul Valley, we made about 1000 crosses. Nine hundred of these crosses were single crosses and the remainder triple or double crosses. The major considerations for choosing the parents for hybridization were yield and adaptation, highpodding capacity, high number of seeds per pod, seed size, high harvest index and growth habit.

During the present 1974/75 winter season, we have sufficient F_1 plants growing from about 600 crosses to produce enough F_2 seed for our own requirements and to supply to interested breeders throughout the world.

The F2 populations from nearly 300 crosses are being grown at ICRISAT during 1974/75. The plant number varies in each F2 population between 1000 and 3000, depending upon the availability of seed. Altogether we have 9 hectares of F_2 populations. (In future years, for multiple crosses 1n particular, it 1s our intention to grow larger populations.)

In an attempt to grow three generations per year, we planted part of 23 F_2 populations in August 1974, before the rains finished. Because of suboptimal growth of this August planted crop, we did not select within these populations. Some segregates matured in mid-December, were harvested and immediately replanted as F3 bulks. We may at some subsequent, date be able to advance early maturing crosses by this method, but it is doubtful three generations per year will be of general applicability at ICRISAT.

A crossing block nursery comprising 343 entries has been planted at three dates of planting for our 1974/75 crossing program. The entries include varieties from India and other countries and were chosen for their resistance to wilt, Aschoctyta blight, high harvest index, high podding capacity, variation in seed size and color, protein content, growth habit and other morphological and yield characteristics. Any of these varieties are available to interested scientists.

Some of the most promising lines from the germplasm collection are being tested in a yield trial this year. The best of them will form part of proposed international nurseries next year.

COOPERATIVE INTERNATIONAL BREEDING PROGRAM

We have not yet developed a program to serve other countries in the semiarid tropics or in countries outside this zone where chickpeas are an important crop, though this is high on our priority list. The objectives of our cooperative program will be:

(1) To make direct introductions of varieties into other countries.

(2) To supply segregating populations to strengthen national and regional programs.

(3) To identify genotypes with wide range adaptability for use in breeding programs.

The materials which we aim to supply are:

(1) Crossing block nurseries (available in 1975).

(2) F_2 population bulks (available in 1975).

(3) Screening nurseries of F_5 and F_6 generation material, (F_5 available in 1976).

(4) Elite trials (available in 1977).

The material for crossing block nurseries and elite trials can be supplied to all cooperating centers. The F2 bulk populations and screening nurseries can be supplied to those institutions which have the qualified staff to deal with them.

The international cooperative programs will expand concurrently with our breeding program at ICRISAT and will obviously become more meaningful as, and when, we gain knowledge of the requirements of chickpeas as a crop and the performance of the products of varietal hybridization.

PHYSIOLOGICAL BASIS OF CHICKPEA BREEDING

While the chickpea breeding program is Initially "going all out for yield", we shall probably, in the course of time, be able to identify other bases for effective selection. Ideotype (Donald 1968) breeding has received much attention recently. An ideotype can be defined as the required plant structure and developmental sequence of a plant which can best suit a particular environment for producing maximum economic return. Donald states that "the design, breeding, testing and exploitation of plant ideotypes is a logical step towards new levels of yield and should be based on ideotypes". He postulates that a successful crop ideotype will be a weak competitor relative to its mass and that there would be a minimal amount of competition between plants in a crop community. An ideotype provides a guideline to a breeder in the selection of the parents to be crossed and in the selection process in the advanced generations. The ideotype may differ depending on species and systems of farming.

The FAO workshop on Biology of Grain Legumes, held in New Delhi in September/October 1974, suggested a common set of components for grain legumes. These components, in relation to chickpeas are given below:

(a) high pod number potential

(b) greater number of seeds/pod

(c) seed size (weight) as great as acceptable within the consumer acceptance class.

(d) a plant and canopy profile designed and structured for maximum light interception.

(e) node number, internodal lengths and branching pattern in keeping with the requirements of (a-d) above.

(f) leaf size and orientation in keeping with items (a-e) and with cultural environmental situations.

(g) a leaf area duration to fit the needs of the cropping system in use but should be as long as possible in the reproductive period.

(h) a root (including nodulating bacteria) and stem morphology (physiology) capable of rendering the crop efficient in nutrient uptake and utilization at all levels of nutrient availability.

(i) growth of structural attributes favoring a high partitioning ratio of total plant dry weight into grain weight (high harvest index).

(j) a programed phasic development of vegetative and reproductive growth that provides the optimum balance of time and environmental resources for these two phases consistent with the length of growing period and time-dependent availability of water, light, nutrients and favorable temperatures throughout the period.

(k) medium statured plants for mixed cropping; tall statured plants for mechanical harvesting.

(l) short duration plants (approximately 115 days) for comparatively hotter climates and long duration crops (about 140-150 days) for cooler climates.

In addition to the above a few other components are important to the breeder but they do not form part of an ideotype in the strict sense, and these are:

(m) erect and nonlodging plant.
(n) multiple resistance to diseases and insect pests.
(o) better quality and quantity of protein,
(p) drought tolerant plants.

Based on the existing information on chickpea, the germplasm collection at ICRISAT will be classified into different ideotypes. After appropriate tests, a few might be used as parental basic stock to be exploited for breeding purposes. In addition, attempts will be made to synthesize ideotypes for maximizing yield in chickpea, but in view of our limited knowledge of chickpeas, this will take time.

DISCUSSION

S. Chandra: We have found using a few combining parents to be effective in breeding, we cross progenies in double crosses and find this effective for combining yield components. Concerning ideotypes—ultimately yield is the criterion. Some bushy types have a low harvest index. Crossing among F2 plants is effective in recombining plant types.

A.K. Auckland: Is double crossing better than other types of crosses?

S. Chandra: We have not compared types of crosses, but have used only single and double crosses.

H.K. Jain: I wanted to hear that yields of chickpea and pigeonpea are not inferior to cereals. The total dry matter production in pigeonpeas is up to 20 tons per hectare- compared with 14 and 15 tons for spring wheat. Chickpea varieties yield up to 11 tons per hectare. Far greater emphasis is needed on partitioning of photosynthate into grain yield.

A.K. Auckland: I am not concerned about harvest index, only yield.

H.K. Jain: Harvest index must be considered, and it can be selected for effectively.

M.C. Saxena: Harvest index and photosynthetic efficiency are related. High photosynthetic efficiency and low harvest index will result in low yield. In pigeonpea, date of planting affects harvest index.

D. Sharma: I agree with Dr. Auckland. Our measurements show high harvest index to be correlated with low yield.

K.B. Singh: Harvest index is important and we are not ignoring it. We plan to classify 500 to 1000 of the germplasm lines for harvest index this year. At Ludhiana, of the three varieties with highest harvest index one was high yielding.

A.R. Sheldrake: Leaf drop influences harvest index measurement. There is a built-in bias in our estimates.

J.S. Kanwar: How are you going to test for fertilizer responsive varieties?

A.K. Auckland: Segregating material is to be grown under good fertility conditions for maximum expression. Responsive varieties are yet to be found.

J.S. Kanwar: What fertilizer will be used?

A.K. Auckland: Phosphate response will be searched for.

B.R. Murty: There is considerable emphasis on early maturity and photoperiod insensitivity. With predictable drought conditions sensitivity may be desirable. In both crops do not emphasize insensitivity too much. –

K.O. Rachie: With emphasis on high yields and stability under tropical conditions, I lean more towards stability. With 300 to 500 kg additional yield, we might gain more than a yield potential of 2500 kg in something not practical to grow.

LITERATURE CITED

Argikar, G.P., 1970: Gram in *pulse crops* of *India*, ed. P. Kachroo pp. 54-135.

Athwal, D.S. and G.S. Gill, 1964. "Genetic variation, heritability and correlations of various yield components in crosses of gram." J. Res. Punjab Agric. Univ. 1: 116-128.

Athwal, D.S. and B.S. Sandha, 1967. "Inheritance of seed size and seed number per pod in *Cicer*. Indian J. Genet. PI. Breed. 27-1: 21-33.

Chandra, S. 1968. Variability in gram. Indian J. Genet, PI. Breed.28-2: 205-210.

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

Gupta, V.P. and S. Ramanujam, 1973. Genetic architecture of yield and its components in Bengal gram. Paper in Second General Meeting of SABRAO, IARI, New Delhi.

Hanson, W.D. 1959. The breakup of initial linkage blocks under selected mating systems. Genetics. 44: 857-868.

Harvey, D. 1970. Tables of amino acids in foods and feeding stuffs. Common W. Bur. Anim. Natr. Techn. Comm. 19, 2nd ed.: 69-70.

Ivanov, N.R., R.H. Makasheva and I.I.C. Miroshinisharko, 1969. World Plant resources of pulse crops. Trudy prike. Bot. Genet. Seleck. 41-1: 136-159.

Jensen, N.F. 1970. A diallel selective mating system for cereal breeding. Crop. Sci. 10: 629-635.

Lal,B. 1972. Diallel analysis of grain yield and some other quantitative traits in Bengal gram (*Cicer arietinum* L.). Unpublished M.Sc. Thesis, Punjab Agricultural University Ludhiana (India) Library, pp. 95.

Niknejad, M., M. Khash-khu1 and 5.R. Ghorashy, 1971. Inheritance of seed size in chickpeas. Crop Sci. 11. 768-769.

Pal, B.P. 1945. Studies in hybrid vigour; notes in the manifestation of hybrid vigour in gram. Indian J. Genet. 5: 106-121.

Ramanujam, S., S.S. Rohewal and S.P. Singh, 1964. Components of variance for yield in Bengal gram. Indian J. Genet. PI. Breed. 24-3: 239-243.

Redden, R.J. and N.F. Jensen, 1974. Mass selection and mating systems in cereals. 14-3. 345-350.

Sandha, G.S. and S. Chandra, 1969. Heritability of some quantitative characters in two crosses of Bengal gram. Indian J. Genet. PI. Breed. 29-2: 216-219.

Singh, K.B. 1973. Exploitation of Moterosis in pulse crops. Paper in Second General Meeting of SABRAO, IARI, New Delhi.

Singh, K.B., R.S. Maihotra and R.C. Luthra, 1973. Heterosis in Bengal gram. Indian J. Agric. Sci. 43-5: 459-463.

Singh, K.B., R.S. Maihotra and Singh (unpublished) correlation and path coefficient analyses in chickpea (Cicer arietinum L.)

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. Veenman and Zonen, Wageningen.

Wallace, Bruce, 1963. Modes of reproduction and their genetic consequences. In Stat Genetics and Plant Breeding. Nat. Acad. Sciences. Washington, D.C. Publication 982.

PERSPECTIVE OF PIGEONPEA AND ICRISAT'S BREEDING PROGRAM

D. Sharma and J. M. Green[1]

INTRODUCTION

Cajanus cajan L. Millsp., known by the common names pigeonpea, red gram, tur, arhar, gandul, and others, is one of the pulse crops included in the ICRISAT'S crop improvement program. Among the grain legumes pigeonpea ranks only sixth in total world production (Table 1). In addition to reported production, it appears likely that the unreported acreage planted on bunds, as hedges and in other fill in situations, may not be substantial but does add to the food supply in a locally significant way. However, Rachie (1973) expressed the view that pigeonpea production is grossly underestimated because the crop is seldom grown in pure stands on a field scale and the produce is almost entirely consumed locally. In addition to reported production (Table 2), pigeonpeas are grown in most tropical countries. In the major producing countries the grain is usually consumed as dhal, a type of split peas, and is of value in a cereal-legume diet. In the Western Hemisphere green peas are eaten, and some of the crop is canned commercially.

Grown almost exclusively in tropical areas, the ability of pigeonpea to utilize residual moisture during the dry season makes it an important crop in the semiarid areas. The several cropping systems in which pigeonpea is utilized enhance its value and take advantage of different maturities, flowering habits, and plant types. The purpose of this presentation is to summarize briefly basic information on the species, and to report the status of the ICRISAT's improvement program. G.N. Pathak (1970) has presented an excellent summary of general information on pigeonpea in Pulse Crops of India. For more complete historical information than is included here, reference can be made to that article.

Cajanus is a monotypic genus of the tribe Phaseoleae, suborder Papilionaceae, and order Leguminoseae (Pathak 1970). Westphal (1974) listed ten synonyms for the species. Early systematists divided the species on the basis of size, maturity and some simple genetic differences such as flower color into separate species all of which are now recognized as one species under the International Rules of Botanical Nomenclature.

Pigeonpeas are grown over a wide range of conditions. They are grown on a wide range of soil types, from light red soils to heavy clay soils. They perform well on alkaline and saline soils up to pH 8, while they seem to be adapted to soil pH as low as 5.0. In India they are grown in areas with 20 to 60 inches of rainfall. The crop is susceptible to

Table 1. World Production of Pulses in 1972 as Reported in FAO Production Year Book

Pulse Crop	1000's metric tons	% of total
Dry beans	10,899	25.0
Peas dry	10,218	23.4
Chickpeas	6,718	15.3
Broad beans dry	5,326	12.2
Vetches	2,042	4.7
Pigeonpeas	1,720	3.9
Cow peas	1,260	2.9
Lentils	1,182	2.7
Lupins	751	1.7
Others	3,569	8.2
Total World Production	43,685	

---

[1] International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, India

Table 2. Area, Yield and Total Production of Pigeonpeas by Countries, 1961-65 through 1972

	Area in 1000's Ha				Yield in Kg./Ha.				Production in 1000's Mt			
	1961-65	1970	1971	1972	1961-65	1970	1971	1972	1961-65	1970	1971	1972
WORLD	2722	2926	2930	2587	652	674	691	665	1776	1972	2024	1720
Africa	128	137	147	147	440	471	483	483	56	64	71	71
Malawi	34	35F	35F	35F	571	571	571	571	19	20F	20F	20F
Tanzania	26	22	22F	22F	628	476	500	500	16	10	11F	11F
Uganda	68	80F	90F	90F	303	425	444	444	21	34F	40F	40F
C. America	41	38	39	39	728	834	886	916	30	32	34	35
Dominican Rep.	27	27F	27F	27F	767	889	963	1000	21	24F	26*	27*
Haiti	6	6F	6F	6F	487	516	516	523	3	3F	3F	3F
Panama	2	2	2F	2F	680	764	750	750	1	2	2F	2F
Puerto Rico	6	3F	3F	3F	810	1058	1063	1086	5	3	3	4
S. America	8	14	11	11	487	537	528	509	4	8	6	6
Venezuela	8	14	11	11F	487	537	528	509	4	8	6	6F
Asia	2544	2736	2734	2390	662	683	700	673	1685	1868	1912	1608
Bangladesh	4	3	3F	4F	788	795	733	771	3	3	2F	3F
Burma	68	62	74	74	361	356	352	405	25	22	26	30
India	2469	2669	2655	2311	671	690	709	681	1657	1842	1883	1574
Pakistan	3	2	2	2F	280	575	494	500	1	1	1	1F

Source : F.A.O. Production Book
Volume 26, 1972

* = Unofficial figure
F = FAO estimate

waterlogging, and with high rainfall it must be planted on well drained soils. Frost readily kills pigeonpea, so it is grown mostly in frost free areas. Early varieties are planted in areas where frost is a hazard.

On deep water-retentive soils pigeonpea is grown as a companion crop with sorghum, pearl millet, cotton, other legumes and minor millets. With the taller companion crops, medium to late maturing varieties are generally used.

The most serious disease is <u>Fusarium</u> wilt. This has been reported from almost all countries where the crop is grown. In some areas of India, sterility virus causes serious damage. While these two are considered the major diseases, they are not the only ones to attack the crop. Further information will be presented in another paper.

Pod boring insects pose a serious threat to pigeonpea production with spraying required for control in many areas. Thrips have been shown to be a factor causing flower drop. Pests attacking the crop will be included in another paper.

Breeding work with pigeonpea has been in progress in India for many years, and Pathak (1970) listed 28 varieties released in eight states from the early forties to the early sixties. Several new releases could be added to that list. Breeders have been successful in developing varieties resistant to wilt, but have reported that the resistance stood up only in local areas. Among the improvements made in the released varieties were higher yield, earlier maturity, larger seed, better flavor dhal, and good cooking quality. Other papers will report such results in more detail, but it should be stated that breeders have been successful in modifying plant structure and maturity to meet their objectives.

One of the breeder's resources is the genetic Information available. A review of the literature has been made in an attempt to bring together current information on studies of gene action in quantitative traits and heritability estimates. A summary of the qualitative traits and their inheritance will not be attempted here because of the greater importance of the quantitative studies to breeders. Not enough genetic analysis has been done to permit chromosome mapping, but the limited amount done has revealed a complex system in flower color and seed color, with the lighter self colors recessive (Dave 1934).

The important agronomic characters in general are primarily controlled by genes with additive effects (Table 3). Dominance and nonadditive effects were detected in the cases of yield, plant height, and protein content. Apparently sufficient genetic control is additive and dominant to permit effective selection.

Heritability estimates are summarized in Table 4. The highest estimates are for days to flowering, with single estimates reported for seed per pod and seed weight also high. Plant width has the lowest group of estimates, while yield and protein content estimates are variable. Such results support refined tests for yield, and suggest that individual plant screening for protein content might not be fruitful.

SPECIAL PROBLEMS IN PIGEONPEA BREEDING

Pollination

In planning a plant breeding program, first consideration must be given to the breeding system in the species. Pigeonpea apparently 1s normally self-pollinated with some intercrossing resulting from bee activity (Pathak 1970). Percentage outcrossing has been reported from 3% (Sen and Sur 1964) to 40% (Khan 1973). In 1973/74 outcrossing was 27.9% in rows of obtuse leaf/exposed stigma mutant (Singh et al. 1942, Deshpande and Jeswani 1956) adjacent to rows of normal at ICRISAT.

The consequence of an assumed 20% effective intercrossing has been calculated using the formula

$$P = P' - P' \left(\frac{1-n}{2}\right) + \frac{1-P'}{2}$$

where P=percentage homozygosis, prime indicates the preceding generation, and h is the percent selfing. Figure 1 shows that at equilibrium expected heterozygosity is approximately 15 2/3%, which is less homozygous than an F4 population with selfing. Also shown is the expected approach to equilibrium when two varieties are mixed in equal proportions and allowed to open pollinate in successive generations.

Lewis (1970) has reviewed the various systems of maintaining varieties of cotton, a crop in which the proportion of self- and cross-pollination is *very* similar to that of pigeonpea. The complexity of most of the systems reviewed indicates the desirability of releasing stable varieties, especially in situations where the cultivator is likely to save his own seed for several years. How the breeder decides to deal with his problem in

Table 3. Reported Gene Effects for important Characteristics in Cajanus

Character	Gene effects	Reference
Plant height	Dominance and nonadditive	Pandey 1972
Days to flowering	Additive	Pandey 1972 Sharma et al. 1972 Sharma et al. 1973
Seed size	Additive	Sharma et al. 1972 a Sharma et al. 1972 b Pandey 1972
Yield	Additive x additive also Dominance x dominance	Pandey 1972
Protein content (whole seed)	Additive x additive also Dominance x dominance	Pandey 1972
	Additive as well as nonadditive	Sharma et al.(in press)

Table 4. Heritability Estimates for Various Characteristics in Cajanus

Character	Heritability %	Reference
Plant height	48 – 85 36 – 74 61.1	Khan and Rachie (1972) Munoz and Abrams (1971) Pandey (1972)
Plant width	13 – 47 28.7	Munoz and Abrams (1971) Pandey (1972)
Days to flowering	70 – 90 60 – 86 95.2 79	Khan and Rachie (1972) Munoz and Abrams (1971) Pandey (1972) Sharma et al. (1973)
Seeds per pod	81.9	Pandey (1972)
100 seed weight	82	Sharma et al. (1972)
Grain yield	76.4 43 – 87 36 – 75	Pandey (1972) Khan and Rachie (1972) Munoz and Abrams (1971)
Protein content	22.6 – 34 59	Sharma et al. (in press) Pandey (1972)

this area will influence the problems faced by seed producing agencies.

For a better understanding of the pollination of pigeonpea, information is needed on the pollen vectors, their feeding habits, duration and distance of their foraging trips and their prevalence. We are interested in research on the bee species visiting pigeonpea flowers at Hyderabad, but realize that prevalence of the species concerned might be location specific and we would need information from different areas.

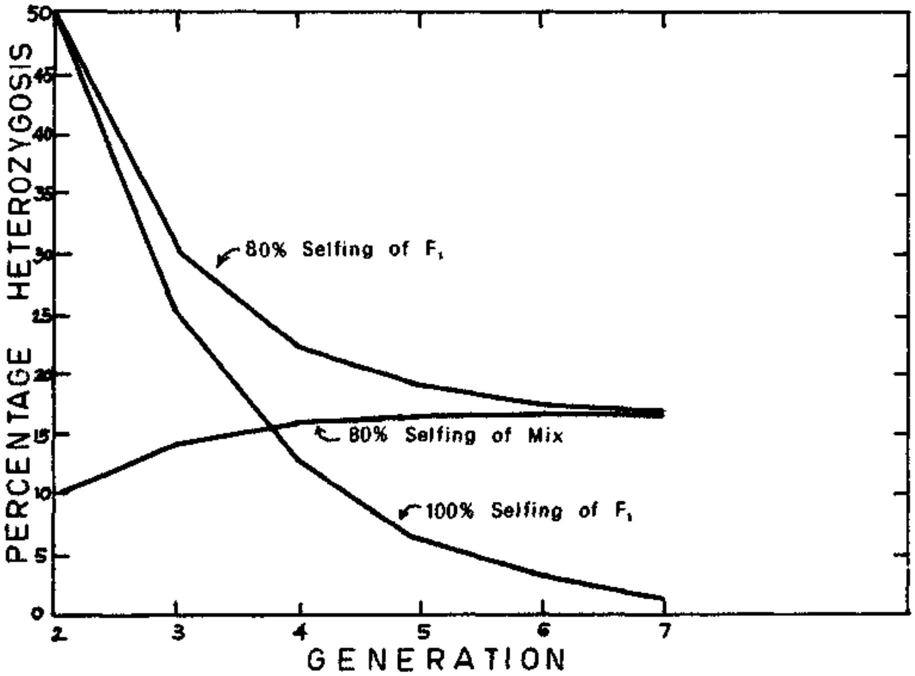
Multiplicity of Cropping Systems

The many cropping systems to which pigeonpea is adapted add to its value, but pose perplexing problems to the plant breeder. The problem of relating the environment of the breeding *nursery* to that of the farmers' fields needs consideration, as does the question of line and variety testing. The breeder is tempted to work with pure stand and to emphasize earlier maturity, both of which simplify his problems. Farmers, however, mostly plant pigeonpea with companion crops and use a wide range of plant densities. The basic problems concern plot techniques for evaluating long duration, indeterminate types with protracted and repetitive flowering and maturity periods.

Generation Time

With early varieties maturing in 120 days and late varieties requiring well over 200 days, it is difficult to advance generations rapidly. Apparently it will be possible to grow an off-season nursery at ICRISAT where the early types will flower and mature. What is needed is a means of forcing flowering in young plants, so that the single seed descent method could be used to advance generations to reasonable genetic stability for effective selection. The possibility of handling large numbers in a small area is particularly important since mature plants *are* up to seven *feet* tall and can occupy as much as 16 to 20 square feet of ground area. If no information is yet available on such a technique, it should be widely investigated. Alternate periods of 17 hours of darkness and 7 hours of light have been tested and found ineffective.

Figure 1. Expected Average Percentage Heterozygosis in Succeeding Generations with 100 and 80 Percent Selfing of F_1 and 80 Percent Selfing of Equal Mix of Two Parents.



THE ICRISAT BREEDING PROGRAM

The broad objective of the ICRISAT breeding program is to increase the level and stability of yield of pigeonpeas in the rainfed semiarid tropics. The specific objectives are:

1. High yielding early types with superior harvest index
2. High yielding later maturing varieties
3. Development of disease resistant (particularly wilt) varieties
4. Development of insect resistant varieties or pest management systems
5. Development of cultivars with acceptable or superior nutritional value and cooking quality.

Currently the second crop is in the field at ICRISAT. A breeding program has been initiated, and the projects comprising the program are set forth below, with the rationale for each briefly stated. It is hoped that the collective experience and knowledge of the workshop participants will provide the basis of effective criticism.

Germplasm Collection and Evaluation

Collecting and classifying the pigeonpea germplasm existing in the world is one of the ICRISAT's objectives. Experience to date indicates that the types grown more often as perennials are more abundant, since in the 1973/74 classification there were 16 early, 1714 midseason and 1184 late types. In a collection reported on in 1933, Shaw et al., distinguished 86 different types from all of India, and Mehta and Dave (1931) listed 36 types from Madhya Pradesh. The present collection is being classified for all readily distinguishable characteristics and should identify many combinations of the characters recorded. However, a broad classification based on plant type and height, maturity, and seed size resulted in the identification of only ten groups of similar types.

Breeding of Superior Varieties

For the purpose of sharpening objectives and identifying individual responsibilities within the program several projects are included in breeding. The development of early maturing varieties and development of photo-insensitive types can be discussed together, since the material will be common, coming from crosses involving all parental types.

Selection among and within the germplasm cultures will provide the first lines for evaluation. The majority of the cultures are variable. In 1973/74, 3602 selections were made on the basis of seed color. Superior rows in this material will be yield tested in Kharif in 1975. Seed of these selections will be available to interested breeders in other locations.

There were 107 crosses made in 1973/74. Most of these are early x later types. The most promising of these will be advanced by the modified bulk method. Work reported by Empig and Fehr (1971) favored the maturity group bulk method, and mass selection in bulk populations has been shown to be effective by Romero and Frey (1966) and by Bhatt (1972). Segregation for maturity in these populations will necessitate grouping. Mild selection will be practised, but since one of our objectives is to make available breeding populations for other areas, stringent selection under local conditions will be deferred until progenies are grown from F_4 plants.

Backcrossing

Backcrossing to recover the early parent genotype with large seed is planned. Smith (1966) and Hartwig (1972) have suggested that a higher number of desirable genes can be transferred using a modified system. Knott and Talukdar (1971) used such a system to transfer large seed size in wheat. Since seed size has high heritability and additive genetic variance (Sharma et al. 1972) phenotypic selection before making the subsequent backcross will be effective and only few backcrosses may be adequate.

Modified Bulk Hybrid Method

The modified bulk hybrid method will be used to advance generations of the best crosses from hybrids made in 1974/75. Included are a diallel of 26 varieties and another diallel set involving the ten groups of germplasm material. Because of the heterogeneous nature of these groups, large F_1 populations will be grown. These, along with the parents, will be divided into replicates in order to determine more precisely the value of the groups as parent material, as well as to select the F_2's to advance.

The emphasis on the bulk hybrid method appears to be justified on the basis of the Increased numbers that can be handled. Also, with the natural crossing prevailing, early application of the pedigree method would necessitate artificial selfing, while with plant selections deferred to F_4, selfing can be started in F_5 when selection efficiency is higher. Two or three additional generations of selfing should suffice to fix simple traits and to minimize danger of genetic drift in succeeding open pollinated, generations.

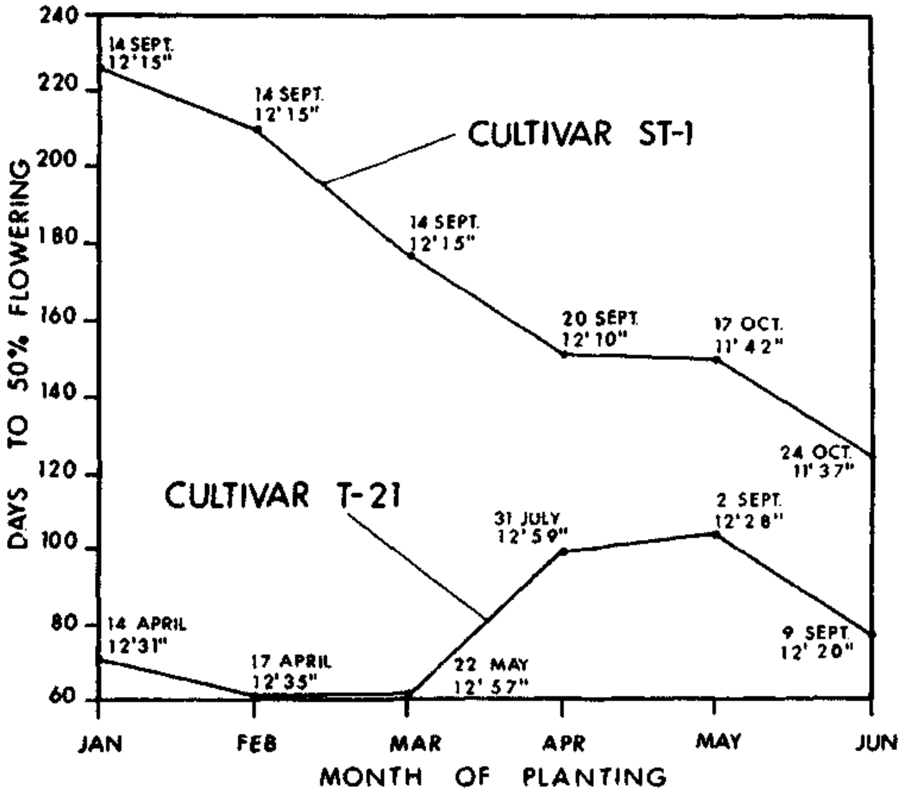
Photoinsensitivity

Selection for photoinsensitive segregates will be done by planting in the off-season at Hyderabad. In general, the early maturing varieties have been found to be relatively insensitive, while the long duration types are strongly sensitive (Figure 2). The range of maturity that can be developed in insensitive types will determine the ultimate value of that character.

Systems of Cultivation

Breeding nurseries to date have been planted as a pure stand. With early x late crosses, it seems advisable to grow the F_2 populations in pure stands to provide an opportunity for early types to develop properly. From F3 onward, medium to late maturing groups of the hybrid populations will be planted with either sorghum or millet. Where early plant yigor is being selected for pure stands will be used, although the question of planting early maturity bulks with an early, low growing legume has not been decided. Advice from this workshop group is requested concerning possibilities of the best use of early, photoinsensitive varieties, the possi-

Figure 2. Days to 50% Flower for an Early Variety, T-21 and a Medium Maturing Variety, ST-1. Planted at Monthly Intervals at ICRISAT. (Hours from sunrise to sunset on the day of 50% flowering are recorded within the figure along with day and month of flowering.)



bilities of different plant spacings, companion crops, and time of planting for increasing usefulness of such varieties must be taken into account by breeders.

Other Breeding Projects

The major emphasis in the program will be on the practical breeding program. Not mentioned above but of considerable importance will be interdisciplinary programs to screen the germplasm cultures and to breed for disease and insect resistance or tolerance. These efforts will be on the scale deemed necessary to deal with the problems, but at the time of writing this summary plans have not been completed.

Study of pollination of pigeonpea is hopefully a short term project designed to determine the patterns and extent of natural crossing and to find effective methods of artificial selfing and crossing. Parchment bags and various sizes of cloth bags were tested during this past season for controlled self-pollination.

Germplasm utilization techniques will include studies on breeding methodology. Present plans include evaluation of population improvement with and without intercrossing by hand; comparison of different population sizes and selection systems in the backcrossing program; and comparison of yield gains in populations from single, double and multiple crosses. These studies will be correlated with the breeding effort, using the same material.

Induced mutations in pigeonpea has as its main objective the induction of photoinsensitivity in sensitive types. Second generation material will be screened in the 1974/75 off-season, and observation for other useful characters will be made.

Intergeneric hybridization will exploit characters transferred from Atyiosia species and investigate the possible value of such hybrids at the tetraploid as well as diploid level. De and Reddy (1972) postulated that Cajanus has derived from Atyiosia lineata, and some derived lines from that cross as well as others are currently in our program. Since Dr. Reddy is associated with the program, it seems advisable to continue this work until more definite conclusions can be drawn on its possible value in pigeonpea improvement.

Cooperative international breeding deserves discussion by all country representatives here. An adaptation trial is planned in 1975, for which representative types of three maturity groups will be made available. Data will be collected and summarized at ICRISAT and the results should serve as a guide in selection of breeding material for different areas. The second stage will be the furnishing of selected breeding lines for single plot nursery observation and selection. Types selected in the germplasm collection may be of interest to some breeders, and such a nursery could be made available for planting in 1975. As populations are developed, these will be available for evaluation and testing by breeders. ICRISAT hopes to coordinate an international testing program for new lines from all breeding programs. This must be a joint effort, planned so it will not duplicate current efforts but will be a valuable addition. We will welcome discussion.

Breeding for improved quality is a project with many unanswered questions. The products of the breeding program will be valuable only if they fill a need in the world's food supply. The quality of new lines will be determined with respect to protein content, and it 1s hoped cooking time and quality as well as food value can be measured. However, it is not apparent which aspects of quality can be handled in the early generations of the breeding program.

Nutritional Value

The range of total protein in the seed is relatively narrow, approximately from 18% to 24%. However, there are reports of up to 30% to 32% protein (van Schaik 1971). Preliminary tests at ICRISAT show that protein in the dhal is 2% to 6% higher than in the whole grain, with a poor relationship between whole grain and dhal protein. Apparently dhal protein should be determined directly. If this trait does not have a higher heritability than does whole grain protein, selection in early generations on a plant basis would not be very productive.

Like other legumes, pigeonpea is deficient in the sulphur amino acids, cystine, methionine and tryptophan. Addition of methionine and tryptophan increases the protein efficiency ratio of pigeonpea considerably (Parpia 1973). With suitable parent material and rapid screening techniques, modification of the amino acid profile could be a realistic breeding objective. Methionine and tryptophan have been found to differ significantly among varieties (Singh et al. 1973) with the wider range occurring in methionine. Variety differences in digestibility of protein were reported by Ramaiah and Satyanarayan (1938) and by Bressani (1973) who found two varieties with 59% to 90% protein digestibility. Such reports encourage consideration of a breeding program to modify protein composition.

More immediate results might be realized through agronomic manipulation. Bressani (1973) reported that the amino acid content of legume grains depends on species, varieties, localities and management practices. He also pointed out that uptake of zinc and application of sulphur increases methionine content in peas considerably. Nikolov and Peterburgskii (1967) reported that application of 0.25% solution of ammonium molybdate in *Vicia faba* increased seed yield, nitrogen content and tryptophan in seed. Also Eppendorfer (1969) reported that methionine and cystine in seed nitrogen were considerably increased by sulphur application. This aspect needs to be investigated in pigeonpeas. It appears to be easier to improve the protein quality by agronomic practices rather than by genetic manipulation in the absence of required variability.

DISCUSSION

W.V. Royes: I use the harvest index concept based on the calculated area which the leaves cover. I assume that yield per unit of area covered is correlated with the photosynthetic and other metabolic efficiency of the plants. I use high selection pressure for selecting single plants by measuring the plant size and determining a calculated measure of harvest index. There is no other way to do it and still retain the plant for seed production. We have selected for earliness and now can get at least three generations per year. This enables us to use the single seed descent method efficiently and effectively.

R.P. Ariyanayagam: Variability in harvest index exists but it is not necessarily correlated with yield. Total dry matter production and harvest index both need to be measured.

B.P. Pandya: In the selection of desirable plants what yield components should be considered?

A.K. Auckland: Reference population in F2 does not represent both generations. We will select the F2 plants to proceed to the next generation. A few years ago, quantitative genetics and later physiological genetics were going to solve the plant breeders' problems. Now it sounds as if harvest index is the thing.

D. Sharma: We plan to delay selection to F4 and self rows in the F5.

S. Ramanujam: Low yield potential is not necessarily true for the grain legumes. Yields of 3 to 3-1/2 tons per ha are possible for pigeonpeas and chickpeas. In protein, this is equal to six tons of cereal production. We should not be looking for small increments on top of low yields. Agronomic and pest control practices are important.

B.P. Pandya: What should be the selection criterion?

J.S. Kanwar: Are there comments on the proposed breeding procedures?

S. Chandra: Photosensitivity, earliness, and drought tolerance should be considered. For drought tolerance smaller seed size dormancy during stress, and quick recovery after stress are needed.

E.S. Wallis: For us photoinsensitivity gives synchrony in flowering.

W.V. Royes: I have bred a daylength insensitive variety which has determinary or synchrony of flowering.

R.P. Ariyanayagam: How do you plan to handle the F_1's of 38 cross diallel ?

D. Sharma: We will select among the F_1s. Hybrid vigor will reflect value of parents. We would like to discuss this point further.

T. Bezuneh: Management can increase yields. A major concern is the percentage of protein.

LITERATURE CITED

Bhat, G.M., 1972. Inheritance of heading date, plant height and kernel weight in two spring wheat crosses. Crop Sci. 12: 95-98.

Bressani, R. 1973. Legumes in human diets and how they might be improved. Nutritional improvement of food legumes by breeding. Proceedings of the conference of protein advisory group of the United Nations system. 15-42.

Dave, B.B. 1934. Inheritance of characters in *Cajanus indicus*. Indian J. Agric. Sci. 4: 674-691.

De, N. and L.J. Reddy. 1972. Homology between *Cajanus* and *Atyiosia* genomes: Origin of Cajanus. Advanced notes of symposium on "Genome Concept". Eukaryota, 59th Indian Sc. Congr., Section of Botany. 19-20.

Deshpande, R.B. and L.M. Jeswani. 1956. A case of pleitropy in the pigeon pea. Curr. Sci. 25: 201-2.

Empig, L.T. and W.R. Fehr. 1971. Evaluation of methods for generation advance in bulk hybrid soybean populations. Crop. Sci. 11: 51-54.

Eppendorfer, W. 1969. Effect of Sulphur and nitrogen on concentrations of cystine and methionine in field beans. Ugeskr. Agron. 114: 20, 392-5 (Biol. 8; Da).

Hartwig, E.E. 1972. Utilization of soybean germplasm strains in a soybean improvement program. Crop Sci. 12: 856-859.

Khan, T.N. 1973. A new approach to the breeding of pigeon pea (Cajanus cajan millsp.): Formation of composites. Euphytica 22: 373-377.

Knott, D.R. and B. Talukdar. 1971. Increasing seed weight in wheat and its effect on yield, yield components, and quality. Crop Sci. 11: 280-283.

Lewis, C.F. 1970. Concepts of varietal maintenance in cotton. Cott. Gr. Rev. 47: 272-284.

Mehta, D.N. and B.B. Dave, 1931. Studies in *Cajanus indicus*. Mem. Dep. Agric. India Bot. 19: 1-25.

Nikolov, B.A. and A.V. Peterburgskil. 1967. The effects of microelements on yields and quality of leguminous crops. Akad. No.4: 141-9. (Bibl. 48; Ru, e).

Pandey, R.L. 1972. Inheritance of some quantitative characters in pigeon pea (Cajanus cajan L. Millsp.). M.Sc. thesis submitted to the department of plant breeding and genetics, J.N.K.V.V. Jabalpur.

Parpia, H.A.B. 1973. Utilization problems in food legumes. Nutritional improvement of food legumes by breeding. Proceedings of the conference of protein advisory group of the United Nations system. 281-295.

Pathak, G.N. 1970. Red Gram. In Pulse Crops of India. 14-53.

Rachie, K.O. 1973. Improvement of food legumes. In Nutritional improvement of food legumes by breeding. Proceedings of the conference of protein advisory group of the United Nations system. 83-92.

Ramaiah and Satyanarayana, 1938. Studies in quality of crops. 11. Nutritive values of proteins of different varieties of red gram (Cajanus indicus). Madras Agric. J. 26: 134-6. (Quoted from Pathak, 1970).

Romero, G.E. and K.H. Frey. 1966. Mass selection for plant height in oat populations. Crop Sci. 6: 283-287.

Sen, S.K., and S.C. Sur. 1964. A study on vicinism in pigeon pea (Cajanus cajan L. Millsp.). Agricultural Louvain 12: 421-426.

Sharma, D.,S.S. Bhadauria, L. Singh, and H.K. Sharma. 1973. Genetic analysis of protein content in pigeon pea. Indian J. Genet, (in press).

Sharma, D., L. Singh, S.S. Baghel, and H.K. Sharma. 1972. Genetic analysis of seed size in pigeon pea (Cajanus Cajan). Can. J. Genet. Cytol. 14: 545-548.

Sharma, H.K., L. Singh, and D. Sharma. 1973. a. Genetic analysis of flower initiation in pigeon pea. Indian J. Genet. 33: 393-397.

Sharma, H.K., L. Singh, and D. Sharma. 1973. b. Combining ability in diallel crosses of pigeon pea. Indian J. Agric. Sci. 43: 25-29.

Shaw, F.J.F., A.R. Khan, and H. Singh. 1933. Studies in Indian pulses. The type of Cajanus indicus Spreng. Indian J. Agric. Sci. 3: 1-36.

Singh, D.N., R.K. Bansal and S.P. Mittal. 1942. Cajanus obcordifolia. Singh (a new species of Cajanus). Indian J. Agric. Sci. 12: 779-84.

Singh, L., D. Sharma, A.D. Deodhar and Y.K. Sharma. 1973. Variation in protein, methionine, tryptophan and cooking period in pigeon pea (Cajanus cajan (L.) Millsp.). Indian J. Agric. Sci. 43: 795-798.

Smith, G.S. 1966. Transgressive segregation in spring wheats. Crop Sci.6: 310-12.

Van Schaik, P.H. 1971. Pulse production status and potential. A. 19-24. Improving the nutrient quality of cereals, report of workshop on breeding and fortification. USAID. Washington D.C.

Westphal, E. 1974. Pulses in Ethiopia, their taxonomy and agricultural significance. Center for agricultural publishing and documentation, Wageningen. 1974.

Table 1. Distribution, Production and Yield of Chickpeas and Pigeonpeas in Different States of India (1971-72)

State	Chickpeas			Pigeonpeas		
	Area (000 ha)	Production (000 tonnes)	Yield (kg/ha)	Area (000 ha)	Production (000 tonnes)	Yield (kg/ha)
Andhra Pradesh	77	20	260	183	41	224
Assam	2	1	500	4	3	750
Bihar	241	170	705	95	59	621
Gujarat	57	40	702	86	44	512
Haryana	1140	661	580	6	4	667
Himachal Pradesh	23	13	565	-	-	-
Jammu & Kashmir	2	1	500	-	-	-
Kerala	-	-	-	51	1	200
Madhya Pradesh	1658	1052	634	495	384	776
Maharashtra	433	133	301	482	251	521
Meghalaya	-	-	-	-	-	-
Mysore	152	62	408	306	163	533
Orissa	22	13	591	51	27	529
Punjab	346	290	838	2	1	500
Rajasthan	1644	886	538	34	20	588
Tamil Nadu	5	3	600	66	24	364
Uttar Pradesh	1989	1555	782	468	529	1130
West Bengal	225	200	889	26	22	846
Delhi	10	7	700	-	-	-
Tripura	-	-	-	-	-	-
Dadra and Nagar Haveli	-	-	-	1	1	1000
All India	8027	5107	636	2311	1574	681

considerations of chickpeas and pigeonpeas, based primarily on the work done in the All India Coordinated Research Project on the Improvement of Pulses, are discussed here.

AGRONOMIC CONSIDERATIONS IN THE PRODUCTION OF CHICKPEAS

Soil and Preparatory Tillage

Salinity

The crop is highly adaptable to different soil conditions but thrives best on deep loam soils free from excessive soluble salts (Moolani and Chandra 1970). High sensitivity of the crop to saline and alkali soil conditions is evident from research in New Delhi, where the crop of G-24 chickpea failed completely on soil with pH 8.4 and electrical conductivity (E.C.) of 1.8 mm hos/cm in 1:2 soil water suspension and irrigated with water having pH of 7.4, E.C. 2.6 mm hos/cm and SAR of 7.8 (Saraf and Davis 1969).

Aeration

Chickpea plants are highly sensitive to poor aeration in the soil (Mehta 1968). This imposes a restriction for production on very heavy soils and calls for special care in seedbed preparation. Datt and Kathavate (1969) have reported that a moderate compaction giving a bulk density value of 1.6 g/cc resulted in best growth of chickpea and higher bulk density reduced the dry weight of stem and roots.

Tillage

The tillage requirements for the crop varies according to soil type. On soils tending toward heavier texture, a rough seedbed is recommended. "Winter" rains will not pack a cloddy surface and the aeration is unobstructed. The opposite effect would occur if the seedbed were finely prepared.

Deep Tillage

For rainfed chickpea, deep tillage during the rainy season has been found to be beneficial as it opens up the ground, ensures greater conservation of moisture and reduces physiological wilt, particularly on the soils which tend to develop hard pans in the root zone (Moolani and Chandra 1970). Bunding and stirring of the soil to promote infiltration during rainy season has been reported to increase yield of chickpea at Rohtak (Argikar 1970).

Planting Variables

Depth of Planting

Depth of planting is an important factor for rainfed chickpeas as it affects both the initial germination and the subsequent mortality. Planting at a depth of about 10 cm is found better than the shallower planting at 5 cm for the rainfed crop, whereas the irrigated crop can be planted at 5 cm. Table 2 shows planting a rainfed crop of G-130 chickpea at Ludhiana at 3 cm on loamy sand soil resulted in about 42.7% mortality compared to a 33.8% mortality when planting was done at 10 cm (Kaul et al. 1974).

Date of Planting

Date of planting has proved to be the single most important variable affecting the yield of chickpeas. Experiments conducted in the All India Coordinated Pulses Improvement Project at different centers over last several

Table 2. Effect of Depth of Planting and Irrigation at 65 Days After Planting on the Plant Mortality in Chickpea Variety G-130 on Loamy Sand Soil of Ludhiana During 1973-74 (Kaul, Sekhon and Dhingra, 1974)

Depth of seeding	Mortality percentage	
	No irrigation	Irrigation
5 cm	42.7	21.0
10 cm	33.8	19.7
CD *5%*	3.7	

Table 3. Yield of Chickpeas (kg/ha) as Affected by Dates of Planting, Row Spacings and Seed Rates at Different Centers in Uttar Pradesh

Treatments	Etawah	Deegh	Varanasi	Kanpur	Azamgarh	Pantnagar		
	1971-72	1971-72	1971-72	1972-73	1972-73	1971-72	1972-73	1973-74
Dates of planting								
October 1	2384	3618				3040	502	
October 15	2739	3393	3218	2760	2690	3039	744	2551
October 30	2591	2354	2603	2898	2750	3026	800	2238
November 15	1946	843	1559	2169	2346	2230	1897	2238
November 30				1406	1809	1898	2118	1554
CD 5*	359	366	124	407	250	446	270	509
Row spacing								
30 cm	2555	2533	2418	2279	2513	2724	1100	2169
45 cm	2274	2571	2502	2337	2272	2645	1328	2123
60 cm						2572		
CD 5%	253	NS	NS	NS	178	NS	102	NS
Seed rate								
75 kg/ha	2445	2544	2767	2248	2392			
100 kg/ha	2375	2550	2942	2369	2392			
"F" test	NS	NS	NS	NS	NS			

Table 4. Yield of Chickpeas (kg/ha) as Affected by Dates of Planting at Different Centers of the All India Coordinated Research Project on Pulse Improvement During 1972-73 and 1973-74

Treatments	Ludhiana		Dholi	Sehore		Hyderabad	Badnapur	
	1972-73	1973-74	1972-73	1972-73	1973-74	1972-73	1972-73	1973-74
Dates of planting								
October 1	1558	1336		2290	2220	2781	1418	2274
October 15	1660	1342	3742	2056	2270	2910	1230	2176
October 30	1661	1293	2363	1842	2460	2738	782	1809
November 15	1027	783	1625	1720	2070	2069	690	1083
November 30			1039	1631	1790	1413	423	600
CD 5%	163	592	181	307	361	140	291	180
Row spacing								
30 cm	1528	1200	3172		2103	2267	864	1529
45 cm	1417	1146	1960		2226	2531	959	1647
60 cm			1445					
CD 5%	NS	NS	111		NS	136	85	36
Varieties								
		G 130	C-235		T-3	BG 482		Chaffa
		L 345	ST-4		C-235	G 130		G-130
V_3		L 550			G.62-404	C-235		C-235

years invariably revealed that planting from 15-30 October was best for most of the chickpea growing areas of the semiarid north Indian plains (Tables 3 and 4). For peninsular India the first fortnight of October was best (Table 4). Delay resulted in conspicuous yield reduction, which could not be compensated by increased plant population.

In the humid subtropical conditions of Nainital Tarai, the response of chickpeas to dates of planting was at variance with that obtained at other centers in the north Indian plains. Late sowing 1n November was better at Pantnagar in the "winter" seasons which were characterized by relatively more rainfall. In dry "winter" seasons the trend was the same as for rest of the north Indian plains (Table 3). This difference was caused by variations in the incidence of Sclerotinia blight and other blights which became more detrimental in seasons of high humidity and in the stands with dense population. Varietal differences in this regard were important, and varieties susceptible to aerial blights (e.g., H-335 and T-3) showed higher reduction in yield under early plantings than the relatively more resistant varieties (Table 5). Scope for variations in dates of planting is available mostly in Irrigated agriculture. For rainfed chickpeas, planting should be done at the first available opportunity when the moisture in the soil is adequate for germination. Studies at Pantnagar revealed that planting at 30% to 50% of available moisture status obtained best germination.

Planting Space

Chickpeas show a high degree of adjustability to the available space; responses to small variations in row spacing are negligible. Generally yields have been higher with 30 cm row spacing compared to 45 or 60 cm row spacing, with fixed plant populations in the trials conducted in the All India Coordinated Pulses Improvement Project (Tables 3 and 4). Similar results (Table 6) have been reported from New Delhi (Bains and Chowdhury 1971).

Interactions Among Planting Variables

Interactions among date of planting and row spacing and among varieties and row spac1ngs have been observed at Pantnagar, where a trend for better performance with wider row spacing (45 or 60 cm) in the earlier dates of planting and narrower row spacing (30 cm) with later planting dates has been observed. Also, varieties susceptible to aerial blight tended to perform better with wider row spacing (Table 5). In peninsular India, there is a trend for 45 cm row spacing to be better than 30 cm (Table 4).

Table 5. Varietal Differences in Response of Chickpeas, in Terms of Grain Yield (kg/ha), to Dates of Planting and Row Spacing at Pantnagar During 1972-73

Treatments	Varieties		
	6-130	H-355	T-3
Dates of planting (D)			
Oct. 1	752	367	390
Oct. 15	968	417	830
Oct. 30	1260	445	695
Nov. 15	2146	1661	1885
Nov. 30	2399	1787	2176
Row spacings (R)			
30 cm	1443	735	1120
45 cm	1574	1132	1270
	V x D	V x R	
CD 5%	229	180	

Seeding Rates

Seed rates of 50 to 75 kg/ha have been sufficient for the Deshi varieties (Table 3), whereas a seed rate of 75 to 100 kg/ha has proved good for Kabuli types (Moolani and Chandra 1970). Studies on planting geometry with C-235 chickpea at Pantnagar revealed no statistically significant advantage of square geometry (1:1) over a deep rectangular one 4:1), although there was a trend toward higher yield with the square (Table 7).

Fertilizer Requirement and Inoculation

Nitrogen Requirements

Studies on removal of nitrogen, phosphorus and potassium by a chickpea crop yielding

Table 6. Effect of Interrow Spacing on the Grain Yield (kg/ha) of Chickpeas at Delhi

Row spacing	Fertility trial (Oct. sown, excessive vegetative growth)	Varietal trial (Normal growth)	Dates of planting trial (Normal growth)
30 cm	2200	3340	3630
45 cm	2160	2810	3360
60 cm	2170	2080	2090
CD 5%	NS	121	225
Varieties	C-235	C-235 G- 24 E- 53 BG- 5	C-235 G- 24

Table 7. Effect of Plant Population and Planting Geometry on the Grain Yield (kg/ha) of C-235 Chickpeas at Pantnagar During 1970-71

Treatment		Grain yield
Plant population	Area per plant	
0.333 million/ha	300 cm^2	1837
0.222	450 cm^2	1248
0.166	600 cm^2	1658
CD *5%*		449
Planting geometry		
1 : 1 Square		1767
2 : 1 Rectangular		1656
4 : 1 Deep-rectangular		1320
CD *5%*		NS

around 30 quintals grain and about 45 quintals of straw (Singh 1969) revealed that with the sandy loam soil of New Delhi, the total removal per ha was 144 kg N (99 kg G + 45 kg S), 31 kg P_2O_5 (23.7 kg G + 7.3 kg S) and 80 kg K_2O (37 kg G + 43 kg S). Most of the nitrogen is obtained from symbiotic N fixation. Hence no positive responses to large applications of nitrogen have been obtained (USDA 1968).

Starter nitrogen applications ranging from 15-25 kg N per ha have given positive responses under farmers' fields (Mann 1968) and in some experimental conditions with poor, sandy soils (Prasad 1964; Manjhi 1968; Singh 1971; Singh and Rathi 1972). In the Coordinated Program of the Pulse Project, the same trend has been observed (Tables 8, 9 & 10). Application of high rate of N (100 kg N/ha), with a view to eliminating symbiotic N fixation, have not proved effective in increasing the yields (USDA 1968). Such a crop tends to become excessively vegetative and its reproductive growth suffers.

Rhizobium Inoculation

Responses to inoculation with the Rhizobium cultures have been marginal, and mostly statistically nonsignificant. Since excellent nodulation has been reported even in uninoculated condition in most cases, it appears the strains being Introduced in the rhizosphere with the culture are not better than the ones already present in the soil. This demonstrates the need for evolving strains which are more efficient than the native flora in the chickpea fields.

Phosphorus Response

Responses to phosphate application have been quite conspicuous on farmers' fields (Mann 1968; Chowdhury 1969; Panikkar 1961). About 20-30% increase in yield was obtained in the simple fertilizer trials on cultivators' fields conducted from 1958-1962 by application of 34 to 67 kg P_2O_5 per ha to rainfed chickpeas on alluvial soils of Bihar-, Punjab, Haryana, Uttar Pradesh, West Bengal and Rajasthan. Thirty to forty percent increase was obtained with the same rate on red and black soils of Uttar Pradesh and desert soils of Rajasthan.

Responses to 50 and 75 kg P_2O_5 application have been positive and statistically significant in all such trials of the All India Coordinated Project where the available soil P status has been low (Tables 8 and 9).

Table 8. Effect of Inoculation, Nitrogen Application and Doses and Method of Phosphorus Application (A=Drilled Below the Seed, B=Foliar Sprayed at Flowering) on the Grain Yield (kg/ha) of Chickpea at Different Centers of the All India Coordinated Research Project on Pulses Improvement Under Rainfed Conditions in Northern Plains of India

Treatments	Ludhiana		Hissar		Dholi	Delhi		Kanpur	Deegh
	1972-73	1973-74	1972-73	1973-74	1973-74	1972-73	1973-74	1973-74	1972-73
<u>Main plots</u>									
Control	1169	1409	1577	1190	1810	1452	1550	2586	2003
25 Kg N/ha	1184	1444	1724	1220	1780	1696	1878	2649	1998
Inoc.*	1399	1466	1783	1310	1860	1451	1617	2718	1703
Inoc. + 25 Kg N/ha	1417	1494	1803	1150	1880	1460	1871	2844	1787
CD 5%	65	NS	NS	90	NS	NS	NS	90	NS
<u>Sub plots</u>									
Control	1245	1250	1558	1230	1820	1340	1669	2546	1905
25 Kg P_2O_5/ha (A)	1261	1405	1847	1250	1790	1540	1816	2763	1999
50 Kg P_2O_5/ha (A)	1374	1464	1788	1310	1830	1571	1692	2760	1966
75 Kg P205/ha (A)	1318	1525	1874	1280	1890	1464	1709	2681	1578
25 Kg P_2O_5/ha(½A+½B)	1240	1426	1792	1240	-	-	-	2741	1808
50 Kg P_2O_5/ha(½A+½B)	1317	1528	1691	1300	-	-	-	2689	1922
75 Kg P205/ha(½A+½B)	1286	1571	1512	1220	-	-	-	2708	1930
CD 5%	NS	77	136	NS	NS	NS	NS	NS	NS
Availabe Soil P status	Medium	Low	Medium	Low	Low	Medium to high	Medium	High	High

* B_7 strain in 1972-73 and C_5 in 1973-74

Table 9. Effect of Inoculation, Nitrogen Application and Doses and Method of Phosphorus Application (A=Drilled Below the Seed, B=Foliar Sprayed at Flowering) on the Grain Yield (kg/ha) of Chickpea at Different Centers of the All India Coordinated Research Project on Pulses Improvement Under Rainfed Conditions in Central and Peninsular India

	Sehore	Badnapur	Digraj	Rajendranagar		Jabalpur	
	1973-74	1973-74	1973-74	1972-73	1973-74	1972-73	1973-74
<u>Main plots</u>							
Control	1324	956	1754	384	683	1113	1906
25 Kg N/ha	1263	1079	1791	599	1135	1218	2023
Inoc.*	1295	1002	1842	373	936	1158	2045
Inoc. + 25 Kg N/ha	1235	970	1910	476	981	1226	2155
CD 5%	NS	75	NS	131	240	NS	NS
<u>Sub plots</u>							
Control	1225	575	1870	461	978	1098	1794
25 Kg P_2O_5/ha (A)	1343	960	1868	450	1122	1164	2087
50 Kg P_2O_5/ha (A)	1380	1089	1839	459	1047	1187	2078
75 Kg P_2O_5/ha (A)	1311	1272	1755	489	1284	1152	2005
25 Kg P_2O_5/ha (½A+½B)	1360	-	-	437	827	1176	2118
50 Kg P_2O_5/ha (½A+½B)	1309	-	-	453	1076	1184	2057
75 Kg P_2O_5/ha (½A+½B)	1272	-	-	454	946	1291	2042
CD 5%	NS	111	NS	NS	131	NS	NS
Available soil P status	-	-	-	-	-	Low	Low

* B_7 strain in 1972-73 and C_5 in 1973-74

Table 10. Effect of Inoculation, Nitrogen and Doses and Methods of P Application on Grain Yield (kg/ha) of Chickpeas at Pantnagar

Treatments	1970-1971	1971-1972	1972-1973	1973-1974
N and Inoculation				
Control	1487	1415	2878	902
Inoc.(IARI Strain)	1567	1652	2885	1145
25 kg N/ha	1557	1259	2894	937
Inoc.OARI) + 25 kg N/ha	1487	1244	2680	902
Inoc.(Local Strain)	-	-	10	1041
Inoc.(Local Strain) + 25 kg N/ha	-	-	-	624
CD *5%*	NS	NS	NS	NS
P treatments				
Control	—	–	2774	937
25 kg P_20_5/ha (A)	-	-	2716	1111
50 kg P205/ha (A)	-	-	2980	1111
75 kg P_20_5/ha (A)	-	-	2704	972
25 kg P_20_5/ha $(^1/_2A + ^1/_2B)$	-	-	3046	972
50 kg P_2O_5/ha $(^1/_2A + ^1/_2B)$	-	-	2701	1041
75 kg P_205/ha $(^1/_2A + ^1/_2B)$	-	-	2920	624
CD *5%*	-	-	NS	NS

No advantage has been obtained from foliar application of P in these trials. Placement of the phosphatic fertilizers below the seed has been better than broadcast application, as this increases the uptake of fertilizer phosphorus, growth and ultimately the yield (Sinha 1972).

Potassium Response

Not much work has been done on the response of chickpea to K application. Studies in the Regional Pulse Improvement Project of the USDA, ARS AND USAID (1968) at different locations revealed lack of response of chickpeas to application of K, which has to be attributed to high available K content of the soil. Depression in yield due to application of 34 kg K_20 per ha was observed at Pusa in Bihar, and in West Bengal (Argikar 1970).

Micronutrients

Studies on micronutrients in chickpeas have also been very limited. The crop seems to be quite tolerant to zinc deficiency (Saxena and Singh 1971). However, under the condition of acute deficiency, as revealed by bronzing and stunting of leaves, the crop is benefitted by foliar spray of 0.5 per cent zinc sulphate with 0.25% lime. Application of molybdenum was found to increase the yield of chickpea by 16% over the control *at* Vijapur in Gujarat (Saxena and Singh 1971).

Water Requirement and Irrigation

Water requirement (transpiration ratio) of chickpeas has been reported to be 1000 compared to 550 for wheat (Leather 1910). A chickpea crop meets this high water requirement from conserved moisture in deep soils which have been properly restored with available moisture during the preceding rainy season. In the absence of enough stored moisture or winter precipitation, the crop responds very well to supplemental irrigation (Saraf and Davis 1969; Chowdury et al., 1972; Mehta 1968; Pastane et al., 1971; Chowdhury 1969).

Work in the All India Coordinated Pulse Improvement Project (Tables 11, 12 and 13) revealed a positive response to irrigation where winter rains were negligible. One irrigation at 45 or 75 days after planting or at pod filling stage generally increased the yield. *On* the *sandy* soils *with a low water* holding capacity, irrigation at earlier stages was more important, as it reduced the mortality of seedlings and physiological wilt considerably (Table 2). Irrigation at pod filling increased the proportion of effective pods. On very heavy soils, an adverse effect of irrigation has been reported because of impaired aeration. The crop does recover when the soil aeration is improved by tillage.

Weed Control

Weeds offer serious competition to chickpea plants in the field and cause a 40%-100%

Table 11. Effect of Irrigation on Grain Yield (kg/ha) of Chickpeas at Different Locations in the All India Coordinated Research Project on Pulses Improvement

Treatments	Location and year									
	Kanpur	Hissar 1973-74			Delhi		Ludhiana		Dholi	
	1972-73	G.130	H.208	L.550	1972-73	73-74*	1972-73	73-74	1972-73	73-74
No irrigation	2773	296	177	237	2028	347	978	1073	-	1330
Irrigation 45 DAP**	-	2503	2607	2570	1948	612	1025	1083	-	1380
Irrigation 75 DAP	2762	2229	2192	2185	1754	641	973	1129	-	1220
Irrigation 100 DAP	2728	-	-	-	-	-	-	-	-	-
Irrigation 45 + 75 DAP	-	2451	2562	2851	1709	661	1072	1338	-	1380
Irrigation 75 + 100 DAP	2423	-	-	-	-	-	-	-	-	-
Early pod stage	-	1118	1407	1311	-	-	-	1459	-	-
CD 5%	NS		211		155	120	73	153	-	NS
Rains during season (mm)	31.5		112				104	38	172	45.2
Varieties	T-3 G-130 C-235		T-3, G-130 C-104, JG-62						H.208, C.235 H.355, BR-77	

* Severe frost injury in unirrigated plots. No pre-sowing irrigation was given.

** DAP = Days after planting.

Table 12. Effect of Irrigation on the Grain Yield (kg/ha) of Chickpeas at Different Locations in the All India Coordinated Research Project on Pulse Improvement in Central and Peninsular India

Treatments	Sehore	Jabalpur		Hyderabad		Badnapur	
	1973-74	1972-73	1973-74	1972-73	1973-74	1972-73	1973-74
No irrigation	1105	2463	1761	922	381	269	1176
Irrigation 45 DAP*	1192	2798	2102	977	819	466	1446
Irrigation 75 DAP	1274	2795	2039	473	414	407	1365
Irrigation 100 DAP	-	-	-	-	-	-	-
Irrigation 45 + 75 DAP	1269	3086	1888	384	399	579	1644
Irrigation 75 + 100 DAP	-	-	-	-	-	-	-
Early pod stage	136[illegible]	-	1925	-	599	-	1412
CD 5%	115	340	224	430	144	106	61
Rains during season (mm)	-	72.9	48.0	63.7	-	-	-
Varieties	JG-62, C-235, G-130, C-104, T-3, Pink 2	T-3, C-235, JG-62 C-104		G-130, T-3, JG-62 C-235, BEG-482		G-130, C-235, I-550, Chaffa	
Soil	Heavy black						

* DAP = Days after planting

Table 13. Effect of Irrigation on the Grain Yield (kg/ha) of Chickpeas at Pantnagar

Treatments	1970-1971	1971-1972	1973-1974
No irrigation	1931	758	1531
Irrigation 45 DAP	2048	1495	1828
Irrigation 75 DAP		1675	1844
Irrigation 105 DAP			2046
Irrigation 45 and 75 DAP	1888	1318	2343
Irrigation 45, 75 and 105 DAP	2145		
SEm +	146	105	115
CD 5%	NS	363	374
Rainfall (mm)	–	8.6	15.4

reduction in the yield (Tripathi 1967, Bains and Chowdry 1971). Depending upon the incidence of weed infestation, the magnitude of loss changes (Tables 14a and 14b). Greater weed infestation usually occurs on the irrigated crop than the unirrigated one.

Common weeds. Chenopodium album, Asphoedelus tenuifolius, Argemone mexicana, Fumaria parviflora. Polygonum plebejum, Lathyrus spp., Vicia sativa, Euphorbia dracunuculoides and Phalaris minor are common annual weeds. Cyperus rotundus, Cynodon dactylon and Cirsium arvense are common perennial weeds.

Mechanical weeding at 30, 45 or 60 days after planting or two weedings at 30 and 60 days after planting have invariably resulted in yields at par with completely weed free conditions. Thus 30-60 days after planting is the most critical period for weed competition.

Prometryne (@ 0.25 kg a.i./ha), alachlore (@ 1 kg a.i./ha), nitrofen (@ 1.0 kg a.i./ha) have proved to be effective preemergence herbicides (Table 14a). Tribunil (@ 2 kg/ha) and Terbutryne (@ 1 kg/ha) have also proved to be highly effective preemergence herbicides at New Delhi (Mani et al., 1974) and Dosanex (@ 1.0 to 1.5 kg/ha) at Ludhiana and New Delhi centers (Table 14a). Spraying of the herbicides MCPB or 2.4DB at 0.75 kg a.i./ha four weeks after sowing has been effective at Hissar (Moolani and Chandra 1970).

Response to Chemicals Including Growth Regulators

Attempts have been made to improve the performance of chickpeas under rainfed conditions by seed soaking in different chemicals, more or less on an empirical basis. Studies at New Delhi (Ahlawat et al. 1973) revealed that H-355 chickpea showed about 20% increase in yield when the seeds were soaked in 0.2 per cent succinic acid solution. However, in subsequent studies (Saraf et al. 1974) no such response was observed with the same variety. In an exploratory study at Ludhiana, the effect of soaking of seeds for five to six hours in aqueous solutions of potassium dihydrogen phosphate, copper sulphate, potassium chloride, zinc sulphate, ammonium molybdate, manganese sulphate, boric acid, succinic acid, ascorbic acid and Regim-8, was studied. Soaking seeds in 0.5 per cent solution of potassium dihydrogen phosphate or 0.05 per cent copper sulphate solution increased the yield by about 41% in these studies (Kaul et al. 1974).

Response of chickpeas to foliar spray of cycocel (2 chloroethyl trimethyl ammonium chloride) at flower initiation was studied at New Delhi (Ahlawat et al. 1973; Saraf et al. 1974) and Ludhiana (Kaul and Sekhon 1974c) using H-355 and G-130 varieties. The responses at New Delhi were inconsistent, whereas at Ludhiana, 0.2 per cent cycocel spray increased effective pod number. Foliar spray of 25 ppm ascorbic acid at flower initiation was also found effective at Ludhiana in increasing the proportion of effective pods.

Response of different chickpea varieties to foliar spray of 2,4,5-triiodobenzoic acid (TIBA) was studied at different centers in the All India Coordinated Pulses Improvement Project, with and without spray of 2% urea solution at pod filling stage (Table 15). Responses at Ludhiana and Hissar were significant. TIBA as well as urea spray increased yield. Growth regulatory effects including temporary opening of the crop canopy were observed at Pantnagar, even at the lowest concentration (5 ppm TIBA), but the yield remained unaffected. Further studies at Ludhiana (Table 16) revealed that the response to TIBA was dependent on the status of soil moisture supply in relation to the stage of crop growth. Regim-8 (0.05%) spray at flower initiation increased yield significantly only when accompanied with irrigation after flowering stage. Thus, considerable variation in the response of chickpeas to the growth regulators such as TIBA might occur depending upon environmental conditions.

Table 14a. Effect of Weed Control on the Grain Yield of Chickpeas at Different Locations in the All India Coordinated Research Project on Pulses Improvement

Treatments	Delhi		Ludhiana		Hissar		Varnasi
	1972-73	1973-74	1972-73	1973-74	1972-73	1973-74	1972-73
	C.235	C.235	G.130	G.130	H.208	H.208	T.3
Weedy (Check)	2513	271	408	692	2081	1620	1629
Weed free	3581	2187	1052	1236	2924	2070	3249
Weeding 30 DAP	3175	1609	731	1240	3125	2050	1986
Weeding 60 DAP	3453	1547	919	1340	2641	2180	2307
Weeding 30 & 60 DAP	3666	1750	1041	1307	2852	2030	2717
* Nitrofen 1.0 kg a.i/ha	3011	578	574	1210	2682	1880	2637
* Nitrofen 1.5 kg a.i/ha	3088	716	641	1292	2562	1940	2825
* Alachlor 1.0 kg a.i/ha	3086	333	600	1085	2464	1800	2452
* Alachlor 1.5 kg a.i/ha	3245	818	689	1122	3177	1970	2474
* Prometryne 0.25 kg a.i/ha	2931	-	848	-	2740	-	2574
* Prometryne 0.50 kg a.i/ha	3278	1656	889	-	2956	-	2569
** Amiben 1.0 kg a.i/ha	3218	-	611	-	2633	-	2849
* Dosanex 0.5 kg/ha	-	-	-	1188	-	-	-
* Dosanex 1.0 kg/ha	-	1120	919	1292	-	-	-
* Dosanex 1.5 kg/ha	-	1547	959	969	-	-	-
CD 5%	583	224	118	63	360	NS	497

* Pre-emergence application
** Post-emergence spray

Chenopodium

Chenopodium, Fumaria,
Phalarisminor
Controlled by Dosanex, a product of Sandoz

Table 14b. Effect of Weed Control Treatments With and Without Inoculation on the Grain Yield of Chickpeas (kg/ha) and Dry Weight of Weeds at Harvest at Pantnagar

Treatments	Chickpea Grain yield (kg/ha)		Weed dry weight (kg/ha)	
	1971-72	1973-74	1971-72	1973-74
No weeding	285	1999	4028	3250
Weeding 30 DAP	972	2844	2824	912
Weeding 45 DAP	-	3255	-	817
Weeding 60 DAP	1402	3255	232	888
Weeding 30 & 60 DAP	1768	3666	139	314
Weed free (IN)	2138	-	-	-
Weed free (UNI)	2188	3333	-	-
* Treflan 1 kg a.i/ha (IN)	877	-	2361	-
* Treflan 1 kg a.i/ha (UNI)	969	-	2176	-
Lasso 1 kg a.i/ha (IN)	196	-	4537	-
Lasso 1 kg a.i/ha (UNI)	242	2288	4550	3039
Lasso 1.5 kg a.i/ha (UNI)	-	2477	-	1793
TOK-E-25 1.0 kg a.i/ha (IN)	178	-	5324	-
TOK-E-25 1.0 kg a.i/ha (UNI)	159	2144	4907	1714
TOK-E-25 1.5 kg a.i/ha (UNI)	-	2333	-	2825
** MCPB 1.0 kg a.i/ha (UNI)	254	-	2662	-
** MCPB 1.0 kg a.i/ha (UNI)	509	-	2083	-
Prometryne 0.25 kg a.i/ha (IN)	-	2888	-	1714
Prometryne 0.50 kg a.i/ha (UNI)	-	2033	-	3119
SEm ± CD 5%	123 358	169 495		

* Pre-planting soil incorporation ** sprayed 40 days after planting

Table 15. Response of Chickpeas to Spray of TI3A at Flower Initiation and 2% Urea Solution at Pod Filling Stage, at Different Centers of the All India Coordinated Research Project on Pulse Improvement

Rates of TIBA spray	Grain yield (kg/ha)									
	Ludhiana		Hissar		Pantnagar		Rajendranagar		Bangalore	
	-N	+N	-N	+N	-N	+N	-N	+N	-N	+N
Water spray	1098	1358	1574	1606	2832	2916	799	913	471	476
5 ppm TIBA	1228	1345	1655	1909	2832	2957	758	765	475	467
10 ppm TIBA	1283	1370	1711	2068	2916	2957	917	825	460	476
15 ppm TIBA	-	-	1747	1812	-	-	-	-	-	-
20 ppm TIBA	1327	1432	1672	1861	2228	2666	777	803	456	472
50 ppm TIBA	1358	1450	-	-	2978	2728	799	1009	463	485
CD *5%*	88		172		NS				NS	
Varieties	G-130		C-235, G-135 H-208, H-355		G-130, T-3 C-235		G-130, C-235 JG-62		H-208, H-355 Annigerl	

Table 16. Effect of Stage and Number of Irrigation and TIBA Application on the Grain Yield of G-130 Chickpeas at Ludhiana During 1973-74 (Kaul & Sekhon, 1974)

Irrigation treatment	Grain yield (kg/ha)			Plant mortality (X)
	Regim 8 spray		Mean	
	Yes	No		
No irrigation	631	597	614	21.8
Irrigation 20 DAP	1053	1182	1117	6.4
Irrigation 30 DAP	1057	1079	1068	8.3
Irrigation 40 DAP	724	755	739	9.4
Irrigation 55 DAP	1097	1155	1126	10.5
Irrigation 65 DAP	933	1111	1022	8.2
Irrigation 65 DAP + Before flowering (BF)	1200	1244	1222	9.9
Irrigation at flower initiation (IF)	634	590	612	13.1
Irrigation at BF + IF	875	768	821	8.5
Irrigation 65 DAP + Pod filling stage	1345	1155	1250	8.1
CD *5%*	137		111	

Nipping

The grain yield performance of chickpeas is highly dependent upon the balance between vegetative and reproductive growth. Excessive vegetative growth, which might occur owing to very high soil fertility and moisture supply (e.g., in the humid subtropical conditions of north Indian foothills) or due to planting at a date much earlier than the optimum, usually results in poor reproductive growth and thus the economic yield is reduced.

Proper nipping of young shoots during the vegetative phase reduces the excessive growth, encourages branching and pod set, and, consequently, yield. Nipping also helps in regulating, to some extent, the onset of flowering which is usually delayed by the practice. Nipping could form an important agronomic tool in preventing the peak phase of flowering from coinciding with the devastating frosty period.

The yield of chickpeas was not affected by nipping at an interval of 10, 20 or 30 days up to 90 days after planting in Hissar (Singh 1973). There is, however, no a priori reason for expecting a universal advantage from nipping, as the response is highly dependent on the plant growth and the prevailing atmospheric conditions.

Mixed Cropping

Chickpea is a popular choice with farmers for mixed cropping with cereals and oilseeds in rainfed agriculture (Argikar 1970; Bains 1968). Common mixtures are (i) chickpeas with wheat, (ii) chickpeas with barley, (iii) chickpeas with rabi (winter) grain sorghum, (iv) chickpeas with toria, sarson, mustards etc., and (v) chickpeas with linseed or safflower. In the mixture, the chickpea seldom gives as large a yield as when grown alone (Tables 17 and 18). However, there is scope for developing planting patterns and agronomy in such a way that the competition from the mixed crop with chickpea might be reduced. Planting chickpeas and Brassica compestris var. toria in alternate rows resulted in better yields of chickpeas than were obtained when the two were mixed together and broadcast sown (Table 17).

AGRONOMIC CONSIDERATIONS IN THE PRODUCTION OF PIGEONPEAS

Most of the agronomic research work done on pigeonpeas in different parts of India until the early sixties was with long duration varieties which remained in the field for eight to ten months and were mostly rainfed. The work in the All India Coordinated Research Project on Pulse Improvement, however, has been restricted mainly to early and medium duration varieties, which fit in well in the double cropping system, and are usually established with preplanting irrigation.

Soil and Seedbed Requirements

Although adaptable to a wide range of soil types, pigeonpeas grow best on well drained, deep loam soils free from excessive soluble salts and near neutral in pH (Pathak 1970). Subsoiling on lands having hardpan in the root zone proves advantageous (Bains and Chowdury 1971). Subsoiling permits both deeper proliferation of roots and greater infiltration of water to the deeper layers of the soil.

The plant has to depend a great deal on this conserved moisture as a major part of its reproductive growth is completed during the post-monsoon period. The seedbed should have a moisture content of about 40% to 50% of the available water to ensure quick and adequate germination. Higher or lower moisture content resulted in poorer germination in the pot culture studies conducted at Pantnagar. Adequate provision for surface drainage is an important consideration in the seedbed preparation of pigeonpeas.

Planting Variables

Date of Planting

For early (T-21) and medium duration varieties (BR-183, Khargaon-2, R6-72, Sharda and Mukta) of pigeonpeas planting in the first fortnight of June, before the onset of monsoon has proved to be best (Tables 19, 20 and 21). Delaying the planting beyond the end of June resulted in a drastic reduction in yield. This trend has been observed in multiyear trials not only at Pantnagar, but also in a two-year study carried out at five other locations in Uttar Pradesh viz., Kanpur, Deegh, Etawah, Meerut and Raya (Panwar and Misra 1973), and in a three year study in West Bengal (Chowdhury 1969).

Table 17. Grain Yield and Economics of Mixed Cropping of Chickpea and Brassica Compestris Var. Toria at Pantnagar (1973-74)

Treatments	Grain yield (kg/ha)		Net Profit (Rs/ha)
	Chickpea	Brassica	
Pure stand of chickpea (C 235)	2466	-	3839
Chickpea + Brassica (Broadcast)	866	1444	4155
Chickpea + Brassica (alternate rows)	1237	1018	3362
Chickpea seeded in the standing crop of Brassica (alternate rows)	170	1703	3362
Chickpea + Brassica (Paired rows)	940	1258	3788
Pure stand of Brassica (Type 9)	-	1549	2770
SEm +	1.05	0.96	
CD *5%*	3.23	2.95	

Trials conducted at New Delhi during 1972 and 1973, and at Rajendranagar (Hyderabad) with T-21, Pusa Ageti and Sharda varieties under the All India Coordinated Pulse Improvement Project, resulted in similar responses to dates of planting. With the delay in planting, considerable reduction occurred in the duration of the crop (Tables 19 and 21), plant height and pod number (Singh et al. 1971). In the case of very early maturing varieties of pigeonpea (duration 120-130 days such as UPAS-120, Prabhat, Pant A-2 and Pant A-3, planting with the onset of monsoon was optimum because with earlier planting the reproductive growth occurred during the period of heavy rainfall causing great flower and pod drop.

Planting Space

For long duration varieties, grown as a pure crop, a row spacing of 120 cm with plant to plant distance of 60 cm has been found to be the best (Pathak 1970). For the short and medium duration varieties, an interrow spacing of 50 to 75 cm and an intrarow spacing of 20 to 30 cm have proved ideal (Singh et al. 1971; USDA 1968). A population of 50,000 to 60,000 plants per hectare proved significantly better than a population of 40,000 plants per ha (Bains and Chowdhury 1971; USDA 1968). For extra early varieties as well as for those having compact growth habit, narrower row spacings of 30 to 45 cm with a population of 100,000 plants per ha produced the best results at different centers in the All Tndia Coordinated Pulse Improvement Project. Response to planting geometry in R-60 (Mekta) variety of pigeonpea was significant at Pantnagar, where a 1:1 planting geometry resulted in significantly higher yield than the rectangular geometries (Table 22).

Soil Drainage

Temporary waterlogging occurs commonly in pigeonpea fields. When the internal drainage of the soil is poor, this waterlogging can cause serious yield reduction. This situation can be ameliorated by planting pigeonpeas on ridges. In a two year study at New Delhi, ridge planting resulted in a 30% increase in yield over flatbed planting (Bains and Chowdury 1971). Such an advantage, however, could not be obtained under Pantnagar conditions, where the internal drainage of the soil was relatively better than that of New Delhi soils (Table 23).

Fertilizer Needs and Inoculation

A crop of pigeonpea var. Pusa Ageti yielding about 20 quintals of grain (G) and

Table 18. Studies on Mixed Cropping with Cereals and Oilseeds in Rainfed Chickpeas at Different Centers in All India Coordinated Research Project on Pulses Improvement, 1973-74

	Grain yield (kg/ha)							
	Pantnagar				Bangalore		Dholi	
	upland		low land					
	Chickpea (C-235)	Mixed Crop	Chickpea (C-235)	Mixed Crop	Chickpea (Annigeri)	Mixed Crop	Chickpea	Mixed Crop
Pure chickpea	1885	-	575	-	715	-	540	-
Chp + Barley (1:1, 30 cm)*	190	3150	303	3136	321	201	88	1806
Chp + Wheat (1:1, 30 cm)*	288	1399	792	3432	319	441	250	1958
Chp + Linseed (1:1, 30 cm)*	729	590	683	878	-	-	208	514
Chp + Safflower (1:1, 30 cm)*	-	-	-	-	345	484	-	-
Chp + Barley (1:1, 50 cm)**	278	1267	668	3179	301	228	147	1611
Chp + Wheat (1:1, 50 cm)**	840	1310	743	2559	350	548	139	1514
Chp + Linseed (1:1, 50 cm)**	507	287	891	1032	-	-	236	653
Chp + Safflower (1:1, 50 cm)**	-	-	-	-	412	509	-	-
Chp + Barley (50:50 mixture)***	163	1209	883	3968	252	256	13	2528
Chp + Wheat (50:50 mixture)***	248	1718	674	3174	312	586	13	2569
Chp + Linseed (50:50 mixture)***	359	490	607	1174	-	-	269	500
Chp + Safflower (50:50 mixture)***	-	-	-	-	364	497	-	-
Pure Barley	-	2581	-	3809	-	382	-	2403
Pure Wheat	-	2029	-	4559	-	995	-	2403
Pure Linseed	-	784	-	1361	-	-	-	1056
Pure Safflower	-	-	-	-	-	802	-	-

* One row of mixed crop between 2 rows of chickpea; inter row distance of chickpea 30 cm.

** Alternate rows of mixed crop and chickpea; inter-row distance of chickpea 30 cm.

*** Seeded at 50% of recommended seed rate of mixed crop and chickpea mixed together and sown in rows 22.5 cm apart.

Table 19. Effect of Date of Planting on the Grain Yield (kg/ha) and Days for Maturity (in Parenthesis) of 4 Varieties of Pigeonpea in 1969 at Pantnagar

Date of Planting	Varieties				
	T-21	BR-183	Khargaon-2	RG-72	Mean
20 May	1258 (188)	2484 (230)	2077 (235)	2178 (242)	2224
30 May	2114 (178)	2681 (226)	2308 (230)	2119 (238)	2305
10 June	1924 (174)	2151 (223)	1818 (225)	1936 (230)	1957
20 June	1575 (168)	2183 (215)	1969 (218)	1621 (224)	1837
30 June	1497 (162)	2006 (208)	1726 (212)	1609 (219)	1709
10 July	1124 (155)	1417 (197)	1240 (200)	1285 (208)	1269
20 July	1291 (151)	1628 (185)	1447 (189)	1102 (197)	1367
30 July	1237 (146)	1544 (174)	1238 (177)	1073 (185	1274
Mean	1616	2011	1729	1616	

	SEm ±	CD at 5%
For comparison of varietal means	50	142
For comparison of date means	74	224
CV (%)	14.3	

Table 20. Effect of Date of Planting, Row Spacing and Plant Population on the Grain Yield of Pigeonpea Variety T-21 at Pantnagar

Treatment	Grain yield (kg/ha)			
	1968	1969	1970	Mean
Planting dates:				
20 May	-	1747	2000	1873
5 June	1951	1789	1860	1866
20 June	1862	1539	1760	1720
5 July	1672	1224	1000	1299
20 July	1290	1025	430	915
SEm ±	40	92	132	
CD at 5%	139	285	407	
Row spacings:				
50 cm	1717	-	1441	1579
75 cm	1721	1458	1396	1528
100 cm	1641	1472	1403	1505
SEm ±	34	25	34	
CD at 5%	NS	NS	NS	
Plant Population				
40,000	1653	1510	1450	1538
50,000	1655	1489	1401	1515
60,000	1773	1392	1390	1518
SEm ±	34	31	34	
CD at 5%	101	86	NS	
CV (%)	12.02	13.00	19.53	

Table 21. Effect of Date of Planting on the Grain Yield (kg/ha)and Maturity of 4 Pigeonpea Varieties in 1970 at Pantnagar

Date of planting	Varieties				Mean
	T-21	S-5	R-60	BR-183	
30 May	1742 (184)	2297 (199)	2464 (218)	1764 (213)	2067
9 June	1831 (173)	2241 (193)	2364 (210)	1786 (207)	2055
19 June	1886 (167)	2161 (186)	2730 (203)	1857 (200)	2164
29 June	1598 (161)	1764 (180)	2364 (197)	1598 (194)	1831
9 July	1475 (154)	1864 (174)	1664 (193)	1731 (189)	1684
19 July	1331 (144)	1476 (158)	1509 (184)	1331 (180)	1412
Mean	1646	1967	2122	1678	
SEm +		95			140
CD at 5%		281			313
CV (X)		6.42			

Days for maturity are given in parenthesis

Table 22. Effect of Planting Geometry on the Grain Yield of Pigeonpea (R-60) in 1970 at Pantnagar

Planting geometry	Grain yield (kg/ha)
45 cm x 45 cm	2902
55 cm x 37 cm	2181
65 cm x 37 cm	1824
75 cm x 26 cm	1971
85 cm x 23 cm	1751
95 cm x 20 cm	1864
SEm +	210
CO at *5%*	600
CV *{%)*	23.02

Table 23. Effect of Method of Planting on the Grain Yield of T-21 Pigeonpea in 1969 at Pantnagar

Method of planting	Grain yield (kg/ha)
Flat planting	1490
Flat planting followed by ridging	1450
Ridge planting (single row)	1721
Ridge planting (double row)	1692
SEm +	100
CD at 5%	NS
CV (%)	10.4

60 quintals of sticks (S) has been reported to remove about 132 kg N (79 kg G + 53 kg S), 25.3 kg P_2O_5 (13.4 kg G + 11.9 kg S) and 64.2 kg K_2O (31.5 kg G + 32.7 kg S) per hectare (Rao 1974).

Response to Organic Fertilizer

The application of bulky organics to pigeonpea crop on sandy loam soil has resulted in conspicuous increases in yield. At Pusa, in Bihar, application of 40 and 80 quintals of farm yard manure (FYM) per hectare increased yield by 114% and 141% over the control. There was an 82% increase from application of rape cake (@ 40 kg N/ha) and 7% increase with green manure (Pathak 1970). Deep placement of FYM (at 20 cm depth) has been found to increase the yields of T-21 pigeonpea by 50% to 140% over the control at New Delhi (Bains and Chowdhury 1971).

Inorganic Nitrogen

Responses of pigeonpea to inorganic nitrogen have been generally negligible or negative (Pathak 1970; Singh and Rathi 1972; USDA 1968; Panwar and Misra 1973). Attempts to substitute symbiotic nitrogen fixation by applying high doses of combined nitrogen did not give positive results (USDA 1968, Table 24).

Phosphate Response

Responses to phosphate application have

Table 24. Effect of Fertility Levels on the Grain Yield of T-21 Pigeonpea at Pantnagar

Treatment	Grain yield (kg/ha)		
	1968	1969	Mean
N and inoculation			
Control	1838	1811	1824
Inoculation	1798	2005	1901
Inoculation + 25 kg N/ha	1840	1918	1879
40 kg N/ha	1772	1795	1783
80 kg N/ha	1768	1826	1797
SEm +	51	68	
CD at *5%*	NS	NS	
P levels :			
Control	1818	1897	1857
50 kg P_2O_5/ha	1760	1886	1823
100 kg PoOc/ha	1818	1824	1821
150 kg P_2O_5/ha	1817	1877	1847
SEm +	45	61	
CD at 5%	NS	NS	
CV *(%)*	11.3	14.8	

been generally positive and in some cases highly significant. At New Delhi, about 95% and 120% increases in yield were obtained with application of 66.7 and 100 kg P_2O_5 per ha, respectively (Bains and Chowdury 1971). Placement was better than broadcast application. Increasing rates of phosphorus application increased the moisture extraction from the deeper layers by pigeonpeas under rainfed condition of New Delhi (Singh 1972). Response to potassium application has been negligible (Panwar and Misra 1973; Pathak 1970; USDA 1968).

Zinc Response

Pigeonpea plants show a high degree of susceptibility to zinc deficiency with little differences among the existing varieties (Saxena and Singh 1970). Soil application of 2 to 4 ppm zinc or foliar spray of 0.5% zinc sulphate with 0.25 per cent lime have proved effective in controlling the deficiency of zinc.

Inoculation Response

Responses to inoculation have been generally inconsistent (Panwar and Misra 1973; USDA 1968). Small yield increases due to inoculation have been generally observed (Tables 24 and 25). Variations in the efficiency of Rhizobial strains have been observed (Table 25). There are indications that pelleting of inoculated seed with charcoal, lime or talc might improve the performance of inoculant (Table 26).

Water Requirement and Management

A transpiration value of 1100 for unmanured and 600 for manured pigeonpeas has been reported by Leather (1910). About 22 cm was the absolute water requirement of the crop yielding about 910 kg grain per ha. It is not surprising that the crop, notwithstanding its high drought tolerance, responds well to irrigation during dry seasons. Rabi season crops of pigeonpea have responded well to irrigation at Hyderabad (Venkateswarlu 1967) and at Bhavanisagar in Tamil Nadu.

Chandermohan (1970) reported 57% and 45% increases in yield of February planted, Co-1 pigeonpea, when irrigation was given at 60% and 80% depletion of available moisture (i.e., a maximum of 2.5 atm. tension measured up to 30 cm depth) compared to irrigation at 100% depletion of available moisture. However, in the whole of north and central India, pigeonpea is rainfed and the rains received during July, August and sometimes in September are sufficient to allow the crop to complete its life cycle without water stress. The moisture stored in the soil profile during this period is used by the crop in the post-monsoon period.

An experiment was conducted in 1970 to study possible advantages from post-monsoon irrigation on deep silty loam soils of Pantnagar (Table 27). No positive response was obtained. In fact, drainage often is more of a problem than the shortage of water, particularly in north India. Ridge planting has proved advantageous as it ensured quick disposal of rain water allowing no stagnation (Bains and Chowdhury 1971).

Weed Control

Pigeonpea is very sensitive to weed competition in the first 60 days of growth.

Table 25. Effect of Inoculation on the Grain Yield and Nodulation of Pigeonpea Varieties at Pantnagar In 1971

Inoculation treatment	Nodules/plant		Grain yield (kg/ha)		
	T-21	S-5	T-21	S-5	Mean
Control	353	237	1549	1299	1424
Inoculation with IARI-4	114	77	1588	1338	1463
Inoculation with IARI-2	311	281	1821	1602	1712
			SEm +		47
			CD at 5%		141

Table 26. Grain Yield of Pigeonpea Under Different Inoculation and Pelleting Treatments

Treatment	Grain yield (kg/ha)		Mean
	1972-73	1973-74	
Control	1183	1242	1212
Inoculation-IARI culture	1558	1227	1392
Inoculation-GBPUAT culture	1549	1519	1534
Inoculation IARI + Talc pelleting	1080	1469	1274
Inoculation GBPUAT + Talc pelleting	1471	1606	1538
Inoculation IARI + Charcoal pelleting	1072	1605	1338
Inoculation GBPUAT + Charcoal pelleting	1655	1590	1622
Inoculation IARI + Lime pelleting	1762	1575	1668
Inoculation GBPUAT + Lime pelleting	1476	1424	1450
Pelleting with Talc without culture		1136	1136
Pelleting with Charcoal without culture		1469	1469
Pelleting with lime without culture		1348	1348
SEm	143	129	
CD at 5%	428	NS	
CV {%)	17.42	17.99	

Table 27. Grain Yield of Pigeonpea T-21 as influenced by Late Irrigation Treatments in 1970 at Pantnagar

Irrigation treatments	Time of irrigation			No. of irrigations	Grain yield (kg/ha)
	75% flowering	Pod formation	Late pod stage		
I_0	No	No	No	0	2019
I_1	Yes	No	No	1	1790
I_2	No	Yes	No	1	2165
I_3	No	No	Yes	1	1624
I_4	Yes	Yes	No	2	2248
I_5	No	Yes	Yes	2	1874
I_6	Yes	Yes	Yes	3	1874
			SEm ±		260
			CD at 5%		NS
			CV (X)		26.77

When protected in this period, the crop makes rapid growth and weeds do not affect its growth thereafter. Cyperus rotundus, Echinocloa colonum, Dactyoctenum aegympticum, Eleusine indica, Setaria glauca, Phragmites karka and Cyperus iria are common grassy weed species. The broad-leaved weeds include Amaranthus viridis, A. spinosus, Commelina benghalensis, Celosia argentia, Phylanthus niruri, Digera arvensis and Portulaca quadrifida. Depending upon the infestation, the grain yield losses in pigeonpea have been variable (Tables 28, 29 and 30), in some cases amounting to 90% and above.

Control

Mechanical weeding at 20 and 45 days after planting has been as effective as complete weed free condition (Tables 28 and 29). Out of various herbicides tried, nitrofen at the rate of 1 kg a.i. per ha as a preemergence application has proved to be quite effective at different centers in the All India Coordinated Pulse Improvement Project. Work at Pantnagar (Table 28) and Coimbatore (Sankaram and Damodaran 1974) has shown the superiority of nitrofen to other chemicals. The efficacy of this chemical and of alachlor, however, is dependent upon the moisture content of the surface and, therefore, adequate care is essential for getting effective weed control. Excessive rains immediately after planting and weedicide application can also make the weed control ineffective, as has been the case at Pantnagar during 1972 and 1973 seasons (Table 29). More effective herbicides, with greater selectivity, have to be identified.

Effect of Growth Regulators

Use of TIBA @ 150 ppm as a foliar spray at flower initiation has proved effective in pushing up the yield by a small margin at Pantnagar. However, the response has been different in two seasons (Table 30). Studies on the effect of different growth regulators on flower drop have been inconclusive, and further investigation is required.

Intercropping and Mixed Cropping

The practice of mixed cropping or inter-

Table 28. Effect of Various Weed Control Treatments on the Grain Yield (q/ha) of Pigeonpea (cv. T-21) and the Dry Weight of Weeds Per Hectare at Harvest

Herbicide treatments	Rate of application kg.a.i./ha	Grain yield (q/ha)		Dry wt. of weeds (q/ha)	
		1968	1969	1968 (30th)	1969 (60th)
Treflan	0.5	19.55	5.33	263	421
(pre-planting)	1.0	18.21	13.30	268	432
	1.5	19.86	9.43	384	466
Lasso (CP 50144)	4.0	16.75		237	
(pre-emergence)	5.0	10.39	-	404	-
	6.0	12.08		253	
Prometryne	0.5	15.11		178	
(pre-emergence)	1.0	17.86	-	305	-
	1.5	23.64		92	
Amiben	1.0		8.30		453
(pre-emergence)	1.5	-	15.53	-	421
	2.0		9.96		397
Linuron	2.0		10.00		418
(pre-emergence)	3.0	-	18.30	-	501
	4.0		10.53		354
TOK E-25	1.0		25.53		236
(pre-emergence)	1.5	-	13.86	-	308
	2.0		9.96		327
Weed free condition	-	21.15	24.96	-	0
Weedy condition	-	0.93	7.16	517	632
CD at 5%		8.15	10.31	40	192

Table 29. Effect of Mechanical Weed Control and Preemergence Application of Certain Herbicides on the Grain Yield of Pigeonpea Variety T-21 and Dry Weight of Weeds at the Maturity of the Crop at Pantnagar

Treatments	Grain yield (q/ha)		Dry wt. of weeds (q/ha)	
	1971	1973	1971	1973
No weeding	6.97	6.76	42.5	92.0
Weeding at 45 days after planting	8.02	11.39	10.8	38.9
Weeding at 20 and 45 days after planting	10.80	26.13	4.2	25.0
Complete weed free condition	10.85	27.29	0.0	0.0
Lasso @ 1 kg a.i./ha	7.91	17.45	36.1	69.4
Lasso @ 2 kg a.i./ha	6.91	13.37	39.4	58.7
Lasso @ 3 kg a.i./ha	-	13.73	-	68.9
Linuron @ 0.3 kg a.i./ha	7.10	-	41.4	-
Linuron @ 0.6 kg a.i./ha	6.83	-	36.4	-
Linuron @ 0.9 kg a.i./ha	9.38	-	32.8	-
Diuron @ 0.3 kg a.i./ha	8.86	-	35.5	-
Diuron @ 0.6 kg a.i./ha	8.05	-	36.1	-
Tok-E-25 @ 1 kg a.i./ha	6.13	11.77	34.2	103.2
Tok-E-25 @ 2 kg a.i./ha	-	10.36	-	92.6
Lasso + Tok-E-25 @ 1 kg a.i./ha each	-	17.23	-	64.8
SEm ±	0.90	2.32		
CD at 5%	2.59	6.86		

Table 30. Effect of TIBA Application on the Mean Grain Yield of Pigeonpea cv T-21 at Pantnagar

TIBA treatment	Grain yield (kg/ha)		
	1971	1972	Mean
No TIBA	1488	1757	1622
TIBA (150 opm)	1659	1781	1720
SEm +	43	36	
CD at 5%	125	NS	
CV *(%)*	11.9	10.0	

cropping has been prevalent in India to a very wide extent. Grain sorghum, pearl millet, finger millet (ragi), corn, urd bean, mung bean, cowpea, groundnut, sesamum and cotton are the common crops used for inter- or mixed cropping. Mixtures with grain or forage sorghum, pearl millet, urd bean and cowpea have been most common (Bains 1968). Mixtures with cereals are quite compatible from the point of view of nutrient and moisture utilization because of differences in the root systems of the component crops.

The practice of mixed cropping has been common with long duration varieties of pigeonpea under rainfed conditions. Although some studies have shown the yields of pigeonpea were reduced by mixed cropping in comparison to pure cropping, the overall combinations were economically advantageous (Pathak 1970).

Possibility of parallel cropping in short duration pigeonpea varieties has also been demonstrated (Bains and Chowdhury 1971; Saxena and Yadav 1971, 1973). These results have demonstrated that short duration varieties of urd bean, mung bean, cowpea, soybean, and dwarf maize can be successfully grown as parallel crops in normal stand of T-21 or Pusa Ageti pigeonpea varieties, without adversely affecting pigeonpea yields. The practice resulted in better utilization of available resources and higher net economic returns.

Intercropping with sorghum, tall maize and pearl millet has generally resulted in reduction in the yield of pigeonpea. This was very clearly demonstrated at various centers under the All India Coordinated Pulse Improvement Project (Table 31). Planting of two rows of parallel crops between two normally spaced (75 cm) rows of pigeonpea has not given any additional advantage over the single row of the parallel crop. Paired row planting also gave no advantage over normal planting (Table 32).

DIRECTIONS OF FUTURE RESEARCH

The productivity of chickpeas and pigeonpeas has to be increased not only by improving their genetic potentiality for photosynthesis and economic sink but also by providing a suitable environment for expressing this potentiality. The role of agronomic research should be identifying optima in the controllable environment and developing cultural practices to suit the needs of the newer plant types for differing environmental conditions. Some of the major areas that need immediate attention are:

(a) To study response of newer genotypes to planting methods, planting geometry, population pressure and planting dates; requirements of photo- and thermoneutral genotypes to these variables.

(b) To develop planting patterns and determine nutrient requirements of parallel cropping, mixed cropping and intercropping with these grain legumes.

(c) To quantify the pattern and magnitude of uptake and determination of critical concentrations in indicator tissues and soil for different macro- and micronutrients. To standardize the soil tests for common fertilizer nutrients.

(d) To devise methods for avoiding incompatibility between combined nitrogen and symbiotic nitrogen fixation in the nitrogen nutrition of the crops. To assess symbiotic N fixation under different conditions and devise ways to prolong it in the growth period of the crop.

(e) To devise methods for increasing the responsiveness of the crops to fertilizer and increasing the fertilizer use efficiency.

(f) To develop methods of raising crops under moderately saline and alkaline soil conditions.

(g) To characterize the nature and magnitude of weed competition in relation to crop age and develop effective weed control schedules

Table 31. Grain Yield of Arhar (q/ha) and Parallel Crops at Different Centers During Kharif, 1972 in AICPIP

Treatments	Ludhiana		Hissar		Bangalore		IARI, New Delhi	
	Pigeonpea	Parallel crops	Pigeonpea	Parallel crops	Pigeonpea	Parallel crops	Pigeonpea	Parallel crops
Pure pigeonpea	19.91	-	22.50	-	6.26	-	8.87	-
Pigeonpea + mungbean	22.78	2.84	20.65	1.40	5.55	0.80	9.80	2.46
Pigeonpea + urdbean	20.69	4.86	21.12	1.15	5.57	0.76	11.20	1.60
Pigeonpea + maize	18.55	29.68	-	-	1.23	17.46	2.80	16.15
Pigeonpea + soybean	9.27	3.25	20.53	1.05	5.29	6.25	12.51	0.90
Pigeonpea + groundnut	18.05	9.26	-	-	4.99	6.88	-	-
Pigeonpea + cowpea	-	-	-	-	5.01	2.53	10.13	0.55
Pigeonpea + <u>ragi</u>	-	-	-	-	2.84	9.29	-	-
Pigeonpea + sorghum	-	-	-	-	-	-	7.05	1.67
CD at 5%	1.648		NS		0.567		3.76	

Table 32. Yield and Economics of Production of Pigeonpea as Affected by Paired Row Planting and Parallel Cropping Treatments in 1973-74

Treatment	Grain yield (kg/ha)		Gross income (Rs/ha)	Cost of production (Rs/ha)	Net profit (Rs/ha)
	Pigeonpea	Parallel crop			
Pure pigeonpea (N) (T-21)	2546	-	4074	1279	2795
Pure pigeonpea (Pr)	2139		3436	1271	2165
P + Mung bean (N) (T-1)	2290	587	4850	1422	3428
P + Mung bean (Pr)	2257	496	4642	1420	3222
P + Urd bean (N) (UPU-1)	2405	762	5183	1428	3755
P + Urd bean (Pr)	2071	722	4601	1421	3180
P + Cowpea (N) (Pusa Dofasli)	2360	638	4807	1429	3378
P + Cowpea (Pr)	2102	606	4316	1428	2888
P + Soybean (N) (Clark-63)	2386	811	5443	1633	3810
P + Soybean (Pr)	2157	760	4973	1623	3350
P + Maize (N) (Dwarf erect)	1891	2828	5842	1821	4021
P + Maize (Pr)	2162	2438	5873	1818	4055

	Parallel crops	Methods	Crops X Methods
SEm +	95	55	135
CD at 5%	-	158	-

N = Normal rows of pigeonpea

including herbicides.

(h) To quantify the moisture use pattern of different genotypes under rainfed and irrigated conditions and study the effect of moisture supply and nutrient supply on moisture use pattern. To devise methods for increasing water use efficiency and conservation of moisture.

(i) To study the tillage needs of the crop and devise methods of tillage for rainfed agriculture under different soil conditions.

(j) To study field responses of the crops to growth regulating substances in relation to various other agronomic variables to raise further the yield plateau.

DISCUSSION

A K. Auckland:	Dr. Saxena, would you recommend F_2-F_3 selection in rectangular planting?
M C. Saxena:	No, because we had only one variety that responded to rectangular spacing.
E J. Corbin:	Why has square spacing of 30 cm been used? We use 15 cm spacings, and consider 30 cm suboptimal.
M C. Saxena:	We expect spacing to vary from place to place, but in India nothing is gained from planting closer than 30 cm. On compatibility of fungicides and inoculum, we have found usable combinations.

LITERATURE CITED

Ahlawat, I.P.S., C.S. Saraf and Attar Singh, 1973. Response of Bengal gram (*Cicer arietinum* L.) to growth regulators. Paper presented at All India Coordinated Rabi Pulses Workshop. Bose Research Institute, Calcutta, 1973.

Argikar, G.P. 1970 Gram. In *Pulse Crops* of *India*. ICAR, New Delhi. 54-135.

Bains, S.S. 1968. Pulses are popular for mixed cropping. Indian Fmg. 17(11):19-22.

Bains, S.S. and S.L. Chowdury. 1971. Agronomy of pulse crops. New vistas in pulse production, Indian Agriculture Research Institute, New Delhi : p.24-46.

Chandramohan, J. 1970. Studies on water requirement of crops in Tamil Nadu. Madras Agric. J. 57:251-63.

Chowdhury, S.L. 1969. Pulse Crops more productive than you think. Indian Fmg. 18 (Sept.).

Chowdhury, S.L., B.M. Sharma, P.C. Bhatia and Sewa Ram. 1972. When and where do Rabi pulses pay more. Indian Fmg. 1972.

Dastane, N.G., M. Yusuf and N.P. Singh. 1971. Performance of different *rabi* crops under varying frequencies and timings of irrigation. Indian J. Agron. 16(4): 483-486.

Datt, N.P. and Y.V. Kathavate, 1969. Effect of compaction of Delhi soils on the growth of gram. Indian J. Agric. Sci. 39: 230-237.

Kaul, J.N. and H.S. Sekhon. 1974a. Response of chickpea variety G-130 to pre-sowing seed soaking in various chemicals. Paper presented at the All India Coordinated Rabi Pulses Workshop held at UPIAS, Kanpur, 1974.

Kaul, J.N. and H.S. Sekhon. 1974b. Response of Bengal gram cultivar G-130 to irrigation applied at different days after planting in conjunction with Regim-8 spray. Paper presented at the All India Coordinated Rabi Pulses Workshop held at UPIAS, Kanpur, 1974.

Kaul, J.N. and H.S. Sekhon. 1974c. Response of G-130 gram and field pea T-163 to growth regulators (seed soaking and foliar spray). Paper presented at the All India Coordinated Rabi Pulses Workshop held at UPIAS, Kanpur, 1974.

Kaul, J.N., H.S. Sekhon and K.K. Dhingra. 1974. Plant mortality in gram G-130 as influenced by irrigation, depth of sowing, seed rate and potash levels. Paper presented at the All India Coordinated Rabi Pulses Workshop held at UPIAS, Kanpur, 1974.

Leather, J.W. 1910. Water requirements of crops in India. Mem. Dep. Agric. India (Chem. Sr.) 1(8): 133-184.

Mani, V.S., K.C. Gautam, G. Kulshrestha and Bhagwan Das. 1974. Chemical weed control in rabi pulses. Paper presented at the Workshop of All India Coordinated Pulse Improvement Project. UPIAS, Kanpur, 1974.

Manjhi, S. 1968. Response of gram to varying levels of P alone and in combination with N and K applied broadcast and at ploughsole. M.Sc. Thesis of P.G. School, IARI, New Delhi, 1964.

Mann, H.S. 1968. Manuring of pulse crops - neglected aspect that results in poor yields. Indian Fmg. 17(11): 7-8.

Mehta, T.R. 1968. Pulses could play a larger role in Indian agriculture. Indian Fmg. 17(11): 23-25.

Moolani, M.K. and S. Chandra. 1970. Gram cultivation in Haryana. Haryana Agricultural University, Hissar. p. 15.

Panikkar, M.R. 1961. Growing pulse crops - 1. Gram. Fert. News 6(3): 16-19.

Panwar, K.S. and A.S. Misra. 1973. Recommendations for the agronomy of *kharif* pulses based on the research work done during kharif, 1971-72, and 1972-73 at the UPIAS, Kanpur. Paper presented at the 9th All India Pulse Research Workers Workshop held at IARI, New Delhi, June 7-9, 1973.

Pathak, G.N. 1970. Red gram. In *Pulse crops* of *India*. ICAR, 14-53.

Prasad, S. 1964. Phosphate manuring of gram under rainfed conditions. M.Sc. Thesis of P.G. School, IARI, New Delhi, 1964.

Rao, J.V. 1974. Studies on fertilizer management of wheat in 'maize-wheat' and '*arhar*-wheat' cropping systems. Ph.D. Thesis submitted to P.G. School, IARI, New Delhi, 1974.

Sankaram, S. and A. Damodaran, 1974. Determination of effective herbicides for weed control in red gram. III. Annual Report, 1973-74, Tamil Nadu Agric. University: 105-106.

Saraf, C.S. and R.J. Davis, 1969. Water management for pulse crops. Symposium on water management. PAU, Hissar, 1969.

Saraf, C.S., I.P.S. Ahlawat and A. Singh. 1974. Report of the agronomic investigations on rabi pulses at IARI, New Delhi, during 1973-74. All India Coordinated Rabi Pulses Workshop UPIAS, Kanpur. 1974.

Saxena, M.C. 1968. Report of the experiments on *Kharif* pulses conducted during 1968 at Pantnagar. Proceedings of 1st Annual ICAR Workshop Conference on Pulse Crops. Feb. 3-5, 1969, New Delhi:63-71.

Saxena, M.C. and N.P. Singh, 1971. Response of gram to plant population and planting geometry. G.B.Pant Univ. Agric. & Tech., Pantnagar, Annual Report, 1970-71: 148.

Saxena, M.C. and Y. Singh, 1970. Relative susceptibility of important varieties of some pulses and soybean to zinc deficiency. Paper presented at III Annual Workshop of Coordinated Scheme on Micronutrients of Soils held at Ludhiana, Oct. 5-7, 1970.

Saxena, M.C. and D.S. Yadav. 1971. How about mixed cropping in short duration *arhar?* Indian Fmg. 20(11): 41.

Saxena, M.C. and D.S. Yadav. 1973. Field studies on parallel multiple cropping with short duration arhar. Bull, on 'Multiple Cropping', Indian Soc. of Agron., 1973: 232-238.

Singh, D. and K.S. Rathi. 1972. Balanced fertilizer use in pulse crops. Seminar on Balanced Fertilization of Commercial Crops. Oct. 25, 1972. F.A.I. & Department of Agric, U.P. at Lucknow.

Singh, K. 1969. Response of 4 Bengal gram varieties to different fertilizer treatments. M.Sc. Thesis submitted to the P.G. School of IARI, New Delhi, 1969.

Singh, L., S.K. Maheshwari and D. Sharma. 1971. Effect of date of planting and plant population on growth, yield, yield components and protein content of pigeon pea (*Cajanus cajan* (1.) Millsp.). Indian J. Agric. Sci. 41 (6): 535-538.

Singh, R.G. 1971. Response of gram (*Cicer arietinum*) to the application of nitrogen and phosphate. Indian J. Agric. Sci. 41(2): 101.

Singh, R.P. 1972. Studies on the efficiency and economics of fertilizer use for major *Karif* and *rabi* crops under rainfed conditions. Ph.D. Thesis submitted to Agra University, Agra.

Singh, S. 1973. Report of the agronomic research work carried out on Rabi Pulses at Hissar during 1972-73. All India Coordinated Rabi Pulses Workshop. Bose Research Institute, Calcutta, Sept. 10-14, 1973.

Sinha, M.N. 1972. Effect of doses and method of phosphorus placement on growth, yield and uptake of phosphorus by gram (*Cicer arietinum*) under rainfed conditions. Indian J. Agron. 17(1): 1-4.

Tripathi, R.S. 1967. Mutual interaction of gram (*Cicer arietinum*) and two common weeds (*Asphodelus tenuifolius* and *Euphorbia dracuncuToTdes*). Trop. Ecol. 8: 105-109.

United States Department of Agriculture, Agricultural Research Service and U.S. Agency for International Development 1968. Progress Report No.6: 123-187.

Venkateswarlu, P. 1967. A brief summary of the pulses work being carried out at the various pulses research stations in Andhra Pradesh. Paper presented at the I All India Pulses Workshop Conference held at New Delhi.

THE ROOT NODULE SYMBIOSIS OF CHICKPEA AND PIGEONPEA

P. J. Dart, Rafiqul Islam and A. Eaglesham[1]

NUTRIENT REQUIREMENTS

Nitrogen

Nitrogen fixation by root nodules can supply most, and sometimes all the nitrogen needed for good yields of grain legumes. Nodulated cowpeas continuously supplied 25 ppm N yielded as much (about 80 g seeds/plant) as plants given up to 240 ppm N continuously (Summerfield, Michin, Eaglesham and Dart unpublished). Large amounts of N in the available soil pool generally inhibit fixation often without increase in grain yield although total N uptake by the plant may be increased. Small additions of N fertilizer occasionally stimulate nitrogen fixation and grain yields.

Inadequate nitrogen fixation is often blamed for poor yields, but this can only be established by comparing yields of the following treatments:

a) seed properly inoculated with an effective *Rhizobium* strain

b) seed also inoculated and nitrogen fertilizer generously added (at least 150 kg N/ha)

c) uninoculated, surface sterilized seed.

If treatment (a) yields more than (c) then inoculation will be necessary. If yields are poor, with little difference between treatments (a) and (b), factors other than poor nodulation and nitrogen fixation are limiting yields, such as pests, diseases, environmental and/or nutritional factors.

Other Nutrients

Deficiencies in the soil nutrients-phosphorus, sulphur, calcium, potassium, molybdenum, zinc, iron, copper and boron--can be overcome with fertilizer addition, often with spectacular results from small additions of 1-5 kg/ha for the trace elements. Most legume varieties have a high requirement for P, and there is a specific requirement for Mo in nitrogen fixation over and above the amount needed for growth on combined nitrogen. In soils where the available phosphate is low, endomycorrhizal associations may enhance legume uptake of phosphorus with consequent better plant growth stimulating nitrogen fixation (Crush 1973; Mosse 1973).

Correcting for excess levels of Mn, Al, and low pH is more difficult, particularly in tropical soils. Liming the soil is often too expensive but pelleting seed with lime may help; any phosphorus fertilizers added should have a high Ca:P ratio. Legumes can perhaps be bred which are more tolerant in their nodulation of high levels of Mn and Al (e.g., Franco and Dobereiner 1967, 1971; Foy 1974).

RHIZOBIA

Yields of chickpea and pigeonpea may be limited with rhizobia present in soils, if they are sparsely and unevenly distributed, or if the strains present are poorly effective in fixing nitrogen. High soil temperatures can reduce numbers of rhizobia, particularly in soils low in organic matter and clay (e.g., Marshall 1968). Little is known about the distribution and numbers of rhizobia in

---

[1] Rothamsted Experimental Station, Harpenden.. Herts, England

tropical soils, partly because counting methods are tedious and space consuming, and require a glasshouse which can be kept near ambient temperatures in a hot climate.

Soils often contain a diversity of strains able to nodulate the same group of legumes. When uninoculated plants yield substantially less than those given N fertilizer, ineffective or poorly effective strains may have induced nodule formation. This may be remedied by inoculation with effective strains of rhizobia, able to form nodules in competition with the existing, less effective population.

Little is known about the factors involved in strain competition in nodule formation. Where the indigenous soil population is large, the technique of inoculation must be such that sufficient rhizobia are added to the seed. The effective strain can be introduced into the soil by other means such as watering into a furrow below the seed. The method must ensure that it is the effective inoculum strain which causes most nodule formation. We do not yet know practical ways of introducing superior strains in the presence of large, less effective populations. The solution could be to find, or produce, strains that are superior competitors as well as good nitrogen fixers, coupled with a new method of inoculation.

A good inoculum strain also needs to be stable genetically, and to be able to persist in the soil as a saprophyte independent of the legume, so that it can nodulate subsequent crops of the same or a related legume.

Soil populations of rhizobia are affected by soil type and chemical composition. The cropping history can vary from field to field. Thus the need to inoculate legumes must be assessed on a local level.

Peat is the preferred carrier for Rhizobium in inoculants because it can carry large numbers of bacteria, adheres well to seeds, and helps maintain Rhizobium viability on the seed before germination. 5obd peat Inoculants should not be costly, and their use is a cheap Insurance against poor nodulation. It 1s essential, however, that they contain adequate numbers of the specified strain of rhizobia, and to ensure this an independent control service is required with legislative powers to prohibit distribution of poor batches of inoculants.

THE CHICKPEA - RHIZOBIUM SYMBIOSIS

Cicer spp. are nodulated only by specific Rhizobium strains which apparently do not nodulate any other legumes (e.g., Raju 1936). On yeast mannitol media, Cicer rhizobia are usually fast growing with much gum production (Okon et al. 1972).

Rhizobium enters chickpea roots through root hairs via Infection thread formation (Arora 1956). The nodules formed are initially elongate with a terminal meristem which may branch several times to form a coralloid structure sometimes up to 3 cm across. Senescence begins fairly early in life of the nodule forming a brown or green zone at the base which enlarges during nodule growth.

Chickpeas in some areas of India and Israel responded significantly to inoculation (Sen 1966; Okon, Eshel and Henis 1972; Sundara Rao, Madhava Reddy and Chandrasekhar 1973; Patil and Medhave 1974), whereas in other experiments inoculation had no effect though yields were low. Soil already containing adequate members of effective rhizobia and other factors limiting the symbiosis could account for this response. Dadarwal and Sen (1973) suggested that inoculation can fail because the rhizobia on the seed rapidly die, possibly as a result of toxic products diffusing from the seed coat.

Low soil moisture and high soil temperatures can restrict the formation and function of nodules. Sen (1966) suggested that high soil temperatures may limit nitrogen fixation by Cicer rhizobia, and we have examined this with a view to selecting strains better adapted to such conditions.

Chopra and Subba Rao (1967) suggest that rapid senescence of chickpea nodules soon after flowering will result in low nitrogen fixation during pod fill. At that time the plant requires rapid nitrogen uptake which the remobilization of already fixed nitrogen within the plant may not satisfy. We have also examined the effect of flowering on nitrogenase activity.

Effect of Root Temperature on Chickpea Nodulation

In one study C. arietinum was inoculated at sowing and grown in a sterilized, *quartz* sand and grit mixture, watered daily with nitrogen-free nutrient solution (Dart, Day and Harris 1972). The pots were placed in water baths maintained at constant temperatures. The common air temperature for all plants fluctuated between 24°-27° C during the day and 18°-21° C at night. The 12h photoperiod of 16,000 lx at seedling level was provided by Warm White Fluorescent tubes. At harvest each nodulated root was assayed for nitrogenase activity. The nodule distribution was recorded and the dry weights and nitrogen contents of the plant parts determined.

In a preliminary experiment a Deshi variety was grown at root temperatures of 15°, 20°, 25°, 30° C and inoculated with strains CB1189 or 27A2. Nodules were present and active at three weeks at 20° and 25° and at four weeks at 15°, but were not active until seven weeks at 30°. No nodules were formed by either strain at 33° C, and plants died at 35° C. At 35 days, dry matter production was slightly less at 30° and 33° C, but by 63 days there were marked differences in growth with the most at 25° C and *very* little at 30° and 33° C(Figure 1). Nitrogen fixation (total plant N - seed N) differed little between 15° and 25° C but no fixation occurred at 30° C. Strain CB1189 was slightly more effective than 27A2. Chickpea is usually grown in the cool season, but in the subtropics temperatures may rise to these levels during part of the growing season.

Root Temperature Effect with Five <u>Rhizobium</u> Strains

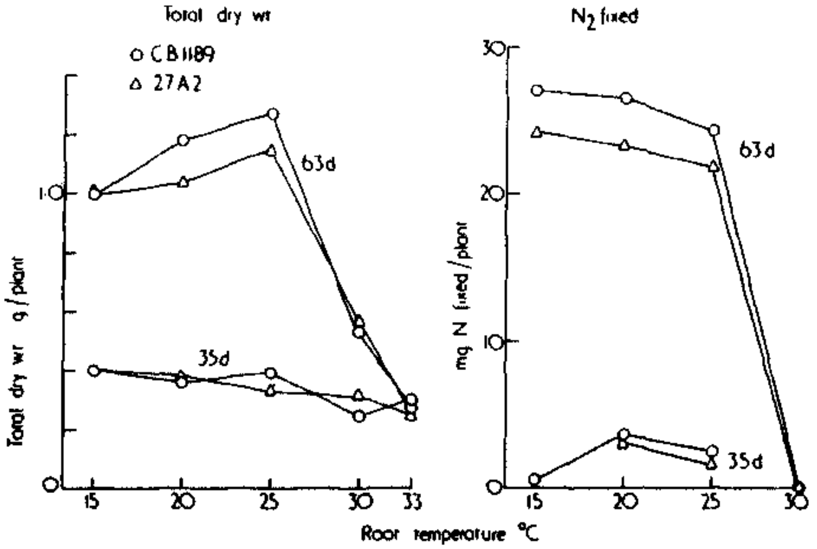
Description of Experiment

Five different Rhizobium strains were used to inoculate an Indian Deshi and Kabuli variety and an Iranian Kabuli variety, growing at root temperatures of 23°, 30° and 33° C to see if the poor performance at high temperatures was affected by strain. Strains Ca-1 and Ca-2 were obtained from the Division of Microbiology, IARI, New Delhi; 27A2 and 27A9 from the Nitragin Company, Milwaukee, U.S.A. and CB1189 from CSIR0 Division of Tropical Agronomy, Brisbane, Australia. Plants were harvested 42 days after sowing.

Results - Nodule Formation

No nodules were formed by any strain at 33° C, even though several amendments such as the addition of 10% Kettering clay-loam soil, peat, small amounts of ammonium nitrate, or growth in soil were tried. Plants given combined nitrogen grew well. The lack of nodulation was not due to lack of rhizobia.

Figure 1. Dry Weight Production and Nitrogen Fixation by 35 and 63-Day Old <u>Cicer arietinum</u> Plants Inoculated with Strains CB1189 and 27A2 and Grown at Root Temperatures from 15 to 33 C



Results - Nitrogen Fixation

Strains differed slightly in the amount of nitrogen fixed at 23° C, with different rankings between varieties (Figure 2). Nitrogen fixation was well correlated with plant dry weight production. The strains differed considerably in nodule weight produced, and in nitrogenase activity per plant and per gram nodule tissue, neither of which correlated well with N fixation. An assay of nitrogenase activity at a single harvest is thus unlikely to be of use in strain selection (Table 1, Figure 2).

At 30° C, less nitrogen was fixed and the differences between strains were much greater. Strain Ca-2 was more effective than the others, fixing more than 60% as much nitrogen as at 23° C with all cultivars. Strain Ca-1 was moderately effective at this temperature but the others were quite ineffective. The effect of the higher temperature was to reduce nitrogenase activity per g nodule tissue, possibly by accelerating basal nodule senescence.

Figure 2. Symbiotic Performances (a-nitrogen fixation, b-nitrogenase activity and c-plant dry weight) by the Strains Ca-I, CB1189, 27A9, 27A2, and Ca-2 at 42 Days with Cicer var. Iranian, Kabuli and Deshi at 23 and 30C Root Temperature

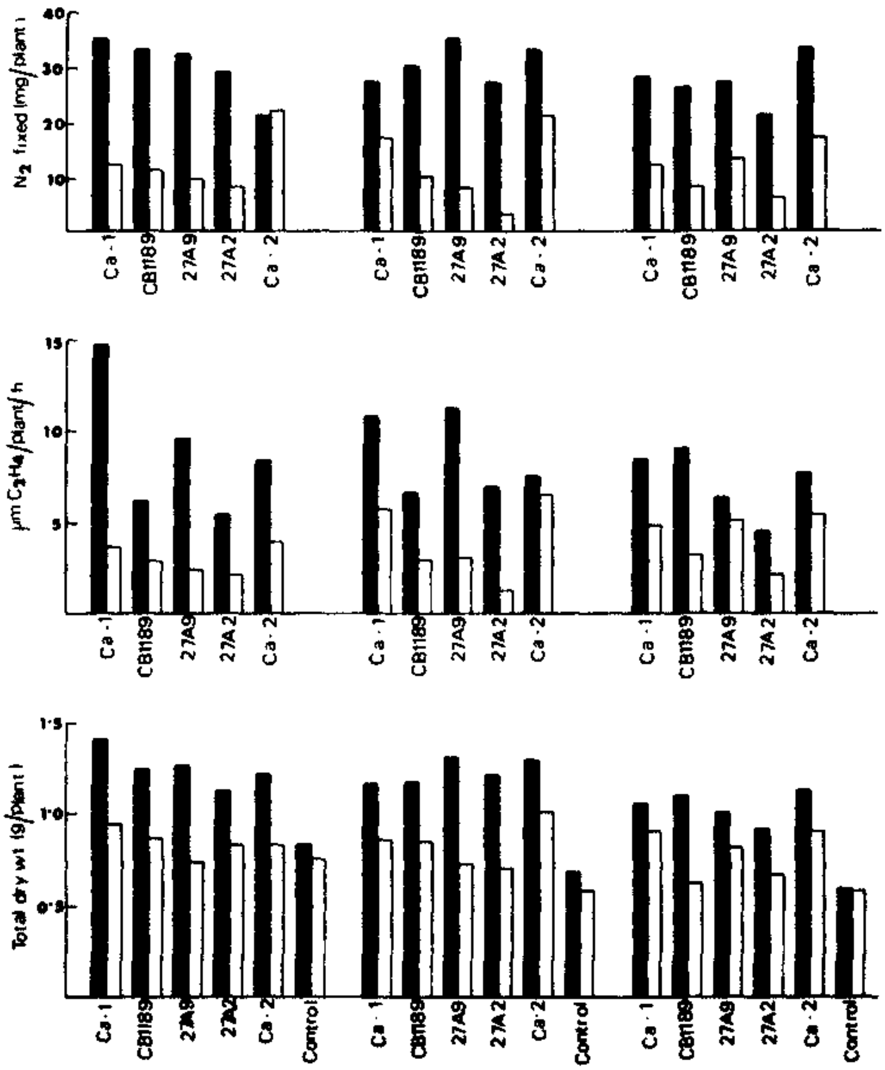


Table 1. Symbiotic Performance of 5 Rhizobium Strains with 3 Cicer Arietinum Varieties at Two Root Temperatures

	Rhizobium									
	CB 1189		27A2		27A9		Ca-1		Ca-2	
Temperature	23°	30°	23°	30°	23°	30°	23°	30°	23°	30°
DESHI										
D. Wt. nod./plant (mg)	89	56	79	55	84	82	82	64	87	76
N_2ase/plant	9.0*	3.1	4.5	2.1	6.3	5.1	8.3	4.8	7.6	5.5
N_2ase/g nodule	105*	51	59	36	75	63	105	76	92	69
N_2 fixed (mg/plant)	26	8	21	6	27	13	28	12	28	17
KABULI										
D. Wt. nod./plant (mg)	98	96	93	65	108	90	78	93	103	85
N_2ase/plant	6.5*	3.9	6.9	1.32	11.3	3.1	10.8	5.7	7.5	6.5
N_2ase/g nodule	68*	41	70	20	104	34	142	65	74	60
N_2 fixed (mg/plant)	30	10	27	3	35	8	27	17	33	21
IRANIAN										
D. Wt. nod./plant (mg)	100	86	86	82	96	70	104	81	96	104
N_2ase/plant	6.1*	2.8	5.5	2.1	9.6	2.4	14.8	3.6	8.3	3.8
N_2ase/g nodule	61*	32	63	23	102	36	139	43	86	37
N_2 fixed (mg/plant)	33	11	29	8	32	9	35	12	21	22

* μ moles C_2H_4/h

42 day harvest

Root Temperature Effect with Ca-2 and 27A2

Description of Experiment

Strain Ca-2 and 27A2, which differed most in their response at 30° C were examined further, using the Indian Kabuli variety. They were grown at 23° C and 30° C root temperatures and harvested at weekly intervals from three to ten weeks after sowing.

Results

Figure 3 shows that little difference occurred in growth between treatments up to five weeks. Thereafter, plants inoculated with strain 27A2 grew and fixed little at 30° C, but those given strain Ca-2 continued growing and at ten weeks had fixed about 60% as much No as at 23° C as in the previous experiment. Strain Ca-2 was again slightly more effective than strain 27A2 at 23° C.

Figure 4 shows that nodule growth was similar for both strains throughout the ten week period. An exception was 27A2 plants grown at 30° C which produced less weight of nodule, although this reduction was not as marked as was plant growth and N_2 fixation. This suggests that the differences in nitrogen fixation were primarily related to differences in efficiency (N_2-ase activity per g nodule weight) rather tnan to total nodule weight.

Figure 5 shows that nitrogenase activities per plant increased until the seventh week for all combinations and then declined, although for 27A2 at 30° C activity increased very little after the fourth week. N_2-ase activities per plant correlated well with the amounts of N_2 fixed. The decline in N_2-ase activity was not associated with flowering which began about 35 days from sowing. By the

Figure 3. Dry Weight Production by Cicer arietinum Inoculated with Strain Ca-2 or 27A2 and Grown at Root Temperatures of 23 or 30°C. (The amounts of N fixed over the 10 week period are also listed.)

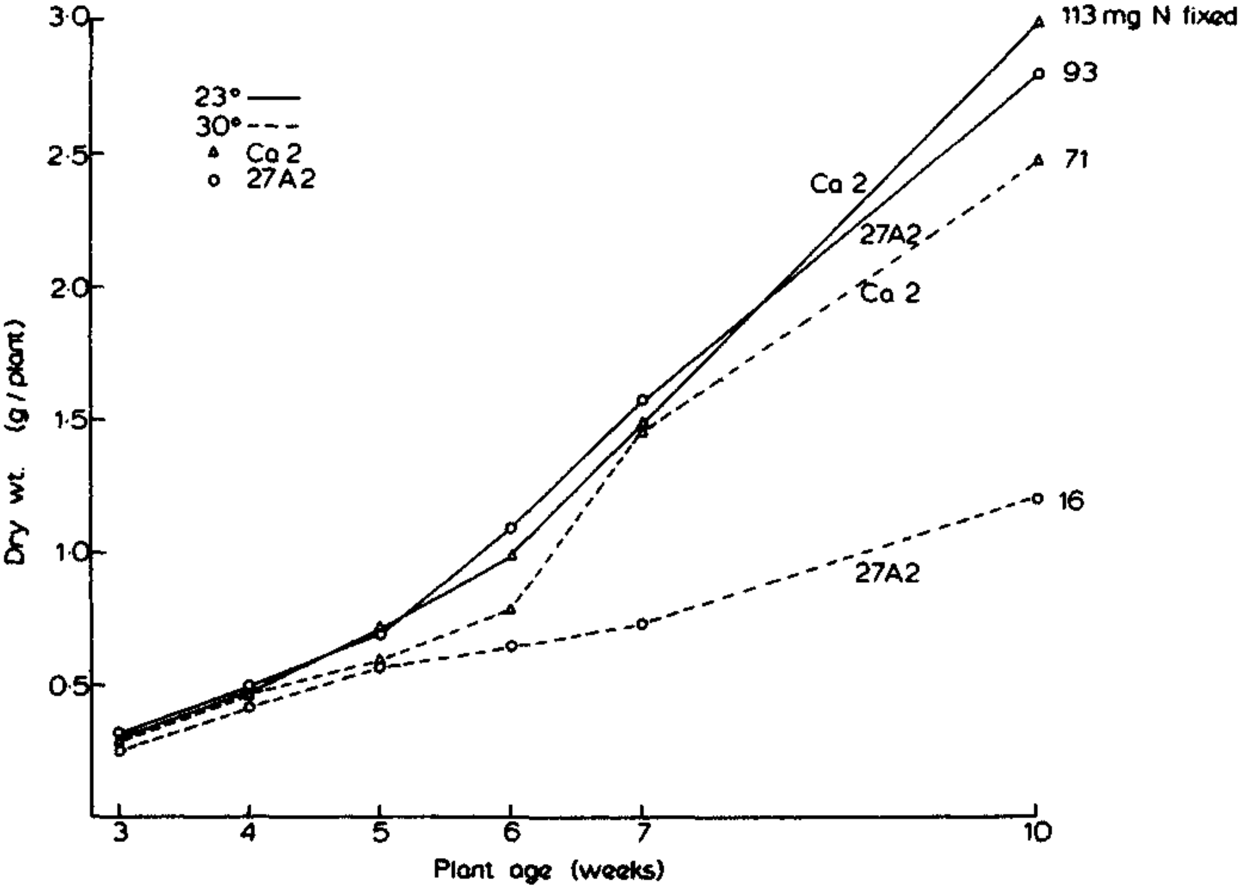


Figure 4. Nodule Production by Cicer arietinum Plants Inoculated with Strains Ca-2 or 27A2 and Grown at Root Temperatures of 23 and 30 C

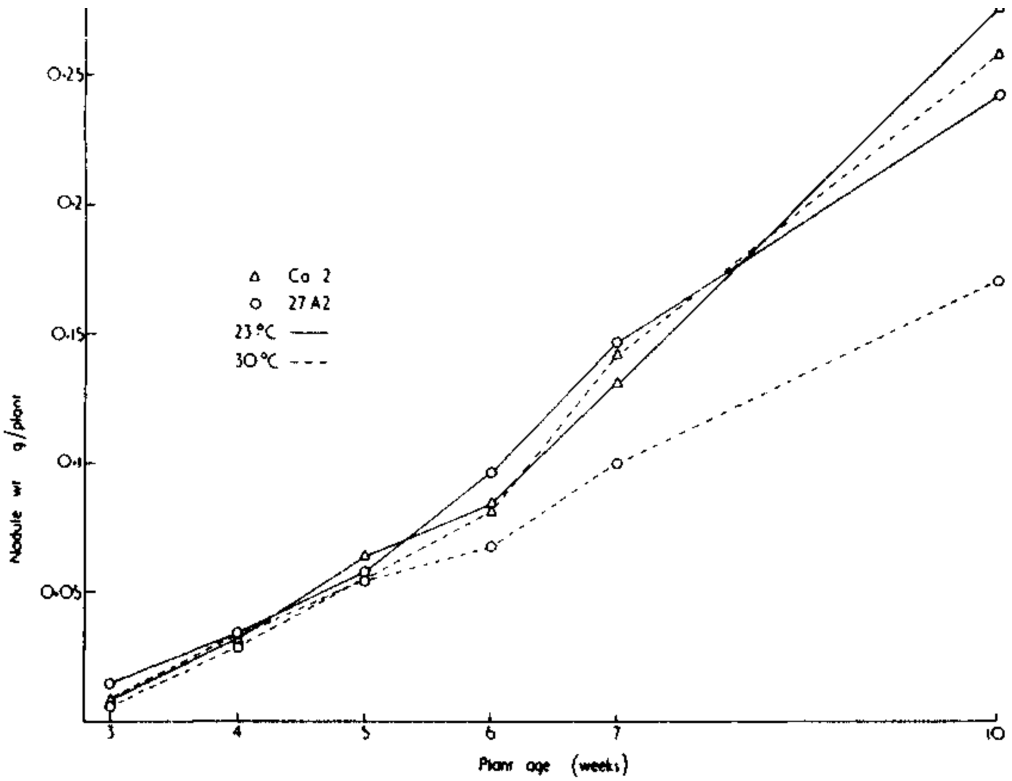
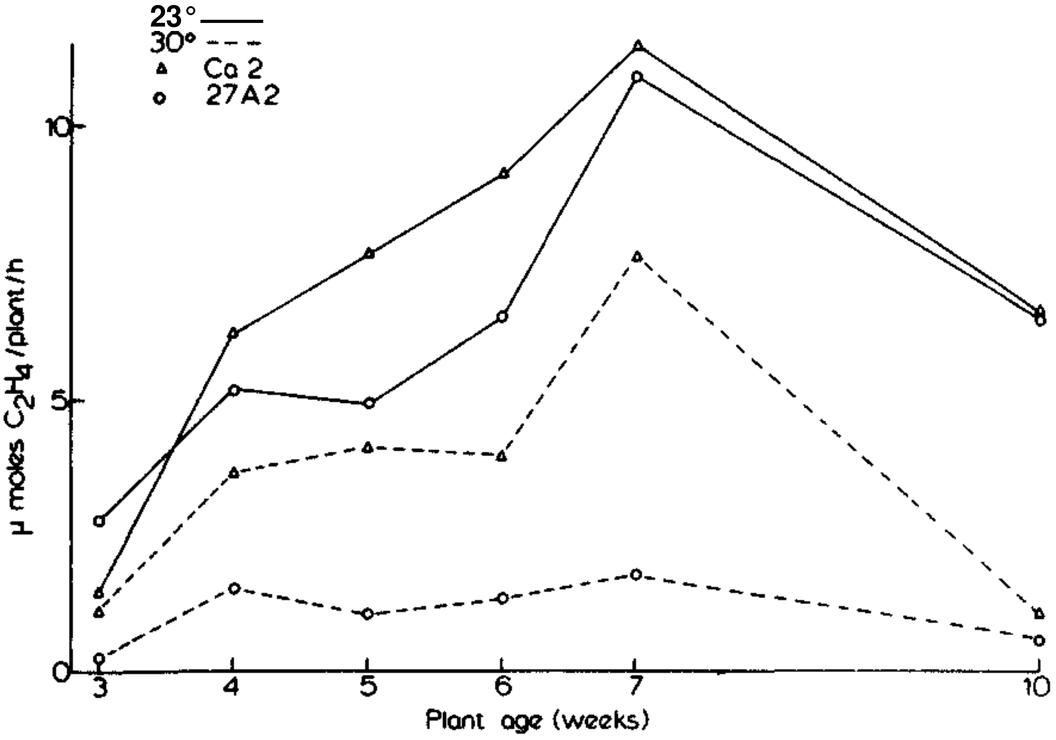


Figure S. Nitrogenase Activity (per plant) for Nodulated Roots of <u>Cicer arietinum</u> Inoculated with Strain Ca-2 or 27A2 and Grown at Root Temperatures of 23 and 30



tenth week, pod fill was well advanced and plants were senescing. Nodule efficiencies declined for all combinations after four weeks of plant growth, when nodules were less than 14 days old.

Figure 6 shows nitrogenase activity of Cicer nodules formed at 23° C, near the optimum temperature for growth and N2 fixation, and incubated at a range of temperatures from 6° to 40° C. Acetylene reduction was found over the whole temperature range with maximum activity between 24° and 33° C, and a rapid decline at higher temperatures. Thus the lower efficiencies of nodules on plants grown at 30° C in the previous experiments were not due to an effect of temperature on the functioning of the nitrogenase enzyme but were related to the amount of enzyme present.

Effect of Transferring Nodulated Plants to High Root Temperatures

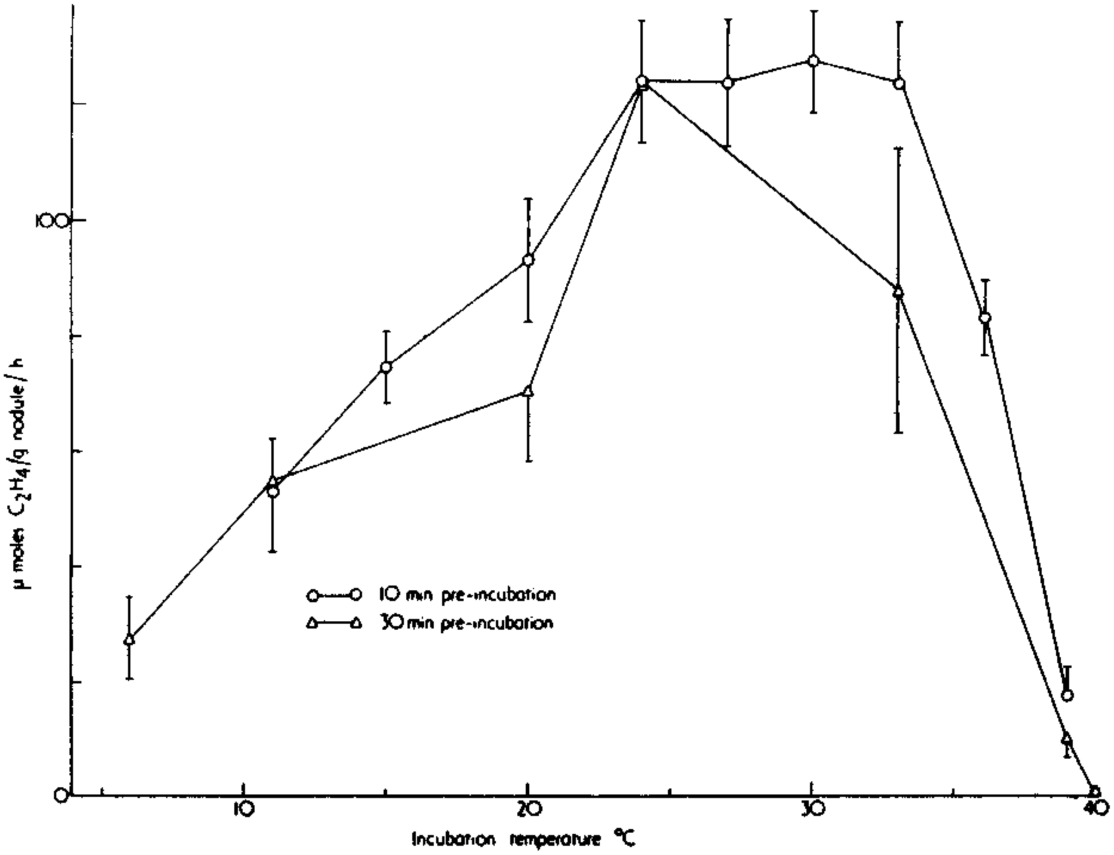
Description of Experiment

Plants nodulated and grown continuously at 23° C were transferred to root temperatures of either 33° or 36° C for periods up to seven days.

Results

Figure 8 shows that nitrogenase activity

Figure 6. **Nitrogenase Activity per g Nodule Weight for Nodulated Roots of Cicer arietinum-Cal Plants Incubated During Assay at Temperatures Ranging from 6° to 40°C. (Bottles containing the roots were equilibrated at the assay temperatures for 10 min. ○—○ or 30 min. △—△ before the C_2H_3 was added. Bars represent standard errors of the means for the eight replicate roots.)**



Rapidly declined under continuous high temperature and was zero after 48h at 36° C. After 72h at 33° C, it was only 17% of the controls at 23° C. When the high temperature treatment was applied for only 5h during the day--a situation perhaps nearer to that in field soils--nitrogenase activity also declined rapidly. Soil temperatures of 33° to 36° C in the zone where nodules form are not unusual in the subtropics. Three daily cycles of high temperature were sufficient to halve N_2-ase activities, with further decline after seven cycles.

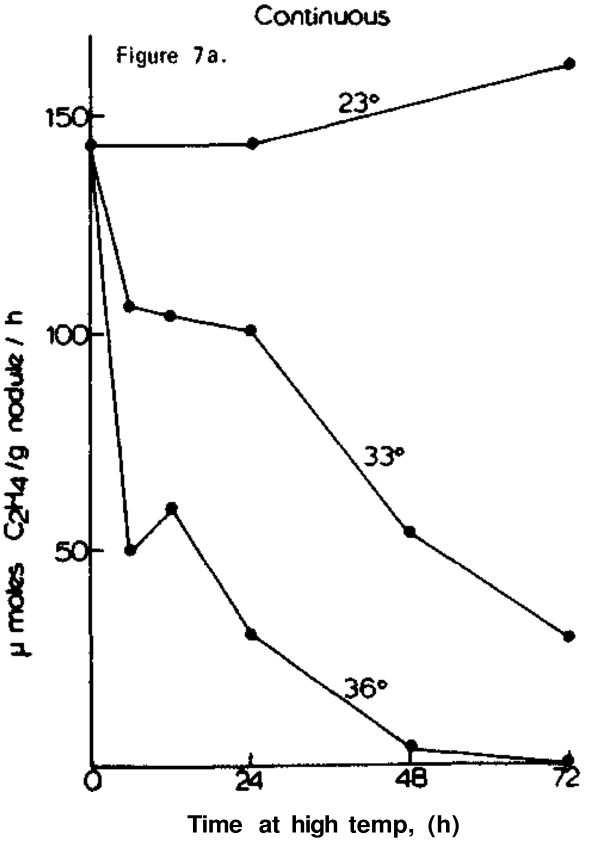
Effect of Transfer From High to Lower Temperatures

Description of Experiment

A subsequent experiment was done to find whether the N_2-ase activity lost during exposure to high temperature was restored when plants were transferred back to a lower temperature. Kabuli plants inoculated with strain Ca-2 were grown at 23° C root

Figure 7a. Effect of Transfer from a Continuous Root Temperature of 23° to 33° or 36° C on Nitrogenase Activity per g Dry Weight Nodule of Cicer ariettnum-Cal Plants. (Nodulated roots were assayed at the transfer temperatures.)

Figure 7b. Effect of Daily Increases of Temperature (cycling) from 23° to 33° or 36 C on N_2ase Activity of Nodulated Roots of Cicer arietinum-Cal Plants Grown at 23° and Assayed at the Transfer Temperature



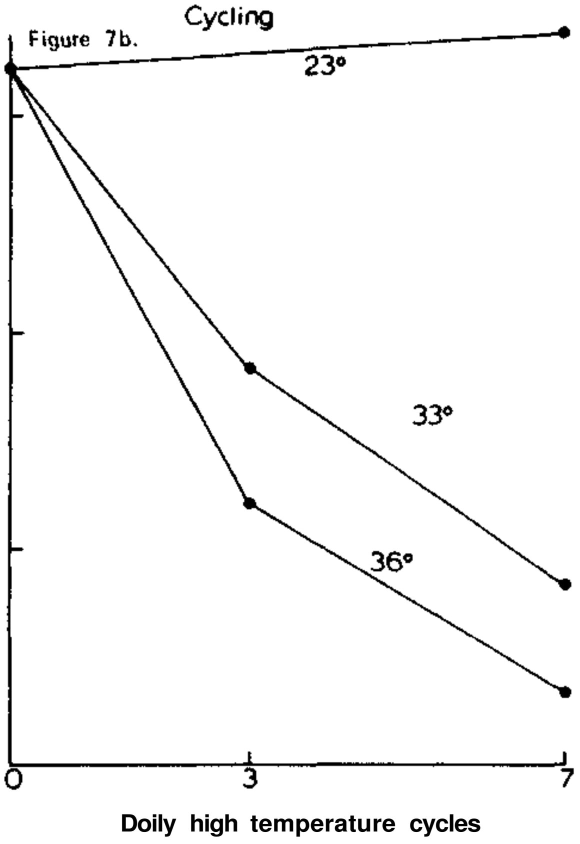
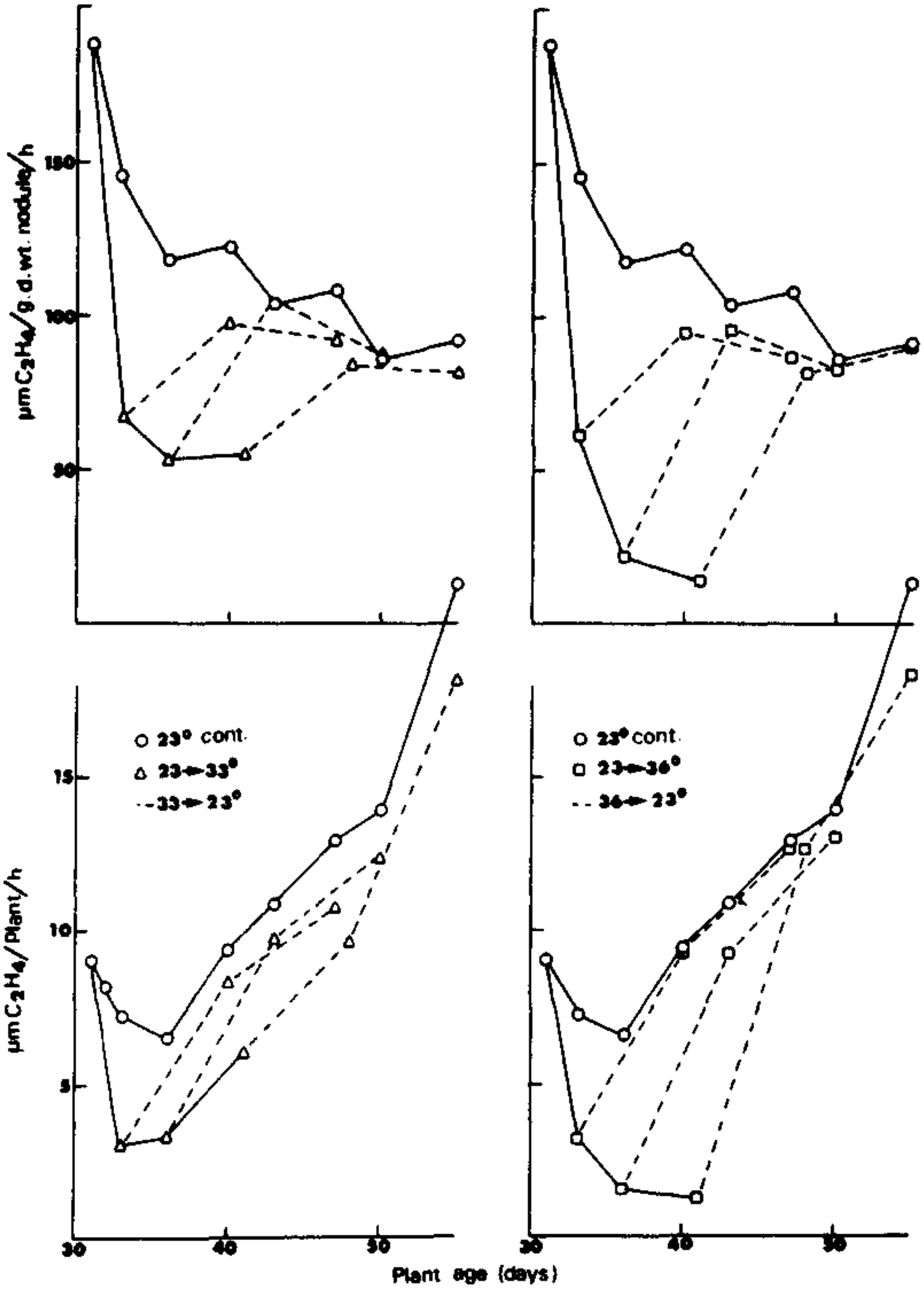


Figure 8. Nitrogenase Activity per Plant and per g Nodule Tissue of Nodulated Roots of <u>Cicer</u> when Transferred from 23° Root Temperature (○—○, controls remaining at 23°) to conditions where the Root Temperature Increased Daily to Either 33° (△———△) or 36° (□———□); Some Plants were Transferred Back to 23° After 2, 5 and 10 Cycles of High Temperature (broken lines)



temperature for 30 days. They were then transferred to baths in which the temperature cycled daily, increasing from 23° C at night to 33° or 36° C during the day (pot temperatures of 32.5° and 35° C), and cooling gradually to 23° C at night. The high temperature cycle began at 9 a.m. each day, taking 1.5h to rise to 33° C and was then maintained at this temperature for 6.5h. Temperature was then raised to 36° C, over 2h and maintained for an additional 6h.

The N2-ase activities of six plants from two replicate pots were assayed at 23° C after 2, 5 and 10 cycles of high root temperatures and just before the start of the next cycle. Some plants were transferred back to 23° C at the end of each of these cycles and their N_2-ase activities assayed after an additional 7 and 14 days growth. Control plants continuously grown at 23* C root temperature were also assayed.

Results

The nodule weight of the plants increased until 55 days in all treatments. Figure 8 shows that the N_2-ase activities of the plants transferred either to 33° C or to 36° C declined sharply during the first two cycles. After further cycles, N_2-ase activity per plant increased at 33° t but decreased at 36° C. Nodule efficiency (umol C_2H_4/g nodule tissue) did not decline further at 33° C, but did at 36° C. As expected, the Np-ase activity of control plants generally increased with time, but nodule efficiency gradually declined.

The rapid decline in efficiency over the first five days may reflect a difference in N_2-ase activity throughout the day. The high value for the initial control assay was possibly obtained because it was done just before the end of the photoperiod, whereas the other assays were carried out within 2h of the commencement of the photoperiod before the daily cycle of temperature increase began. When the plants were transferred back to 23° C after the cycles of high temperature, N2-ase activity returned to 60-100% of the control activity within seven days of transfer. This recovery resulted mainly from the rapid development of new, leghaemoglobin containing, bacteroid tissue.

Although N_2-ase activity was considerably decreased by two cycles at 33° C or 36° C compared to control plants grown continuously at 23° C, this had little effect on plant dry weight, measured 14 days after the high temperature treatment. With further cycles of high temperature, particularly at 36° C, dry matter production decreased compared to the control plants (Figure 9). However, the plants continued to accumulate dry matter even though N2-ase activity was decreased by longer root treatments.

Nitrogen fixation per plant followed this pattern (Table 2), and decreased by 21% and 28% at 33° and 36° C respectively after five cycles and by 34% after ten cycles at 36° C. With ten cycles at 33° C, N_2- fixation was less inhibited (by only 18% of the controls), presumably reflecting the recovery of activity during the last five cycles of the treatment. However, it seems unlikely that plants given five or ten cycles at high temperature could subsequently compensate for the loss in nitrogen fixation occurring during this period.

Effect of Daylength on the Chickpea Symbiosis

This section describes the effect of two different photoperiods, 11h and 20h, on chickpea symbiosis, for a comparison between similarly aged plants in either a vegetative or a reproductive phase.

Uniform seeds of an Indian Deshi and Kabuli variety, and a Bulgarian Kabuli variety were inoculated with strain CB1189 and sown in 1 sand: 1 grit mixture, watered with nitrogen-free nutrient solution (Carpenter 1966). Plants were grown in Saxcil MK II Controlled Environment Cabinets in 11h or 20h photoperiods. All plants received an 11h photosynthetic period of 26,000 1x, but one photoperiod was extended to 20h by nonphotosynthetic, incandescent light of 430 lx for 4.5h before and after the photosynthetic period. The day temperature of 23° C also lasted for 11h with a night temperature of 19° C. The relative humidity inside the cabinet was between 70% and 80%.

Plant Form and Dry Matter Production

All varieties produced more branches (>10 branches/plant) in 11h than in 20h. Figure 10 shows that new branches continued to form until 56 days for Deshi and 63 days for the Kabuli and Bulgarian varieties. Deshi produced slightly more branches than the other two. In 20h, the Bulgarian variety formed most lateral branches; some plants did not produce any lateral branches and others formed only two

Figure 9. Dry Matter Production of Cicer Plants Grown Continuously at 23° Root Temperature or when the Plants were Transferred to Conditions where the Root Temperatures Rose to 33°or 36° for 7h and 6h Respectively Each Day for 2, 5 and 10 Days and then Transferred Back to 23° for 14 Days Before Dry Weights Measured

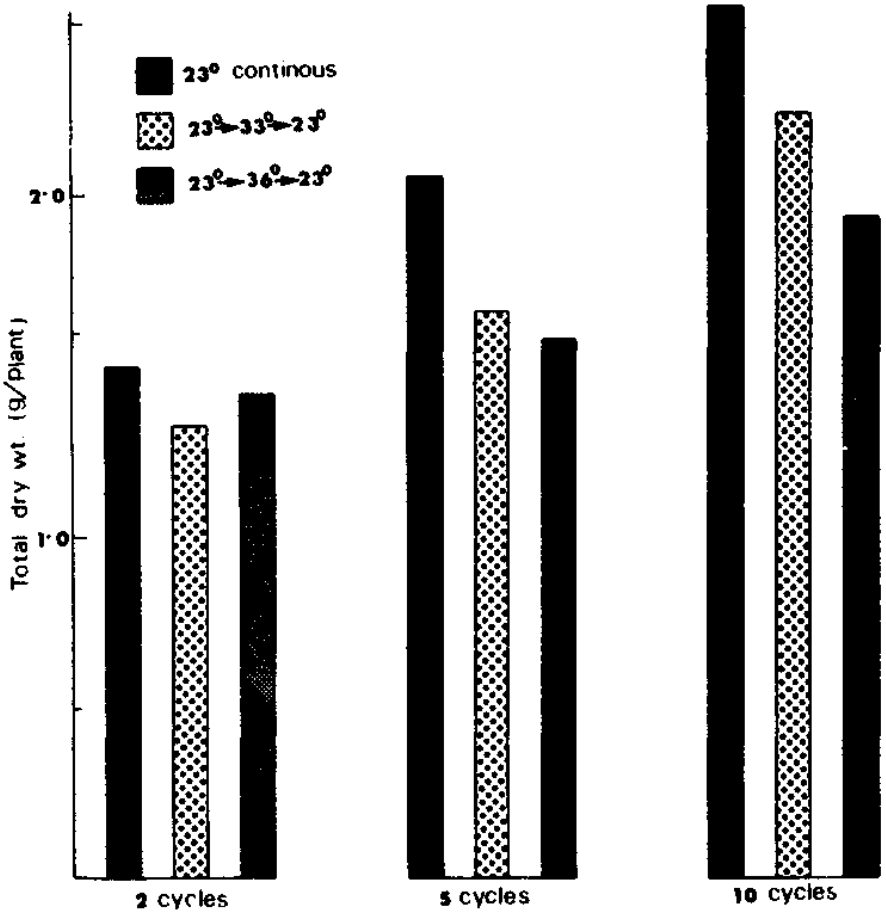
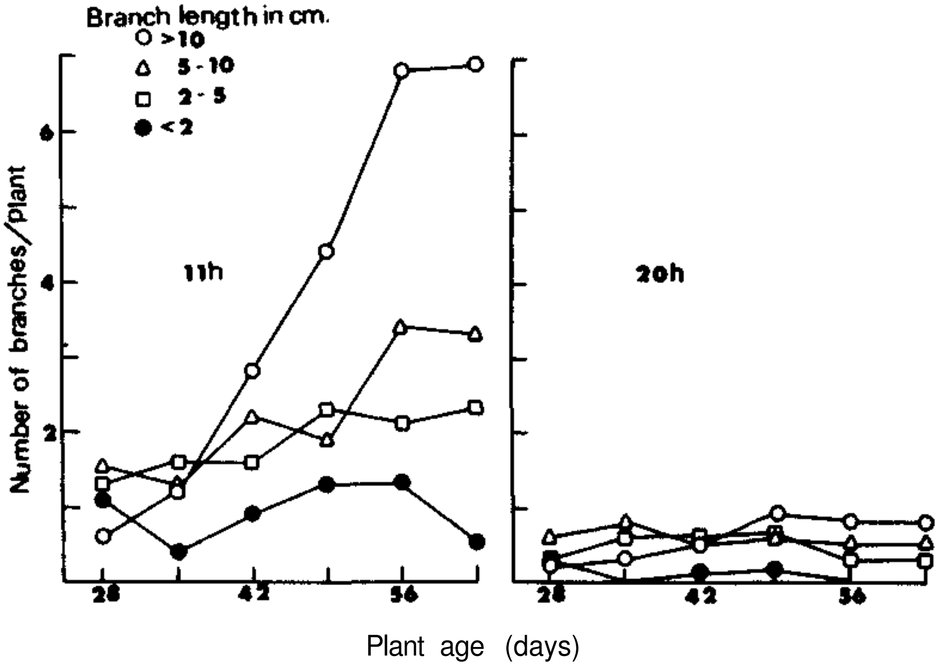


Table 2. Effect of Several Cycles of High Root Temperature on Nitrogen Fixation (mgN/plant) in Cicer

Temp. °C			
23° continuously	47.3	65.2	78.4
	Cycles at high temperature		
	2	5	10
23 --> 33 --> 23	38.8	51.8 (21%)*	64.5 (18%)
23 ---> 36 —> 23	45.9	47.0 (28%)	51.6 (34%)
	Age at harvest, 14 days after transfer back to 23°		
	46	49	54

* % decrease in fixation of controls

Figure 10. Lateral Branch Production by Deshi Cicer in 11h and 20h Photoperiods (11h photosynthetic period)



to five per plant.

In 11h, new branches were produced rapidly after 28 days and these also elongated rapidly. The early formed branches produced secondary branches up until about 56 days. In 20h the few branches formed elongated rapidly to more than 10 cm by 49 days. Virtually no new branches were produced after 42 days.

The height of the central axis for each variety in 20h increased very rapidly until 35 days and then more slowly. In 11h, the central axis continued to elongate until 65 days becoming taller than in the longer photoperiod for Deshi and Kabuli.

In 11h, Deshi and Kabuli flowered at 35 days but the Bulgarian variety had not flowered by 86 days. Deshi and Kabuli flowered at 28 days and Bulgarian at 33 days in the 20h photoperiod. In the 11h photoperiod most of the flowers were on lateral branches but many failed to form pods (Figure 11). A greater proportion of the flowers in 20h developed into pods. Failure to develop pods by many of the flowers and failure of pods to mature could be an incident of the cabinet conditions, and light quality may be the important factor. Daylength however has a striking effect on plant development in chickpea.

Most dry matter was produced in 11h (Figure 12). There was little difference between varieties in either daylength.

Nodulation and N_2-fixation

Plants nodulated within 14 days from sowing. There was much variation in the number of primary root nodules formed even among the three plants of the same pot. All three varieties produced more nodule tissue in 11h than ir 20h. In short days, nodule growth on Deshi continued until 86 days, until 78 days for Kabuli and 65 days for the Bulgarian variety. Nodule growth ceased by 50 days in 20h and after this time degeneration increased very rapidly.

Nitrogenase activity was present in all treatments by 18 days, only 4 days after the appearance of the first nodules. Nodules formed in short days were more effective with significantly different patterns of activity between varieties. Nitrogenase activity per plant increased until 45 days for Deshi, and 53 and 65 days for Bulgarian and Kabuli varieties in the 11h photoperiod. In 20h, activity reached a maximum at 40 days and then declined rapidly (Figure 13).

Daylength had little effect on the efficiency of the nodules (N_2-ase per g nodule).

Figure 11. Flower and Pod Formation on the Main Stem and Lateral Branches by Deshi Cicer in 11h and 20h Photoperiods (11h photosynthetic period)

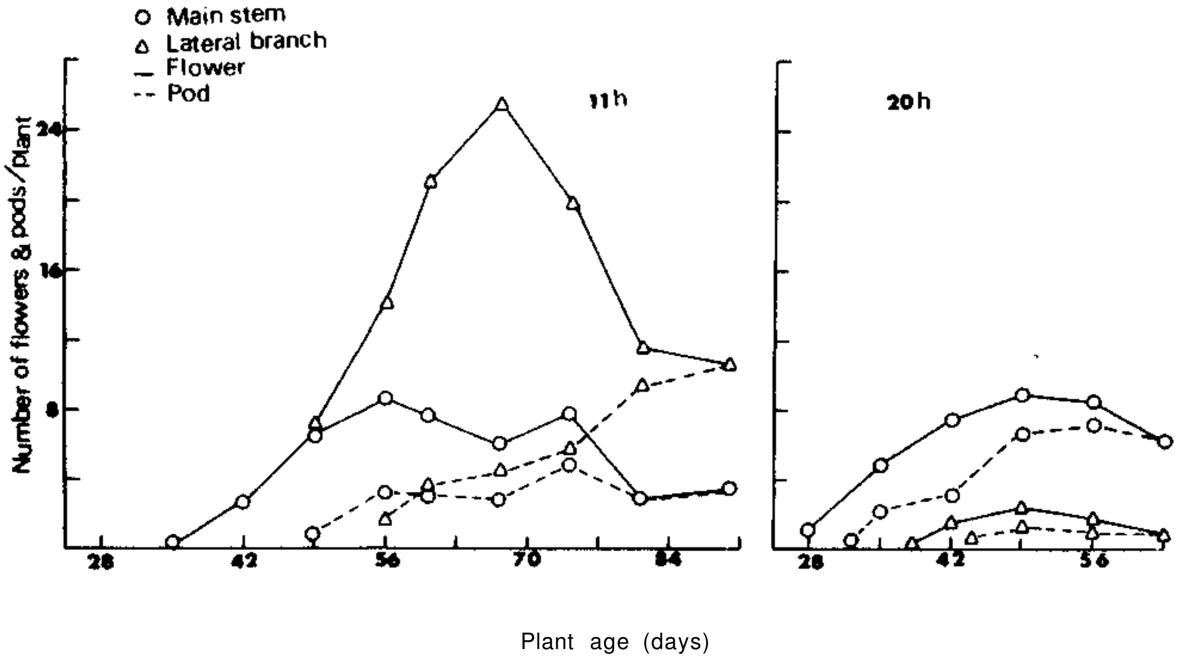


Figure 12. Dry Matter Production by Deshi, Kabuli and Bulgarian Cicer in 11h and 20h Photoperiod, 11h Photosynthetic Period

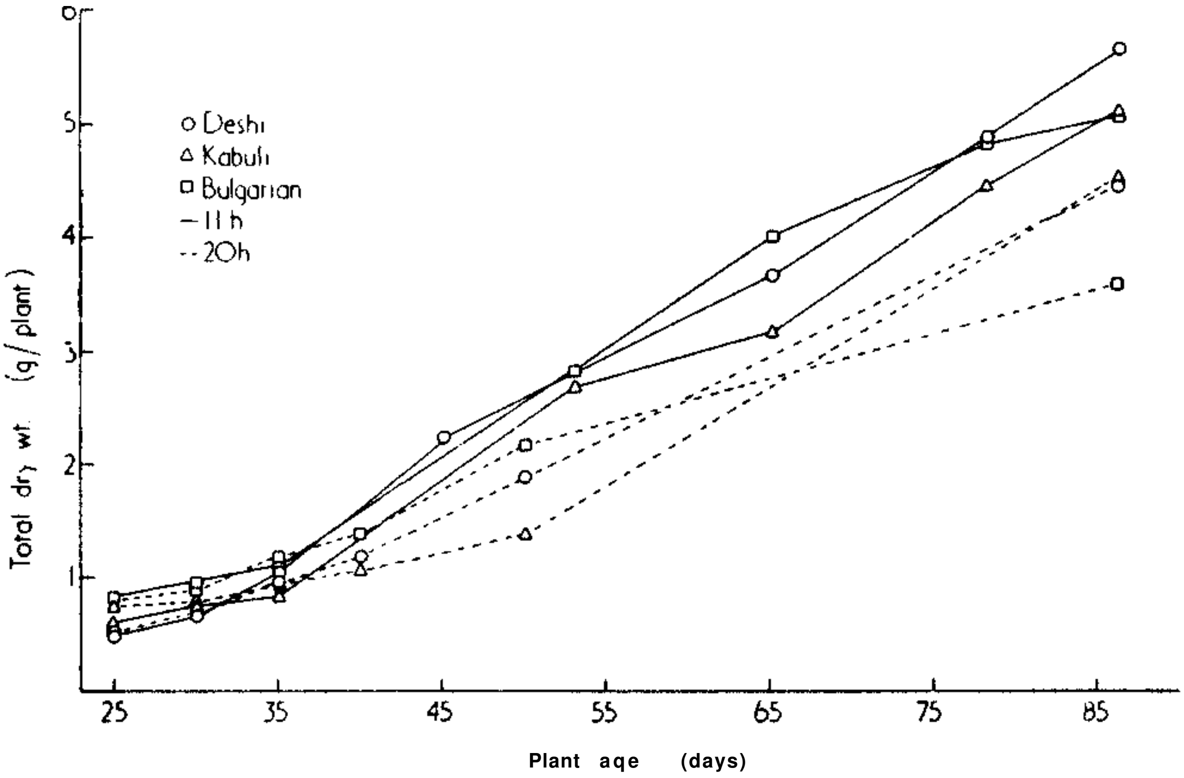
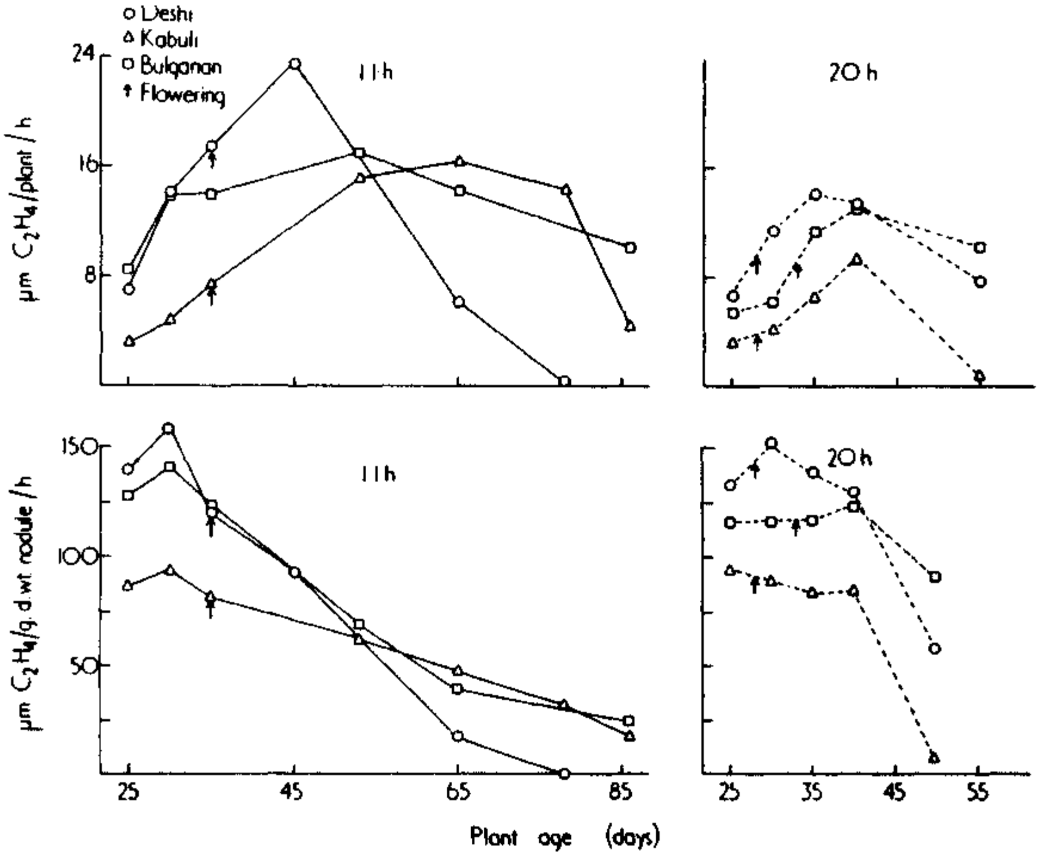


Figure 13 Nitrogenase Activity per Plant and per g Dry Weight Nodule for Nodulated Roots of Cicer in 11h and 20h Photoperiod, with an 11h Photosynthetic Period for Both



The higher activity per plant in 11h reflected the increase in nodule weight per plant. Generally as plants and nodules grew, nodule efficiency decreased, partly because some of the nodule tissue at the base of the nodules had started to senesce and had little or no N_2-ase activity.

Flowering had no immediate influence on N_2-ase activity. Although the Bulgarian variety did not flower in 11h this was not reflected in the pattern of N_2-ase activity. Compared to plants grown in tanks in the temperature experiments, the nodules had much more nitrogenase activity per g nodule tissue. The increased efficiency of the nodules in the daylength experiment was probably because the light intensity was about 10,000 lx greater in the growth cabinets than in the temperature experiments.

Table 3 shows that plants fixed more nitrogen in an 11h photoperiod than those grown in 20h. By 90 days, Deshi had fixed 24% and Kabuli 27% more nitrogen in 11h than in the 20h photoperiod, although the plants in 11h had only 13.5% more dry matter.

Table 3. **Effect of Daylength on Nitrogen Fixation (mg N/plant) for Deshi and Kabuli Cicer in 11 and 20 h Photoperiods**

Daylength (h)	Variety	Days from sowing			
		42	49	76	90
11	Deshi	8.1	14.1	39.3	51.0
	Kabuli	9.3	11.4	35.3	54.5
20	Deshi	5.3	5.9	28.7	38.7
	Kabuli	6.5	8.2	27.1	39.7

The increase in nodulation (both number

and weight per plant) in 11h could have two causes. The plants in 11h produced more root tissue with a consequent increase in infection sites for nodule formation. These plants also had more branches with many more leaves and thus photosynthesis probably supplied more carbohydrate to the roots to stimulate nodule formation and development. Singh (1958) also found that the reduced nodulation in Cicer in daylengths greater than 12h was associated with a decrease in leaf number.

Little is known of the effect of daylength on the translocation of carbohydrate or hormones to the roots and the subsequent effect on nodulation. Nodules are strong sinks for both. It seems likely that the main effect of daylength is on photosynthesis, as several varieties of nonnodulated Cicer plants, depending on inorganic combined nitrogen for their growth, produced more dry matter in a 12h day of 28,000 lx compared to either 16 or 8h days with the same light intensity (Sandhu and Hodges 1971).

PIGEONPEA EXPERIMENTS

Pigeonpea rhizobia are of the cowpea cross-inoculation group. This group of plants, have the ability to reciprocally nodulate with strains of rhizobia from most other plants in the group. Several subgroupings have been defined where relationships between host and strain are more specific, particularly for effective nodulation to occur, e.g., Stylosanthes spp. The cowpea rhizobia are usually slow growing strains with little gum production, but a few fast growing strains have been isolated. Pigeonpea nodules are usually elongate with a terminal meristem, with rhizobia disseminated in the nodule by cell division (Kapil and Kapil 1971).

We report here the response of pigeonpea cv Trinidad Dwarf No.5 (seed kindly supplied by Dr. John Spence, University of West Indies), cowpea cv K2809 (from IITA), and Siratro, to inoculation by Rhizobium strains isolated from Africa. Table 4 gives the origin of the strains.

Description of Experiment

Plants were grown in the summer in England in a heated glass house with day temperatures ranging from 27°-35° C and a night temperature of 25° C. The plants were inoculated at sowing into the sand:grit rooting medium which was flushed through daily with a nutrient solution containing 25 ppm N as nitrate, with care taken to prevert cross contamination. Uninoculated control plants remained unnodulated.

Dry Matter Production

Figure 14 shows the pattern of dry matter production. The three hosts responded quite differently to the 14 strains. Strains CB756 and CB1024 performed poorly, emphasizing the difficulty of choosing strains effective on a range of host species. An interaction between cultivar and strain may also complicate the selection and we found a marked interaction for cowpea (Summerfield, Minchin, Eaglesham, and Dart, unpublished). Both CB756 and CB1024 were selected for Poona cowpea and probably also under cooler soil temperatures than in our trial.

Performance of Strains

Strain 5018 was effective for all three hosts, but field testing would be essential before it could be recommended as a strain for inoculant production. The differences in the host responses illustrate the need to select strains which nodulate and fix N_2 well with other hosts in the cross-inoculation group. This is necessary because there is a strong likelihood that other plants in the group (which includes groundnut) would be sown later in the same field. Inoculant production is easier if one strain is suitable for several legumes. The limitations of inoculants containing more than one strain can be deduced from our results. One of the strains may well form most of the nodule tissue on a plant, i.e., is competitive in nodule formation, but be poorly effective in fixing N_2.

Figure 15 shows the pattern of nodule production by these strains. All strains nodulated siratro—often used as the test plant when counting the numbers of Rhizobium in the cowpea group by a serial dilution-plant nodulation method because of its small seedling size. Strain 5017 nodulated siratro only. Strains 5000, 5016 and 5011 did not nodulate pigeonpea, but did nodulate cowpea. Nodule tissue production was well correlated with plant growth for pigeonpea and siratro but not for cowpea.

Figure 14. *Rhizobium* Strain Trial with Isolates from Nigeria, Uganda and Rhodesia, with Cowpea cv K2809, Pigeonpea cv Trinidad Dwarf No. 5 and Siratro. (Total dry weight production per plant at 8 weeks for cowpea and pigeonpea, 7 weeks for siratro.)

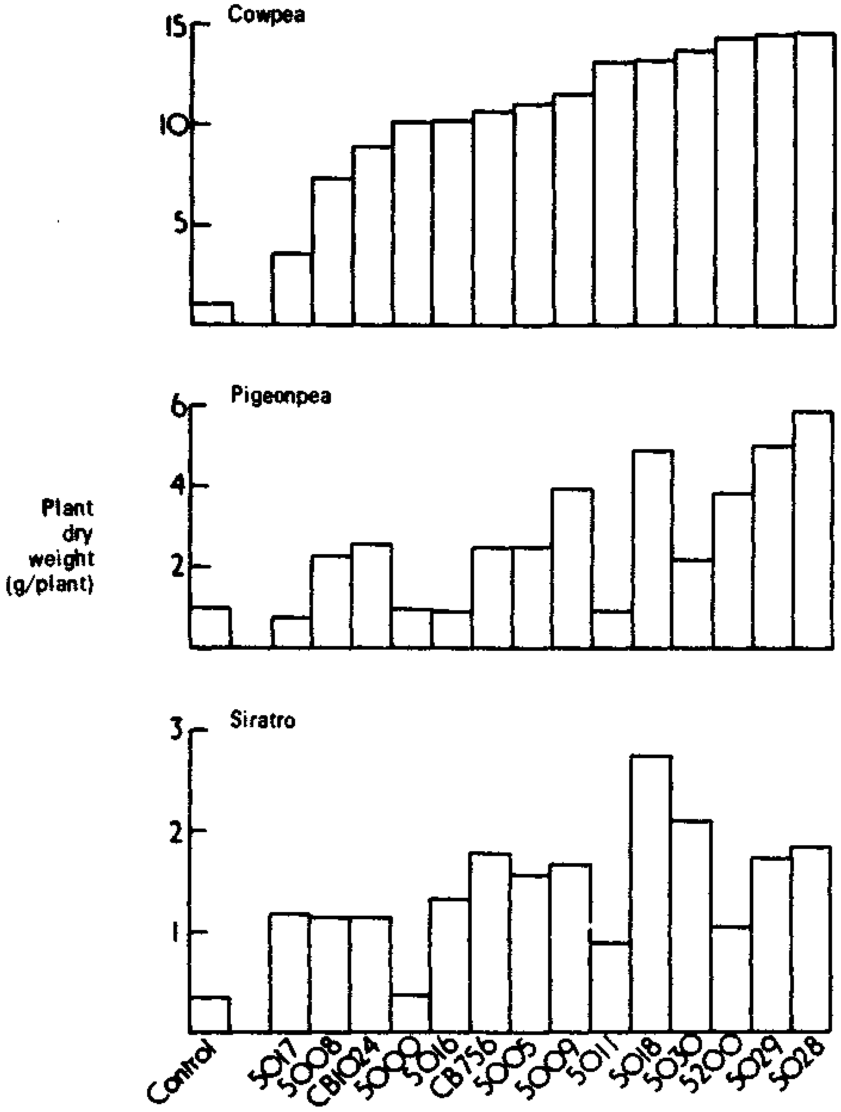


Figure 15. *Rhizobium* Strain Trial with Cowpea cv K2809, Pigeonpea cv Trinidad Dwarf No.5 and Siratro. (Nodule production, g dry weight per plant, at 8 weeks for cowpea and pigeonpea, 7 weeks for siratro.)

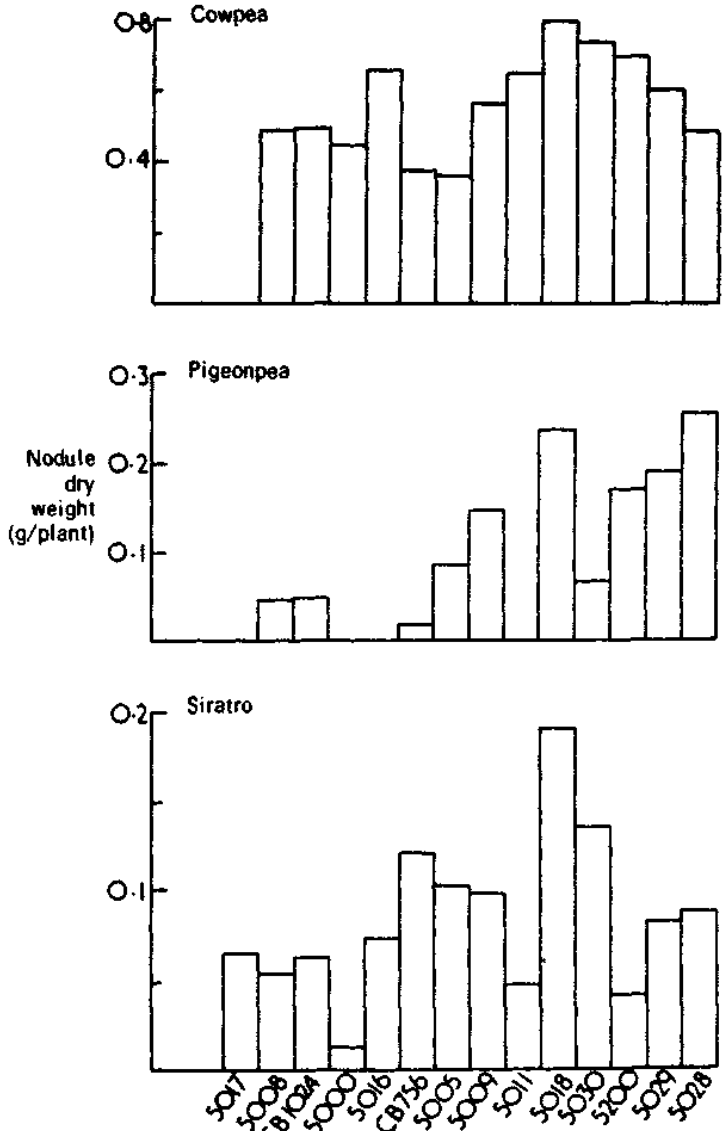


Table 4. Origin of Rhizobium Strains

Strain No.	Host plant	Source of inoculum
5005	Prima cowpea	IITA, Ibadan, Nigeria
5008	Groundnut	"
5009	Cowpea	"
5028	Pale green cowpea	"
5029	Winged bean	"
5030	Stylosanthes humilis	Moor plantation, Ibadan
5017	Cowpea	Lagos, soil around Dolichos spp.
5000	Cowpea	Samaru, N. Nigeria
5011	Cowpea	Samaru, Stylosanthes mucronata soil
5016	Cowpea	Kano soil, N. Nigeria
5018	Cowpea	Makerere Univ. Uganda soil
5200	Pigeonpea	"
CB756		Rhodesia
CB1024		ex CSIR0, Brisbane Australia

Strain CB1024 is a likely replacement for CB756 for use in commercial inoculants produced in Australia for the cowpea group.

OBSERVATIONS

It is important to select the best Rhizobium strain when the particular species is absent or present in low numbers in the soil. Once a strain becomes established in soil it is difficult to replace with a more suitable one.

There is a dearth of knowledge on the performance of the chickpea and pigeonpea symbioses under field conditions. It is uncertain how much of the nitrogen uptake by the plant comes from its N2-fixation, and the Influence of soil conditions—particularly soil nutrient and organic matter content (Dart, Day, Islam, and Dobereiner 1975). We need new ways to inoculate legume seeds 1n advance of sowing so that Rhizobium numbers remain high enough to nodulate plants with the better strains we may select, even in soils already containing rhizobia capable of nodulating the seeds.

Because host genes also determine the ability of legumes to nodulate and to fix nitrogen, plant breeders' material should be tested for ability to nodulate and fix N_2 at every stage in the selection process.

Source-sink relationships within the plant are important for the maintenance of nodule function. If newly fixed N is required during pod fill, it is necessary that nodules obtain enough carbohydrate to fix this N_2 and reexport it. Another dilemma facing the breeder is the reduction in root size that often accompanies good nodulation. A good root system is essential not only for uptake of nutrients. Deep roots are necessary also for water supply to the nodules to maintain their export of fixed nitrogen when soil around them is too dry for direct moisture uptake. Nodules can receive water from roots deeper 1n the soil.

A more complete understanding of the microbiological and physiological processes Involved In the symbiosis of chickpea and pigeonpea would contribute to increasing their productivity.

SUMMARY

Temperature has a marked effect on the chickpea symbiosis. Similar amounts of nitrogen were fixed between 15° and 25° C root temperature, but much less at 30° C. One *Rhizobium* strain fixed much more at 30° than the four others tested, although there was less difference at 23°. There was also a host cultivar—*Rhizobium* strain interaction in nitrogen fixation. At 33° C nodules were not formed although plants grew on combined nitrogen. The nitrogenase of nodules formed at 23° C was active when incubated at temperatures from 6° to 40° C, with maximum activity between 24° and 33° C. Transferring nodulated plants from 23° to 32.5° or 35° root temperatures caused a rapid decline in nitrogen fixation. When the root temperature rose during the day to 32.5°, there was some recovery of activity after five daily cycles; there was no recovery at 35° C. Two cycles had no effect on plant-dry weight and N_2-fixation, but five and ten cycles caused a reduction of 18% to 34% when measured 14 days after the treatment.

Chickpea grown in an 11h photoperiod flowered later than plants grown in 20h (llh of light capable of supporting photosynthetic intensity extended to 20h by low light intensity), but flowering had no immediate effect on nodulation or nitrogenase activity. Plants in llh branched and flowered more, produced more dry matter, and fixed more nitrogen than those in the 20h photoperiod.

Pigeonpea, cowpea and siratro produced different amounts of dry matter in response to inoculation by fourteen strains of rhizobia from the cowpea miscellany, with much difference between strains. Nodule weight per plant correlated well with plant dry weight for pigeonpea and siratro but not cowpea.

All strains nodulated siratro but three strains did not nodulate pigeonpea and one of these did not nodulate cowpea.

ACKNOWLEDGEMENTS

Our work has been supported by the U.K. Overseas Development Administration.

DISCUSSION

A.K. Auckland: Chickpeas are given 70 kg superphosphate per ha and N is optional. Temperature in the chickpea season seldom reaches 30°C.

Y.L. Nene: With regard to effect on nitrogenase activity of temperature: was there yellowing of the plants when they were moved from low to high temperature?

P.J. Dart: Yes. The early planted crop at ICRISAT in October experienced soil temperatures in excess of 30°C. Nodules appeared to be ineffective. Selection of Rhizobia whose symbiosis is more tolerant of high temperature is possible, but other factors need to be measured—such as the effect of fluctuating soil temperatures on nodule formation. There is nothing concerned with flowering itself that inhibits nitrogen fixation in chickpeas.

J.H. Hulse: In P1sum sativum a variation in nitrogenase activity among varieties has been demonstrated. Does this exist in chickpeas and pigeonpeas?

P.J. Dart: It is possible to find host cultivar - Rhizobium strain combinations with an extended period of nitrogen fixation in Pisum sativum. In the associations of chickpea tested so far no differences were found in the duration of nitrogen fixation.

W.J. Kaiser: What is the effect of chemical seed treatment on inoculation?

P.J. Dart:	There are some fungicides less toxic to Rhizobia, but nematocides and insecticides are more difficult. A new technology of inoculation is needed.
J.S. Kanwar:	Your experiments were in sand culture. Can you get high responses under soil conditions with Rhizobia cultures?
P.J. Dart:	Chickpea growth in controlled environments is something which produces early senescence, but plants grown in sandy soil low in N at Woburn near Rothamsted nodulated well and fixed much nitrogen.

LITERATURE CITED

Arora, N. 1956. Histology ot the root nodules on Cicer arietinum L. Phytomorphology 6, 367-378.

Carpenter, G.A. 1966. A packaged plant growth cabinet with uniform intensity of illumination. Nature 209, 448-450.

Chopra, C.L., N.S. Subba Rao, 1967. Mutual relationship among bacteroids, leghaemoglobin and nitrogen content of Egyptian clover (Trifolium alexandrinum) and Gram (Cicer arietinum). Arch. Mikrobiol. 58, 71-76.

Crush, J.R. 1974. Plant growth responses to vesicular-arbuscular mycorrhiza VII Growth and nodulation of some herbage legumes. New Phytol. 73, 743-749.

Dadarwal, K.R., A.N. Sen, 1973. Inhibitory effect of seed diffusates of some legumes on rhizobia and other bacteria. Indian J. Agric. Sci. 43, 82-87.

Dart, P.J., J.M. Day, D. Harris, 1972. Assay of nitrogenase activity by acetylene reduction. In: IAEA/FAO, Vienna Technical Booklet, No.149 "Use of Isotopes for Study of fertilizer utilization by Legume Crops", pp. 85-100.

Dart, P.J., J.M. Day, R. Islam, J. Dflbereiner, 1975. Symbiosis in tropical grain legumes–some effects of temperature and composition of the rooting medium. Symbiotic nitrogen fixation in plants. Ed. P.S. Nutman, Cambridge; Cambridge Univ. Press.

Franco, A.A., J. Dflbereiner, 1967. Host plant specificity in Rhizooium and bean symbiosis and the interference of several nutrients. Pesq. Agropec. Bras. 2, 467-474.

Franco, A.A., J. Dflbereiner, 1971. Manganese toxicity in an acid soil affecting the soybean-Rhizobium symbiosis. Pesq. Agropec. Bras. 6, 57-66.

Foy, CD. 1974. Effects of aluminium on plant growth. In: The Plant root and its environment. Ed. E.W. Carson. Charlottesville: Univ. Virginia Press, 601-642.

Joshi, N.V. 1920. Studies on the root nodule organism of the leguminous plants. India Dept. Agr. Mem., Bact. Ser. 1, 247-276.

Kapil, R.N..N. Kapil, 1971. Root nodules of Cajanus cajan: Origin, structure and ontogeny. Phytomorph. 21, 192-202.

Marshall, K.C. 1968. The nature of bacterium-clay interaction and its significance in survival of Rhizobium under arid conditions. Tran. 9th Int. Cong. Soil Scl. 3, 275-280.

Mosse, B. 1973. Advances in the study of vesicular-arbuscular mycorrhiza. Ann. Rev. Phytopathol 11, 171-196.

Okon, Y., Y. Eshel, Y. Henis, 1972. Cultural and symbiotic properties of *Rhizobium* strains Isolated from nodules of *Cicer arietinum* L. Soil Biol. Biochem. 4, 165-170.

Patil, P.L., N.S. Medhave, 1974. Seed Inoculation studies in Gram (*Cicer arietinum* L.) with different strains of *Rhizobium* sp. PI. Soil 40, 221-223.

Raju, M.S., (1936). Studies on the bacterial plant groups of cowpea cicer and dhaincha 1. Classification. Zentlbl. Bakt. Parasitkde Abt. 11.94, 249-262.

Sandhu, S.S., H.F. Hodges, 1971. Effects of photoperiod, light intensity and temperature on vegetative growth, flowering and seed production in *Cicer arietinum* L. Agron. J. 63, 913-914.

Sen, A.N. 1966. Inoculation of legumes as influenced by soil and climatic conditions. Indian J. Agric. Sci. 36, 1-7.

SECOND

SESSION

PRESENT STATUS OF CHICKPEA RESEARCH IN AUSTRALIA

E. J. Corbin[1]

INTRODUCTION

Australian agriculture has traditionally been dependent on wheat and other winter grown cereals for its major source of cash crop income. In recent years, the average area sown to these crops has been nine million hectares or 69% of the total area under cultivation (Leeper 1970).

This cereal production occurs in the temperate zones of Australia, approximately between latitudes 27° and 37* south. The climate of these zones varies from true Mediterranean in south-western Western Australia and South Australia, to humid mesothermal climates with a more or less even rainfall throughout the year in Victoria, New South Wales and southern Queensland. Theoretically, a large proportion of this temperate cropping area would suit chickpea production.

In northern Australia, between latitudes 12° and 15°S, chickpea cultivation may be possible on soil moisture stored during the wet season. To date, only very limited areas of cropping of any type has been attempted there. In eastern Australia between latitudes 21° and 27°S, certain areas of eastern Queensland may also be suitable for chickpea production. These are broadly referred to as the brigalow lands (Wadham et al. 1967) and suitable crops and cropping strategies are at present being evaluated for this area (Anon. 1973).

overproduction of wheat, in relation to export markets, led to the imposition of production controls in 1969. This caused great interest in alternative crop production. Potentially useful grain legume crops came under consideration for two reasons. First, world demand for protein is increasing in relation to supply. Second, grain legumes satisfactorily inoculated, can contribute to soil nitrogen reserves and can yield satisfactorily without expensive nitrogen fertilizer inputs on deficient soils. So far, the only successful, widely adapted grain legume on the Australian scene has been alkaloid free varieties of narrow leafed lupin (Lupinus angustifolius). These varieties, bred in Australia, have been found most suited to the milder, higher rainfall areas of the southern wheat belt. The areas in which this crop can be grown are limited by the susceptibility of present cultivars to temperature or moisture stress at flowering (Southwood and Scott 1972).

Surprisingly, chickpea which is relatively tolerant of stress at flowering time, has not received sufficient attention from researchers or farmers in Australia. Research Investigations have been rare and, prior to the 1970's, germplasm introductions were few. The rising consumption of chickpea, under the name of garbanzo bean, has been met by imports.

EARLY ATTEMPTS AT CHICKPEA GROWTH

The first references to experiments with chickpea in Australia are between 1892-1897 (Anon. 1892; Valder 1893, 1896) when the crop was sown in New South Wales. Yields of up to 1712 kg/ha were recorded, and the ability of the crop to perform well under hot, dry conditions was noted. Work and interest in chickpea then waned for reasons not recorded. It can only be surmised that attacks of Heliothus spp. reported 1n these experiments became more severe. In the absence of ready means of control, production attempts may have ceased.

Sporadic attempts to grow chickpea have been made over the last thirty years. Grain legume screening trials were conducted between 1958 and 1959 at five sites in the New South Wales wheat belt (Cameron 1961). Two lines of chickpea from Greece were tested, and these were reported as being tolerant to frost and

---

[1] Agricultural Research Institute, Wagga Wagga, New South Wales, Australia

drought. Both these characteristics are of value in southern Australia, where autumn sown crops may be subjected both to late frosts and hot dry conditions during maturation in the spring.

Further research was not undertaken until 1971, when a new program commenced at the Wagga Agricultural Research Institute.

THE POTENTIAL FOR CHICKPEA IN AUSTRALIA

Although chickpea production is not yet under way, it is possible to make assumptions about the place of the crop in the typical rotations presently practiced. In the wheat belt, the common rotation consists of three to five years of legume pasture, usually followed by an exploitative phase involving about three successive autumn-winter sown cereal crops, before returning the land to legume pasture. Grain legume crops such as chickpea could be used to extend the cropping phase. In those areas of subtropical and tropical Australia where chickpea may be an economic proposition, the place of this crop in the cropping rotation is yet to be determined. On irrigated areas in the far north it could be sown to utilize the soil moisture from previously irrigated crops. It could also be sown on natural flood out areas as the soil dries out after the wet season. This is the coolest part of the year in northern Australia.

Chickpea Geographic Range

In Table 1, climatic details of a range of representative sites where chickpea evaluation is in progress are given. Other evaluation sites currently being used fall within this range. Figure 1 shows approximately zones in Australia where chickpea production may be possible.

Future Production Potential

If varieties of chickpea consistently yielding between 1800 and 2500 kg/ha under reasonable conditions could be developed, the crop should become popular. It would be realistic to forecast that the area sown to the crop in Australia would occupy 120,000 hectares within six years from release provided, however, the demand for protein grains increases at its present rate. Small plot yields of 3000 kg/ha have been obtained from autumn sowings, which were harvested in early summer. If these yields could be obtained commercially, the future prospects for large scale production are good.

AGRONOMIC RESEARCH IN AUSTRALIA

In Australia, agricultural research is undertaken within each state by the respective Departments of Agriculture. In addition, the Commonwealth Scientific and Industrial Research Organization (CSIRO) has a wide ranging commitment to agricultural research throughout the country.

Research Sites

Current chickpea research in Australia may be summarized as follows:

New South Wales Department of Agriculture The chickpea research program involves one research agronomist and one plant breeder at the Agricultural Research Institute, Wagga Wagga. Screening of germplasm is also being carried out at the agricultural research stations at Condobolin and Trangie. Pathology research into root rot complexes of chickpea is carried out on material from these programs at the Agricultural Research Centre, Yanco.

Queensland Department of Primary Industries. Screening of cultivars to define suitable types is being carried out at research stations at Warwick and Emerald. Research into virus diseases of chickpea is in progress at the Plant Pathology Branch, Brisbane.

In the department of the Northern territory, Animal Industry and Agriculture Branch, evaluation of a small number of lines has commenced at Berrimah Experiment Farm, near Darwin.

In Western Australian Department of Agriculture, screening of a small number of widely contrasting lines is being carried out at Mt. Barker and Chapman Research Stations and at Lancelin.

In South Australian Department of Agriculture, Initial screenings have commenced at Turretfield Research Station.

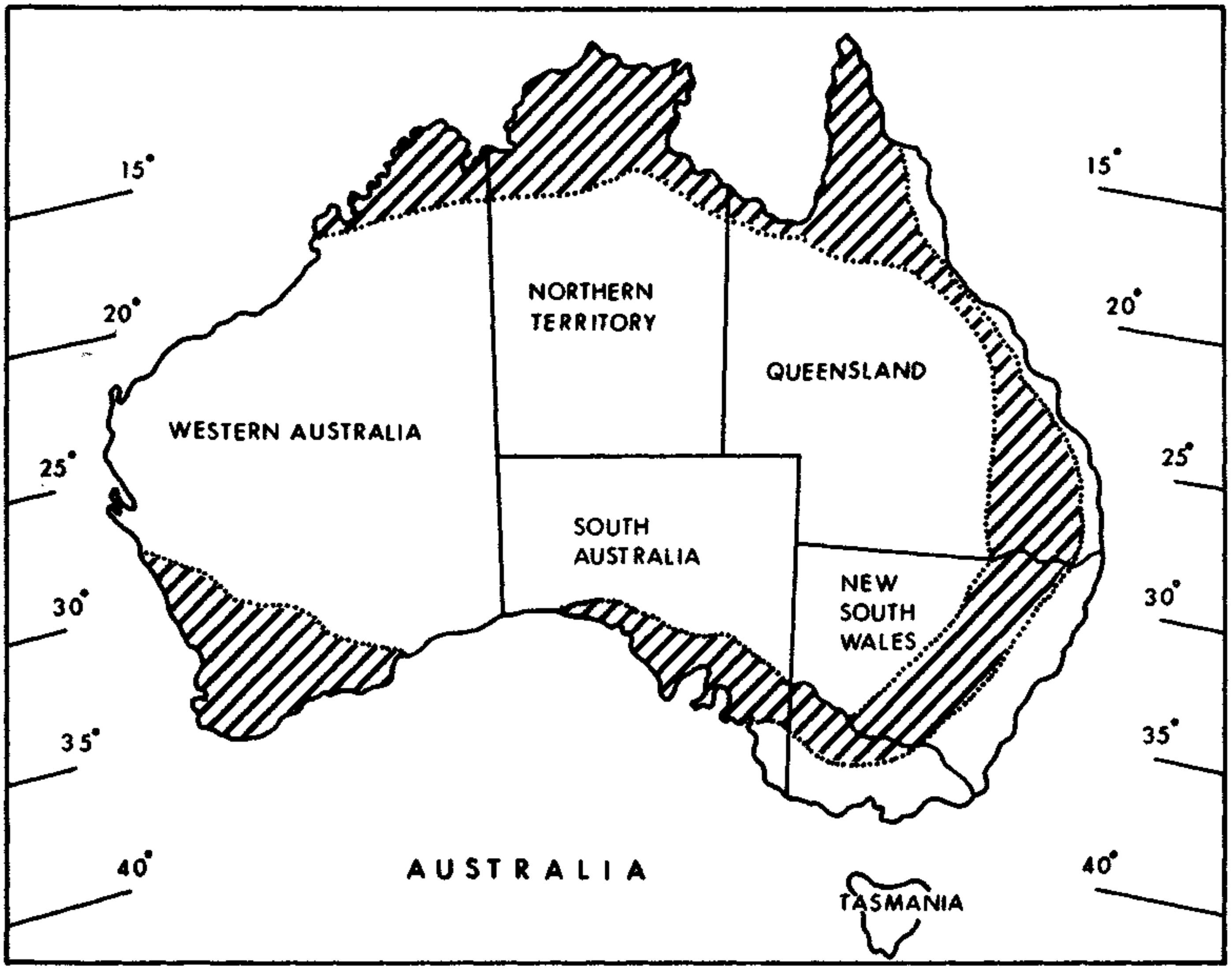
In Victorian Department of Agriculture. Screening of introduced cultivars is in

Table 1. Climatic Details of Representative Chickpea Research Sites in Australia

ITEM	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
WAGGA, N.S.W. 35°07's												
1	32	32	29	23	19	14	14	16	19	23	27	30
2	16	16	14	9	6	4	3	4	6	9	12	15
3	35	42	42	43	42	62	49	55	43	49	38	42
MT.BARKER, W.A. 34°36's												
1	26	26	23	20	17	15	14	15	17	18	22	24
2	12	12	12	10	8	7	5	6	7	8	10	11
3	29	25	36	57	93	99	no	95	80	73	38	29
WARWICK, QLD. 28°14's												
1	30	29	27	25	21	18	17	19	22	26	29	30
2	17	17	15	11	7	4	3	3	7	11	14	16
3	85	62	54	35	32	43	46	27	38	53	72	88
EMERALD, QLD. 23°28's												
1	35	33	32	30	26	22	22	25	28	32	34	35
2	21	21	19	15	11	8	7	7	12	16	19	20
3	97	74	66	30	20	46	31	18	25	34	63	84
KATHERINE, N.T. 14°29's												
1	35	34	35	34	33	30	31	38	35	38	38	36
2	24	23	22	19	16	13	13	14	19	23	24	25
3	243	193	161	34	5	3	1	1	1	31	78	187

Key to item numbers.
1. Average Daily Maximum Temperature in °C
2. Average Daily Minimum Temperature in °C
3. Average Monthly Rainfall in mms.

Figure 1. Zones of Australia with a Potentially Suitable Climate for Chickpea Production



progress at Rutherglen and Walpeup Research Stations.

In Tasmanian Department of Agriculture. A small number of lines are being evaluated at Cressy Research Station.

At the University of Adelaide, Waite Agricultural Research Institute, evaluation of a large collection of imported chickpea lines is under way. Comparisons are being made with a number of species of Vicia, Lathyrus, and Lupinus.

At the University of Melbourne, School of Agriculture. Genotype-environment interaction studies of chickpea material held in Australia are in progress. Temperature and photoperiod responses are also being studied.

In the CSIRO, Division of Tropical Agronomy, Brisbane. Evaluation of lines is being coordinated from the Cunningham Laboratories, Brisbane. Sites include Kununurra Research Station in northwestern Australia, and Gatton in Queensland. Photoperiod and temperature response studies are being carried out in collaboration with the research program of the New South Wales Department of Agriculture.

CSIRO Division of Plant Industry, Canberra. A thorough evaluation of Rhizobium strains carried out in conjunction with the New South Wales program, is almost complete.

As yet, no research workers are engaged solely on chickpea research in Australia. Workers on the crop are involved, as a general rule, in investigating the role of other new crops in their respective regions. Facilities available to these workers are modern and adequate to the task.

Chickpea Problems in Australia

This previous lack of enthusiasm for chickpea research can reasonably be attributed to three factors. The cultivars introduced to Australia were short: the usual maximum height attained was between 35-60 cms. Since Australian agriculture is wholly mechanized, these cultivars with their lowest pods close to ground level were not suited to large capacity machine harvest and failed to generate interest. Second, many of the earlier introductions made slow winter growth and competed poorly with weeds. Third, since suitable strains of Rhizobium were not available, the performance of uninoculated cultivars was below their true potential.

New Chickpea Strains

These initial objections to chickpea have now been largely overcome by the New South Wales research team. A number of erect cultivars from the U.S.S.R. bearing the most pods in the 35-80 cm height range, grow up to 100 cms tall under southern Australian conditions. The problem of slow winter growth has been partially overcome by the identification of lines which have superior growth rates under low temperature conditions. Reasonably cheap suitable selective herbicides have lessened the weed problem. Investigations commenced in 1971 (Brockwell and Gault 1972) and further studies have led to the identification of Rhizobium strains giving excellent field nodulation.

Phenological Research

Another research achievement has been a tentative identification of the factors governing phenological development in some of the lines held in Australia. It appears that some are critically photoperiodic. Others are insensitive to daylength and flower after heat summation requirements are satisfied. There is evidence to suggest that an intermediate type of mechanism may also be operating in some groups. The New South Wales germplasm collection has been screened for vernalisation requirement, but no varieties have been found that have this characteristic Such a characteristic would be useful in sections of the southern Australian environment, since it would allow early autumn sowings without the risk of late winter flowering. Control of flowering date may also be satisfactorily achieved in these same regions using lines with specific photoperiodic requirements. Photoperiod insensitive varieties will be required for northern Australia. Further work on factors affecting phenological development will be undertaken in developing suitable varieties.

FUTURE RESEARCH PROGRAMS

Aspects of agronomic research to be covered in future years include optimum plant density, phosphatic fertilizer requirements, determination of the most suitable soil types and soil pH range. Optimum sowing times will also be investigated.

Moisture

The areas suitable for chickpea cultivation in Australia are subjected to varying degrees of moisture stress, with considerable variations from year to year. The efficiency of moisture usage by the crop will be important, and studies on this are to begin in 1975. There is a special interest in moisture foraging capabilities, since it has been reported that chickpea is able to draw moisture from greater depths than cereals (van der Maesen 1972).

Xeromorphic Structure

The xeromorphic structure of chickpea is also of interest because the plant usually will be setting seed under the hot, dry conditions in Australia. It has been observed that some varieties have a marked tendency to orient their leaflets in a plane parallel to incoming sunlight during the hottest periods of the day. Studies will be undertaken to determine whether such types have reduced transpiration rates.

CHICKPEA COLLECTIONS IN AUSTRALIA

Two main germplasm collections are held in Australia. The collection in New South Wales consists of 260 lines. The main countries of origin are India, Ethiopia, U.S.S.R., Iran, Afghanistan, Pakistan, Turkey and Israel. At this stage it is known that this collection contains material with a reasonable maturity range, with about 56 days difference when sown in autumn at latitude 35°S. A small number of lines have good field resistance to root rot complexes. There is a wide variation in seed shape, testa color and 100 seed weights. Plant height and branching structure Is also diverse. Only two lines have two flowers per peduncle, but many have two seeds per pod. Differences in early growth vigor under cold conditions are quite noticeable. A second collection, located in South Australia, consists of 1000 lines obtained from the Ford Foundation project in Lebanon. The background of this collection is not known, but it is presumed to be reasonably representative. Further intensive appraisal of both collections needs to be carried out.

It is not felt that large numbers of additional accessions are required. New lines will be imported for specific purposes, using prior information from other countries regarding disease resistance, insect tolerance, high yield or high protein. The rate of new introductions is limited by quarantine regulations. These are aimed principally at excluding Ascochyta rabiei from Australia, and require plants to be grown for one generation in controlled glasshouses.

CHICKPEA IMPROVEMENT IN AUSTRALIA

At this stage, selections from the germplasm studies have been used in the initial stages of a breeding program. This has produced material to the F3 stage, so it will be at least five years before advanced material is available for large scale testing against the best yielding introductions.

Height-maturity Relationship

As breeding proceeds, a number of problems are being investigated. The relationship between height and maturity is important. Generally the tallest lines are late maturing, while the shortest lines are early maturing. Studies are in progress to determine whether tall, early segregates in advanced generations can be recovered from crosses between short early parents and tall late parents. The former are of Ethiopian origin, and the latter from the U.S.S.R.

Testa Color

As testa color is important in determining potential markets for chickpea, the segregation of testa color in F_2 populations is being studied. Crosses between white, brown, green, black and reddish brown colored seed types have been made. The objective is to determine whether, and with what frequency, certain colors, particularly white, can be recovered.

Seed Size

The variation in seed size from near homozygous lines obtained from crosses between large and small seeded parents will be studied using single seed descent. It is possible that *an* appreciable *amount* of nonadditive gene action may be involved. In this case, selection for large seeded, Kabuli type varieties may need to be delayed until later generations in the breeding program.

Presumably, there is a relationship between seed size and seed number per pod. There may be an optimum combination of these two yield components for maximum yield expression. Attempts will be made to determine whether this optimum combination exists, initially using F_6 families.

DISEASES AND INSECT PESTS

Diseases and insect pests which may limit yield in Australia still need to be fully evaluated. Root rot diseases are causing reduction 1n plant density. The overall appearance of diseased sowings is poor. Pathological investigations are well under way. Species of Rhizoctonia, Pythium and Fusarium have been isolated and identification studies are proceeding. In the short term, fungicidal seed dressings are being evaluated, but the longer term approach is to breed less susceptible varieties.

Lettuce necrotic yellows virus has appeared on experimental sowings in northern New South Wales and southern Queensland. The disease could become serious, as weeds common in those areas *are* alternate hosts for the virus.

Under moist conditions, Botrytis cinerea has caused a large percentage of mortality, but there appears to be a range of tolerance to the pathogen within the germplasm held. Scelerotinia sclerotiorum and S. minor also have been recorded.

The only insect pests reducing yield are Heliothus armigera and Heliothus punctigera. These attack the developing pod. Insecticides give good control, but the long term aim is to breed varieties which are tolerant to attack. Reference to the possible existence of such types has been made (van der Maesen 1972).

CHICKPEA QUALITY

The production of chickpea high in protein is an important objective of the Australian program. Analyses of grain from the 1973 sowings gave an average protein level of 26%. The highest value recorded was *30%.* In subsequent sowings, the protein level of all lines will be determined when grown under uniform conditions. Analyses of amino acids will be carried out, 1n an endeavor to identify lines high in the sulphur containing amino acids. Biological assays using laboratory rats will be carried out on material grown during the 1974 season. The end result of all the research outlined above should be the commercial release of adapted Australian chickpea cultivars in the 1980's.

DISCUSSION

M.C. Saxena:	Which selective herbicides have been found effective by you?
E.J. Corbin:	Simazine has been found cheap and effective. Trifluralin has been found to affect nodulation. Simazine had the added advantage that it is out of patent and therefore cheap.
J.S. Kanwar:	What are the yields of Chickpea in Australia?
E.J. Corbin:	The best yields have been obtained from Indian cultivars at levels up to 2400 kg/ha. Among the best cultivars were C235 and 6543. Unfortunately they were short and were not suitable for mechanical harvesting, and, therefore, of limited use in Australian conditions.
D.W. Thome:	Is any mechanical combining of Chickpea done in Australia?
E.J. Corbin:	A commercial type combine has been used with success. A Massey Ferguson 6 ft cut German made autoheader has been used.

J.S. Kanwar: In which part of Australia is the major thrust on Cicer being made? Was it in south Australia?

E.J. Corbin: Besides the large effort in southern Australia major work is being carried out in Queensland, and the Northern Territory. These northern areas are a long way from markets, and trade outlets would probably have to be found to the north of Australia. In southern Queensland small plots have given 2400 - 2600 kg/ha. I feel sure that in these areas over 3000 kg/ha could be achieved.

D. Sharma: What is the mechanism of the effect of Simazine? The experience in India was that field peas among the legumes, were very susceptible.

E.J. Corbin: I agree that field peas are very susceptible. The residual effect of these herbicides was so often dependent on soil type. In this instance the soils were heavy loams and clays and the herbicide caused no problems. On sandy soils the situation could well be different.

J.S. Kanwar: It is very interesting to learn that in Australia chickpea tested had high protein- 26-30%. In India it is considerably lower.

E.O. Corbln: This could be due to more effective rhizobium activity-but the dry finishing conditions could also be a factor. There was of course range of variability in protein content depending on cultivar.

LITERATURE CITED

Anon. (1973). Annual Report 1972-73 Division of Tropical Agronomy CSIRO. Commonwealth Scientific and Industrial Research Organisation, Brisbane.

Anon (1892). Notes on economic plants-Chickpea. Agrlc. Gaz. of New South Wales. 3: 559-560.

Brockwell, J., R. Gault (1972). Evaluation of symbiotic response in 21 introduced lines of chickpea. CSIRO Pl. Intr. Review. 9: 4-11.

Cameron, D. G. (1961). Legumes tested for soil conservation. J. Soil Cons. Ser. New South Wales. 17: 3-22.

Leeper, G. W. 1970. The <u>Australian Environment</u>. Melbourne. Melbourne Univ. Press.

Southwood, O. R., R. C. Scott. (1972). Sweet Lupins. Agric. Gaz. New South Wales. 83: 99-101.

Valder, G. (1893). Experiments with pulses-chickpea. Agric. Gaz. New South Wales. 4: 916-917.

Valder, G. 1896. Experiments with pulses-chickpea. Agric. Gaz. of New South Wales. 7:41.

Van der Maesen, L. (1972). Cicer L. A monograph of the genus with special reference to the chickpea, its ecology and cultivation. Mededelingen Landouwhogeschool Wageningen, Nederland. 72-10

Wadham, S., R. K. Wilson, J. Wood (1964). Land utilisation in Australia. Melbourne. Melbourne Univ. Press.

STATUS OF CHICKPEA PRODUCTION AND RESEARCH IN ETHIOPIA

T. Bezuneh[1]

Chickpwa is one of the most important pulse crops cultivated in various parts of Ethiopia. It occupies about 300,000 ha of land or approximately 30% of the total production area devoted to pulses. Over 95% of the chickpea production in Ethiopia is consumed locally. The seed is mainly used for human food. In the central highlands and northern Ethiopia, it is traditionally grown in rotation with cereals.

During the last decade limited research, mainly at Debre-Zeit, has been conducted to develop new varieties of chickpea. A national coordinated chickpea research program was started in 1972. This paper reviews the status of chickpea production and research in Ethiopia.

CHICKPEA PRODUCTION IN ETHIOPIA

Climate

Ethiopia lies between 3°N and 18°N latitudes. Altitude or topographic features play a major role in the amount of precipitation received and temperature conditions. Chickpea is cultivated to a large extent between 1400 to 2300 meters above sea level. In the central highlands and northern Ethiopia where chickpea is one of the major pulse crops the amount of rainfall varies from 700-2000mm. In most regions there are two rainfall peaks. The "small rains" usually occur from February to April. The "big" rainy season occurs from June to part of September. Over 70% of the total precipitation is received during June to the end of August. Chickpea is grown under moderate temperatures of 16°-22°C between September and February.

Soils

Chickpea is grown on black land vertisol soils that are typically clay in texture. The average clay content of these soils is about 50%. According to Murphy (1963), the dark color of the soil is due to its humification and contents of parent material. The pH of these soils ranges from 6.4 to 7.9. The organic content of the black land soils is from 2% to 3% and the phosphorus content in most areas averages about 0.06%. Swelling and cracking is a common physical characteristic of these soils.

Distribution

The area planted to chickpea is apparently quite stable. During the past decade the Increase has been limited to 20,000 ha in the central highland and northern Ethiopia (Figure 1). Chickpea is grown as the major rotation crop following cereals such as tef (*Eragrostis* tef) wheat, and neug (*Guzotia abyssinica*). Table 1 presents recent trends in plantings and production of chickpeas and other pulses.

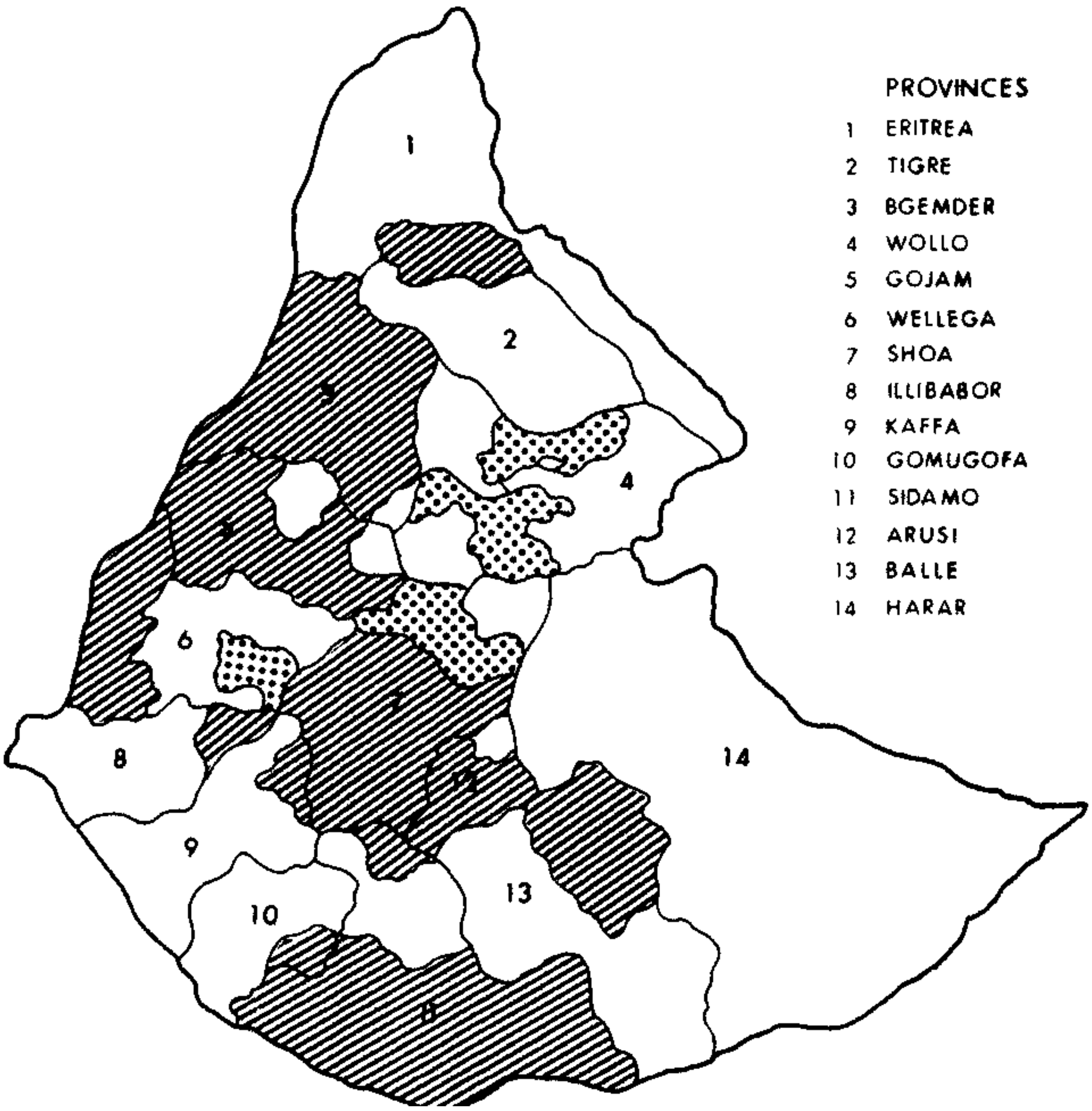
Local Consumption

A relatively small portion of the total production of chickpea is exported. Chickpea export constituted about 14% of total pulse exports in 1967 and 1968, and approximately 8% during 1969 and 1971 (Table 2). In 1970, the export of chickpea was only 3% of the total pulse crops exported. Most of the chickpea produced is sold at the local market.

---

[1] Debre-Zeit Agricultural Experiment Station, Debre-Zeit, Ethiopia

Figure 1. Geographical Distribution of Chickpea Cultivation in Ethiopia



▨ PRIMARY AREAS OF CHICKPEA PRODUCTION

░ SECONDARY AREAS OF CHICKPEA PRODUCTION

SOURCE: Final Report on Crop Condition Survey for 1972-73, Planning and Programming Unit
Ministry of Agriculture, Ethiopia.

Table 1. Pulse Crop Production in Ethiopia

	1969-70		1970-71		1971-72	
	Area in 1000 ha	Yield in 1000 tons	Area in 1000 ha	Yield in 1000 tons	Area in 1000 ha	Yield in 1000 tons
Chickpea	294	185.3	298	192	300	196
Field pea	135	126.4	136	129	140	137
Horsebean	144	137.8	147	145	150	148
Lentil	174	106.5	176	110.6	180	112
Beans	94	72.3	95	75	120	120
Total	841	628.3	852	651.6	890	713

Source: Statistical abstracts 1973, published by Central Statistics Office, Ethiopia.

Table 2. Structure of Pulses in Export Economy

	Eth. $ Million					% of Pulse Exports				
	67	68	69	70	71	67	68	69	70	71
Pulses	19.666	21.324	21.949	15.836	22.170	...	-—	---	...	...
Lentils	5.192	7.526	9.292	4.915	5.654	26.4	35.3	42.3	31.1	25.5
Dried Peas	0.126	0.200	0.234	0.112	0.139	0.6	1.0	1.1	0.7	0.6
Horse Beans	5.151	3.613	5.256	3.521	4.442	26.2	16.9	23.9	22.2	20.1
Haricot Beans	6.257	6.895	5.042	6.783	16.093	31.8	32.3	23.0	42.8	45.5
Chickpeas	2.859	3.038	1.865	0.505	1.793	14.5	14.3	8.5	3.2	8.1
Mixed Peas	0.081	0.052	0.260	...	0.049	0.5	0.2	1.2	...	0.2

One US dollar = Two Ethiopian dollars

RESEARCH ACTIVITIES AND ORGANIZATIONS

The chickpea improvement research program in Ethiopia is at an infant stage even though this crop has been cultivated in Ethiopia for centuries. The major research work on chickpea has been carried out at Debre-Ze1t Agricultural Experiment Station for the last eight years. A coordinated national research program on chickpea was launched in the 1972 crop season.

Research Organization

Similar to other major crop research programs, the improvement of chickpea is coordinated through the National Crop Improvement Committee (Figure 2). The major cooperating stations where the national yield trial was conducted during 1973-74 crop season were:

State Location	Altitude Meters	Location
Debre-Zeit	1850	Central Ethiopia
Arba-Minch	1000	Southern Ethiopia
Arussie Neghele	1860	Southern Ethiopia
Awassa	1700	Southern Ethiopia
Bako	1650	Western Ethiopia
Kulumsa	200	South Central Ethiopia
Kobo	1450	Northern Ethiopia
Dembere Kella	1750	

AREAS OF RESEARCH EMPHASIS ON CHICKPEA IN ETHIOPIA

Germplasm Collection

The collection and evaluation of indigenous genetic material has been initiated. Limitations in staff and financial support have so far restricted collections to the immediate vicinities of established experiment stations. However even these efforts appear to have been fruitful. The two highest yielding varieties in past national yield trials were selections from material collected from the Debre-Zeit area and evaluated at the Debre-Zeit Experiment Station. An extensive collection of genetic material from all chickpea growing areas in Ethiopia and systematic characterization and evaluation is a high priority for future chickpea improvement.

Chickpea National Yield Trial

Since 1972, outstanding local cultivars and some exotic varieties of chickpea were included in the national yield trial to be evaluated under different ecological conditions in Ethiopia. The Debre-Zeit Agricultural research station has major responsibility for coordinating this program. During the 1973 crop season, 14 varieties were included in the National Yield Trial program and their mean yields at eight locations were as follows:

Variety	Mean Yield in Kg/ha. for eight locations
Awassa White	1330
CAD-54	1680
Dubile	1600
C-57	940
C-410	1330
DZ-10-1	1040
DZ-10-2	1720
DZ-10-11	1760
H6-26-12	1270
H-54-10	1590
H-60-10	1250
H-61-9	1240
M-9637	710
24-B	1560

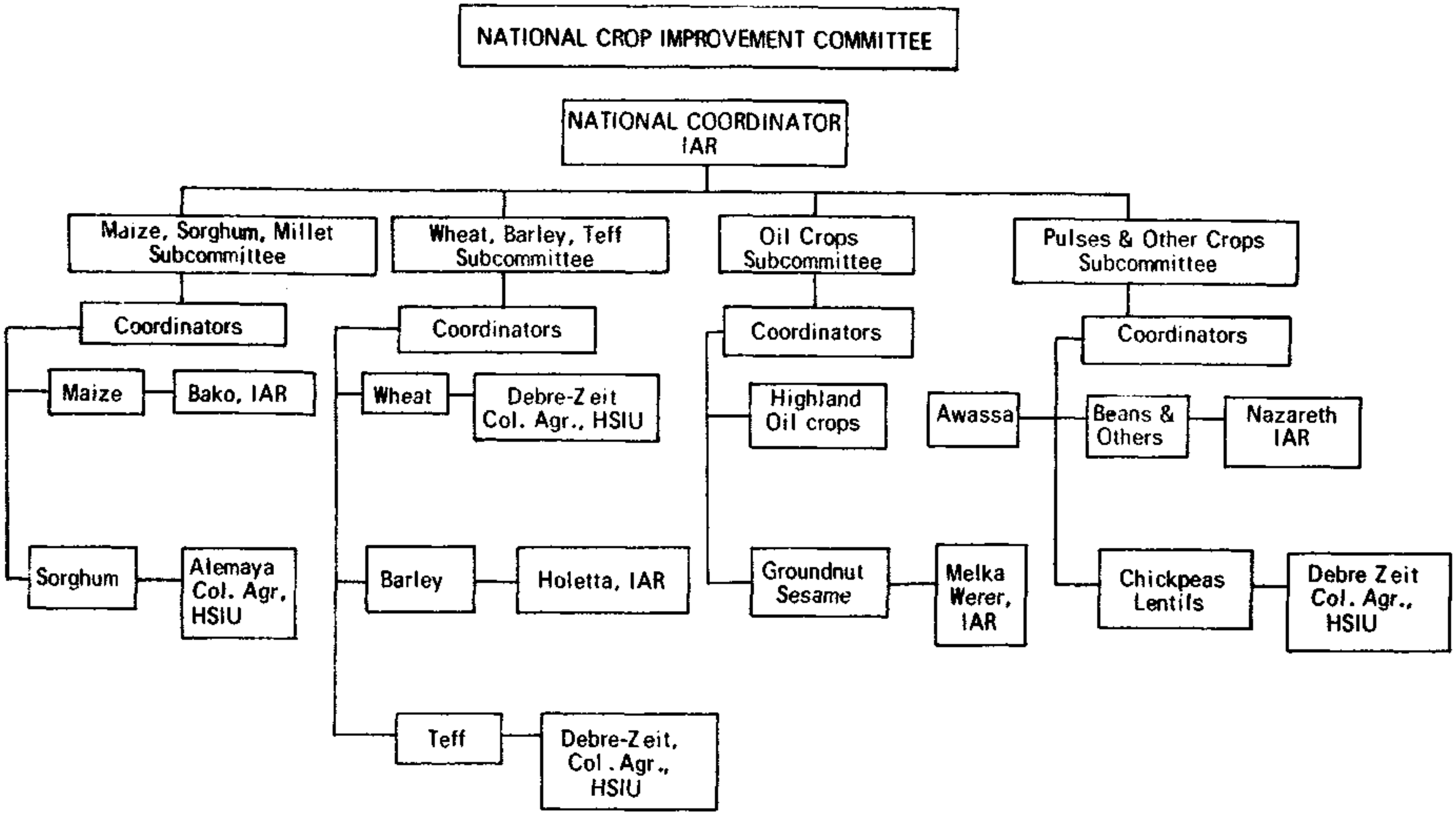
Source: Debre-Zeit Agricultural Experiment Station Annual Report 1972-73.

CHICKPEA REGIONAL AND NATIONAL NURSERY PROGRAM

Continuous research effort is being exerted to evaluate several hundred chickpea lines or varieties for yield, disease resistance and quality, with special emphasis for the export market. The primary germplasm chickpea material used in the screening nursery is from local and international sources. This year the chickpea nursery observation trials Included varieties or lines received from:

ALAD—1020 lines
International Biological adaptation trial, 86 lines
ICRISAT—24 wilt resistant lines
Local collections, 33 lines
Selections from crosses.

Figure 2. Organizational Chart for Major Crop Research Programs in Ethiopia, 1975



Promising lines or varieties are promoted every year and included in the National Yield Trial program for further evaluation particularly for yield and root rot resistance in different regions of Ethiopia.

Screening of Chickpea Strains for Root Rot Resistance

Root rot inflicts neavy damage on chickpea stands in the field at various stages of growth. Reduction of yield under field conditions is reported to approach 50%. There has been little research on controlling chickpea diseases and pests because of the lack of trained personnel in this field. Pathological investigations made thus far, particularly on wilt diseases, seem to indicate that there is some relationship between seedcoat color, plant survival and yield. The dark colored strains seem to be relatively more tolerant than lighter seed coated chickpea strains.

Cultural Practice Studies

Plant population and date of planting are also being studied. Date of planting seems to have a definite influence on yield. Early planting gave relatively high yield with all six local varieties studied (Table 3). The maximum yield obtained with DZ-10-1 under favorable climatic conditions compares with theoretical optimum yield 4800 Kg/ha as calculated by van der Maesen (1972).

SIGNIFICANT RESULTS

The root rot wilt complex is the most serious disease of chickpeas in Ethiopia and is perhaps the major limitation to higher yields. Very recent laboratory and greenhouse studies indicate that at least six different pathogenic organisms are involved. Pathogens identified to date are Rhizoctonia spp., Sclerotiuni spp., two species of Fusarium and MacrophomTna spp.

Selection of Cultivars

The selection of high yielding cultivars such as DZ-10-1, DZ-10-2 and DZ-10-11 1s a significant research output. A record yield was achieved when some local cultivars were planted at different dates (Table 3). A theoretical optimum yield of 4820 Kg/ha as calculated by van der Maesen(1972) was achieved. Under Ethiopian climatic conditions the black seed coated local cultivars have shown better tolerance to the root rot diseases complex than exotic varieties. However, the dark seed color is generally not suited for export markets which limits the potential.

Table 3. Seed Yield of Six Chickpea Varieties Planted at Three Dates at Debre-Zeit

Variety	Date Planted			
	Sept.I	Sept.10	Sept.20	Variety Mean
	Kg/ha			
Dubie	4240	3290	3260	3600
DZ-10-1	4820	3140	3080	3670
DZ-10-2	4670	3800	3460	3980
24-B	4340	3080	3410	3610
H-26-12	4170	3120	2850	3380
H-54-10	3640	4010	3300	3980
Planting Date Mean	4480	3410	3220	3700

Source: Debre-Zeit Agricultural Experiment Station Annual Report 1972-73.

SUMMARY

Outside the Indian subcontinent, Ethiopia is one of the major chickpea producing countries. Diverse types of chickpea are grown in different parts of the country. Collection and evaluation of different types of chickpea will be one of the major research undertakings in order to broaden the genetic variability of chickpea both for local and International chickpea improvement programs.

Since Ethiopia is admirably located to export chickpea to neighboring countries, future research emphasis would be developing desired varieties or lines for the export market. The major areas of research emphasis on chickpea would be:

1) develop varieties that are resistant to root rot and wilt diseases.

2) enlarge the chickpea germplasm collection by launching systematic collection, classification and evaluation program in Ethiopia.

3) strengthen the breeding program on chickpea in order to facilitate the development of high yielding varieties.

DISCUSSION

K.B. Singh: I am interested in the seed size and color preferences and marketability of different cultivars in Ethiopia.

T. Bezuneh: Cream to white color is preferred for the local and export markets together with a large seed size. However, for consumption on the homestead there appears to be no definite preference.

A.K. Auckland: I want to know how ICRISAT could cooperate best with the established Ethiopian program. I have noted the higher yielding local varieties referred to and wonder whether we could possibly introduce some of these varieties, cross them to exotic germplasm, and return resulting progenies for test.

T. Bezuneh: We are prepared to collaborate.

Y.L. Nene: I am not convinced about the suitability of criteria adopted for assessing tolerance to pathogens, since 50% loss has been recorded in many lines. How high was the percentage loss in local types?

T. Beiuneh: The study was a limited one, but local types often showed 70* survival.

S.C. Hawtin: What was the relative importance of the various pathogens?

T. Bezuneh: Mo systematic survey was done but the most important ones were Rhizoctonia and Sclerotium, two species of Fusarium and Microphonia.

M.C. Saxena: I am Intrigued by the marked differences In yield. How could you explain such large differences?

T. Bezuneh: The variety trials were run at a large number of sites where the growing conditions were very different. But even in these up to 30 quintals per ha yields were obtained. The sowing date trials were conducted in closely supervised conditions at a limited number of sites.

LITERATURE CITED

Murphy, H. F. 1963. Fertility and other data on some Ethiopian Soils. Exper. Sta. Bull. No. 4, College of Agriculture, HSIU.

Van der Maesen, L.J.G., 1972. *Cicer*. L. A. Monograph of the genus, with special reference to chickpea (*Cicer arietinum* L.). Its ecology and cultivation. Meded. Land Hogesch. Wageningen Nether!ands.

Westphel, E. 1974. Pulses 1n Ethiopia, Their taxonomy and agricultural significance. Joint publication of the College of Agriculture, Haile-Sellass1e I University, Ethiopia and the Agricultural University, WagenIngen, Netherlands.

THE STATUS OF CHICKPEAS (CICER ARIETINUM) IN IRAN

J. Jaffari[1]

INTRODUCTION

Grain legumes are ranked fifth in Iran after wheat, barley, rice and cotton in area under cultivation. Cultivated legumes in Iran are chickpeas, beans,mung beans, lentils, broad beans and cowpeas. According to the 1973 statistics of Plan Organization of Iran, the total area under legume cultivation is more than 200,000 hectares, of which chickpeas are 60%, beans are 15%, and other legumes, 25%.

Grain legumes are ranked second after wheat for nutrition with an average of seven g of consumption per capita.

Grain legumes have been cultivated in Iran since the thirteenth century, when they were grown sparsely in different parts of the country. The program for extension of legumes and their breeding was started by Department of Agriculture.

In 1964, a joint project for pulses was started in cooperation with the USDA, the Department of Agriculture, and University of Tehran College of Agriculture in Karaj. Since most of the experiments on pulse has been carried out in Karaj, a description of the region follows.

KARAJ CLIMATIC CONDITION

Karaj is located about 45 kilometers west of Tehran at the base of Alborz mountain range, at a latitude of about 36N degrees, and longitude of about 51 E degrees. The altitude is about 4000 feet above sea level. Average annual precipitation is around 250 millimeters in the form of rain ln late fall and early spring, and snow between December and February. The summer weather is characteristically hot and dry, with little precipitation between May and October. Karaj has a frost free season of about seven months.

TYPES OF CHICKPEA IN IRAN

Chickpeas (Cicer arietinum L.) are of considerable importance in all countries of the Near East and South Asia. There are three main types based on characteristics and end use of the seed. The rather angular and pointed shape of chickpea and seed was the source of the species designation "arietinum," which means "similar to a ram's head". The three main types are as follows:

The first class of chickpeas is large seeded (about 25-35 grams per 100 seeds). The seed is white to cream colored, and it is used almost exclusively for cooking as a vegetable and with rice. The second type has a smaller seed (15-25 grams per 100 seeds) which is also from white to cream in color. It is used primarily for roasting and eating in the hand, as Americans eat popcorn. The most common chickpea type grown in Pakistan and India has this seed size, but is usually darker in color. The third type is a very small seeded type (8-12 grams per 100 seeds). The seed has a reddish-brown or black seed coat which is normally removed. The yellow green split seed is then used as a vegetable. In Iran, the black seeded varieties of this type are normally used. The reddish-brown type which is very common in Pakistan and India, is only used to a limited extent in the eastern sections of Iran.

Characteristics

There is very little difference in vegetative characteristics of these three types.

---

[1] University of Tehran, Karaj, Iran

In general, plants of the large seeded types are somewhat larger. There are indications that there is greater resistance to such diseases as Peronospora (mildew) and Fusarium (wilt) in the smaller colored seeded types.

CHICKPEA RESEARCH

In our research work we were not only trying to raise chickpea to the level of international standards, but also to make further progress in our country. In the last ten years the pulse project has initiated research studies in the breeding, pathology, pest control, irrigation and use of fertilizers in pulse crops.

Breeding

Here is a summary of our breeding work in the last nine years. In 1965, observation nurseries consisting of single row, non-replicated plots were planted in Karaj (Table 1).

All materials planted in 1964 were included 1n 1965 for further observations and screening. In addition, the 1965 nurseries contained new introductions made through the New Crop Research Branch, USDA, ARS, through FAO and directly from Turkey and Pakistan. From the 1964 planting, a number of strains with desirable characteristics were chosen for inclusion in a number of replicated yield trials. These yield trials were planted in Karaj and 10 more stations.

Work in 1965 was concentrated on six crops: Chickpeas (Cicer arietinum), Cowpeas (Vigna sinensis), beans (Phaseolus" yulgares), mungbeans (Phaseolus aureus), Lentils (lens esculenta), and broad beans (Vicia faba).

Table 1. The List of Single Rows, 1965

Crop	Number of single rows
Lentils	1311
Chickpeas	3154
Mung beans	950
Drybeans	1793
Cowpeas	875

Germplasm Collection

In 1966, collections were established in both Iran and India. These materials were collected from a wide variety of sources, including USDA, FAO, and individual countries. A uniform system was developed for cataloguing this material. Some project proposals were submitted for collecting, classifying, and cataloguing these collections.

Varietal Improvement

During 1966, varietal improvement work consisted of three undertakings: i) evaluation of indigenous and exotic germplasm; 2) preliminary trials for yield and other character-: istics of strains screened in 1964; and 3) testing of promising materials in advanced yield tests

Since final use of black and white chickpeas differ, and plant type is somewhat different, the nursery and yield trials were divided into black and white types on the basis of seed and plant characteristics.

CHICKPEA RECOMMENDATIONS

In 1967 two varieties of chickpeas were recommended with the following data:

Black chickpea (Pyrouze):
RPIP Accession No. 12-071-05436 tested as strain no. 416 M.
Origin: Garyeh gole, Khorasan province.

Variety characteristics

Length of growing period: 119 days
Disease rating: relatively good.
Grain yield (experimental condition): 2100 kg/ha
1000 seeds weight: 140 gm.
Plant height: 26 cm.
Seed shape: slightly elongated, wrinkled.
Seed coat color: brownish.
Cooking time: 28 minutes.
Taste: sweet and floury.

Black chickpea (KA KA):
RPIP Accession No. 12-071-5437 tested as strain no. 438 M.
Origin: Karaj, Iran

Variety characteristics

Length of growing period: 119 days

Disease rating: relatively good
Grain yield (experimental condition) : 2100 kg/ha
1000 seeds weight: 116 gm
Plant height: 26 cm
Seed shape: small and wrinkled.
Seed coat color: uniform black.
Cooking time: 28 minutes.
Taste: sweet.

In 1968, two strains of chickpea reported to be resistant to blight (*Ascochyta rabiei*) were obtained from Israel, with four other varieties.

In 1969, two varieties of white chickpeas recommended:

White Chickpeas (Jam)
RPIP Accession No. 12-071-10025 tested as Source No. 111.
Origin: Esfahan.

Variety characteristics

Length of growing period: 120 days.
Disease rating: relatively good.
Grain yield (experimental conditions): 2400 kg/ha
1000 seeds weight: 250 gm
Plant height: 30 cm

White Chickpeas (Kourosh)
RPIP Accession No.12-071-10014 tested as source No. 162
Origin: Shahpour

Variety characteristics

Length of growing period: 120 days
Disease rating: relatively good
Grain yield (experimental condition): 2300 kg/ha
1000 seeds weight: 245 gm
Plant height: 30 cm

In 1969, seventy crosses were made with blight resistant and bruchid resistant chickpeas. Crosses to incorporate good seed quality, high yield, blight and bruchid resistance were planned. Advanced generations of crosses were made at two stations in the summer of 1971 and the winter of 1971-72 to obtain two generations a year.

DISTRIBUTION OF SEED

From 1971 to 1975, our main objective was to Introduce and distribute the improved varieties to farmers. For this purpose we made a handbook for each of pulse crops. As of now with cooperation of Ministry of Agriculture and Extension Service, we have succeeded in distributing about 200 toni seeds of the improved varieties which cover about 2000 ha in 15 states of Iran.

PLANT PATHOLOGY

Plant diseases are often a limiting factor in the cultivation of food legumes in many parts of the world. Serious crop losses due to diseases in Iran have been caused by soil fungi, nematodes and viruses. Several viruses affecting pulses in Iran have been identified by project experts.

Major Viruses

These viruses are: Alfalfa mosaic virus (AMV), Bean common mosaic virus (BCMV), cucumber mosaic virus (CMV), Bean yellow mosaic virus (BYMV), Cowpea aphid-borne mosaic (CAMV), Pealeaf roll (PLRV), Pea enation mosaic (PEMV), and, possibly, curly top (CTV). Some of these viruses are restricted in their host ranges (e.g., BCMV) while others have very wide host ranges (e.g., CMV).

Disease surveys have been made yearly since 1966 by the project team of various pulse growing areas of Iran. These have shown that virus diseases are widespread and contribute annually to decreased yield and quality of food legumes. Diseased and healthy pulse crops were collected from various areas of the country. From individual plants, isolations were made from root and stem tissues on agar media, while foliar portions were assayed for virus infection on different test plants.

Ascochyta blight (*A. rabiei*), the cause of a foliar disease of chickpea, is often a limiting factor in the cultivation of *Cicer*, especially in areas with high rainfall and/or high humidity during part of the growing season. The effects of nutrition and environment on growth, sporulation, and survival of isolates of the fungus from various chickpea growing areas of Iran have been studied in the laboratory, greenhouse, and field.

The optimum temperature for growth and sporulation was usually 20°C, although on some agar media, maximum sporulation occurred at 10° to 15° C. Higher temperatures reduced mycelial growth and sporulation. The fungus usually ceased growing or was killed at 32° to 35°C. An agar medium utilizing crushed chickpea seed was found to increase sporulation of all isolates of A. rabiei by three to ten times over conventional agar media such as potato, dextrose agar. Light has also been found to greatly increase sporulation of the fungus.

In nature A. rabiei appears to survive in seed or plant tissue from infected chickpea. Only the imperfect (Pycnidial) stage of the fungus has been found in Iran. The importance of diseased chickpea tissue in survival of the pathogen was studied at different temperatures, relative humidities and soil. In naturally infested chickpea tissue, A. rabiei survived at least 80 weeks at 10° - 35° C, 58 weeks at 0-30% relative humidity, and 54 weeks on, the soil surface. The fungus lost its viability rapidly at 60% and 100% relative humidity or at soil depths of 10 to 40 cm. The pathogen survived over 90 weeks in naturally infected chickpea seed stored in a weather station shelter in southwestern Iran where summer temperatures often exceeded 50°C.

A technique has been developed for inoculating chickpea lines to locate sources of resistance to Ascochyta blight. Chickpea selections have been screened against Iranian isolates of A. rabiei, and several, especially black seeded types, were moderately to highly resistant to the fungus in field and greenhouse trials. Isolates of A. rabiei from Iran exhibited a wide range of variation in colony appearance, mycelial growth, and spore production. However, it has not been established whether races of the pathogen occur in Iran which vary in their pathogenicity the affects of foliar and seed treatment fungicides. The newer systemic chemicals are currently under investigation.

Pests

Entomology and pest control activities were centered on identification of the major pulse pests and methods of controlling them. On chickpeas, the major pest is Heliothis species of which Heliothis armigera, the cotton bollworm, is the most serious. However, Heliothis dipsocea is also an important pest in some areas. The other important pests on chickpeas are: Liromyza congesta (leaf miner), Aeyrthosiphon Pisum, Therio aphis trifolii, Hylema-cilicrura (seed corn maggot).

DISCUSSION

A K. Auckland:	What is the mode of resistance to Bruchids in Indian lines grown in Iran?
J. Jaffari:	The losses to Bruchids are considerable in Iran and crosses have been made in Iran, but not enough seed has been obtained for a thorough test.
A. K. Auckland:	I wonder which particular character conferred the resistance. For instance, is it seed color, coat thickness or texture?
K. B. Singh:	I think the line referred to was probably B 100.9-1 which has been found resistant to Bruchids in limited tests. It has been found that the mode of action was preference rather than resistance since, if no choice was offered to the pests, this variety was also badly damaged.
S. Ramanujam:	It has been found that a rough seed coat is not preferred and that one of the two species of bruchids normally found on chickpea, C. chinensis do not attack rough seeded types. The other species Bruchus sp. is not deterred. There may also be other factors involved.
M. C. Saxena:	I wish to know from Dr. Jaffari whether the bold seeded varieties in Class I out-yielded the small seeded ones in Class II and III.
J. Jaffari:	The larger seeded varieties only yielded about 2000 kg/ha in Iran, and the smaller seeded varieties out-yielded them. Market preference

was for large seeded varieties and strenuous efforts are therefore being made to improve the yields of the large seeded types. Black varieties are often used as splits.

W.V. Royes: Certain varieties of legumes have been found in South America with resistance to insect pests. These had certain amino acids in them--unfortunately they were toxic to man as well as to insects.

Y.L. Nene: I have scanned the world literature on the pathogens of Cicer. Iran is the only country where a considerable number of viruses are found, while in India with a very variable and wide range of growing conditions few have been recorded, though some plants showing virus-like symptoms have been found.

W.J. Kaiser: I found five viruses in Iran while serving there. I believe that the prevalence is related to the large number of alternative host plants, in particular Medicago, and the excellent conditions which favored aphid increase. I found some of the viruses were persistent and some nonpersistent. Medicago was not the only host--Melilotus, aubergine and weeds were also implicated. There were also a number of perennial species. There is also the difficulty of isolating the viruses which is experienced in many developing countries as greenhouse work and detailed transmission tests are needed and there has been little of this type of work in semiarid tropics. The symptoms of some of the viruses are very similar to wilt and when such material was tested by back transmission one did get typical virus symptoms.

LITERATURE CITED

Kaiser, W.J., and D. Danesh. 1971. Etiology of virus included with of Cicer arietinum, Phytopathology 61: 453-457.

Kaiser, M.J. and D. Danesh. 1971. Biology of four viruses affecting Cicer arietinum in Iran. Phytopathology 61: 373-375

Kaiser, W.J., D. Danesh, M. Okhovat, H. Mossahebi. 1968. Diseases of pulse crops (edible legumes) in Iran. Plant Dis. Reptr.: 52: 687-691.

The progress reports 1965-1974. R.P.I.P.

THE STATUS OF CHICKPEA RESEARCH IN THE MIDDLE EAST

G. C. Hawtin[1]

SUMMARY

The chickpea is an important pulse in the Middle East, being second only to broadbeans in terms of acreage. It is grown mainly as a dryland crop, planted in the spring. Relatively little research has been carried out to date on chickpeas in the region, with the exception of the RPIP program in Iran. Research undertaken by this program included breeding, pathology, entomology and agronomy. Some basic agronomy trials and selections from local landraces have been made in Algeria, Egypt, Ethiopia, Lebanon, Sudan and Turkey.

The Regional Food Legume Program was started by ALAD in 1972 to develop research on chickpeas, broadbeans and lentils in the Middle East and North Africa. The program so far has been concerned with training and with obtaining, distributing and evaluating a wide range of germplasm. It is probable that the program will expand in the future to include research on nutrition and pathology.

INTRODUCTION

In 1968, the Arid Lands Agricultural Development Program (ALAD) was started by the Ford Foundation to study problems relating to increasing agricultural productivity in the Middle East and North Africa. The research was initially concerned with wheat, maize, forage and sheep production but has since broadened in scope to include a wide range of crops. In 1971, Dr. L. House of the Rockefeller Foundation joined ALAD and took over the sorghum and millets work and started the regional program on food legumes to study the major pulses of the region—chickpeas, broadbeans and lentils. This research is now sponsored by the IDRC although the program also relies heavily on support from the Ford Foundation, the Agricultural Research Institute of the Lebanese Government and the governments of the various countries within the region.

THE REGION

The region covered by the food legume program extends approximately from Morocco (10° W) to Afghanistan (70° E) and from Ethiopia (5° N) to Turkey (40° N). Throughout most of this region, the dominant climate is semiarid and temperate, with a winter rainfall pattern. The annual rainfall varies considerably from below 25 mm per year in parts of Egypt and Sudan to around 1000 mm per year in parts of Turkey, Algeria, Tunisia and Ethiopia. Most of the agriculturally important areas, however, have an annual rainfall of between 250 mm and 600 mm and in these areas, dryland agriculture is of the greatest importance. In some countries, notably Egypt and parts of Sudan, the agriculture is almost entirely irrigated but these are the exceptions within the region, and chickpeas at least are very rarely irrigated elsewhere.

CHICKPEA PRODUCTION IN THE REGION

Chickpeas vary in importance throughout the region, though the distribution appears to be related as much to local preferences for the pulse as to the suitabilitv of land and climate. Table 1 shows the area under the production of chickpeas in relation to the total area under cultivation and the areas devoted to the other major pulses, broadbeans

---

[1] Arid Lands Agricultural Development Program, Ford Foundation, Beirut, Lebanon

Table 1. Land Area Under Major Pulses in Countries of the Middle East and North Africa

Country	Total area (1,000 Ha)	Total area under arable and permanent crops (1,000 Ha)	Area under Broadbeans (1,000 Ha)	Area under Lentils (1,000 Ha)	Area under Dry Beans (1,000 Ha)	Area under Chickpeas (1,000 Ha)	Area under Chickpeas as % total area under Pulses*
Algeria	238,174	6,787	23	23	5	35	39
Egypt	100,145	2,843	135	20	5	3	2
Ethiopia	122,190	12,900	152	180	96	298	34
Iran	164,800	16,560	-	55	10	95	59
Iraq	43,492	10,163	15	6	10	5	14
Jordan	9,774	1,300	2	22	-	3	11
Lebanon	1,040	316	1	3	7	3	33
Morocco	44,505	7,900	180	35	8	120	30
Sudan	250,581	7,100	8	-	5	-	13
Syria	18,518	5,899	7	129	3	29	17
Tunisia	16,415	4,510	50	3	-	26	33
Turkey	79,058	27,378	30	103	110	100	22

Source: F.A.O. Production Yearbook, 1971.

* Including chickpeas, broadbean, lentil, dry bean and dry pea.

(Vicia faba), lentils (Lens culinaris) and dry beans (Phaseolus vulgaris). All the main pulse growing countries of the region are included in the table with exception of Afghanistan for which no data was available. Table 2 shows the annual production and mean yields of these crops for 1971. The a ea under chickpea cultivation has increased in the region by 34% in the period from 1950 to 1971 and mean yields have also increased in that same period by over 23%, primarily as a result of improved agronomic practices.

Drop in Chickpea Production

Production in the last three or four years, however, has tended to level off and even drop slightly, due chiefly to a greater acreage being sown to wheat because of high world prices and the high yield potentials possible with modern production practices and varieties.

If the decline in chickpea production is to be halted or even reversed, ways must be found of making the production more competitive with the cereals through increased yields and prices or means must be found of fitting the crop into productive rotations or multiple cropping systems. Several governments are showing interest in ways of including a legume, possibly chickpeas, into the present system of wheat and fallow rotation. In Turkey and Algeria in particular this system is very important, and if chickpeas could be included every second or third year in the rotation this would open up large areas of land for chickpea cultivation.

Breeding Programs for Productivity

Multiple cropping systems are currently being investigated at the American University of Beirut (A.U.B.), and from the preliminary work so far it seems possible that chickpeas could form a useful early crop to be followed by a summer crop, perhaps a forage. If this is to become an important system, it is desirable to develop varieties and cultural practices which would enable the chickpeas to be harvested one or two weeks earlier to allow a longer growing period for the succeeding crop. Throughout most of the region chickpeas are sown in spring from February until mid-April but if cold-tolerant lines can be found (and sufficient cold tolerance appears to be present in many genotypes) autumn planting will become a possibility, resulting in earlier harvesting and perhaps a better use of the available water. It is planned to screen about 600 lines of chickpeas for cold tolerance in Lebanon this coming season.

In Egypt, Sudan and Ethiopia chickpeas are generally planted in the autumn from September to early November and are harvested from January to April. During the growing season in these countries, however, the temperature rarely drops below 5° - 10° C and cold tolerance is not a problem.

Chickpeas are almost always grown as a monoculture throughout the region, with the exception of parts of Ethiopia where they are occasionally found in admixture with other crops such as safflower or sorghum (Simoons 1960).

The type preferred in most of the countries in the Middle East and North Africa are those with bold, buff-colored seeds and a premium price is often paid for these varieties. In Ethiopia, Iran and Afghanistan, however, smaller colored seeds are also common and mixtures of these, together with buff-colored types can often be found in the markets.

CHICKPEA RESEARCH IN THE REGION

To date relatively little research work has been undertaken on chickpeas in the region apart from some selections from local landraces and basic agronomic studies.

While attempting to summarize the work done in the region so far, it must be borne in mind that research may have been carried out of which I am unaware, especially in Morocco and Turkey. Apologies are given for any omissions.

RPIP was set up in 1963 financed by the USAID and the Agricultural Research Service of the USDA. This project started in 1964 in Iran following an agreement with the Government of Iran allowing for participation in project operations of the plan organization, the Ministry of Agriculture and Karaj Agricultural College. In 1966 similar cooperative research was started with Pahlavi University in Shiraz. The research is well summarized in the annual reports and only a

Table 2. Production of Pulses in Countries of the Middle East and North Africa

Country	Chickpeas		Broadbeans		Lentils		Dry Beans	
	Production (1,000 tons)	Yield (tons/ha)	Production (1,000 tons)	Yield (tons/ha)	Production (1,000 tons)	Yield (tons/ha)	Production (1,000 tons)	Yield (tons/ha)
Algeria	18	0.51	16	0.70	9	0.39	4	0.70
Egypt	6	1.74	296	2.19	39	1.93	8	1.74
Ethiopia	189	0.63	143	0.94	109	0.61	74	0.77
Iran	45	0.47	-	-	37	0.67	11	1.10
Iraq	6	0.60	12	0.80	4	0.62	7	0.65
Jordan	1	0.50	4	1.75	22	1.00	-	-
Lebanon	1	0.50	1	1.10	2	0.56	2	1.20
Morocco	100	0.83	190	1.06	22	0.61	5	0.63
Sudan	2	1.03	13	1.63	-	-	6	1.10
Syria	24	0.81	10	1.36	87	0.68	4	1.33
Tunisia	13	0.50	24	0.47	1	0.37	-	-
Turkey	120	1.20	43	1.43	105	1.02	155	1.41

Source: F.A.O. Production Yearbook, 1971.

brief outline will be given here (Progress Report, RPIP 1964-1971).

There were four main areas of research: breeding, agronomy, pathology and entomology. The crops studied included a wide range of pulses in addition to chickpeas.

Plant Pathology

A major objective of the varietal improvement work was to transfer genes for resistance to blight (Ascochyta rabiei) from a resistant line (Accession No. 12-074-006625) to better agronomic strains. A number of crosses were also established between bruchid resistant lines, double-podded lines, high yielding lines and lines with good seed quality. Several genetic studies were also undertaken, and a large germplasm collection was made including a comprehensive collection of local Iranian material (Khosh-Khui and Niknejad 1972; Niknejad and Khosh-Khui 1972; Niknejad, Khosh-Khui and Shorashy 1971).

The pathology work was mainly concerned with the control (Kaiser, Okhovat and Mossahebi 1973), and factors affecting growth, sporulation pathogenicity and survival (Kaiser 1973) of Ascochyta rabiei. Virus diseases were also studied and a total of five viruses were isolated from naturally infected chickpeas (Kaiser, Okhovat and Mossahebi 1972). These were alfalfa mosaic (AMV), bean yellow mosaic (BYMV), cucumber mosaic (CMV), pea ennation mosaic (PEMV) and pea leaf roll (PLRV).

Three lines of chickpeas were found with resistance to bruchids and two with resistance to root knot nematode (Meloidogyne sp.). Little success was reported, however, with chemical control of insect pests, primarily because of low levels of natural infestation.

The agronomy studies with chickpeas were concerned with plant population density and irrigation. In their experiments, no yield advantage was found by increasing the population above 300,000 plants per hectare in 50 cm rows and in general, irrigation at twelve day intervals resulted in slightly lower yields than irrigation at either six or nine day intervals.

The RPIP program was terminated in Iran at the end of 1971, although much of the research started by the project has continued under local funding, and the pulse work currently being undertaken is still among the best in the region.

OTHER MIDDLE EAST PROGRAMS

Apart from the Iranian program, most of the work has consisted of basic agronomy trials and some development of improved varieties by selection from the local germplasm.

In.both Egypt and Sudan, there are grain legume research sections in the respective Ministries of Agriculture, but in neither country have chickpeas received much attention owing to the comparatively unimportant position of this pulse in their agriculture. In Egypt, a collection of local germplasm has been made and one selection from this, designated Gizal, is now the standard recommended variety. Planting date trials have been undertaken in Sudan and currently the effects of certain soil treatments on sodium toxicity are being investigated at Hudeiba Research Station.

An initial collection of local landraces of chickpeas has been made in Turkey, and plans exist for additional collection in the future, in conjunction with the FAO sponsored scheme on the conservation of plant genetic resources. The collection is being maintained at the Plant Introduction Center at the Ministry of Agriculture Research Station, Menemen, Izmir.

A small collection of local germplasm is also being maintained at the Debre-Zeit Research Station of Haile Sellassie I University in Ethiopia. A number of selections have been made from this material which have been shown to be superior in yield to the unselected local landraces. Trials for soreening for resistance to wilt (Debre-Zeit Agricultural Experiment Station 1972-73) were undertaken in 1973, but with little success. Selections were made from local and introduced germplasm in Algeria for several years prior to independence in 1962, and some very good genotypes were developed having a tall and erect growth habit suitable for mechanical harvesting. This work was largely discontinued after 1962, however, and it is only within the last few years that interest in the crop has been revived.

In Lebanon, trials have been conducted on various agronomic aspects of chickpeas at the American University of Beirut. In addition tc the multiple cropping work mentioned previously, the effects of planting date, plant population density and other factors have been the subject of several investigations (M.Sc. Thesis 1970: M.Sc. Thesis 1973). A grant to the Faculty of Agriculture Sciences at the

A.U.B. was recently approved by the IDRC to finance work on nutritional and food processing aspects of sorghum, millets and food legumes of which the chickpea will be one of the main pulses studied.

THE REGIONAL FOOD LEGUME PROGRAM

The regional food legume program in Lebanon has two main aspects: practical crop improvement and training.

In view of the relatively few trained scientists working on pulses in the region it was felt that a top priority should be given to building up a body of skilled research workers 1n the region who would be capable of running effective field experimentation. With this aim in mind, a training course was held in Lebanon from mid-March until mid-August, 1974, which was attended by 16 students from a total of ten countries. The training given was mainly of a practical nature aimed more at teaching field skills related to plant improvement (land preparation, crossing techniques, note taking, etc.)'rather than the theoretical aspects.

In view of the generally rather narrow gene base available to breeders from their local genotypes, the program so far has concentrated almost entirely on obtaining, maintaining, increasing and distributing germplasm. In 1973, pulses were collected in Lebanon, Syria, Iraq and Jordan and germplasm was also obtained from breeders both within and outside the region. A five-week pulse collecting expedition was mounted in Afghanistan in July and August, 1974, at the request of the Afghanistan government. Of a total of nearly 900 samples collected during the trip, 289 were chickpeas.

In 1972 and 1973, the chickpea collections were screened in Egypt, Sudan, Tunisia and Lebanon. On the basis of these nurseries, a regional chickpea nursery comprising 168 entries was distributed in 1974 to 12 countries in the region (Morocco, Algeria, Egypt, Sudan, Ethiopia, Jordan, Lebanon, Syria, Cyprus, Turkey, Iran and Afghanistan). The information received back from these nurseries, however, was poor and this season an enlarged regional nursery of nearly 400 entries has been distributed for evaluation.

Single plant selections from the genotype collections have been evaluated in Egypt, Sudan and Lebanon. In 1974, the progeny from over 3500 selected plants were evaluated in Lebanon and several of the lines appeared to be very promising, maturing as early or earlier than the local varieties and having greater vigor. Some of the best of these lines will be put in a preliminary yield trials this season. Interesting genetic differences were observed in the nursery with regard to the effects iron deficiency (or unavailability) in the soil. A number of lines showed very obvious symptoms of stunting and yellowing and in several cases failed to produce any seed. Other genotypes, however, showed no apparent symptoms although, of course, it is not known whether the yields were affected.

Genotypes have been identified for including in a crossing block this season and it is planned to make crosses between superior genotypes and the best locally adapted variety in each country. The segregated seed from these crosses will be distributed for selection. Eleven locally adapted lines were included in the 1974 ICRISAT crossing block. It is intended that the F 's of these crosses will be evaluated this season in Lebanon, and the F2 seed will be distributed to the region for selection work.

The program will make a major contribution to breeding in the region through the organization of off-season nurseries, enabling breeders in many of the countries to grow more than one generation per year. A high elevation site in Lebanon was evaluated in 1974 as on off-season location and from the results it appears that by growing a normal crop at low elevation followed by a second crop at high elevation, two generations can be grown between April and the end of October. If this is coupled with the normal growing season in Egypt or Sudan, three generations can be grown each year.

FUTURE WORK

As the regional program develops, it is hoped that the research will be expanded to include pathology and nutrition. There is now a strong possibility that an international agricultural research center will be established for the Middle East region, and if this comes about a rapid expansion of the food legume program activities should be available. There already exists a good cooperation between the ALAD program and the ICRISAT program—and it is hoped that this too will develop further in the future.

DISCUSSION

W.J. Kaiser: The problem of movement of plant and seed material in the Middle Eastern area is very serious. This could affect the program on chickpea (and pigeonpea) considerably.

G.C. Hawtin: I agree that there is a danger of introducing new pathogens to areas where they do not exist and caution is necessary. In general, quarantine regulations in the area have been loosely interpreted and very free movement of material has been possible.

K.B. Singh: I have noted the excellent collection of Cicer available in the Middle East and wish to know how ICRISAT could "mesh in" with the work already underway.

G.C. Hawtin: I feel that there are many fields in which mutual benefit could be obtained. In my experience ICRISAT could take over a large part of the crossing work and greatly assist in provision of early cross material for test in the Middle East area. In fact, any work ICRISAT could do by way of providing data on germplasm would be very welcome. ICRISAT is ideally situated to maintain the germplasm collection, and in due course will have better germplasm storage which will be of immense value to workers in the semiarid tropics and adjacent areas. There is no doubt that ICRISAT could also assist in the organization of yield trials as its cooperative research program in the semiarid tropics develops.

L.J.G. van der Maesen: Will Dr. Hawtin mention the number of species of wild *Cicer* which have been obtained from Afghanistan.

G.C. Hawtin: To date, only one species, Cicer *fungens*, has been obtained from Afghanistan. C. *chlorosannicum* has not been found. However, a former trainee has now returned to Afghanistan and will be looking for wild species.

H.K. Jain: I note that extensive germplasm collections exist but wonder whether any cultivars have been found which are resistant to wilt. I feel that there is a need to develop screening procedures for this very important disease.

G.C. Hawtin: I agree that wilt is a major problem and that a great deal more work is required. There appear to be lines that are resistant in some places and when tested elsewhere the resistance has broken down, possibly indicating that "wilt" was caused by several different pathogens or strains and therefore work must be intensified on this aspect.

B.P. Pandya: I wish to know about the progress made with the double podded lines and green seeded types.

G.C. Hawtin: This work was done by the RPIP and possibly Dr. Jaffari is in a better position to give the current situation report.

J. Jaffari: So far as I know, not much work has been done on those aspects. The double pods were found on a black seeded type and the work has not been followed up in detail.

LITERATURE CITED

Annual Research Report. 1972-73. Debre-Zeit Agricultural Experiment Station, Haile Selassie 1 University Ethiopia.

Grami B. 1970. Effect of date planting and plant population on chickpea production. M.Sc. thesis. A.U.B. Lebanon.

Kaiser, W.J. 1973. Factors affecting growth, sporulation, pathogenicity and survival of Ascochyta rabid. Mycologia 65(2) 444-447.

Kaiser, W.J., M. Okhovat, and Gh. Mossahebi. 1972. Virus diseases of pulse crops in Iran. Karaj, Univ. of Tehran Agricultural College. RPIP.

Kaiser, W.J., M. Okhovat and Gh. Mossahebi. 1973. Effect of seed-treatment fungicides on control of Ascochyta rabiei in chickpea seed infected with the pathogen. Pl. Dis. Rep. 57 (9) 742-746.

Khosh-Khui, M. and M. Niknejad. 1972. Plant height and width inheritance and their correlation with some of the yield components in chickpeas (Cicer arietinum L.) J. Agric. Sci. Camb. 78 37-38.

Niknejad, M., and M. Khosh-Khui. 1972. Natural cross-pollination in gram (Cicer arietinum L.) Indian J. Agric. Sci. 42 273-274.

Niknejad, M., M. Khosh-Khui and S.R. Ghorashy. 1971. Inheritance of seed size in chickpeas (Cicer arietinum L.) Crop Sc1. 11 768-769.

RPIP Progress Report. Published annually 1964-1971. Iran.

Simoons, F.J. 1960. Northwest Ethiopia, peoples and economy. Madison. Univ. of Wisconsin Press. Quoted by Westphal E. 1974. Pulses 1n Ethiopia. Centre for Agricultural Publishing and Documentation, Wageningen.

Syed. Hafiz-ul-Hague. 1973. Performance evaluation of some chickpea (Cicer arietinum L.) varieties In Lebanon. M.Sc. Thesis. A.U.B. Lebanon.

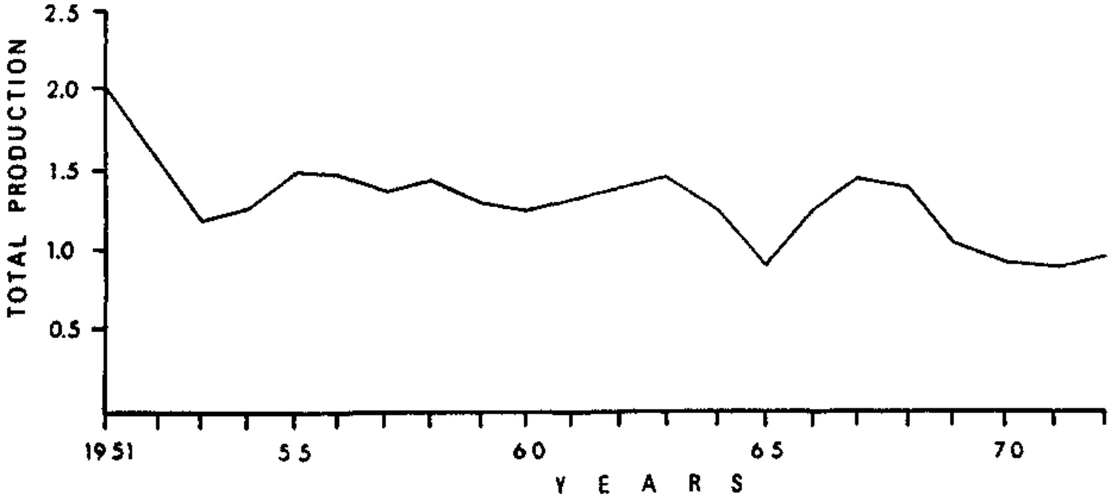
THE RESEARCH ON THE CHICKPEA (CICER ARIETINUM) IN SPAIN

J. I. Cubero[1]

INTRODUCTION

The chickpea (Cicer arietinum L.) has been a very popular leguminous seed in Spain, used as human and animal food. Even now, with the cultivation declining (Figure 1), one of the most popular dishes of the Spanish kitchen (the "cocido") is made with the chickpea grain. Perhaps paradoxically, when the cultivation is disappearing from large regions of the country, the "cocido" is moving from its original rural zones to the most luxurious restaurants of the main towns. The paradox is only superficial; indeed, like many other popular dishes, the "cocido" is Itself a complete meal, very rich in proteins, carbohydrates and fats, and for this reason was *very* much appreciated in the zones poorest in livestock. With the rise of the standard of living, the vegetable proteins are substituted by the animal ones, and the traditional dishes begin to be appreciated not for their nutritious value but for their "non essential" ones --that is, the mixture of flavors, colors and tastes.

Figure 1. Evolution of the Total Production of Cicer Arietinum in Spain



---

[1] InstitutO National de Investlgaciones Agrarlas, Centro Regional de Andalucia, Cordoba, Spain

Decline of Culture

The tendency towards the declining of the chickpea culture as seen in Figure 1 needs comment. On one hand, even when the official data do not explain this question, the decline of the crop is greater in animal feed than in human food. The main reason is the decrease in the commercial value of chickpea because of the availability of more efficient crops—soybean and sunflower, for example. On the other hand, the decrease of cultivated area has been greater in the agronomically richest zones, available for other crops of higher economic value than in the poorest ones where the choice of a culture is strongly limited by the environmental conditions. In connection with this point, it is necessary to add that the high price paid for the best varieties for human food (as a reference, one dollar USA/kilo) has moved many farmers of the richest soils to plant chickpea again as a possible commercial crop.

Yield Quantity and Quality

Low yield in chickpea is a very important factor. There are three reasons for the low yield: the use of not selected varieties, the use of old cultivation systems and the presence of two cryptogamic diseases *Phyllosticta rablei* Trot, or *Micosphaerella rabiei* Kov. and *Fusarium* sp.

Progressive farmers have been able to double the yields by changing the traditional system of cultivation and using fertilizers and pesticides as modern agriculture requires. In the future, it will be interesting to study the more adequate plant densities, quantities and types of fertilizers, etc., but only when the use of selected varieties is common.

BREEDING EXPERIMENTS

Breeding to obtain selected varieties was initiated by the Puerta's team in the late fifties. A large collection was formed and considering the strict autogamy of this species, a plant-to-line method was followed. The result was the obtaining of some varieties with higher yield than those previously known, but unhappily this was coincident (years 1964-66) with the lowest point of Interest on chickpea, and the diffusion of the new material was interrupted. Perhaps it is a good moment to study those varieties again, particularly in the zones where the cultivation of the crop is becoming Important, as in the South of Spain (Figure 2). As a member of the Puerta's team, and because of my actual situation in the Instituto Nacional de Investigaciones Agrarias (INIA) at Cordoba (see C in Figure 2), I think that in the coming years I shall be able to do something in this way for the Andalusian farmers. A typical yield in Spain varies between 5 and 8 Q/Ha, depending on the zone. With new methods of culture or new varieties these numbers can be doubled.

Selection for Quality

The same team began the selection for quality. The Spanish material was, in this sense, excellent and it was not necessary to use hybridization as a system of breeding. The same selection used for production gave us very good varieties for cooking. It is the traditional point of view of the farmers that a variety is better for cooking when its grains are larger (45-55 per ounce are the most appreciated) and rougher than the others. It is a prerequisite that the variety be white flowered.

It is necessary to add here that the quality is not only a varietal question, but it is also affected by the soil. It is well known that the lime soils make the grain

Flour. 2. Cultivated Araa of Cicer Arietinum in Spain (Hectares)

harder and the best quality is obtained on sandy soils, although this kind of soil is not agronomically the best for the chickpea.

Disease and Pests

When I began to work with Puerta in 1962, the most (and perhaps the only) known disease of chickpea was the blight disease produced by Phyllosticta rabiei (Pass.) Trotter, the imperfect form of the ascomycete Mycosphaerella rabiei Kov. Some works not only of selection (Puerta 1964) but also of some physiological aspects of the parasite were initiated to solve the problem.(Cubero 1965). Some human and ecological factors contributed to the interruption of that work, but in all cases I sowed the complete collection that I received from Puerta every year from 1966 until now—with the exception of 1970—first near Madrid and, from 1971, in Cordoba and other places of Andalusia. The fungus seemed to have disappeared. Evidently, the reduction of the cultivated area can have played a role, as well as the use of cuprics to prevent the attack. Few farmers used cuprics twenty years ago, but that is not sufficient to explain the disappearance of this disease.

Perhaps another reason is the spread of another disease more serious than this one: the fusariose produced by Fusarium sp. In 1962, during a journey across Andalusia to collect material, I observed the coexistence of both diseases and the potential danger of the Fusarium wilt. A few years later, I did not see any more blight and a complete infection of wilt. Since 1972, I have grown the collection now composed of about 700 entries, in naturally infected fields. Next year, I shall begin some tests to study the selected material in agronomic conditions.

The small fly Lyriomyza cicerina causes some damage on the chickpea. It is said that the losses are small, but they have not been thoroughly evaluated. Perhaps in a country with so many sunny hours as Spain, the losses of parenchyma caused by the fly are less serious than in other countries.

SYSTEMATICS, EVOLUTION AND GENETICS

A large collection of varieties and populations enables studies of all kinds. The methods of numerical taxonomy were used to study some problems concerning the systematics of this species. First we used the Mahalanobis' Group Distance (Rao 1952) and then we tried the Principal Components Method. These two methods, completed with a deep pure botanic study, constitute the theme of the doctoral thesis of my coworker and his wife Ma Teresa Moreno. Some aspects of this work are given here. The main systematic characteristic is the seed size or its equivalent, the pod size. In connection with that, the species shows a discontinuity in a region of the variation range. In our conditions, this point is in the region of 21-22 mm for length of pod or of its equivalent in seed size, 100-110 grains per ounce. We separate, for this reason, two groups: macrocarpa and microcarpa. The analysis of components shows that it is possible to differentiate in the latter two subgroups, micro and mesosperma, separated in the zone of 180-200 grains per ounce.

Distribution of Chickpea

When the collection is classified according to these systems, and the results are represented in a map (Figure 3), it is seen that a trend exists between the eastern and western natural limits (Iran and Spain-Morocco)"! It is well known that the Indian chickpeas were introduced as a culture. I have discussed the implications of this result in another paper (Cubero 1974), considering that same type of variation has been observed in Vicia faba and also in Lens esculenta. Perhaps the center of differentiation for Cicer arietinum is the region in the South of Turkey and the North of Mesopotamia. The agricultural center of diffusion had to be, as for many other crops, the Near East (Mesopotamia-Nile Delta).

Hybridization

Hybridizations were intensively made for genetic, systematic and breeding purposes. We have found that incompatibility barriers are not present among the three mentioned groups, but intra-group (inter-varietal incompatibility) exists (Table 1). Many crosses have been performed, which are permitting the study of quantitative characteristics. At the moment we are analyzing the $F1$ results following the Diallel Analysis of Hayman (1954), but we intend to continue the analysis of the F2 and other generations. The extreme variation of the material in the crosses will make selection for resistance to Fusarium very interesting. We will follow the pedigree

Figure 3. World Distribution of <u>Cicer Arietinum</u> by Seed Size

Table 1. Cicer Arietinum, Hybridizations

	M 108	M 1492	me 12	me 1341	m 1543	M 1550	m 1473	me 1569	M 127	me 1288	
M 108	-	24 20.83 5	46 8.70 4	56 5.36 3	-	22 22.73 5	28 46.43 13	50 30.00 15	38 36.84 14	48 31.25 15	esp
M 1492	21 9.52 2	-	45 22.22 10	48 2.08 1	-	39 7.69 3	36 19.44 7	34 23.53 8	30 23.33 7	52 13.46 7	esp
me 12	57 0.00 0	83 3.61 3	-	58 6.90 4	-	37 2.70 1	34 0.00 0	51 23.53 12	50 10.00 5	61 11.48 7	esp
me 1341	51 0.00 0	52 1.92 1	42 26.19 11	-	36 0.00 0	32 15.63 5	43 2.33 1	19 5.26 1	48 14.58 7	58 1.72 1	mj
m 1543	-	-	-	23 4.35 1	-	-	-	-	-	-	ind
M 1550	35 5.71 2	50 2.00 1	57 17.54 10	32 9.38 3	-	-	26 15.38 4	26 23.08 6	34 20.59 7	37 2.70 1	ind
m 1473	32 25.00 8	44 6.82 3	35 14.29 5	47 12.77 6		37 8.11 3		43 23.26 10	51 13.73 7	51 17.65 9	ind
me 1569	47 21.28 10	42 42.86 18	33 33.33 11	23 26.09 6	-	53 11.32 6	45 26.67 12	-	39 17.95 7	39 23.08 9	balc
M 127	83 6.02 5	52 15.38 8	44 15.91 7	58 0.00 0	-	40 7.50 3	53 5.66 3	49 16.33 8	-	19 15.79 3	esp
me 1288	73 4.11 3	62 1.61 1	64 12.50 8	56 1.79 1	-	54 11.11 6	50 26.00 13	49 22.45 11	35 8.57 3	-	mj
	esp	esp	esp	mj	ind	ind	ind	balc	esp	mj	

Legend

M = Macrosperma
me= Mesosperma
m = Microsperma

hybrid
% success
pods numbers

esp = Spain
ind = India
mj = Mexico
balc= Balkan

method looking logically for resistance, quality and yield.

THE FUTURE

I hope that in the future there will be more researchers. The selection work started in Madrid by Puerta has been continued by me in Cordoba, along with other studies as mentioned above. The funds available for developing research in chickpea are very meager, but I am optimistic because of the new interest in this cultivation shown by modem farmers.

DISCUSSION

L.J.G. van der Maesen:	I would like to know how many grams there are in the Spanish ounce.
J.I. Cubero:	There are approximately thirty.
A.K. Auckland:	What are the fertility barriers between groups of chickpea which are described?
L.J.G. van der Maesen:	If I could interpose, the interspecific crosses in the crop have 1n my experience never succeeded. Initial interest in crossing 1n the different forms of cultivated <u>Cicer</u> has been limited, and crossing appears to be difficult between the major groups. I feel that barriers certainly do exist but that to date the number of crosses made has been too small to determine their nature.
J.I. Cubero:	I agree that the number of crosses made to date is small, but the barriers do exist and it is difficult to interpret the existing situation. There appears to have been a drift of genes which had been fixed randomly between the different forms. I have not found fertility barriers between macrosperma, microsperma and mesosperma, but I have found them within these groups. There is no definite pattern in the fertility barriers.
A.K. Auckland:	I feel that further work on this problem is necessary.
S. Chandra:	It may be of interest for you to know that some work has been done in India and there appeared to be a chemical barrier to Interspecific crosses. Possibly protein is the cause of this problem.

LITERATURE CITED

Cubero, J.I. 1965. Estudio sobre elementos nutritivos necesarios y condiciones de medio exigidos por el honga Phyllosticta rabiei (Pass) Trotter. Bol. de Patol Veg Entom Agri 28:1-36.

Cubero, J.I. 1974. On the evolution of Vicia faba L. Theor. Appl. Genetics, in the press.

Hayman, B.I. 1954. The theory and analysis of diallel crosses. Genetics 39: 789-809.

Puerta, J. 1964. La "rabia" del garbanzo: aislamiento del hongo Phyllosticta rabiei (pass) Trotter e investigacion de posibles variedades de garbanzo resistentes. Bol. de Patologia Vegetal y Entom. Ayric. 27: 15-52

Rao, C.R. 1952. Advanced statistical methods in biometric research. New York: John Wiley & Sons Inc.

THE SITUATION OF RESEARCH OF CHICKPEA AGRICULTURE IN TURKEY

D. Eser[1]

INTRODUCTION

Geography

Turkey is a bridge between Europe and Asia, surrounded by seas on three sides. Area of Turkey is 779,452 km^2, and the population is 40 million.

Turkey is divided into the following principal regions for purposes of geographical analysis:

Black Sea Region
Marmara Region
Aegean Region
Central Anatolia Region
Mediterranean Region
East Anatolia Region
Southwest Anatolia Region

Climate

Since it is situated in the temperate zone, Turkey has various climatic types in different parts of the country. A brief description of temperature and precipitation patterns as observed in different parts of the country is given below.

Temperature

The average annual temperature varies between 18-20° C on the South Coast, falling to 14-15° C on the West Coast, and fluctuating between 4-18° C in the Interior depending on altitude. During the two hottest months of summer, July and August, the mean temperature is 27° C or more on the Mediterranean and Aegean Coasts and is 22-24° C on the Marmara and Black Sea Coasts. Being away from moderating maritime Influences, most of the Interior regions receive heat more rapidly and are subject to a hot summer. During the coldest months of the winter, January and February, substantial variations in temperature between coastal and considerably colder interior regions are observed. The south coast of Turkey is usually warm during the winter with the mean temperature between 8-12° C. The winters are not very severe on the north and west coasts of Turkey; the mean January temperature varies from 5°C to 7°C. The east Anatolian and the interior parts of Turkey are subject to cold winters because they are cut off from moderating effects of the sea wind by the coastal mountains. Average temperatures in these areas are between 0° and -10° C in winter.

Precipitation

Generally there are heavy rainfalls on the slopes of mountains facing the seas. Annual precipitation is over 600 mm in these areas. Toward the interior areas the rainfall gradually becomes less. In the central parts it decreases to 250-300 mm. On the Marmara, Mediterranean and Aegean coasts the rainy season begins in autumn and continues until late spring. The Black Sea Coast receives rain throughout the year. In the interior areas and Southeast Anatolia rainfall mostly occurs in the spring (Anon. 1973 a).

Distribution of Arable Land

General distribution of agricultural land

---

[1] University of Ankara, Ankara, Turkey

of Turkey is as follows (Anon. 1973 b);

Area (in 1000's Hectares)	
Total cultivated	25,013
Total sown	16,061
Total fallow	8,952
Cereals sown	13,304
Pulses sown	450
Other crops sown	2,140

Including the nine million hectares fallowed for cereals, the total area devoted to them adds up to 8956 of the area cultivated. Wheat is the major crop with 8.9 million hectares. More than 90% of the cultivated land cannot be irrigated and dry farming practices have to be applied. Pulse crops (chickpea, lentil, dry bean, broad bean pea and kidney bean) cover 2.8% of the area sown and 1.8% of the cultivated land.

CHICKPEA CULTIVATION

The Place of Chickpea in the Agriculture of Turkey

Chickpea had 80-90 thousand hectares area sown and 90-100 thousand tons production until 1969, with some fluctuations from year to year.

In the last four years, an increase in area sown and production occurred.

Year	Area sown 1000's hectares	Production 1000's tons	Yield kg/ha
1970	100	109	10*0
1971	110	133	1209
1972	178	183	1028
1973	186	185	995

Distribution of the Chickpea Growing Area

Except for the Black Sea Coasts and the eastern part of Anatolia, chickpea is grown in all parts of Turkey with some fluctuations in area sown and production. However, the major growing areas are the interior parts of west Anatolia (500-60C mm of annual precipitation) and Central and Southeast Anatolia (300-400 mm of annual precipitation). Irrigation is not applied to chickpeas which are grown in rotation with winter cereals, especially wheat.

Consumption of Chickpea in Turkey

Chickpea has a long history in human nutrition and is known as a national food crop. It is also used as leblebi, which is a kind of snack. It is believed among Turkish people that leblebi reduces the acidity in the stomach helping to cure ulcers. Some types with dark colored seeds are used as animal feeds. Also, perennial types used for grazing. Chickpea is also exported almost every year.

In summary, the importance of chickpea for our country is as follows:

1. Human and animal nutrition.
2. Increasing the fertility ot soils in dryland areas in crop rotation with cereals.
3. As an export crop of Turkey and therefore a contributor to the national income.

CHICKPEA RESEARCH

Though there are these positive effects, chickpea has not been handled as it should be. We still do not have a registered variety distributed to farmers. The varieties grown are essentially local varieties. They can be classified according to their seed size, color and weights. Size: a. Ram's head shaped; b. Pea shaped; c. Intermediate -- snack type, seed coat wrinkled superficially -- (Genckan 1958).

As mentioned above, there is no national project for chickpea growing and breeding. In the third five-year development plan, prepared in 1970, 116 thousand hectares of growing area, and 150 thousand tons of production were projected for 1975—but no efforts are being made to realize it. However, area sown and production in 1973 was more than that projected for 1975.

Research Organization, Centers of Research and Staff Facilities

At present, the Plant Growing and Breeding Department of the Faculty of Agriculture of the University of Ankara acts as the center of the research on chickpea. In addition, some adaptation trials are made at the Eskisehir Agricultural Research Institute and some materials are available from the Seed Introduction Center in Izmir.

Research

A study on the correlations between plant yield and some morphological characters of chickpea (Cicer arietinum L.) has been completed by Prof. Dr. Osman Tosun and is about to be published. This research was made with 14 native and 87 foreign varieties in 1973. A total of 101 varieties were grouped according to seed size (Genckan 1958), color, and weight, as follows:

1. Big, pale yellow and ram's head shaped.
2. Small, yellow and ram's head shaped.
3. Big and white snack type.
4. Black and ram's head shaped.

Within each of the four groups and across groups yield per plant, 100 seed weight, height and spreading at flowering time, pod and seed number and primary and secondary branch number per plant were investigated for all possible correlations. Coefficients of yield with each correlation of the other characters are presented in Table 1.

Results

Correlations between plant yield and 100 seed weight, seed and pod number: Significant and positive correlations at the 1% level were found between plant yield and seed number and pod number within each of the groups and across groups. No correlation was found between plant yield and 100 seed weight in the 1st, 2nd and 3rd groups but in the 4th group where the varieties were not much different for seed and pod number, a positive and significant correlation at the 1% level was found.

Correlations Between Plant Yield and Primary and Secondary Branches

Correlations for both characters in the 1st group were positive and significant at the 5% level; in the 2nd group and in the 4th group at the 1% level; in the 3rd group for primary branch number at the 1% level, for secondary branch number at the 5% level, and across groups for both characters at the 1% level.

Correlations Between Plant Yield and Plant Height and Spreading at Flowering Time

Between plant yield and plant height, in the 1st and 3rd groups positive and significant at the 5% level; within the 2nd and 4th groups and across groups at the 1% level. No correlation was found between plant yield and spreading within the 1st and 3rd groups, but in the 2nd and 4th groups and across groups, and because they were made up of more varieties, positive correlations at the 1% level were found.

Correlations Between Characters Except Plant Yield

For 100 seed weight, only in the 4th group, positive correlations at the 1% level were found between primary and secondary branch number, height and spreading. In the 1st group, except correlations between seed number and spreading and between pod number and spreading, the other characters were correlated positively with each other, some of them being non-significant. However among them, within groups and across groups, the highest positive correlation at the 1% level was between seed and pod number (1st group r=0.988**, 2nd group r=0.926**, 3rd group r=0.992**, 4th group r=0.912** and across groups r=0.914**).

Observations

As is seen, all of the characters except 100 seed weight and plant spreading have given significant correlations with plant yield. One hundred seed weight was effective on yield only with Individuals which are not much different in other characters (especially for the pod and seed number). High heritability values have been reported by other researchers

Table 1. Correlation Between Plant Yield and 100 Seed Weight, Seed and Pod Number per Plant, Primary and Secondary Branch Numbers per Plant, Plant Height and Plant Spreading Within the Groups and Between the Groups

Groups	Number of varieties	Degrees of freedom	r at 1%	r at 5%	100 seed weight	Seed number per plant	Pod number per plant	Primary branch number per plant	Secondary branch number per plant	Plant height	Plant spreading
1. Big, pale yellow rams head shaped	6	4	0.917	0.811	0.500	$0.921^{**)}$	$0.921^{**)}$	$0.885^{**)}$	$0.866^{**)}$	$0.900^{*)}$	0.180
2. Small, yellow ram head shaped	20	18	0.561	0.444	0.322	$0.813^{**)}$	$0.689^{**)}$	$0.846^{**)}$	$0.807^{**)}$	$0.867^{**)}$	$0.600^{**)}$
3. Big, white, snack type	7	5	0.874	0.754	-0.245	$0.909^{**)}$	$0.878^{**)}$	$0.943^{**)}$	$0.821^{**)}$	$0.841^{*)}$	0.748
4. Black, rams head type	68	66	0.315	0.242	$0.636^{**)}$	$0.598^{**)}$	$0.615^{**)}$	$0.624^{**)}$	$0.740^{**)}$	$0.600^{**)}$	$0.669^{**)}$
5. Across groups	101	93	0.263	0.202	$0.508^{**)}$	$0.674^{**)}$	$0.651^{**)}$	$0.692^{**)}$	$0.752^{**)}$	$0.696^{**)}$	$0.622^{**)}$

(Khosh-Khui and Niknejad 1972, Sandhu and Singh 1972, Singh et al. 1973 and Gupta et al. 1974) for pod number per plant, branch number per plant, plant height and 100 seed weight. The first three characters appear important for plant selection for yield. Where there is not much difference for pod and seed number, 100 seed weight is to be considered an important character for selection.

Spacing and Row Distance

Another study has been started on the effects of different plant spacing and row distance on the yield and plant morphology by Prof. Dr. Osman Tosun in 1974. A chickpea variety has been sown with 20 cm, 30 cm, 40 cm, 50 cm row spacings and 5 cm, 10 cm, 15 cm, 20 cm, plant spacings with four replications in each treatment. We already have data for yield per m^2, number of plants per m^2, yield per plant, plant height, primary and secondary branch number per plant, seed and pod number per plant and 100 seed weight which are being analyzed statistically.

Pathology

A study by pathologist Dr. Haluk Soran has been started on "Comparative investigation of native and foreign chickpea varieties under the ecological conditions of Central Anatolia for earliness, yielding ability and resistance to diseases" with 36 native and 16 foreign varieties. Resistance to root rot and anthracnose are of special importance in this research.

In 1973, fifty-one samples were collected from the chickpea growing areas of Turkey and they have been classified into 125 types according to seed size, color and seed weight. Another group of 35 samples has been obtained from Izmir Seed Introduction Center. A total of 160 samples were sown in 1974. There are 180 single plant selections which did not have any sign of disease and had yields of more than 10 g per plant which will be sown in 1975.

Hybridization Studies

In 1973, two white seeded, high yielding native varieties which are not resistant to diseases were crossed with one black seeded variety from Israel and one black brownish colored variety from Morocco which had some degree of resistance. Native varieties were used as the female parent.

The parents and their F_1 generations are being studied for plant height, primary and secondary branch numbers, pod length, width and thickness, seed number, seed length, width and thickness, 100 seed weight and plant yield. F_2 plants will be investigated in 1975.

Perennial chickpea (Cicer montbretii Jaub. et Spach) collected from the western parts of Turkey was grown with the aim of hybridization. Though we were not successful, we intend to carry on research in this study.

Problems Affecting Yield and Research Status

As has been mentioned before, research on chickpea is very new in Turkey. Native edible types are all susceptible to anthracnose and root rot to some degree. Chickpea leaf miner fly is the most harmful insect. Bruchus sp. is not a problem. Good cultural techniques are not widely used. Broadcast seeding is used in general and fertilizer and chemical protection are not applied. Therefore we believe that determination of the proper cultural methods and finding high yielding, early maturing and disease resistant varieties are of first importance. Then we can proceed to research on the nutritive value of the crop in relation to the protein deficiency and rapidly increasing population of our country and the world.

DISCUSSION

G.C. Hawtin:	I want to know if the perennial chickpea which was grazed by animals in Turkey was seeded.
D. Eser:	It was growing in the mountains of southeast Anatolia and was not seeded.
B.R. Murty:	In Iran, the small seeded varieties appeared to be found in the south while in Turkey they were in the north, in the area bordering the U.S.S.R. It is strange that this wide separation occurred.
D. Eser:	There has been no large scale issue of an approved variety to farmers

in Turkey. Black seeded varieties are grown in southeast Anatolia and on the whole farmers do not grow large seeded types. Many primitive types are still grown in remote areas.

L.J.G. van der Maesen: I think that the small seeded types are rudiments of seed which has been grown for generations by farmers having little contact with the outside world. I am, however, keen to know if these primitive types could still be obtained in Turkey or whether the types mentioned by Genckan are now mixed.

D. Eser: The types are still discrete and could be obtained. I agree, however, that they *are* not present in the Izmir collections and would have to be looked for.

P.J. Dart: Would you care to comment on the reported expansion of production of chickpea in the past four years in Turkey. I wonder whether this is due to an expansion into areas where the crop was not previously grown, an increase in acreage in existing areas, or increase in price which had encouraged interest in the crop.

D. Eser: The prices are not very good on the whole, but the population has increased and exports have been stimulated, and farmers appreciate the return they get for the crop. I feel that part of the increased production is due to the use of the chickpea in rotation with the increased wheat acreage. Perhaps there would not have been a big increase in acreage devoted entirely to the crop in the absence of these factors.

P.J. Dart: The object of my question is to direct attention to nodulation as a factor if large acreages are being opened up for the crop in previously uncropped areas.

LITERATURE CITED

Anon. 1973 a. Statistical yearbook of Turkey. State Institute of Statistics. Publication No.710.

Anon. 1973 b. The Summary of agricultural statistics. State Institute of Statistics. Publication No. 708.

Genckan, S. 1958. Turkiye'nin onemli nohut cesitlerinen baslica vasiflari uzerinde arastirmalar. Ege Universitesi, Ziraat Fakultesi Yayinlari 1:40-42.

Gupta, S.P., R.C. Luthra, Gill. 1974. Studies on yield and its components in gram. Plant Breeding Abstracts 44: 242.

Joshi, S.N. 1973. Variability and association of some yield components in gram (Cicer arietinum L.).

Khosh-Khui, M., M. Niknejad. 1972. Plant height and width in heritance and their correlation with some of yield components in chickpeas (Cicer arietinum L.). The J. of Agric. Sci. 78:37-38.

Sandhu, T.S., N.B. Singh. 1972. Genetic variability, correlation and regression studies in gram (Cicer arietinum L.). Plant breeding abstracts 42:181.

Singh, L., G.S. Tomar, P.K. Mishra. 1973. Variability interrelationships and path coefficients for some quantitative characters in Bengal Gram. Plant Breeding Abstracts 43: 529.

THIRD

SESSION

STATUS OF RESEARCH ON PIGEONPEAS IN TRINIDAD

R. P. Ariyanayagam[1]

INTRODUCTION

The Importance of Pigeonpea Crop in General Agriculture

Pigeonpea production in Trinidad and Tobago is essentially a small farmers' enterprise. In terms of production acreage, it is the most important leguminous crop in the nation's agriculture. It outstrips by far the production of cowpeas, the next in production importance. Yet pigeonpea has not departed widely from its age-old status of a backyard subsistence crop. So to define its importance, it is necessary to first understand the agricultural organization of Trinidad and Tobago.

The crops grown in Trinidad and Tobago may be classified as strictly commercial crops, such as sugarcane, tobacco,citrus, cocoa,coffee, coconuts, and vegetables and those termed semi-commercial or semi-subsistence crops. All of the crops termed as commercial except tobacco, coconuts, and vegetables have been traditionally export crops. All or most of the crops termed as semi-commercial or semi-subsistence are known as domestic food crops. These include rice, corn, pigeonpeas, cowpeas, root crops, fruits and vegetables, and others, such as sorrel. Some of these semi-commercial domestic food crops have export market potentials. Pigeonpeas are already exported on a small scale as canned goods.

A survey of pigeonpea producers in 1964 (Cropper and Aryu 1974) showed that the majority of farms growing pigeonpeas were less than ten acres and grew less than three acres of pigeonpeas. Furthermore, the majority of farms (81%) grew peas as an intercrop. Yields in the survey ranged from 200 to 4000 lbs per acre of fresh peas with an average of 1585 lbs.

Farms producing pigeonpeas being small, farmers prefer to sell a large proportion of their produce retail or direct to retailers since such sales provide a much greater margin of profit, than sales at the guaranteed price paid by the Central Marketing Agency and the processing plants. There are three 1n the country. This guaranteed price is TT$0.16 per lb, while the retail rate ranges from TT$0.20 to 0.46 per lb. Farmers therefore tend to limit production to quantities that can easily be disposed of in the retail market.

To complete the picture, it 1s necessary to compare the production of pigeonpeas to other domestic food crops. Table 1 provides us with the acreage devoted to domestic food by country and nationally for the *year* 1971. This picture will at the same time provide us with an idea of the relative place of the pigeonpea crop in the cropping scheme of the country. The status of pigeonpea production in the other islands served by the University of the West Indies is not too dissimilar to that in Trinidad and Tobago.

Expansion of Cultivation

Data on pigeonpea production or acreage planted is unavailable for the years after 1971. Further, data collection on the farms 1s hampered by the fact that farmers do not produce pigeonpeas in pure stands. Rather, they tend to Intercrop their pigeonpea crop with food crops such as corn and root crops such as eddoes, yams, or cassava. Hence, the estimation of acreages devoted to pigeonpea production has been left to speculation and guesses.

Despite these limitations it is possible

---

[1] University of West Indies, St. Augustine, Trinidad, West Indies

Table 1. **Area Devoted to Domestic Crops and their Relative Position in the Cropping Scheme**

Country Crops	St.George Acres	Caroni Acres	Victoria Acres	St.Patrick Acres	Nariva Acres	Mayaro Acres	National Acres
Commercial Crops							
Sugar Cane	5,818 (1)	47,438 (1)	60,257 (1)	3,676 (1)	1,511 (1)	5	118,703 (1)
Tobacco		870 (5)					1,037 (7)
Domestic Food Crops							
Grain and Legumes				(4704)			
Rice		4,550 (2)	1,803 (2)	3,547 (1)	1,314 (2)		9,214 (2)
Corn	262	461 (8)	528 (5)	683 (4)	219 (4)	35 (4)	2,243 (6)
Pigeonpeas	340 (2)	863 (6)	979 (3)	417 (5)	197 (6)	65 (3)	2,949 (4)
Bodi	71	45	521 (6)	55	15		707(11)
Soya Bean	118						(16)
Root Crops				(301)			
Sweet Potatoes		2,096 (3)	63(11)	51	202 (5)	33 (5)	2,554 (5)
Cassava	61	390 (9)	206 (7)	33	52		769(10)
Eddoes		703 (7)	41		32	20 (6)	796 (9)
Yam	8	39	65(10)				112(23)
Tannia		78	26	49			153(19)
Dasheen	30	196(11)	28	162 (6)	183 (7)	215 (2)	814 (8)
Vegetables				(244)			
Tomato	143	95	89 (9)	63 (8)	10		400(13)
Cabbage	83	21	22				126(22)
Cauliflower	14						14(27)
Lettuce	42		6				48(26)
Cucumber	21	69	33	27	12		162(18)
Pumpkin	40	222(10)	134 (8)	96 (7)	17 (9)	9 (9)	508(12)
Pepper	49	105(13)	26	3	24	9	216(16)
Melongene	91		42		57	15 (7)	205(17)
Others		(6)	(66)				
Sorrell	11	129(12)		2			142(20)
Banana	409	2,016 (4)	914 (4)	1,744 (3)	319	254 (1)	5,690 (3)
Plantain		146	41	77			356(14)

(Bracketed figures indicate relative position.)

to forecast that future production trends will be towards expansion due to increasing domestic demands; setting up recently of three processing plants capable of canning the fresh peas as well as the dry seeds; a guaranteed minimum price and advances in technology.

RESEARCH ORGANIZATION

The Faculty of Agriculture of the University of West Indies has in recent years assumed leadership in research dealing with the improvement and production of pigeonpeas. This was made possible initially in 1967, when the Rockefeller Foundation provided grants for research on grain legumes and root crops. In 1970 Spence and Williams (1972) demonstrated that dwarf determinate varieties planted in December instead of the usual May-June planting were immediately subjected to flower inducing conditions (short day). This made the crop amenable to intensive row cropping and mechanization at all levels, especially at harvesting. The new system, as may be expected Introduced several hitherto unexplored agronomic and other problems warranting close cooperation among many disciplines of research. Hence a multidisCipHnary program funded by International Development Research Center (Canada) and Overseas Development Agency (U.K.) was set up in 1972. The program includes the following areas of work each with emphasis on improving the row crop system: (1) Agronomy; (2) Crop Breeding; (3) Biochemistry; (4) Crop Protection; (5) Economics; (6) Food Technology; (7) Microbiology; (8) Microclimatology; (9) Physiology; (10) mechanization (Spence 1972). The disciplines are located in the Faculties of Agriculture Engineering and Natural Sciences.

Centers of Research

The research in progress at St. Augustine is aimed at improving pigeonpea production in the Caribbean region. Hence, testing new varieties and cultural practices at suitable locations within the region is an integral part of the program. Research centers for such testing extend from a site at the equator in Guyana up to 18°N in Jamaica. Collaboration with workers in Florida is possible and this will allow testing as far as 26°N. Additional sites can be obtained in Guadeloupe and Puerto Rico.

The main bulk of the research activity is centered at St. Augustine. Laboratory and greenhouse studies are confined to the campus, where reasonably well equipped laboratories exist for microbiology, crop protection, crop physiology and other investigations. The campus also has two to three acres of irrigable land that could be used for field experimentation.

The University maintains a 305 acre farm three miles west of the St. Augustine Campus for research and educational purposes. A research laboratory, machine shop, root laboratory, and herbicide testing laboratory are a few of the facilities available at the farm. A wide range of machinery and wheel tractors are available too.

Trinidad has a wide variety of soils. Five of these, basically loams, are represented at the Field Station. The terrain is relatively flat. Fields are formed into cambered beds ranging between 30' and 60' in width. Sprinkler irrigation facilities are available for approximately 140 acres. The breeding experiments, m1croclimatological studies, and fertilizer and cultural investigations are located at the Field Station.

Staff Facilities

There are three categories of staff in the program.

1. Full time research personnel include: the microbiologist, plant pathologist, plant breeder and plant physiologist.
2. Teaching or research personnel of the University in the agriculture, biological sciences and engineering faculties participate in the program in varying degrees.
3. The staff of the Ministries of agriculture of the participating countries collaborate in regional trials.

EXPERIMENT RESULTS

Microbiology

Forty-five Rhizobium strains have been isolated from pigeonpea plants grown in soil cores collected throughout Trinidad. Rhizobium strains adapted to diverse soil types will be isolated using the soil core method and will be available for screening for effectiveness of nitrogen fixation in association with pigeonpea (Donawa and Quilt 1973).

Time phase studies of nodule development in pigeonpea indicate low and variable rates of nitrogen fixation in field conditions throughout the growing period of the plant. This may reflect low numbers of Rhizobia present in the soil and/or fluctuations in soil inorganic N content following precipitation and concurrent mineralization of organic N. Inorganic N applied to soil at rates as low as 10 kg N/ha were shown to depress nodule weight and N fixation.

Pigeonpea varieties grown in the same soil type differed in dominant Rhizobium strain forming nodules on the plant. Thus the Indian variety (UF 3104) appeared to select a dominant Rhizobium strain markedly different from that associated with tall and dwarf varieties. This fact suggests that effective Rhizobium partners of pigeonpea could be eliminated in a breeding program, if sufficient care was not exercised.

Modulation on three varieties of pigeonpea (Dwarf, Indian, Tall) grown under a range of soil moisture deficiencies was examined. In each variety a marked depression of nodule dry weight occurred (Up to'84%) as soil moisture deficit increased.

Microclimatology

Row cropping of pigeonpea Involves growing the crop in the dry season. In addition some of the islands are *very* arid (Table 2). Although pigeonpea is frequently cited as being a drought resistant species, the nature of the resistance has not been adequately characterized. Studies Intended to designate the microclimate in relation to drought stress, and factors likely to be of Importance in drought tolerance, are in progress (Spence and Fordham 1973).

Effect of Different Soil Moisture Regimes on Contrasting Varieties

A container experiment designed to study four soil moisture conditions on three contrasting varieties of pigeonpea has been completed. Preliminary indications are that there was a significant effect of the soil moisture treatments, but little differential response among varieties.

Stomatal Resistance

Stomatal resistance is being determined with a diffusion porometer. Preliminary data indicate that stomata in the upper epidermis appear to be more sensitive to reduction in leaf water potential. Under dry conditions values of around 20 sec cm^{-1} have been recorded whereas typical values for well watered plants were three to five sec cm^{-1}.

An increase in stomatal resistance may be expected to reduce transpiration to a greater extent than it will reduce photosynthesis, since the pathway for carbon dioxide entry includes large additional resistances associated with the mesophyll (Spence and Fordham 1973). Water use efficiency may probably be increased by breeding for high stomatal resistance. More detailed information on varietal differences to stomatal resistance will be undertaken shortly.

Drought Hardening

Preliminary observations indicated that presoaking and drying of pigeonpea seeds might be effective in Improving seedling growth under dry conditions.

Crop Physiology

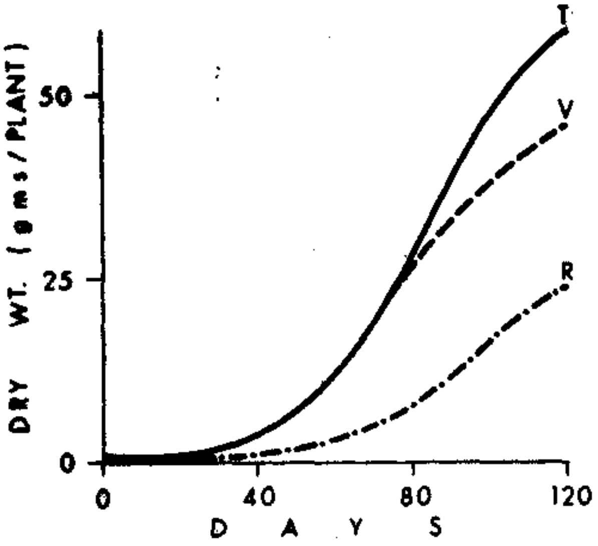
The partitioning of dry matter was Investigated (Spence and Edwards 1973) in three contrasting varieties? tall, intermediate and U.W.I. Dwarf. Figure 1 shows dry matter allocation to various parts of the plant in a U.W.I, variety of determinate habit.

Dry matter allocation to vegetative structures, it may be noted, continues unabated during the period when reproductive parts show an ascending trend. Probably due to the simultaneous addition of dry matter to vegetative as well as reproductive organs, the harvest Index of this variety was 20%. Published data for determinate soybean on the other hand showed that leaves senesce at about the time that the weight of reproductive structures increase and harvest Index in this variety exceeded 50% (Egli and Leggett 1973). Unpublished data of the author involving several early and medium maturity pigeonpea varieties indicated that harvest Index ranged from 12% to 30%.

Table 2. Climatic Data - Islands of the West Indies

COUNTRY	(°F) TEMPERATURE			RAINFALL (ins)			HUMIDITY (%)			
	Max.	Min.	Aug.Mean	Max.	Min.	Tot.Mean	Max.	Min.	Tot.Mean	LATITUDE
Antigua	83.5	73.05		59.13	28.84		84.2	76.0		17 12 N
Dominica	80	71		104.63	54.25	78.95	73	68		15 25 N
St. Vincent	85.6	71.3		-	-	99.01	81.2	72.9		13 17 N
Guyana	84.9	74.2		-	-	107	84	74		6 0 N
Jamaica	87	71		84.9	55.5				86	18 15 N
St. Kitts, Nevis & Anguilla	83.6	74.3				54.9			72.3	17 0 N
Guadeloupe			75.2						39-393	16 25 N
Puerto Rico	86	83				55.150				18 15 N
Martinique	80.6	75.2	77.0			70.8-394			82	14 40 N
Trinidad & Tobago	87	71		144	63				52-64	11 17 N
Barbados			79			59.73	-	-	-	13 15 N

FIG. 1 DRY MATTER DISTRIBUTION IN PIGEONPEA 27/4A



R - REPRODUCTIVE
V - VEGETATIVE
T - TOTAL DRY MATTER

Agronomy

Row cropping at high plant populations of 55,400 plants per acre as against 6000 plants 1n the traditional system gave gross profits of $270.00, while the profit in traditional system was $167.00. Varieties have also been found to respond differently to plant population changes (Personal communication J.A. Spence and A. Edwards). Efforts are underway to select plant types capable of high production at tense plant stands.

Crop Protection

Sclerotium Rolfsii Disease

Young seedlings between the ages of 27 and 45 days were found to be susceptible to Sclerotium rolfsii wilt. The first symptom of the disease is drooping of the leaves. In elder plants this is more evident in the lower leaves. Within five days a dark brown necrotic lesion appears at the base of the stem, on which mycelium containing sclerotia develop. The root system of wilted plants show extensive necrosis (Phelps 1973).

The pathogen is saprophytic on dead leaves and stem sections of Paspalum fasciculatum, which is a common weed in many parts of Trinidad.. Infection occurs if colonized sections of the weed are present close to the host.

Differences in susceptibility among varieties have been noticed. Most of the determinate varieties tested were highly susceptible, but semi-determinate varieties from India, 10/246, 4/95 and 5/119, showed marked tolerance to the pathogen.

Mechanical Harvesting

The initial design consisted of a reciprocating mower that cuts plants 0.3m from the ground and a vining machine to remove pods from the cut branches before passing them to the sheller, which is an Independent unit. When the mower/viner were tested 1t became apparent that separating pods from plants could be effected much more easily while the branches were still attached to the bush. A combining device was developed to perform this function satisfactorily. However, several problems associated with this device remain to be solved. Uniform growth of plants was found critical, to avoid plants wrapping around the reel. Plant to plant variation not exceeding 6 inches was assessed ideal for efficient harvesting (Dennis and Naryan 1973). Selection for plant populations with this requirement will be attempted. In the meantime, improvements on the combining device to eliminate wrapping around the reel are in progress.

BREEDING

An extensive breeding effort started in January, 1974, has been carried forward to the second generation. The objectives of the program will be dealt with in brief here. The emphasis, as in the earlier programs will be centered on fresh peas since the demand for this product 1s expected to expand 1n the years ahead. However, selection and, if necessary, breeding for dhal varieties will receive attention as local production is likely to be encouraged.

For fresh peas, the short term objective is to breed varieties suitable for row crop cultivation of the crop, so that late planting could be combined with the conventional early planting to extend the availability of higher pigeonpea yields from October to April. The long term aim is to push the period of availability of peas to cover all the months of the year.

The main Characters envisaged in the future plant type for the short and long term programs are: (a) dwarf habit; (b) determinate podding habit; (c) either resistance or field tolerance to rust; (d) large pods - 6 or more seeds; (e) large seeds; (f) acceptable cooking quality and flavor; (g) earliness.

As information on traits such as protein content and biological value, drought resistance, harvest index, production efficiency, nitrogen utilization, day neutral character etc. become available and when germplasm for these characters are identified, they will be introduced into the main gene pool.

At the moment the search for some of these traits is conducted through routine screening of introductions from all corners of the world. Arrangements are also underway to Induce mutations for these traits by cobalt 60 gamma rays, X rays, neutron irradiations and chemical mutagens.

In order to accommodate the main characters and to make the program elastic enough to introduce desirable characters at later stages in the breeding program, a diallelselective mating scheme, based on the proposals of Jensen (1970) for small grains is in operation. A ten parent diallel mating has been accomplished among F1 single crosses.

With respect to extending the period of availability of pass beyond April, it is observed that certain genotypes introduced from India and Africa flower freely during long day conditions. Tests to ascertain the critical daylength of this germplasm is expected to commence shortly. In the meantime, this germplasm is being crossed with local material to transfer their ability to flower during the long day periods of May, June and July.

GERMPLASM COLLECTION

The germplasm collection may be grouped into (a) recent introductions obtained from October 1973 onwards; (b) selections with a history of eight to ten generations of self mating.

The second group initially produced by H.J. Gooding in 1956 and developed by V. Royes consists of 18 cultivars. These include both determinate and indeterminate types but all are daylength sensitive, late maturing, produce large pods and seeds, and are well accepted in the Caribbean Market. In this group 1s included a cultivar known to possess resistance to rust. Another seems to possess field tolerance to pod borer damage. The harvest Index of this group is low.

The origin of the recent introductions and number of strains Introduced are shown below:

Origin	No. of introductions
1. Caribbean area	104
2. Australia	17
3. Sri Lanka	50
4. India	69
5. Columbia	4
6. Sudan	1
7. Africa	6

The introductions from the Caribbean area, with the exception of those obtained from Puerto Rico, are generally indeterminate, late, large seeded types. The cultivars from the other sources are typically small seeded, and may have originated at some earlier period from India. This group contains early, medium and daylength sensitive cultivars. Preliminary Investigations show that tolerance to rust may be present In some of the recently introduced cultivars. Harvest Index among the early and medium cultivars is generally higher than the Caribbean germplasm, but it has not exceeded 30%.

The commercial cultivars of today include those developed in the first pigeonpea Improvement effort of 1934 and the 1956 effort of H.J. Gooding. The earliest releases were St. Augustine, Tobago and Lasiba. These are tall, indeterminate, large seeded, late, daylength sensitive cultivars; Tobago and Laslba are popular with small fanners even today. The *former i*s claimed *to* have a soft seed coat and in the green stage 1s claimed to be sweet. Lasiba bears usually seven to nine large seeds per pod. This variety produces a rather thick walled pod, which appears to have field tolerance to pod borer damage.

Several determinate, semidwarf cultivars came out of the 1956 effort. The most popular among these are GC 12/3, GI 26/2, and GI 54/3. These cultivars have a shorter cropping period than the earlier releases and are amenable to row cropping 1f planted in December. Like the early releases, these are daylength sensitive.

PROBLEMS AFFECTING YIELD AND RESEARCH STATUS

Within Crop Variation

The market value and consumer preference of fresh peas is governed by the appearance, size and stage of maturity of the peas. Hence, harvesting most of the crop at the appropriate stage of maturity, if not all, in as few harvests as possible would ensure profitable yields. This, however, does not occur in practice due to differences in stage of maturity among pods both within and between plants of commercial populations of the crop. The w1th1n-plant variation for maturity of the commercial determinate cultivars, is affected by two factors: (a) the flowers in the compressed flowering stalk open from the periphery Inwards, and the Interval of flowering between the outermost and Innermost to open is great; (b) flower bud differentiation 1s variable among branches of individual plants. Maturity differences arising from these two factors are generally larger than the between plant differences. It is possible to reduce the latter variation by appropriate cultural and management practices. Up to now, germplasm for reduced within-plant maturity variation has not been identified.

Abscission of Flowers and Pods

Another factor that could have an influence on yield is abscission of flowers and pods. Pigeonpea produces many more flowers than pods, probably as an Insurance against adverse conditions. In the Caribbean area, pod set of 3.6%-17.6% and 4.0%-19.1% for two cultlvars in Guadeloupe (Derieux 1971); 2.2%-63% in Jamaica (Hammerton 1974) and approximately 35% in Trinidad have been reported (Personal communication A. Edwards).

Abscission has been noted to occur mostly within four to nine days of flowers opening 1n Jamaica (Hammerton 1974). Similar trends were observed (Personal communication A. Edwards) in Trinidad. Differences among varieties for pods reaching maturity have been reported" (Hammerton 1974). Detailed investigation Into this aspect is in progress at Trinidad with the view to locate desirable genotypes.

Other Factors Influencing Yield

Biological yield, harvest index and production efficiency are other factors likely to influence yield of pigeonpeas. Preliminary investigations for harvest Index involving several early and medium cultlvars from India and the Caribbean area showed variations ranging from 12%-30%.

AGRONOMIC PROBLEMS AND PROBLEMS OF NUTRITIONAL QUALITY

Some features of late planting and row cropping were discussed earlier. It 1s anticipated that the traditional system, at least in the larger commercial farms, will be replaced by the new system 1n the years ahead. With the advent of row cropping, problems related to efficient use of land, Introduction of suitable crops to fill the gap between May and December when the land will remain fallow, fertilizer and management problems related to the new sutuation are expected to arise. This 1s one area receiving limited attention at the moment.

With regard to nutritional quality, germplasm with desirable levels of sulphur containing amino acids and high biological value are yet to be identified. Facilities to screen for amino acid levels and protein quality exist in the region. High protein germplasm, when Identified, will be channeled into the elite gene pool.

DISCUSSION

J.C. Davies:	You said that you have the variety Laslba which produces a thick-walled pod and is therefore tolerant to the pod borer damage. What 1s that pod borer?

R.P. Ariyanayagam: It is the common borer, but I do not know the name.

M.C. Saxena: You have stated in your paper that in the varieties you studied, a marked depression of nodule dry weight occurred (up to 84%) as soil moisture deficit increased. Would you elaborate on this?

R.P. Ariyanayagam: Dr. Dart may want to comment on this.

P.J. Dart: As you increase soil moisture tension, the nodule weight decreases. The mechanism however is not clear. I must point out there are difficulties in working out satisfactory methodology for such studies.

M.C. Saxena: I want to make a comment. We found that when nitrogen was applied late in the season, it pushed up the protein content of the grain.

W.V. Royes: I think we should have more data on the aspect of nitrogen-protein relationship.

LITERATURE CITED

Cropper, J. and N. Aryu. 1974. An evaluation of a new system of pigeonpea production in Trinidad and Tobago. Paper read at the 12th Annual Meeting of Caribbean Food Crops Society.

Dennis, R. and C. Naryan. 1973. Grain legume programme (Eastern Caribbean). Annual Report P:26-27.

Derieux, M. 1971. Quelques donnees sur le comportement due pois d' angule en Guadeloupe (Antilles francaises). Annls. Amel. Pl. 21:373-407.

Donawa, A. and P. Quilt. 1973. Grain legume programme (Eastern Caribbean). Annual Report P:18-19.

Egli, D.B. and J.E. Leggett. 1973. Dry matter accumulation. Patterns in determinate and undeterminate soybeans. Crop Sci. 13:220-223.

Hammerton, J.L. 1974. Preliminary studies on pod-setting and pod development in Pigeon Peas (Cajanus cajan (L) Millsp.). Proc. Caribbean Food Crops Soc.

Jensen, N.F. 1970. A diallel selective mating system for cereal breeding. Crop Sci. 10:629-36.

Phelps, R. 1973. Sclerotium rolfsii disease on pigeon pea. Grain legume programme (Eastern Caribbean). Annual Report:22.

Spence, J.A. Grain legume programme (Eastern Caribbean). Annual Report:7.

Spence, J.A. and A. Edwards. 1973. Grain legume programme (Eastern Caribbean). Annual Report:16-17.

Spence, J.A. and R. Fordham. 1973. Grain legume programme (Eastern Caribbean). Annual Report:20-22.

Spence, J.A. and S.J.A. Williams. 1972. Use of photoperiod response to change plant design. Crop Sci. 12:121-122.

STATUS OF RESEARCH ON PIGEONPEAS IN PUERTO RICO

R. Abrams[1]

IMPORTANCE OF CROP

Pigeonpeas are produced in Puerto Rico for canning and for the fresh market. The farm value of the crop is estimated at present to be over three million dollars per year.

During the last two decades, the farm value of the crop has increased continuously mainly due to the increase in demand for canning, for the fresh local market and for shipping as fresh and canned produce to the continental market, mainly New York and Chicago. The demand for the fresh local and export market as well as for canning is expected to increase in the future according to present trends.

In this paper I will discuss the most relevant research work with pigeonpeas conducted by the University of Puerto Rico.

PIGEONPEA CULTIVATION

Weed Control

Because pigeonpeas are fast growing plants that rapidly shade the soil (4 to 5 weeks), early season weed control is most important. During the last five years, several preemerge herbicides have been tested and evaluated for successful weed control without detrimental effects in yield. Of this group, Prometryne (commercially Caparol) at the rate of 3.33 kg/ha has been the most effective providing a protection of 4 to 5 weeks free of weeds.

Paraquat (commercially Gramaxone) at the rate of 1.18 liter/ha is recommended for post-emergent weed control when necessary and plants are about 45 cm tall.

Lime and Fertilizers

The research work conducted on this area in Puerto Rico indicates that pigeonpea does not respond to fertilizer applications. The data in Table 1 show the effect of different levels of N, P, and K with and without Ca, Mg and calcium silicate on yield, plant height, date of flowering, seed weight and protein content of pigeonpeas. No significant difference resulted between the several fertilizer treatments and the control for any of the above plant characters or mineral elements. This study confirms previous results showing that fertilizer treatments have no effect on yield and protein content of pigeonpeas. Apparently pigeonpea makes an efficient use of the minerals present in this oxysol to meet its requirements.

Date of Planting, Row Width, and Plant Populations

During 1970-71, an experiment was established to determine the effect of planting date, plant population and row spacing on green pod yield, date of flowering, plant height, protein content of the dry seed and on the components of yield. Figure 1 indicates that green pod yields were significantly higher in the early plantings of April, May and June than in the late plantings of September and October. Yield also tended to be higher at lower spacing between rows and highest population regardless of row spacing.

Plant height, number of days to flower and protein percent of the dry seed were unaffected by row spacing and plant population. All these characters were affected significantly by date of planting. Figures 2 and 3 show the effect of planting date on plant height and number of days to flower.

Of the yield components, pods per plant increased markedly as spacing was increased with early plantings. Seed size and number of seeds per pod were not affected by date of planting, row spacing and plant population.

Cultural Practices

A group of four determinate and four indeterminate type lines of pigeonpeas were grown during 1970-71 to determine the effect

---

[1] University of Puerto Rico, Mayaguez, Puerto Rico

Table 1. The Effect of Different Levels of N, P, and K With and Without Ca, Mg and Calcium Silicate on Flowering Date, Plant Height, Seed Weight, Green Pod Yield and Protein Content of Kaki Pigeonpea

Fertilizer						Plant height	Planting to flowering date	Yield	Weight per 100 seeds	Protein
N	P	K	Mg	Ca	Si					
Lbs	Lbs	Lbs	Lbs	Lbs	Lbs	cm.	days	kg/ha	grams	percent
0	0	0	0	0	0	175.3	158	6,053.4	39.6	21.3
0	150	150	50	75	0	175.3	157	5,829.2	35.8	20.6
100	150	150	50	75	0	172.7	158	5,605.0	38.8	21.4
0	150	150	50	0	4,000	172.7	157	5,605.0	37.9	21.8
0	150	150	50	0	8,000	175.3	161	6,053.4	38.2	21.2
0	150	150	100	75	0	175.3	156	5,717.1	37.8	21.1
0	0	150	50	75	0	172.7	158	5,605.0	36.9	21.5
0	150	0	50	85	0	180.0	156	5,829.2	39.7	21.1
0	150	150	0	75	0	170.2	162	5,492.9	36.5	21.0

Figure 1. Effect of Date of Planting on Yield of Green Pods of Pigeonpea

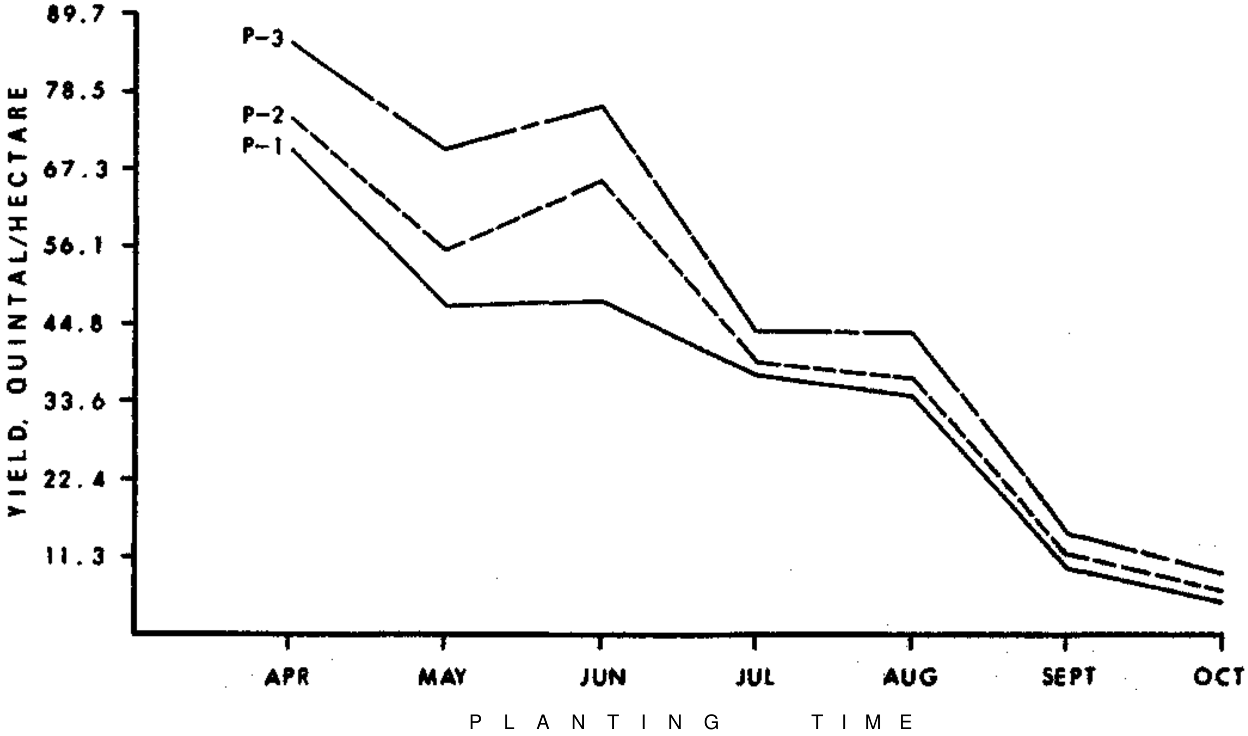


Figure 2. Effect of Date of Planting on Plant Height of Pigeonpea

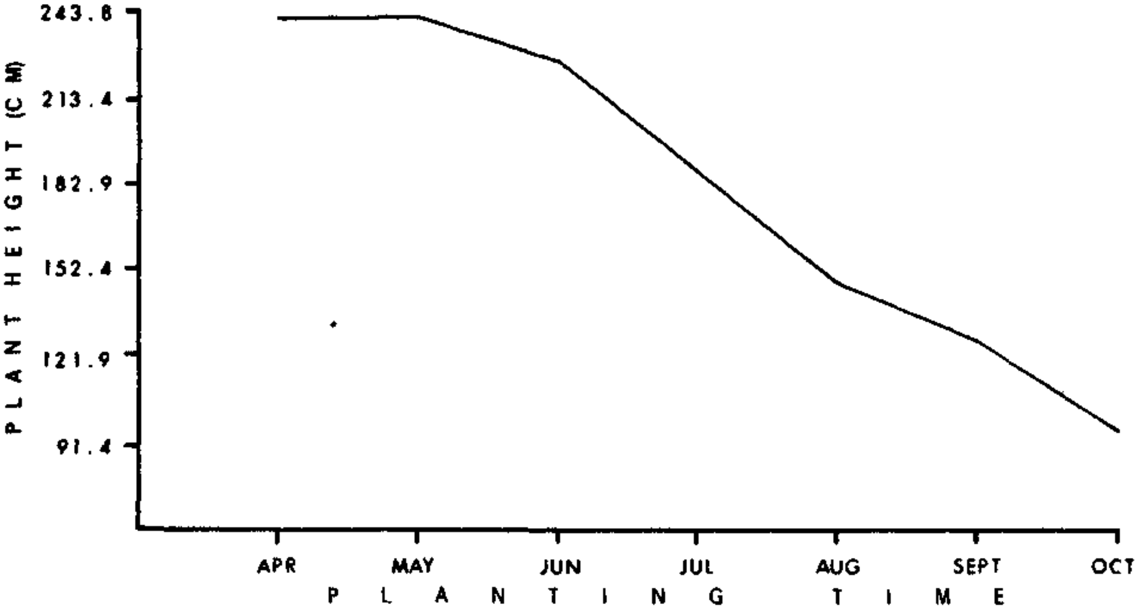
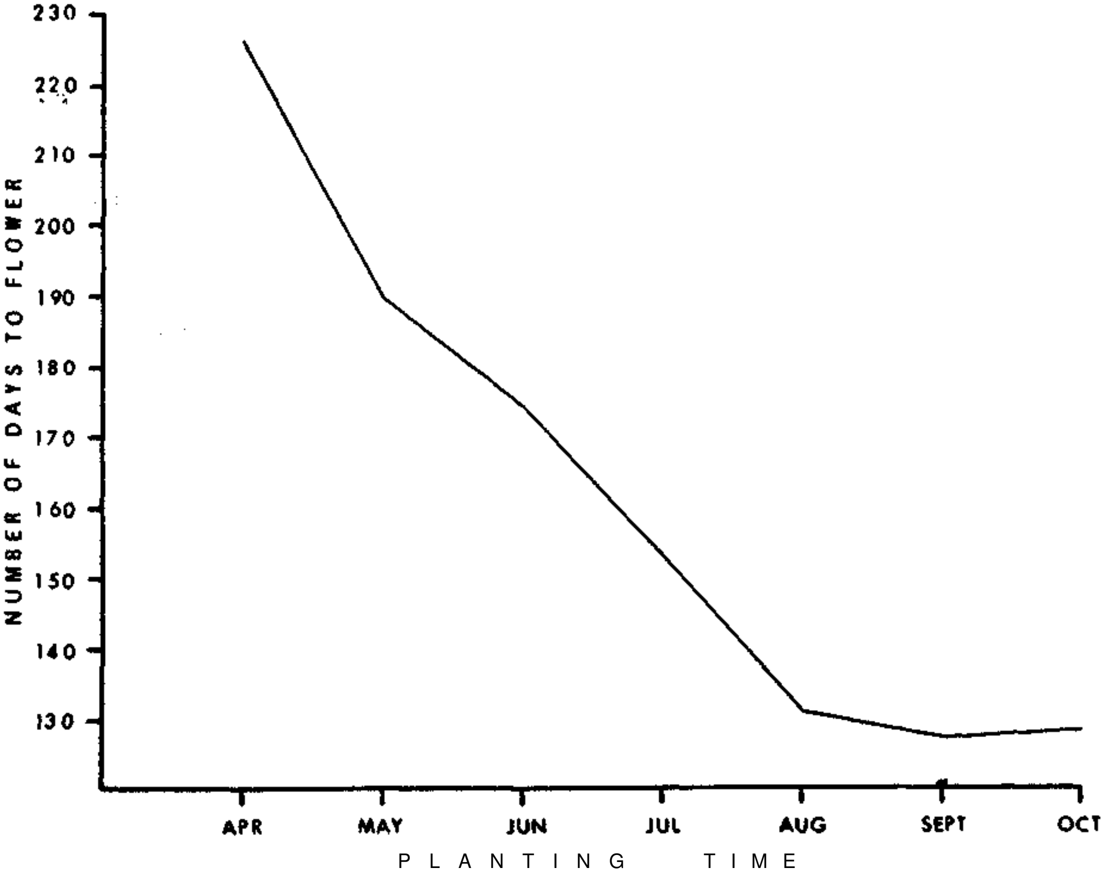


Figure 3. Effect of Date of Planting on Days to Flower for Pigeonpea



of mechanical, hand, chemical and no weed control practices on the yield of pigeonpeas.

Table 2 shows that the chemical weed control treatment increased significantly the green pod yield of pigeonpeas as compared with the other three treatments.

With the determinate type group, the yields were in general the same for all treatments. This group of lines are early short cycle plants and apparently this explains the no treatment response as shown in Table 3.

BREEDING PROGRAM

Our breeding program is focused toward two main objectives:

a) To develop high yielding high quality indeterminate types of early, intermediate and late maturity groups.

b) To develop semidwarf or dwarf determinate types resistant to leaf rust and adapted for mechanical harvesting.

Table 4 summarizes results of the last two years' trials which includes selections from the indeterminate type group. It can be observed that a group of these selected lines are superior in yield to the commercial varieties included. We have in progress a seed increase program to release the superior material for the farmers.

With the determinate type group we have been conducting trials planting late in the season, i.e., August, September, October, November and December at very high population rates. The results are shown in Table 5. We are *very* optimistic about this group of lines because at populations of 143,318 plants/ha, we have obtained yields above 50 quintals/ha of green pods. In addition, these lines will come into production during February, March and April, extending the production period two more months, and they are well adapted for mechanical harvesting since their mean plant height is approximately 70 cms.

At present we are also focusing our breeding program toward the development of true dwarf plants (not more than 60 cms tall) which are photoperiod insensitive. To this end we have treated seeds of our shortest and earliest line, 28-Bushy, with gamma rays trying to induce mutations toward these types. We have been introducing material from IITA, India, and Trinidad which could be useful in our breeding program toward these goals.

GENETIC STUDIES

Natural Cross-Pollination

The extent of natural cross-pollination occurring in pigeonpeas in Puerto Rico has been determined by means of genetic markers. Homozygous lines with the dominant marker red flower and maroon blotched pods were planted adjacent to lines having the recessive marker yellow flower and green pods. Results showed that cross-pollination ranged from 5.47% to 6.33% with an average of 5.80% in a population of 5328 plants. To maintain pure stocks under our conditions they should be grown in isolation or with the flowerbuds covered with finely woven nylon bags to prevent cross-pollination by insects.

Quantitative Inheritance

The F2, F3 and parents of 5 crosses were used for this study. Genotypic variability was studied and genotypic correlations were calculated for all crosses in the F2 and F3 generations.

Genetic coefficient of variation and heritability estimates were computed for four traits in five crosses and for six traits in one particular cross. There was much greater variation for all crosses, in general, for seed weight, plant height, and flowering date than for number of seeds per pods.

With the exception of number of pods per plant, the correlations between seed yield and other traits were not great enough to provide reliable indications for yield. Good progress by selection in early generations could be made by breeders in traits such as flowering date, plant height and seed weight which showed high heritability values.

Variety-Environment Interactions

Twenty varieties of pigeonpeas were evaluated at two locations for a three year period. Analysis of these data provided estimates on the nature and magnitude of the variance components for yield, date of flowering, plant height, and weed weight.

The first and second order interactions

Table 2. Mean Green Pod Yields of Four Indeterminate Pigeonpea Lines Grown With Different Weed Control Methods

Cultivar	Weed Control				
	Mean green pod yield in q/ha				
	None	Hoe	Mechanical	Herbicide	Average
Kak1	103.9 A	108.2 A	97.9 A	110.0 A	104.6 A
Line 7	107.9 AB	94.5 B	114.7 AB	130.1 A	108.2 A
Line 12	83.2 C	115.2 AB	92.1 B	135.6 A	106.4 A
Line 142 A	90.3 B	106.9 AB	104.6 AB	126.8 A	107.0 A
Average	93.9 b	106.1 b	102.1 b	127.8 a	

Table 3. Mean Green Pod Yields of Four Determinate Pigeonpea Lines Grown With Different Weed Control Methods

Cultivar	Weed Control				
	Mean green pod yield in q/ha				
	None	Hoe	Mechanical	Herbicide	Average
Line 8 AB-2	35.4 B	45.1 A	46.4 A	44.4 A	42.7 B
Line 8 AB-7	28.9 B	30.5 B	32.1 B	39.4 A	32.9 C
Line 16 A	36.6 B	41.0 A	46.4 A	39.4 AB	40.6 B
Line 21 B	59.4 B	55.7 AB	56.9 AB	63.8 A	58.9 A
Average	39.9 b	43.1 ab	45.6 ab	46.7 a	

Table 4. Indeterminate Pigeonpea Types Variety Trials .Summary of Two Years' Trials -1972-73,1973-74

Varieties	Yield Q/ha	Height cm.	Days to flower
Kaki	86.8	264	140
Line 7	91.5	264	134
Line 12	98.1	273	139
Line 142-A	81.2	282	153
Line 69-KT-l	64.7	270	135
Line 69-KT-2	71.9	261	140
Line 69-KT-6	55.0	264	139
Line 69-52	54.7	294	155
Line 69-68	88.6	246	139
Line 69-58-1	71.3	276	139
Line 69-58-2	62.3	270	159
Line 82-A	52.2	300	139

Table 5. Performance of Four Semi-dwarf Determinate Type Lines of Pigeonpeas. Combined Results of Years 1972-73, 1973-74 -

Lines	Planting dates														
	August			September			October			November			December		
	Yield Q/ha	Ht cms.	Days to flower	Yield Q/ha	Ht cms.	Days to flower	Yield Q/ha	Ht cms.	Days to flower	Yield Q/ha	Ht cms.	Days to flower	Yield Q/ha	Ht cms.	Days to flower
28-Bushy	91.34	139.3	84	72.87	113.7	84	44.44	77.2	84	45.89	67.5	86	51.63	67.8	75
16-A	66.65	147.2	84	52.09	116.0	87	37.63	72.5	87	33.19	68.7	89	35.58	65.0	77
21-B	79.18	147.8	88	48.36	114.7	84	38.36	68.5	87	34.88	65.0	85	32.42	64.7	75
69-73-1	77.82	159.7	92	45.97	119.0	90	39.78	86.0	89	43.78	81.5	90	46.17	80.6	83
MEAN:	78.74	148.5	87	54.82	115.8	86	40.05	76.1	87	39.43	70.7	87	41.45	69.5	77

for all characters studied were not so large as the variety component of variance. The variety x location x year Interaction, although statistically significant, was of small magnitude, and equal to, or smaller than, the variety x year interaction. These are clear indications of the Importance of interaction of varieties x year in this study, which suggests that the number of years should not be fewer than three when testing for these characters. The variety x location interaction was of much smaller magnitude than the variety x year Interaction, and was statistically nonsignificant.

Protein Studies

Over 200 varieties, Introductions and lines have been analyzed for protein content. The range of variability is from 16% to over 30%. A study is in progress to determine the mode of Inheritance and heritability of protein in order to attempt to Improve the quality and quantity of protein in pigeonpeas.

DISEASES

This crop has no major disease problems in Puerto R1co. Rhincosia virus cases have been observed sporadically in commercial plantings, but the incidence is very low. We have already material resistant to this virus in case it becomes a threat to the crop.

INSECTS

The most troublesome insects are the pod borers during the green pod stage and the seed weevil for the dry seed. Several insecticides have been screened for the control of the pod borers and the best results have been obtained with Endosulfan, at the rate of 2.24 kg/ha during the peak of the flowering period. Two applications at 2 week Intervals give a very good control.

PROCESSING

Canning Pigeonpea

A group of studies of economic importance in the processing of this crop have been conducted by the Food Technology Laboratory. An improved method for canning pigeonpeas was developed by this department. With this method, it is possible to obtain a canned product with an almost colorless brine which compares favorably in quality with other canned peas. The process requires heating the pod at atmospheric pressure to inactivate the peroxidase of the peas. The inactivation of the enzyme system before shelling is the most important step in this new process, since only through proper enzyme inactivation is it possible to obtain a brine low In color, viscosity and turbidity. A short heating just sufficient to inactivate the enzyme system is essential as excessive heat may affect the flavor of the peas adversely and make shelling difficult. The method has been registered in the U.S. Patent Office.

Freezing Pigeonpea

Fresh pigeonpeas are available in Puerto Rico only during the winter months from December through February. Fresh peas are preferred by consumers, and studies were conducted to determine the feasibility of the commercial freezing processing techniques and estimates of the shelf life of the frozen product and Its consumer acceptance. The results showed that for freezing, pigeonpeas may be processed in the same way as for canning, except that the blanching treatment should be five minutes at 195° F to ensure complete enzyme inactivation. If the enzyme system is completely inactivated by proper blanching, no appreciable changes in flavor, texture, appearance, or Intensity of off-flavor takes place during storage at 10° F for two years. Marketing tests run in four supermarkets Indicated that frozen pigeonpeas offered to consumers in the off-season may be one of the best sellers among the frozen products.

DISCUSSION

W.J. Kaiser: I am acquainted with disease problems of pigeonpea 1n Puerto R1co. Rust is very Important while Scierotlum and Phytotophthora can cause a level of mortality, but are of secondary importance.

M.C. Saxena: We should be careful about the use of paraquat since 1t 1s a general herbicide.

PIGEONPEA (CAJANUS CAJAN (L.) MILLSP.) RESEARCH IN AUSTRALIA

E. S. Wallis, P. C. Whiteman and J. O. Akinola[1]

INTRODUCTION

Pigeonpea has been grown in Australia for many years although large scale commercial production has not been attempted. The crop was grown primarily as a green manure crop following pineapples and sugarcane In coastal Queensland. Small scale production of seed for raising pigeons and a minor cultinary market has been carried out.

In 1969, in an attempt to find a dry season stand over forage for tropical and subtropical Australia, 95 lines of pigeonpea were Introduced and evaluated by Dr. J.O. Akinoia as a Ph.D program. The project was under the supervision of Dr. P.C. Whiteman, senior lecturer in tropical agronomy. As a result of these studies, several accessions that produced high seed yields were selected for further investigation as a potential seed crop. As a result of this work, a series of papers have been published. These will be referred to in the text of this review. A comprehensive review of the agronomy of pigeonpea has been accepted for publication in the Review Series of Field Crop Abstracts (Akinoia, Whiteman and Wallis 1975).

Work has been carried out by the Queensland Department of Primary Industries at Parada (Dr. R.W. Dones, Mr. I.B. Staples) and at Theodre (Mr. J.H. Wildin). This work was restricted to comparative production trials with a range of Introduced legume species. Recent Interest has been shown by the University of Sydney (Professor M.J.T. Norman) in the use of pigeonpea as a potential autumn-winter forage.

RESEARCH PROGRAM

In the period 1961-64 at Parada (17°S) pigeonpea was compared with a number of Introduced legume species and showed some promise (Downes 1966). Downes concluded that the short-lived nature of this species appeared to be a major limiting factor in that environment. Downes suggested that these problems may be overcome by breeding and he noted that presumptive hybrids between Cajanus cajan and Atylosia grandlfolia (a native shrub) had been obtained.

Inconclusive grazing trials were performed at Parada in 1964, where pigeonpea was used for deferred dry season grazing (Staples personal communication). These trials did show that liveweight loss could be delayed by use of pigeonpea when compared with native pastures. Little further work was carried out.

At Theodre in 1966-67, pigeonpeas were compared with Phaseolus sp. Vigna, Dolichos (including Lablab purpureus) Glycine and Clitoria. C. cajan produced a nigh yield of vegetative material but both the young and mature pods were severely attacked by pod borers (Wildin personal communication). Wildin concluded that Lablab purpureus was the outstanding species tested and was superior to C. cajan with regard to establishment, yield of edible forage and seed production. No further work was carried out with C. cajan at Theodre.

Numerical Classification

Ninety-five accessions of Cajanus cajan from eleven countries were field grown and studied throughout a year at Redland Bay, Southeastern Queensland (Akinola and Whiteman 1972(a)).

Description of Classification

Using the MULTCLAS hierarchial program,

---

[1] University of Queensland, St. Lucia, Brisbane, Australia

the accessions were classified Into 15 groups. Thirty-one attributes were used Including plant and leaf morphology, growth, flowering patterns, disease tolerance and components of seed yield. Hard seed and an unusual terminal Inflorescence were noted 1n some accessions. The 95 accessions were completely homogeneous in only one important character, the chromosome number, which was diploid with 2n=22 (Akinola and Whiteman 1972(b)).

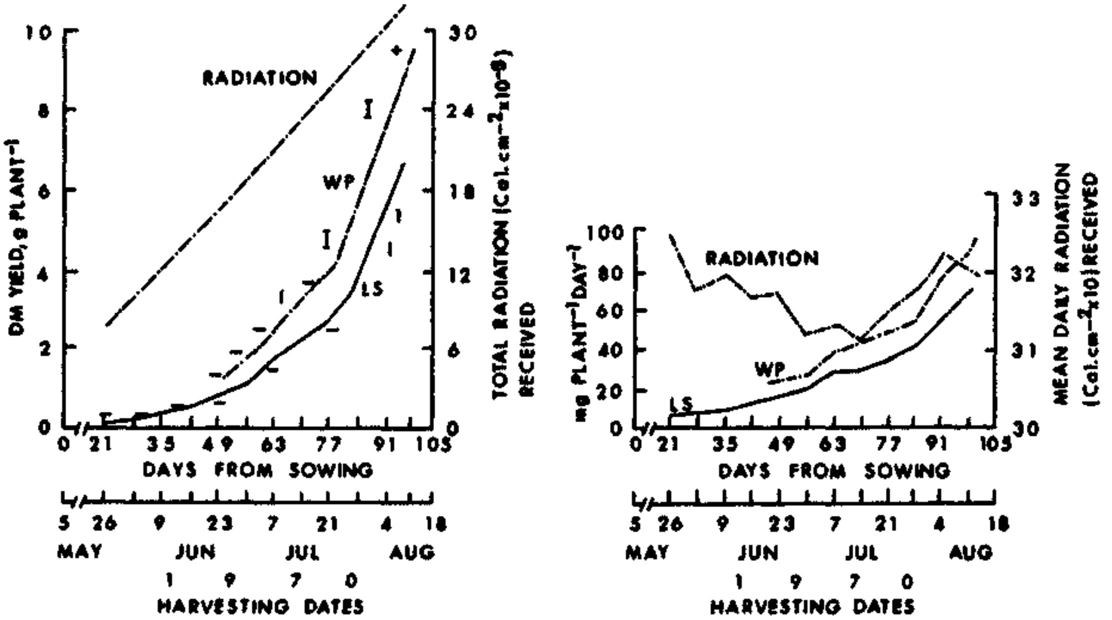
The significance of this classification lies in the application of the various groupings to agronomic problems, particularly selection and/or breeding for specific purposes.

Growth Analysis

Glasshouse

This study was initiated to investigate the patterns of growth of C. cajan in relation to age (Akinola 1973). The reiults of this work show that, after a slow start, dry matter accumulation and crop growth rate increased rapidly with age (Figure 1).

Figure 1. Total Dry Matter Yield and Growth Rate of C.CAJAN Accession UQ1 as Functions of Days from Sowing and Total Radiation Received up to the Day of Harvest



A. TOTAL DRY MATTER YIELD AND TOTAL RADIATION RECEIVED UP TO DAV 98

B. GROWTH RATE AND MEAN DAILY RADIATION RECEIVED UP TO DAY 98.

Log * Total DM yield (Y) as a function of days from sowing (x)

(i) Leaf + Stem (LS); $Y = -4.2599 + 0.10003x - 0.0003916x^2$; $r = 0.997^{**}$
(ii) Whole plant (WP); $Y = -2.2161 + 0,05182x - 0.0000713x^2$; $r = 0.997^{*}$

Total DM yield (Y) as a function of total radiation(x) received

(i) Leaf + Stem (LS); $Y = 13271 - 0.24011x + 0.012724x^2$; $r = 0.994^{**}$
(ii) Whole plant (WP); $Y = 6.5780 - 0.73642x + 0.025689X^2$; $R = 0.997^{**}$

+ Standard error
- Significant at 1% level

Nodule weight per plant followed a similar pattern to dry matter yield per plant in that the Initial lag phase was followed by a period of rapid increase (Figure 2).

Field

Four accessions were sown at 0.914 m x 0.914 m and harvested at fortnightly intervals for seven months. Little difference existed between dry matter yield of the accessions until late in the growth period (Figure 3).

Three growth phases were clearly marked: an Initial lag phase up to day 84, a very rapid growth phase lasting until day 168 and a final phase of slow dry matter accumulation.

Up to day 70, the leaf and stem fraction contributed equal amounts to total plant weight (Figures 4a and 4b).

However beyond day 84, the stem contributed significantly more to total plant yield. Leaf dry matter accumulation reached a peak in all accessions on day 140 before declining as a result of leaf senescence.

Maximum leaf area index, which was *very* high, was recorded in all accessions on day 140—in agreement with time of peak leaf yield (Figure 5).

Crop growth rates in the field are shown in Figure 6 and this again clearly shows the Initial lag phase in crop growth. This shows the high potential of C. <u>cajan</u> for dry matter production.

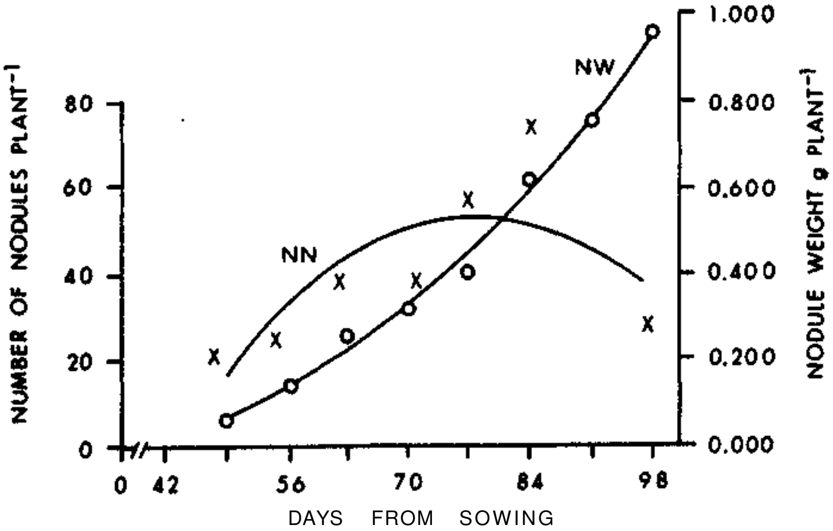
LAI and the percent light interception are related as shown in Figure 7. Percent light interception was linearly related to LAI on day 98. By day 140 virtually all light had been intercepted at LAI values greater than six.

Response to Photoperiod

Induced Changes of Photoperiod in the Glasshouse

The response to photoperiod in the field via changes in sowing date is of great importance if mechanical harvesting is to be accomplished. It was found that short photoperiods

Figure 2. Number of Nodules per Plant (NN) and Nodule Weight per Plant (NW) as Functions of Days from Sowing



NN $Y = 205.648 + 6.620\ x - 0.0423\ x^2$ $r = 0.769^*$

NW $Y = 0.259 - 0.0143\ x + 0.000217\ x^2$ $r = 0.993^{**}$

Figure 3. Trends in Dry Matter Accumulation of Leaf + Stem of Four C.CAJAN Accessions up to Day 238

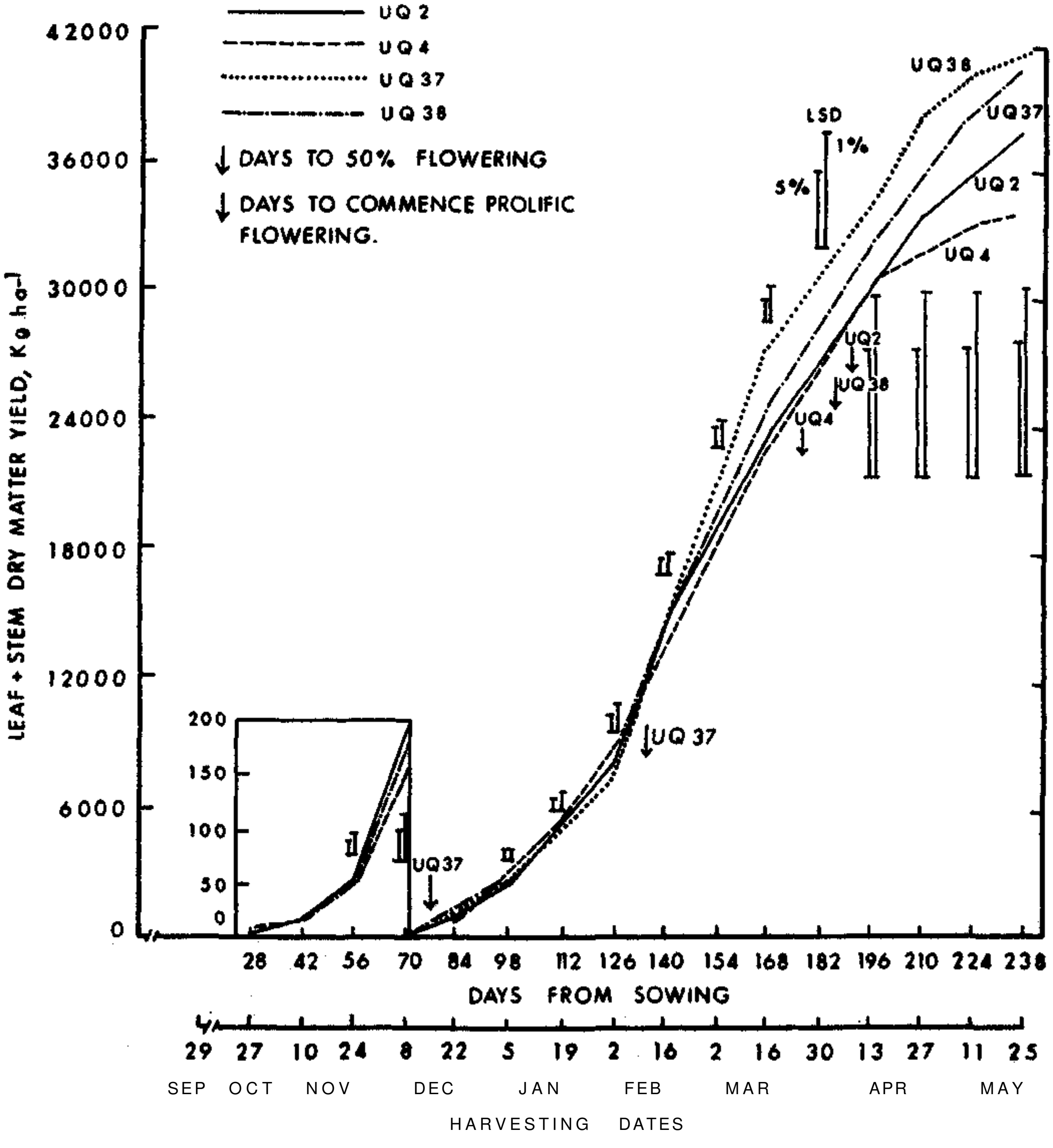
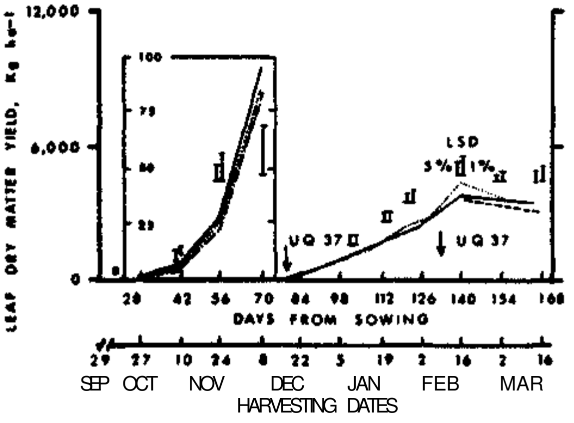


Figure 4. Trands in Dry Mattar Accumulation of Leaf and Stem of Four C.CAJAN Accessions up to Day 168

A LEAF DRY MATTER YIELD



B. STEM DRY MATTER YIELD

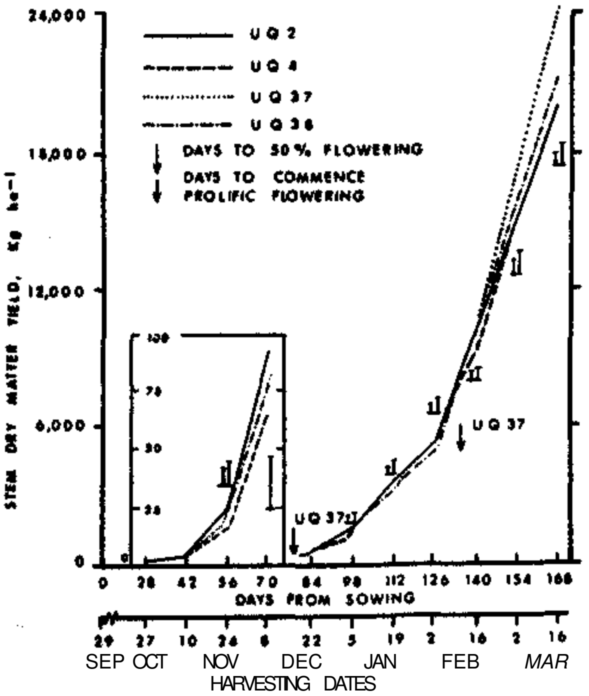
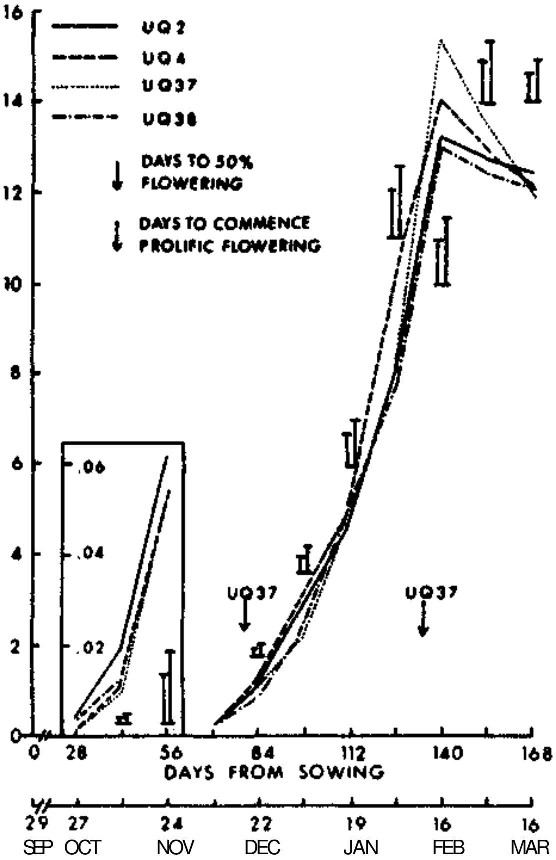


Figure 6. Leaf Area Index Values in Four C.CAJAN Accessions up to Day 168



reduced over-all vegetative growth and period to flowering, pod filling and pod ripening. The data suggested that the variety used in this study (UQ1 in group CII) was quantitatively short day. However, as discussed below, a range of photoperiod response is found over a broader group of accessions.

Response to Sowing Date in the Field

A split plot design was used to investigate the vegetative and reproductive responses of two early and two late maturing C. cajan accessions to eight sowing dates at a density of 2990 plants per hectare (Akinola and Whiteman 1975(a)).

The effect of sowing date on the reproductive phase is shown in Figure 8. These data Indicated that UQ1 and UQ38 were photo-

Figure 6. Crop Growth Rates (CGR) of Four C.CAJAN Accessions up to Day 238

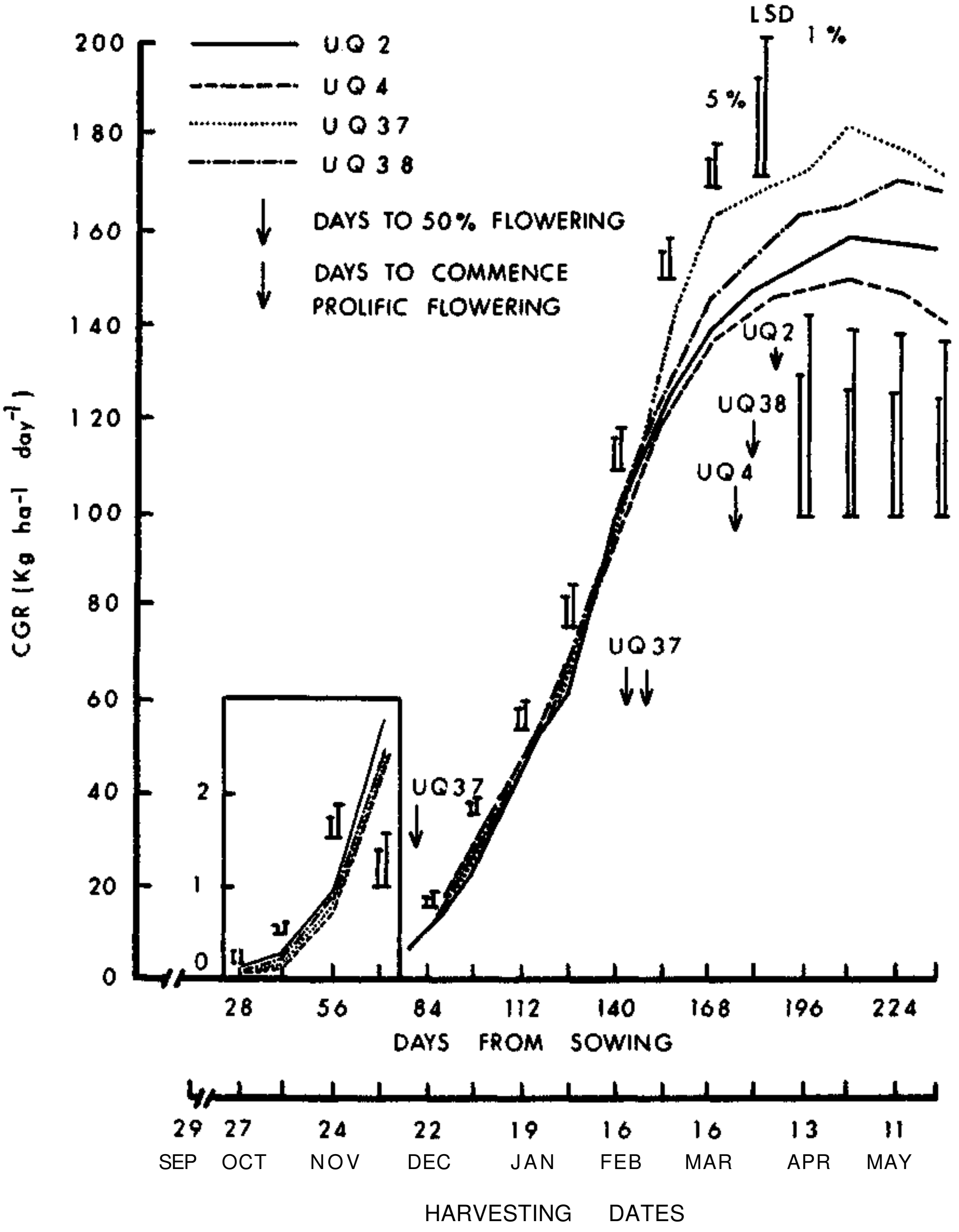
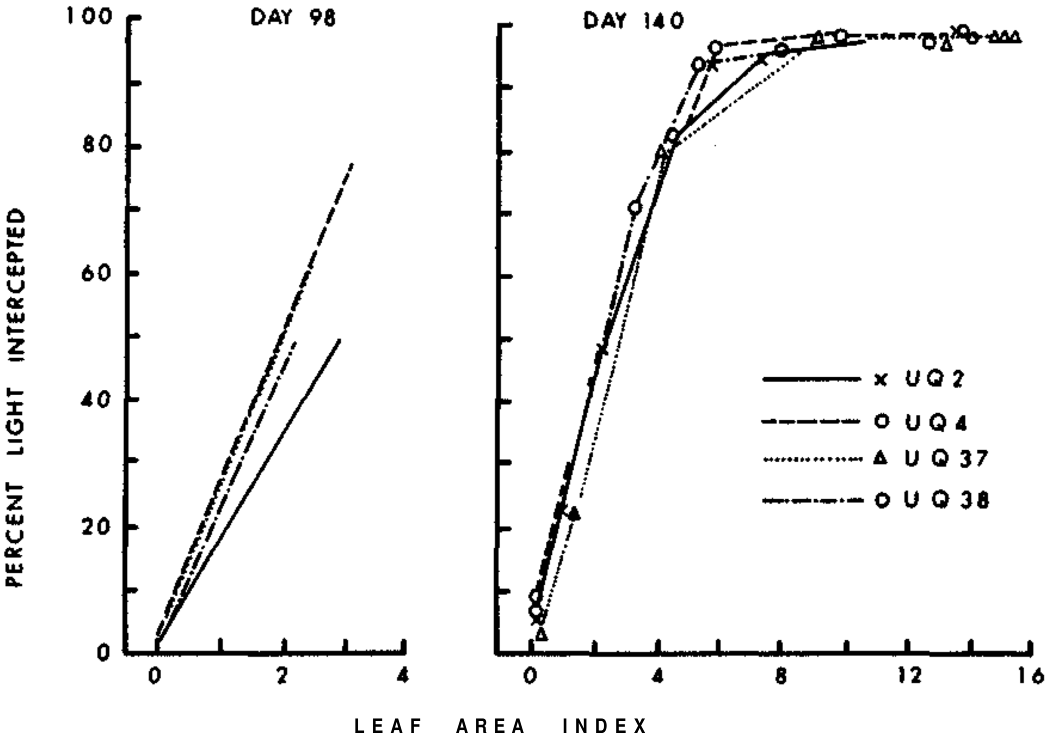


Figure 7. Relationship Between Percent Light Intercepted and Leaf Area Index of Four C.CAJAN Accessions, 98 and 140 Days from Sowing



period sensitive and quantitative short day plants. UQ39 was less photoperiod sensitive, but flowered more rapidly under shorter days. UQ37 was Intermediate. Thus the results are not clear cut and a range of response may be expected from other accessions.

Maximum dry matter yield per hectare over all accessions declined with delay in sowing (Table 1).

The highest total annual seed yield per hectare was recorded with accessions sown in late November.

Thus optimum sowing times were Identified as late November to mid-January for dry seed production in late maturing accessions and not later than December for periodic green pod picking in early maturing accessions in the environment of southeastern Queensland.

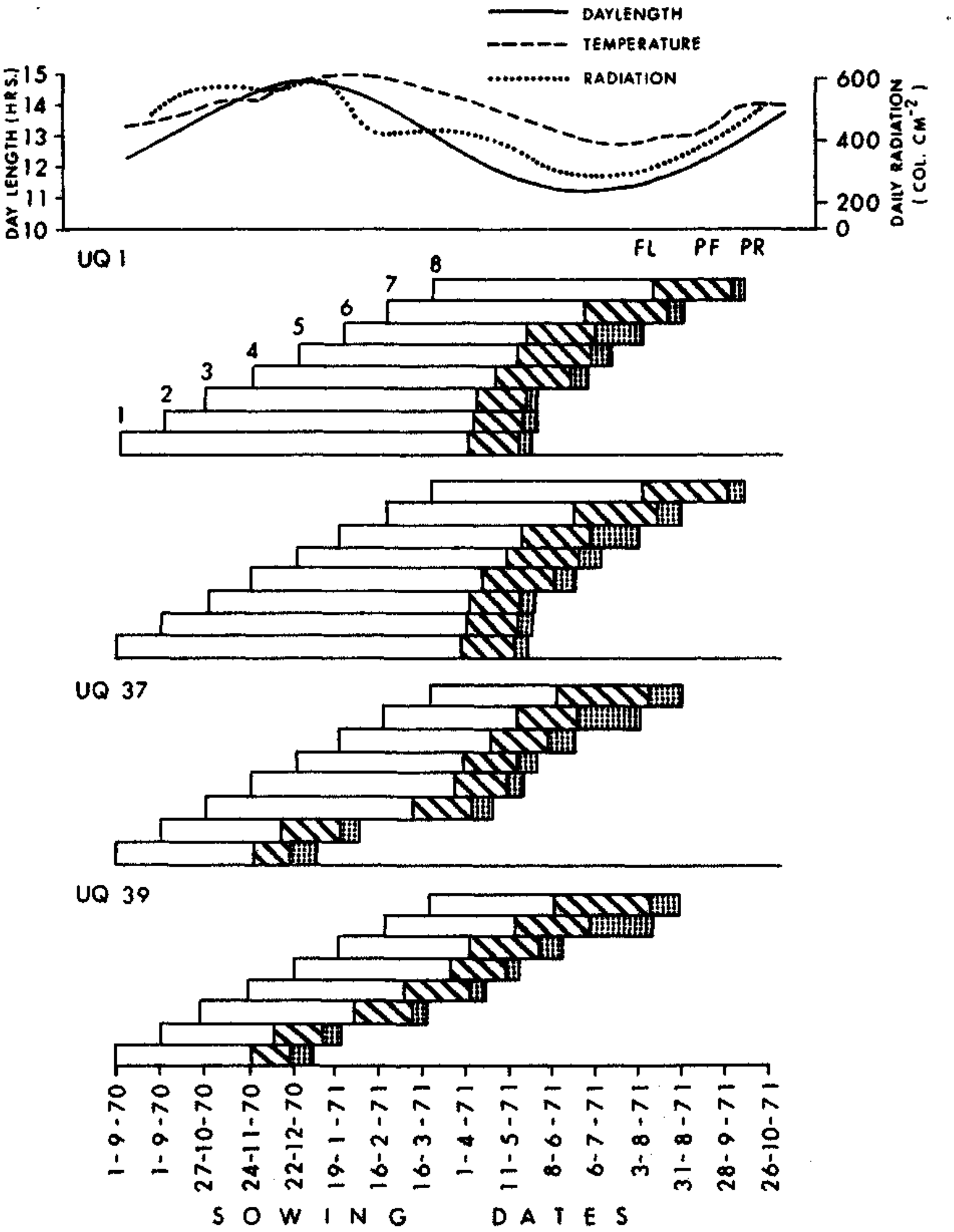
Effect of Density on Seed and Dry Matter Yield

Vegetative and seed yield in C. cajan accession UQ1 were Investigated over nine sowing densities ranging from 6727 to 215,278 plants per hectare (Aklnola and Whiteman 1975(b)).

Dry matter yield per plant declined asymptotically with increasing density, while the yield per hectare density relationship was described by a parabolic curve. The highest yield per hectare (22,950 kg) was produced at the 0.305 m x 0.305 m spacing (107,639 plants per hectare) (Figure 9).

Maximum seed yield (2774 kg/ha) was

Figure 8. Phenology of C. CAJAN Accessions in Response to Sowing Dates



DATES FROM SOWING (1-8) TO 50% FLOWERING (FL), POD FILLING (PF) AND POO RIPENING (PR)

Table 1. Split Plot Analysis Showing the Effects of Sowing Dates on Total Dry Matter and Seed Yields in Four C.Cajan Accessions

(a) Dry matter yield, Kg/ha^{-1} yr^{-1}

Sowing dates	Accession				Sowing date mean
	UQ 1	UQ 38	UQ 37	UQ 39	
1/ 9/70	13422	16739	16953	9990	14273
29/ 9/70	12219	14183	14550	10121	12768
27/10/70	11632	13752	14019	8296	11925
24/11/70	10166	12112	9527	5933	9434
22/12/70	7395	9160	6725	4221	6875
19/ 1/71	3447	3162	1833	1213	2414
16/ 2/71	2386	2366	1235	1290	1819
16/ 3/71	1977	1876	1365	1458	1669
Accession mean	7831	9169	8276	5304	

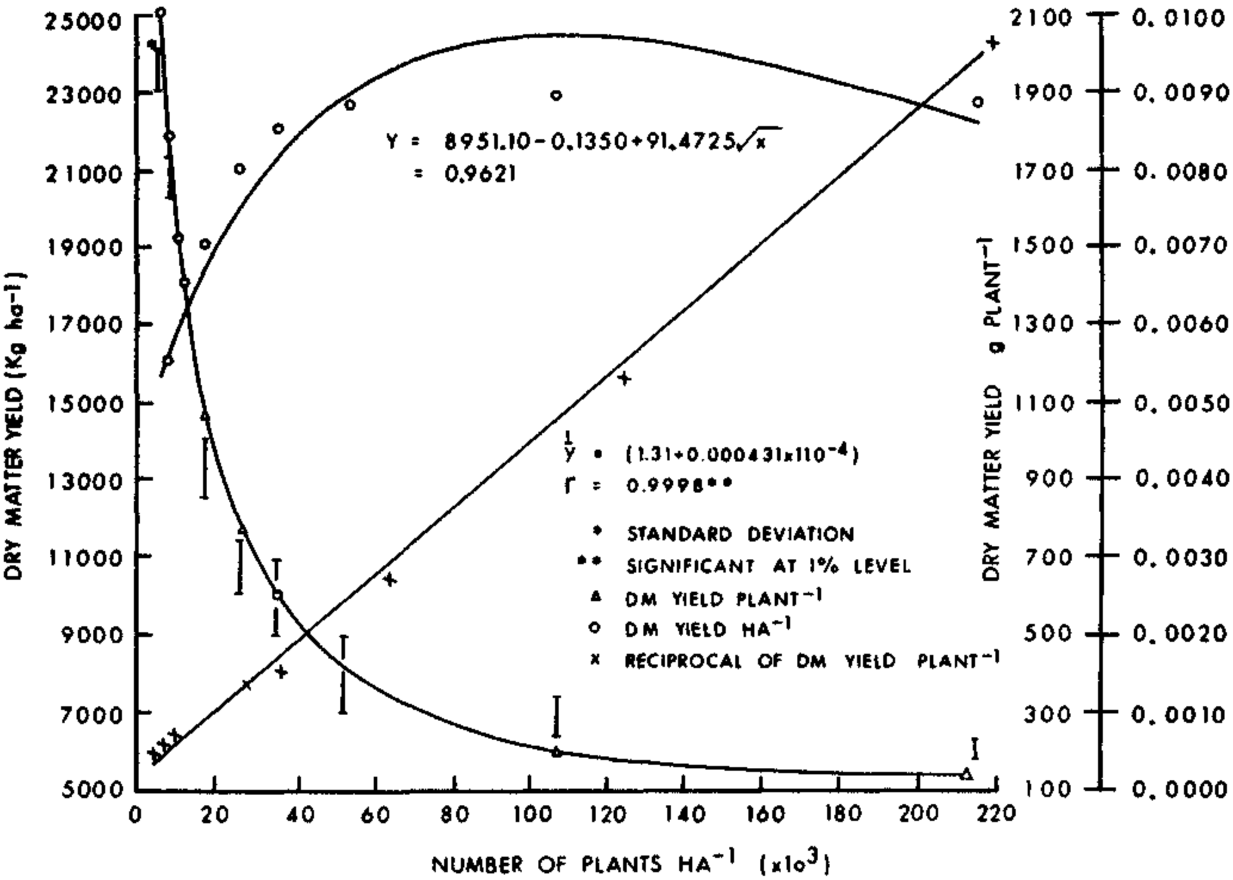
	LSD 5%	1%
Mainplot (sowing date) means	1538	2093
Subplot (accession) means	743	988
Subplot means within the same mainplot	2101	2795
Mainplot means within the same accession	2374	3193

(b) Seed yield, Kg/ha^{-1} yr^{-1}

Sowing dates	Accession				Sowing date mean
	UQ 1	UQ 38	UQ 37	UQ 39	
1/ 9/70	4434	5066	4203	3698	4350
29/ 9/70	3468	4778	4597	3442	4071
27/10/70	2986	3052	4606	2337	3245
24/11/70	5187	6021	5296	3115	4905
22/12/70	3848	5258	3104	2625	3709
19/ 1/71	3838	3879	2391	1643	2937
16/ 2/71	1554	1460	872	872	1190
16/ 3/71	1019	913	706	1142	945
Accession mean	3292	3803	3222	2359	

	LSD 5%	1%
Mainplot (sowing date) means	481	655
Subplot (accession) means	367	488
Subplot means within the same mainplot	1038	1381
Mainplot means within the same accession	1020	1953

Figure 9. Dry Matter Yield per Plant, Dry Matter Yield per Hectare and Reciprocal of Dry Matter Yield per Plant as Functions of Number of Plants per Hectare



attained at a relatively low density at a spacing of 0.914 m x 0.610 m (17,940 plants per hectare). At higher densities increased stand mortality and reduced pod number per plant resulted in severe yield reductions (Figure 10).

Effect of Defoliation on Seed and Dry Matter Yield

Description of Experiment

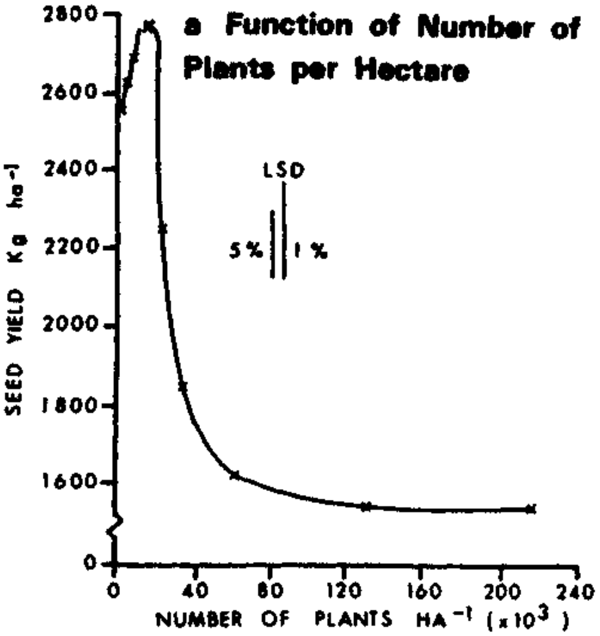
Two field experiments were used in the investigation. The first experiment examined the effect of height and frequency of defoliation on dry matter and nitrogen yield of components (leaf, flower, pod and stem) in four C. cajan accessions (Figure 11(a) and (b)).

Thus, two early maturing and two late maturing accessions of C. cajan grown in the field for 161 days were defoliated to 90 cm "stubbles" *every* 4, 8, 12 or 16 weeks over a period of 72 weeks.

Results

Evidence from total and seasonal dry matter and nitrogen yield performances, stand survival and stubble yield at the termination of the experiment suggested that 8 to 12 week defoliation frequencies could be successfully integrated to incorporate cattle grazing for forage and seed production into a single

Figure 10. Seed Yield per Hectare as a Function of Number of Plants per Hectare



management system. The later maturing accessions were shown clearly to be better adapted to cutting, provided that basal green leaves always remained on the "stubble".

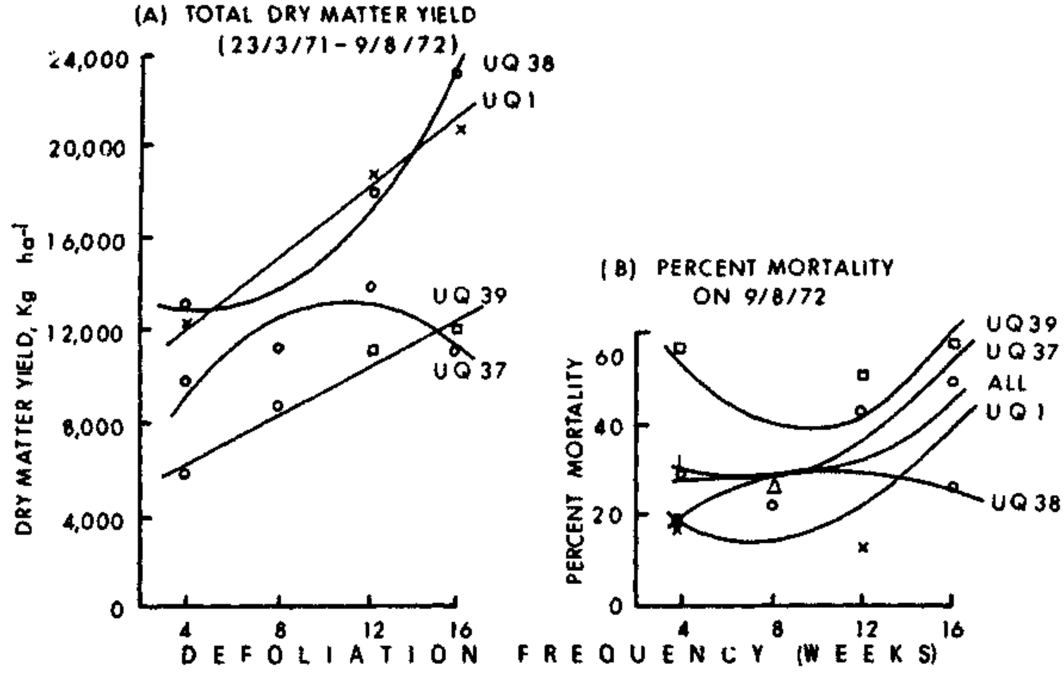
Description of Second Experiment

The second experiment was undertaken to examine the effects of a single defoliation, designed to reduce plant height and so facilitate mechanical harvesting, on seed yield in the high seed yield selection UQ50 (Tables 2 and 3) (Aklnola and Whiteman 1975 (a)).

Results

Defoliation of UQ50 to reduce plant height and to facilitate subsequent harvesting led to reduced annual seed yield. The first seed

Figure 11. Total Dry Matter Yield and Percent Mortality of Four C.CAJAN Accessions as Functions of Defoliation Frequency



UQ1; $Y=8872.0+804.85x$; $r=0.981^{*}$
UQ37; $Y=3581.7+1710.36x-75.547x^2$; $r=0.911$ NS
UQ38; $Y=14045.5-539.07x+70.719x^2$; $r=0.998^{*}$
UQ39; Y=4311.5+505.8Qx; $r=0.992^{**}$

UQ 1; $Y=35.20-5.28x+0.350x^2$; $r = 0.819$NS
UQ37; $Y=36.92-3.04x-0.261x^2$; $r = 0.937$NS
UQ38; $Y=5.70+5.54x-0.203x^2$; $r = 0.983$NS
UQ39; $Y=85.97-10.02x+0.533x^2$; $r = 0.773$NS
ALL ACCESSIONS
$Y=40.92-3.46x+0.236x^2$: $r = 0.989$NS

Table 2. Seed Yield (kg/ha-) in Defoliated and Undefoliated C. Cajan Accession UQ50 Plots

<table>
<tr><td colspan="4">Podpicking Treatments</td><td>Mean Seed Yield</td></tr>
<tr><td colspan="4">T1 Undefoliated, harvested July-August 1971</td><td>1343</td></tr>
<tr><td colspan="4">T2 Undefoliated, harvested October 1971</td><td>2652</td></tr>
<tr><td colspan="4">T3 TI T2</td><td>3995</td></tr>
<tr><td colspan="4">T4 Defoliated, harvested October 1971</td><td>2680</td></tr>
<tr><td rowspan="3">LSD 5%</td><td>TI and T2</td><td>TI and 74</td><td>T2 and T4</td><td>T3 and T4</td></tr>
<tr><td>732</td><td>567</td><td>724</td><td>911</td></tr>
<tr><td>1214</td><td>940</td><td>1201</td><td>1511</td></tr>
</table>

Table 3. Seed Yield Components

Treatment	Seeds per pod	Ratio of seed wt. to pod wt.	Wt. of 100 seeds (gm)	Pod length (cm)
TI	4.43	1.34	13.00	6.59
T2	3.85	1.31	11.07	6.53
T4	3.35	1.27	9.33	6.50
LSD 5X	0.16	0.03	0.17	0.08
1%	0.23	0.05	0.25	0.12

crop was lost because the cutting removed the reproductive material.

Animal Production Trials

Grazing Trial

The results of two years cool season grazing of five C. cajan accessions at Mt. Cotton, southeastern Queensland have been reported (Akinola, Birch, Whiteman and Wallis 1975). Cattle liveweight gains on C. cajan have been compared with nitrogen fertilized Setaria anceps cv Kazungula.

Dry matter and nitrogen yields for C. cajan and s. anceps are presented in Table 4.

Results

Production was markedly reduced in the second season and there would be little value in maintaining C. cajan stands into the second grazing year. This reduction can be explained in part by damage due to heavy scale insect (Coccus longulus Douglas) attack. This would appear to be the first reference to this pest occurring on pigeonpea (J.D. Galloway personal communication).

This reduction in production is reflected in the survival of C. cajan at the beginning of grazing in the second year (Table 5).

Animal production on C. cajan was good (up to 1.0 kg/hd/day) while adequate pod and leaf was available early in the grazing period. Liveweight was maintained longer in both years on S. anceps.

Thus careful management would be required in commercial usage to adjust stocking rates to avoid rapid decline in available feed, to prolong grazing time and possibly to increase survival of plants from season to season.

Chicken Feeding Trial

The aim of this investigation was tc assess the potential of pigeonpea seed as a major protein source in poultry starter rations. Pigeonpea seed meal was fed to chickens from hatching to 6 weeks, at levels between 5% and *30%* of the total ration. This

Table 4. Dry Matter and Nitrogen Yields (kg/ha-^{1}) in C. Cajan and S. Anceps Pastures Prior to Grazing in 1972 and 1973

	C. cajan			Grass in C. cajan			S. anceps		
	Plant Total	L+F+P*	Stem	Total	Green	Dead	Total	Green	Dead
1972 DM	6181	2222	ND	ND	ND	ND	ND	2974	1988
N	ND	58.2	ND	ND	ND	ND	ND	25.97	ND
1973 DM	1740	570	1170	1600	760	840	4150	2320	1830
N	ND	21.2	ND	29.6	17.6	12.40	77	59.5	17.5

* L = LEAF P = POD F= FLOWER ND = NOT DETERMINED

Table 5. Percent Survival of Pigeonpea Prior to and After Grazing in 1973

Accession	% Survival Prior to Grazing	% Survival After Grazing
UQ2	71	43
UQ38	70	32
UQ50	64	28
UQ68	55	28
UQ72	50	18
Mean	62	30

resulted in body weights as good as or better than those of control birds, fed a starter ration of maize and soybean meal (Table 6).

Table 6. Body Weights, Feed Conversion, and Mortality of Chickens Fed Pigeonpea Seed Meal (Cajanus Cajan) For a Period of Six Weeks

	Body Weight(gm)			
% Pigeonpea	Hatch	Week 6	Feed Conversion	Mortality/20
0	39.1	750.9 b*	2.6	1
5	39.8	793.5 a	2.5	0
10	39.1	801.1 a	2.5	1
20	39.3	776.8 a	2.7	0
30	37.7	750.5 b	2.8	0
40	38.3	690.7 c	3.0	0

* Body weight means at 6 weeks not followed by the same letters differed significantly ($P<0.01$).

At 40% pigeonpea meal, treated birds' body weights were significantly lower than those of the controls ($P<0.01$). This reduced weight gain may be due to an amino acid deficiency: possibly cystine, tryptophan or phenylalanine (Springhall, Akinola and Whiteman 1974).

CONCLUSIONS FROM COMPLETED WORK

From the work of Akinola (1973) it may be concluded that high seed yields can be obtained experimentally from UQ50 in the Redland Bay environment of southeastern Queensland.

It is also evident that with the manipulation of sowing date and density of planting, mechanical harvesting of pigeonpea seed would be possible.

A major problem is the slow crop growth , rate in the early stages of growth. This slow beginning has led to serious weed problems in the early stages of growth. This problem may be overcome by the use of weedicides or by rigorous cultural techniques.

CURRENT RESEARCH PROGRAM

Aims

On the basis of previous work it was considered necessary to develop research along the following lines:

(a) Variety evaluation in a range of environment and soil conditions

(b) Assessment of interaction between sowing date, density, environment and genotype to obtain maximum yields.

(c) Development of suitable mechanical harvestingtechniques.

Genotype x Environment Interaction

In 1973-74, variety evaluation trials were conducted at four environments in south-eastern Queensland. The varieties were selected from the previous classification. The environments selected ranged from humid subtropical coastal to a dry inland environment. The rainfall range was 1300 mm on the coast to 700 mm inland.

The date of occurrence of the first frost is considered an important limiting factor to pigeonpea production in southeastern Queensland and therefore the interaction of sowing date and days to pod set in different varieties are critical factors.

Yields have been disappointing but this is in part due to adverse seasonal conditions. The later maturing varieties (UQ34 and UQ68) were killed by frost prior to pod set. The early varieties UQ11 and UQ 18 yielded up to 750 kg/ha^{-1} at an inland site while the mid-season UQ50 has yielded well at the coastal site (yield data yet to be finalized). This trial will be resown in 1974-75.

Sowing Date x Density Interaction

In 1973-74 at Redland Bay, UQ50 was sown at three sowing dates (mid-October, mid-December and early March) and four densities (10,000, 18,000, 33,000 and 110,000 plants per hectare). This trial was considered important because of the sensitivity to photoperiod demonstrated previously. In order to facilitate mechanical harvesting, optimum density must be combined with optimum sowing date to maximize yield and maintain plants at a harvestable height.

Preliminary results show that a December planting at 33,000 plants per hectare would be optimum for UQ50 under Redland Bay conditions. Final yields are not yet available.

The short day response of this variety was clearly demonstrated by significant reduction in height at later sowings. Further investigation is required at late sowing dates at much higher densities (up to 300,000 plants per hectare) to determine whether the crop has a future for autumn sowings and growth over the cool season, provided frost is not present and temperature is not limiting.

Genotype x Environment x Sowing Date x Density Interactions

Two genotypes (UQ11, UQ50) will be sown at three locations in the 1974-75 season at four densities (12,000-55,000 plants per hectare) and three sowing dates (October, November, January). Information from this experiment will allow recommendations of optimum sowing date and density for different genotypes of different locations. This information is required before commercial production could be contemplated.

Mechanical Harvesting

A small amount of seed was harvested with an "all crops" combine harvester in 1974. In order to quantify problems involved in harvesting, an area of 2 hectares (1 hectare each of UQ50 and UQ11) will be sown at optimum density and sowing date. At maturity the crop will be mechanically harvested. Recovery of seed by mechanical harvesting will be measured.

Preemergent Weedicides

Because of the slow crop growth rate of pigeonpea in early stages of development an effective preemergent weedicide will be required. Several glasshouse trials have been conducted with two weedicides Dacthal (Chlorthal Dimethyl) and Treflan (Trifluralin). Dacthal has controlled grass weeds without adverse effects on pigeonpea at rates of 6.75 kg active ingredient per hectare. Treflan has a marked effect on pigeonpea growth, stunting and deforming seedlings even when applied at rates below recommendation. The same result was obtained on a range of soil types and planting depths. These results may have important limitations to the use of Treflan as a preemergent weedicide in the field, although Getner and Danielson (1965) have recommended its use.

Maturation of Seed and Pods

In an experiment to determine the time at which maximum seed dry weight is obtained flowers were tagged and pods picked at weekly intervals. Dry weight of seed reached a maximum at 7 weeks after flowerina after which it remained constant (Figure 12, M. Smith unpublished data). At 7 weeks moisture content was still 70%.

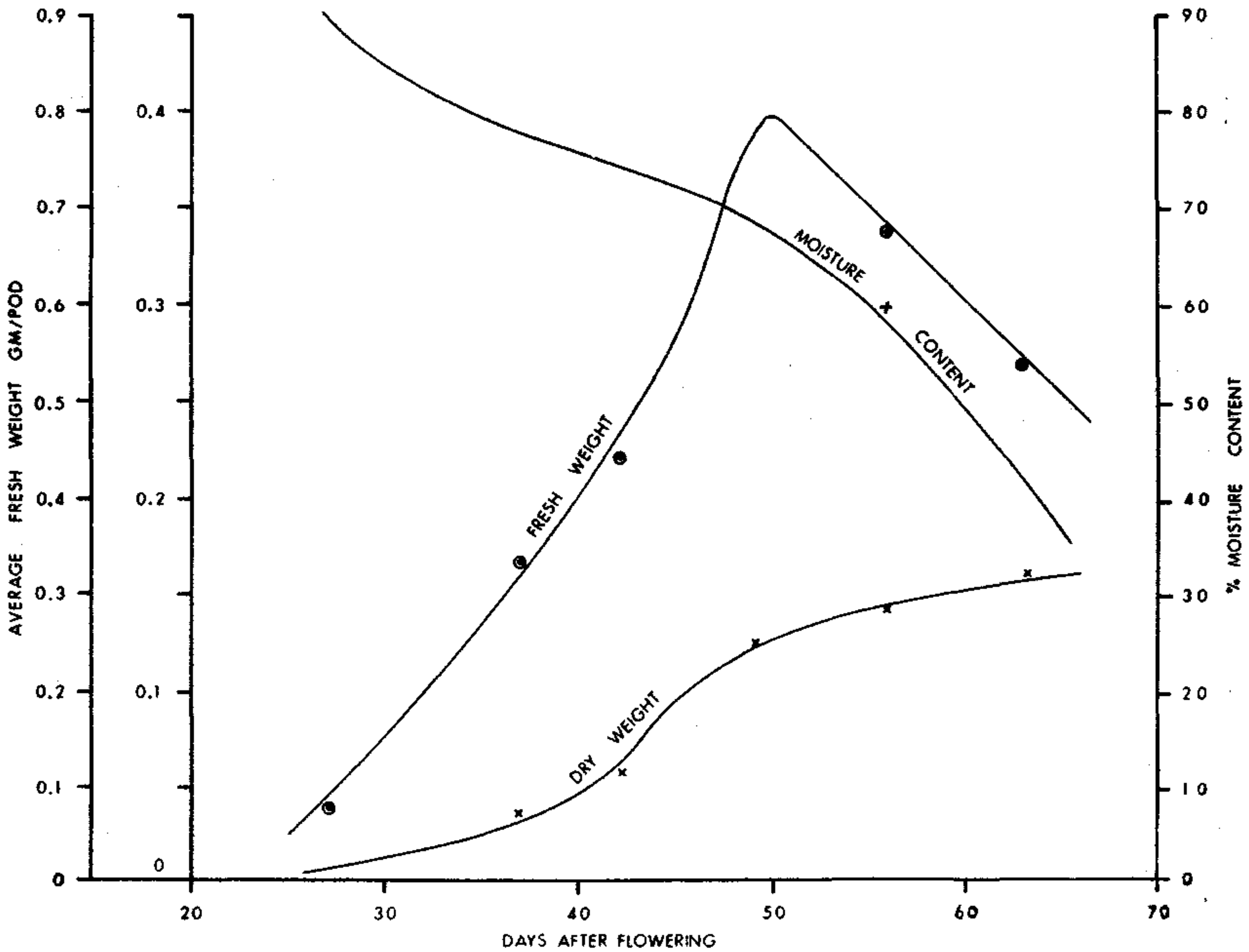
These data have important implication in the harvest of seed for dry seed yield determination.

CONCLUSION

At present grain legume crops account for only 1% of total crop production in Australia, compared with 1.5% for oil seeds and 97.5% for cereals (Farrington 1974). Recently there has been Increasing interest in grain legume production, particularly in soybean, peanuts, lupin and field peas. The University of Queensland has begun a research program to evaluate the potential of pigeonpea for commercial production in Australia.

Experimental yields of pigeonpea in southeastern Queensland have been encouraging, but high yields have yet to be obtained under commercial conditions. Attainment of high

Figure 12. Average Fresh and Dry Weight of Seed per Pod and Moisture Percent of <u>C.CAJAN</u> UQ50 as a Function of Days from Flowering



yields on a larger scale will be necessary for acceptance of pigeonpea Into any cropping system.

Investigation of agronomic factors such as planting date, density and genotype x environment interaction are being undertaken to determine the future of the crop for Australian conditions.

Detailed studies have been completed on classification, growth analysis, response to photoperiod, effects of density and defoliation on seed and dry matter yields and animal production of both seed and forage.

This work has created some Interest in the crop from commercial producers and other research Institutions. Pigeonpea may, therefore, be a potential crop in tropical and subtropical environment, particularly on the poorer coastal soils and marginal dryland cropping areas of Australia. Any development of commercial cropping of pigeonpea will, of course, be dependent on the availability of markets.

DISCUSSION

D. Sharma:	Dr. Wallis, you have Indicated that the cultivar UQ 38 gives yields close to 6000 kg/ha. Is this a tall determinate type?
E.S. Wallis:	UQ 38 is naturalized in Australia. It is a tall Indeterminate type.
R.P. Ariyanayagam:	Where did it originate?
E.S. WalUs:	I do not know.
P.J. Dart:	In these studies was nodule formation due to natural inoculation?
E.S. Wallis:	No, strain CB 756 was used.
M.C. Saxena:	You found trifluralln adversely affected pigeonpea. Did you attempt to use it as a preemergent herbicide? It would have been safer 1f you had applied it as a preplanting herbicide.
E.S. Wallis:	We used it as a preplanting herbicide.
A.R, Sheldrake:	How were the exceptionally high leaf area Indexes determined?
E.S. Wallis:	I am not sure, but believe it was by accepted leaf area meters.

LITERATURE CITED

Akinola, J.O. and Whiteman, P.C. 1972a. A numerical classification of *Cajanus cajan* (L.) Millsp. Accessions based on morphological and agronomic attributes. Aust. J. Agric. Res. 23: 995-1005.

Akinola, J.O., Pritchard, A.J. and Whiteman, P.C. 1972b. Chromosome number in pigeonpea (*Cajanus cajan* (L.) Millsp.). J. Aust. Inst. Agric. Sci. 38: 305-306.

Akinola, J.O. 1973. An agronomic evaluation of pigeonpea (*Cajanus cajan* (L.) Millsp.). Unpublished Ph.D. Thesis, University of Queensland.

Akinola, J.O.and Whiteman, P.C. 1975a. Agronomic studies on pigeonpea (*Cajanus cajan* (L.) Millsp.). I. Field responses to sowing time. Aust. J. Agric. Res. 26: (in press).

Akinola, J.O. and Whiteman, P.C. 1975b. Agronomic studies on pigeonpea (*Cajanus cajan* (L.) Millsp.). II. Responses to sowing density. Aust. J. Agric. Res. 26: (in press).

Akinola, J.O. and Whiteman, P.C. 1975c. Agronomic studies on pigeonpea (*Cajanus cajan* (L.) Millsp.). III. Responses to Defoliation. Aust. J. Agric. Res. 26: (in press).

Akinola, J.O., Birch, C.J., Whiteman, P.C. and Wallis, E.S. 1975. Grazing evaluation of pigeonpea (*Cajanus cajan* (L.) Millsp.) at Mt. Cotton, southeastern Queensland. Proc. Aust. Conf. Trop. Pas. (in press).

Akinola, J.O., Whiteman, P.C. and Wallis, E.S. 1974. The agronomy of pigeonpea (*Cajanus cajan* (L.) Millsp.). Rev. Ser. Fid. Crop Abs. (in press).

Downes, R.W. 1966. The Introduction and preliminary evaluation of species for improving cattle feed in the dry tropics of Queensland. Queensland Department of Primary Industries, Agriculture Branch, Technical Report Number One.

Farrington, P. 1974. Grain legume crops: their role in the world scene and in Australian agriculture. J. Aust. Inst, agric. Sci. 40: 99-108.

Getner, W.A. and Danielson, L.L. 1965. Evaluation of selected herbicides on several pulses. Proc. Amer. Soc. Hort. Sci. 87: 359-362.

Springhall, J., Akinola, J.O. and Whiteman, P.C. 1974. Evaluation of pigeonpea (*Cajanus cajan*) meal in chicken rations. Proc, 1974 Aust. Poul. Sci. Conv. p. 117-199.

GENETIC DIVERSITY. STABILITY AND PLANT TYPE IN PULSE CROPS

S. Ramanujam[1]

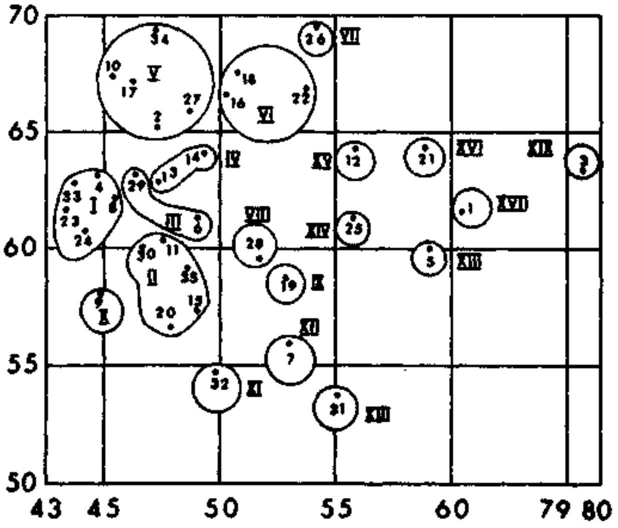
INTRODUCTION

Genetic variability, or rather the lack of it, has been implicated in the relatively limited progress made in the improvement of pulse crops in India and presumably elsewhere. We had occasion to examine the genetic divergence in a set of 10 elite Mung bean genotypes from different states of India and of the 25 hybrids between them. Observations were recorded on yield, yield components (branches/plant, pods/plant, inflorescences/plant, pods/bunch, 100 seed weight), developmental characters (days to flowering and days to maturity) and quality characters (percent protein, grain density). Genetic divergence was studied using principal component analysis as well as generalized distance analysis.

Analyses of Divergence

Figure 1 (taken from Ramanujam, Tiwari and Mehra 1974) presents a two dimensional representation of the divergence among the 35 (10 parents and 25 F_1's) genotypes using the first and second canonical vectors as the coordinates. Superimposed on this are the clusterings obtained through D^2 analysis. Canonical analysis revealed the importance of maturity and flowering time in the first vector and seed density and seed size in the second vector. The two vectors together accounted for 80% of the variation. D^2 analysis stressed the importance of seed density, maturity time, seed size and flowering time while yield or its components had limited influence on geneticdiversity.

Figure 1. Two dimensional representation of divergence of 35 genotypes of mung bean (10 parents and 25 hybrids) using the first two canonical vectors (Z1, Z2) as coordinates. The groupings obtained from D^2 analysis are superimposed. The genotypes included in the different clusters are: I.T.44, Pusa Baisakhi", T.44 x Hyb. 45, T.44 x R.1. "Pusa Baisakhi x R.1; II. K.11 x B.I, K.11 x Khar, 1, BR.2x T.44, J.781 x Pusa Baisakhi, R.1 x 'Madira'; III. Khar 1, Khar 1 x Madira; IV. K.11 x T.44 K.11 x Hyb. 45; V.B.1 'Madira'. B.1 x T.44, Khar.1 x 'Pusa Baisakhi', 'Pusa Baisakhi x 'Madira'; VI. B.1 x BR.2, B.1 x Hyb.45 BR. 2 x 'Pusa Baisakhi", VII. Khar 1 x J.781; VIII. Khar. 1 x R.1; IX. B.1 x J.781; X. R. 1; XI. J.781 x 'Madira'; XII. J.781; XIII. J.781 x R.1; XIV. Hyb.45 x 'Madira'; XV. K. 11 x BR.2; XVI. RB.2 x Hyb.45; XVII. K.11; XVIII. Hyb.45; XIX. BR.2



Clustering

It is interesting to note that the ten

---

[1] Indian Agricultural Research Institute, New Delhi, India

parents fell into as many as eight well separated clusters (I, III.V, X, XII, XVII, XVIII, XIX), the distance between the clusters being substantial in most of the cases. The 25 hybrids formed as many as 14 different clusters. Many of the clusters contained one or two hybrids, well separated from the parents. In some instances, hybrids occupied the same cluster as one of their parents. Some hybrids having the same parent fell in the same cluster, but others were widely dispersed (hybrids involving BR-2 or J 781).

DIVERGENCE ANALYSIS

It is important to consider the reality of the genetic divergence assessed by such analysis. One method would be to look at the relationship between the divergence of two parents and the heterosis obtained 1n hybrids between them, as there 1s fair agreement that these two parameters are related to a large extent. Table 1 presents the relationship between genetic divergence and heterosis 1n respect to a developmental character, a component of yield, and grain yield/plant. It can be seen that, in general, there is fair agreement between the presence of heterosis and the distance between the parental clusters. Since internal balancing or even cancellation of the various components of heterosis can restrict the expression of heterosis, it must be considered that distance analysis has estimated genetic divergence in this material.

Analysis Results

It appears, then, that substantial genetic diversity has been generated from crosses involving only a limited sample of 10 genotypes of mung bean. The alleged lack of genetic variability in this and presumably other pulse crops needs therefore to be reexamined.

The wide divergence found in the restricted sample of mung bean examined by us, in contrast to the findings in wheat (Somayajulu, Joshi and Murty 1970) is interest ing. The wheat genotypes, many of them products of hybridization involving exotic wheats, fell into four or five clusters only.

The available genotypes in mung bean, and presumably other pulses, have not undergone, apparently, selection for similar maturity, grain size or disease resistance as have the wheat types, and this has preserved greater divergence. It appears feasible, by synthesizing a gene pool by Intercrossting as large a number of varieties as possible, to build up an immense store of variability which the breeder can seek to appropriately manipulate.

NEED FOR IDEOTYPE FOR PULSE IMPROVEMENT

It is possible that a major reason for the lack of progress in pulse improvement might be not lack of genetic variability per se, but rather the lack of an ideotype that the breeder should look for. The concept of plant type has received much attention in the lifting of yield ceilings in cereals. It is not clear, however, what would be the ideal plant type to aim for in grain legumes. Any attempt to use the morphological framework developed for high yielding cereals would perhaps be irrational. It might, therefore, be useful to consider Information obtained from association analysis which may have a bearing on this question.

Correlation Analysis

Much of the information available on association of plant characters with grain yield has been based on data obtained in a limited number of genetic backgrounds and does not go beyond suggesting that number of pods/plant and seeds/pod show strong association with yield, as would perhaps be expected even on a priori grounds. Correlation analysis on data obtained from 1500 F_2 plants derived from 25 crosses are presented in Table 2. It can be seen that most of the development and component characters exhibit significant association with yield. Pods/plant and seeds/pod again turn out to be highly correlated, but other characters such as bunches/plant, pods/bunch, number of inflorescences/plant, leaves/plant, chlorophyll depth, harvest index and branches/plant also show significant and appreciable correlation with grain yield/plant.

Methods of Breeding for Ideotype

Association analysis suggests that a plant which produces larger number of pods/plant with greater number of seeds/pod would be desirable. The question now 1s how these Increases, especially in number of pods/plant, are to be attained. This could, of course, be

Table 1. **Relationship Between Genetic Diversity and Heterosis in Respect of Three Important Characters in 25 Kharif Grown Mung Bean Hybrids**

Cross	Divergence (D^2) between parental clusters	Percent heterosis over mid-parent		
		Days to 50% flowering	No. of seeds/pod	Grain yield/plant (gm.)
BR-2 x Pusa Baisakhi	35.10	-29.07**	16.02**	107.59**
BR-2 x T-44	35.10	-34.95**	11.12*	6.09
B-1 x BR-2	33.21	-32.11**	19.85**	61.99**
BR-2 x Hyb.45	20.70	-27.02**	13.09*	105.45**
K-11 x BR-2	19.85	-39.84**	15.53**	147.59**
K-11 x T-44	15.93	-21.21**	5.68	115.34**
T-44 x Hyb.45	15.52	-22.08**	3.25	22.67
B-1 x Hyb.45	14.99	-10.28**	- 0.81	71.81**
Hyb.45 x Madira	14.99	- 7.79**	6.02	41.78
K-11 x B-1	14.67	-15.58**	- 8.88	-11.36
J-781 x Madira	14.31	9.44**	-21.12	-60.04**
B-1 x J-781	14.31	- 2.57	- 7.19	- 2.38
K-11 x Khargone-1	13.87	-14.28**	-14.52**	50.40*
J-781 x R-1	9.81	1.87	8.23	13.99
J-781 x Pusa Baisakhi	12.36	- 2.67	- 4.04	-27.43
R-1 x Madira	9.73	2.40	- 7.56	-25.47
Khargone-1 x J-781	9.32	4.80	9.52	14.75
B-1 x T-44	6.36	- 1.98	2.42	42.97
Pusa Baisakhi x Madira	6.36	0.00	3.19	9.39
Khargone-1 x Madira	6.09	- 4.69	- 5.32	32.52
Khargone-1 x R-1	5.11	0.02	1.24	- 0.28
Pusa Baisakhi x R-1	4.98	4.80	10.50*	- 1.38
T-44 x R-1	4.98	- 5.25	0.87	33.48
Khargone-1 x Pusa Baisakhi	4.97	0.00	7.87	25.19
K-11 x Hyb.45	4.80	-25.64**	- 4.42	71.86**

Table 2. Correlation in 1500 F, Plants of Green Gram (Phaseolus Aureus)

Characters	Yield	Pods/pl	Seeds/pod	Br. No.	Branches/plant
Branches/plant	0.304*	-	-	-	
Leaves/plant	0.366	0.323	0.191	0.623	-
Inf./plant	0.430*	0.514	0.360	-	-
Bunches/plant	0.600	0.781	-	-	-
Pods/plant	0.725@	-	-	-	-
Pods/bunch	0.470*	0.635	-	0.580	0.093
Seeds/pod	0.5620	-	-	-	-
Chlorophyll Depth	0.329	-	-	-	-
Habit	0.223	-	-	-	-
100 seed weight	0.101*	-	-	-	-
H.I.	0.364	-	-	-	-

- Correlations non significant; does not arise

@ Correlations significant in Correlation analysis at parental/F, population level

* Correlations non significant at parental/F_1 population level

done by increasing the number of branches/plant or by manipulating number of bunches/plant and pods/bunch. The fact that branch number has a lower association with yield than bunches/plant or pods/bunch would suggest that it might be feasible to increase pods/plant without Increasing the number of branches. The breeder should look for a larger number of leaves, with a larger proportion of these having inflorescences in their axil, borne on a fewer branches. This may mean shorter Internodes with flowering starting at as early an Internode as possible. Since synchronous maturity showed a negative association with pods/plant, breeding for nonshattering or capacity to hold the seeds for a comparatively longer time may be needed.

An alternative path to reach larger number of pods/plant would be to look for a larger Inflorescence combined with better pod set. If pod set could be Improved it may be possible to attain the objective even more easily. Flower drop has been, indeed, one of the major factors in not realizing the full potential Inherent in many legumes. Since removal at random of flowers does not help to reduce flower drop (Hicks and Pendelton 1969 in soybean) shortage of photosynthate may not be the prime cause. An understanding of the physiological basis of flower drop is urgently needed.

Results with Heterogen Hybrids

Among the 25 hybrids studied, five outyielded the best parent, the extent of heterosis ranging from 50%-82%, in the main or monsoon season. Since these estimates are based on field raised plantings using agronomic practices recommended for large scale cultivation, it would be reasonable to assume that those differences are real. It would, then, be Interesting to compare the behavior of these heterotic hybrids with the top parent so as to obtain some idea of the suitable plant type. Such a comparison is presented in Table 3. From such a comparison we found that compared to the top parent, the heterotic hybrids generally:

1. have flowered as early or earlier
2. reach maturity as late or slightly later
3. show less synchrony in maturity
4. possess 1.5 to 2 times the number of pods/plant
5. have slightly larger number of seeds/pod
6. have considerably smaller seeds
7. show a more or less similar harvest index
8. possess fewer or equal number of branches/plant
9. bear equal or larger number of bunches/plant
10. have greater number of pods/bunch
11. have similar number of leaf axils and proportion of such leaf axils bearing inflorescences
12. flower at a slightly earlier node
13. show no particular pattern in respect of protein content, methionine in flour or percent methionine in protein

The plant type suggested by association analysis and that emerging from a comparison of heterotic hybrids and top parent agree to a considerable extent.

EXAMINATION OF GENOTYPE BEHAVIOR

An important aspect of all crop production, but particularly of grain legume production, is the stability of yield. It might be interesting then to look at the picture in chickpea. This has been attempted (Ramanujam & Gupta 1974) through an analysis of G x E interaction adopting the approach of Eberhart and Russel (1966). Through this approach, it becomes possible to define the behavior of a genotype over locations using three parameters over-all mean performance over a sample of environments, regression on the potentiality of each of these environments and a measure of the deviation around this regression line.

Description of Experiment

A sample of 35 genotypes were grown in suitable layout at three locations: Sirsa, Delhi and Hyderabad. At each location, three environments differing in the N and P_2O_5 application was available giving a total of nine environments. For the present purpose, it might be sufficient to examine the extent of predictable (nil or linear) and non-predictable (nonlinear) components of G x E Interaction and the relationship of mean performance, responsiveness and deviation from responsiveness of yield and of its component characters.

G x E Interaction

Table 4 shows the proportion of the mean square due to G x E interaction which is explained by the linear regression and that which is due to deviations from linearity. It is obvious that for most of the characters except seed/pod, number of primary and secondary branches and sulphur content, the linear portion of G x E interaction was substantial. A striking thing was the large proportion of genotypes which showed predictable behavior. Even in respect of yield, nearly 45% showed predictable behavior. In respect to protein content, nearly 50% of the genotypes have a predictable behavior but with respect to sulphur content and protein value index (sulphur content in relation to protein content), a majority of the genotypes showed a predominant nonlinear component and as such are likely to exhibit unpredictable behavior.

Correlation in Yield and Other Components

The relationship between yield and its components in respect of the three stability parameters is examined in Table 5 which presents the correlation between these parameters for yield and for the other components. High performance (d_1) in respect to yield seems to be associated with responsiveness (capacity to respond to better environment) in respect to number of pods/plant, but with lack

Table 3. Comparison of Heterotic Munf Bean Hybrids With Best Parent Grown in the Monsoon Season

Character	Hybrid					Best parent
	1 x 3	1 x 4	1 x 5	3 x 5	3 x 8	
Yield/plant	10.3	9.3	8.5	9.4	9.3	5.7
50% flowering	43	39	43	51	44	48
50% maturity	81	67	68	81	74	70
Synchrony	6.4	8.7	6.7	5.9	7.5	7.0
Pods/pl.	27	26	20	19	28	14
Seeds/pod	12	12	11	12	12	10
Harvest Index	0.28	0.29	0.26	0.22	0.30	0.28
Protein	26.7	26.1	26.3	26.3	27.0	26.7
Methionine	2.2	2.3	2.6	2.9	3.0	2.1
Branches/pl.	2.1	1.4	1.8	2.5	1.7	2.0
Bunches/pl.	9.3	6.8	6.7	6.3	7.1	6.8
Pods/bunch	3.0	3.4	3.1	3.2	3.7	2.0
Leaves/pl.	17	15	14	16	14	17
Inflor./pl.	4.6	4.0	2.2	3.7	3.8	4.3
Nodes to I Infl.	7.2	7.0	7.8	7.9	6.8	8.1

Table 4. Magnitude of Linear and Nonlinear Portion of Genotype x Environment Interaction

Character	Linear %	Nonlinear %
Yield/plant	73.61	26.39
Number of pods/plant	77.43	22.57
Seed/pod	48.98	51.02
Seed size	78.99	21.01
Days to flower	59.18	40.82
Plant height	69.13	30.87
Plant length	62.41	37.59
Plant breadth	73.26	26.74
Growth index	86.13	13.87
Yield/g.1.u.	84.49	15.51
Number of primary branches	34.21	65.79
Number of effective secondary branches	55.36	44.64
Sulphur content	54.34	45.66
% protein content	68.55	31.45
Protein value index	58.51	41.49

Table 5. Correlation Between Genetic (d_i) and Stability Parameters (B, s_d^{-2}) for 15 Characters Including Yield Per Plant and Between Parameters for Yield/Plant and Other Characters

Character	di of yield with			B_i of yield with			S^2di of yield with		
	d_i of other traits	B_i of other traits	S^2di of other traits	B_i of other traits	di of other traits	S^2d of other traits	S^2di of other traits	di of other traits	B_i of other traits
No. of Pods per plant	0.841*	0.458*	0.382*	0.766*	0.401	0.004	0.373	0.141	0.178
Seeds/pod	0.593*	0.008	-0.026	0.272	0.182	0.049	-0.130	0.011	0.058
Seed size	0.341*	-0.518*	-0.486*	-0.421	-0.213	-0.172	-0.203	-0.308	-0.003
Days to flower	0.368*	0.072	-0.142	0.003	-0.142	-0.208	-0.143	-0.025	0.208
Plant Height	0.132	0.253	-0.167	0.316	-0.480*	-0.077	0.162	0.065	-0.179
Plant length	0.100	0.432*	-0.337*	0.025	-0.440*	-0.333*	0.317	0.253	-0.019
Plant Breadth	0.109	0.323*	-0.314	-0.174	-0.420*	-0.149	-0.211	0.140	0.008
Growth Index	0.079	0.153	-0.164	-0.409*	-0.493*	-0.084	-0.143	-0.281	0.056
Yield/g.i.u.	0.656	0.554*	0.198	0.727	0.690*	0.394*	0.020	0.079	-0.027
No. of primary branches	0.140	0.197	-0.004	0.144	-0.052	-0.092	-0.060	0.004	-0.055
No. of effective secondary branches	0.381*	-0.197	0.069	-0.289	0.321*	0.076	0.298	0.161	0.057
Sulfur content	0.134	-0.176	0.095	-0.320*	0.015	0.068	0.130	0.093	-0.166
% Protein content	-0.405*	-0.478*	-0.021	0.119	-0.156	0.214	0.085	0.121	-0.026
Protein value index	0.340	-0.114	0.143	-0.333*	0.095	-0.079	-0.100	0.103	-0.152

of responsiveness for seed size. High yield is associated with responsiveness in respect to ratio yield/g.1.u. but not for g.1.u. (a measure of vegetative growth) itself. Interestingly high performance for yield is associated with responsiveness for protein content.

Predictability of Yield and Other Characters

It might be Interesting to look at the predictability of yield (as measured by regression over environmental index and deviations therefrom) and that of other characters. Correlation analysis of the relevant B_1 and $s^2\ di$ values is in Table 5.

There is very little relationship between the measure of deviation from the response line of any other character and mean performance or responsiveness for yield. Except in the case of pods/plant, there is no correlation of deviation from response line for yield and that for any other character. However, responsiveness in respect to yield is positively related with responsiveness in respect to pods/plant, yield/g.i.u., but nonresponsiveness in respect to vegetative growth. There is no relationship between responsiveness for yield and for protein content.

BREEDING FOR GENOTYPE PERFORMANCE

To build up a genotype capable of giving a good performance under optimum conditions, one would have to look for responsiveness for number of pods/plants and grain yield for unit of vegetative growth. This would mean larger number of pods through greater number of pods/branch and not through greater number of branches/plant. Ways of achieving this might be to look for greater number of pods per node, shorter internodes, restricted development of the compound leaf, reduction in flower wastage and more than one seed per pod. The agreement between the desired architecture 1n chickpea arrived at by this approach and that for mung bean described earlier is quite striking.

Comparison with Chickpea Leaf Mutants Experiments

It might be interesting to recall in this connection some leaf mutants described earlier in chickpea. In one of these mutants, designated the simple leaf mutant, the compound leaf is replaced by a simple lamina. Since this is one of the ways suggested above of improving the harvest index, 1t might be interesting to compare the behavior of this type with normal types. Table 6 presents such a comparison with C. 235, one of the elite varieties grown at the conventional 30 x 10 cm spacing as well as at a narrower spacing of 15 x 7.5 cm. Simple leaf mutant as well as T1ny leaf mutant were grown at the narrower spacing. In the Tiny leaf mutant, the leaves show a second order of branching and 1n a sense are moving in the direction opposite to the simple leaf mutant. It probably would not be justifiable to compare the yields/plot because of two factors: the fact that simple leaf flowered earlier and suffered extensive flower drop due to an unusual cold spell and the fact that C. 235 is probably the best elite type available. Extensive wilting late in the season also affected all the plots.

When we look at the harvest index, however, we find, both on a plant basis and on a plot basis under similar spacing, simple leaf has done much better than C. 235 or Tiny leaf. There is little difference between the latter two genotypes. C. 235 has suffered considerably in harvest index when spacing is reduced from 30 x 10 to 15 x 7.5 cm, rank growth, lodging and shading being apparent in the field. It was felt that simple leaf might stand even narrower spacing and thus higher population pressure without any detrimental effect. Such approaches to reduced vegetative growth may need more serious evaluation in grain legume improvement.

Table 6. Comparison of Normal, Compound Leaf Type With Simple Leaf and Tiny Leaf Mutant

Variety/spacing	Mean of 20 plants randomly selected from two crops									
	Branches per plant	Nodes to I pod	Nodes to last pod	Pods/ plant	Seeds/ plant	Growth wt. of plant (gms)	Seed wt. per plant (gms)	Total Pl. weight (gms)	Seed/ plot gm	H.I.* pl. b plot b
C. 235 (30 x 10 cm)	6.3	16	23	19.7	236.2	76.1	22.9	4260	1046	30/25
C. 235 (15 x 7.5 cm)	4.5	16	22	80	95.8	39.1	9.9	3380	706	25/21
Simple leaf (15 x 7.5 cm)	2.4	16	21	42	51.2	20.9	7.7	1460	354	37/24
Tiny leaf (15 x 7.5 cm)	2.9	16	22	33	48.7	32.6	7.9	3060	629	24/20

* Harvest Index (Seed wt./plant + seed wt) on single plant basis/plot basis

DISCUSSION

D. Sharma:	You have talked about genetic diversity, performance of crosses, and complicated analyses. Is this all necessary for the practical plant breeder? In my opinion we should look for simple criteria like high yield.
S. Ramanujam:	Yield is a complex factor and therefore we may not look for a simple approach. In P. aureus, seed density, maturity and seed size make different quantums of contribution to yield.
B.R. Murty:	The technique of using multivariate analysis 1s not new. It is 40 years old. However its application has now become wider. Such analyses are necessary for understanding the factors of divergence.
E.S. Wallis:	Further developments of classification methods have been used at University of Queensland (Akinola and Whiteman AJAR 1972 and Margumery, Shorter and Byth AJAR 1974).

LITERATURE CITED

Eberhart, S.A. and W.A. Russel. 1966. Stability parameters for comparing varieties. Crop Sci., 6:36-40.

Hicks, D.R. and W.A. Pendelton. 1969. Effect of floral bud removal on performance of soybeans. Crop Sci., 9:435-37.

Ramanujam, S. and V.P. Gupta. 1974. Stability of yield and its components in bengal gram and its bearing on plant type. Proc. II SABRAO Congress (1973). Indian J. Genet., 34(A):757-763.

Ramanujam, S., A.S. Tiwari, and R.B. Mehra. 1974. Genetic divergence and hybrid performance in mung bean. Theoret. Appl. Genet., 45.

DEVELOPMENT OF HIGH YIELDING VARIETIES OF PULSES: PERSPECTIVE, POSSIBILITIES AND EXPERIMENTAL APPROACHES

H. K. Jain[2]

COMPARISON OF PULSE AND CEREAL YIELDS

Pulses, in general, give lower yields than cereals. This observation has suggested to some that pulses may have a lower genetic potential for yield than the cereal crops (for a good review see Milner 1973; Swaminathan 1973; Swaminathan and Jain 1973). However, there is no compelling evidence at present to suggest that this is so. On the contrary, the available evidence .indicates that the pulse crops have as high or a higher genetic potential for yield than the cereals.

The lower yields of pulses compared to creals at the present time are not difficult to understand. Unlike the cereals, pulses have been grown for hundreds of years under marginal conditions of moisture stress and low soil fertility. If we compare the yields of pulse crops with those of cereals grown under similar conditions of moisture stress, we may find that some of the cereals give lower yields.

Man began agriculture in developing countries like India nearly five thousand years ago when the present day crop plants were first domesticated. Following human selection during this period, the domesticated species have changed many of their morphological and physiological characteristics in association with improvement in yields. It is important, however, to appreciate that not all crop plants have been subjected to the same degree of human selection. The cereals crops like wheat and rice have received far greater attention than the pulse crops for they have been the staple food of most people. It would be true to say that even after their domestication several thousand years ago, many of the pulses have continued to be grown in countries like India under conditions which are not very different from those found in their original habitats. Under these conditions of poor crop management, natural selection has been a much greater determinant in the plant type and other characteristics of the pulse crops than human selection.

Role of Natural Selection

It is well known that the needs of natural and human selection are very different. Natural selection is more concerned with those characteristics of the plant which enable it to perpetuate itself under highly competitive conditions. Under these conditions and a fluctuating environment, adaptation becomes far more important than yield. In order to give high yields, crop plants have to develop certain agronomic characteristics, which may be of relatively little value under the competitive and stress conditions of a primitive agriculture.

Experimental Evidence of Natural Selection

The experiment of Harlan and Martini (1938) on a number of barlev varieties is a

---

[1] Based on a manuscript prepared for the Indian Journal of Genetics and Plant Breeding

[2] Indian Agricultural Research Institute, New Delhi, India

classical study which shows clearly how natural and human selections favor different traits in crop plants. These authors selected a number of high yielding varieties of barley developed in different parts of the United States and grew them in unselected mixtures for a number of years at different locations. The mixture was initially constituted by bulking equal number of seeds of each of the varieties. The bulk seed harvested from the mixed crop was replanted year after year in each of the locations without any selection. Harlan and Martini found at the end of a twelve year period that the variety which was known to be highest yielding at a particular location was not necessarily the most successful at that location when grown in these varietal mixtures. A relatively lower yielding variety was found to show a greater increase in the proportion of its seeds than the high yielding variety, because of its greater competitive ability.

Potential for Grain Legumes

If we recognize that the genetic limitations to yield are no greater in the case of grain legumes than cereals and undertake equally intensive breeding programs, we have reason to believe that high yielding varieties similar to those of cereals can be developed in these crops. We already have examples from soybean, broadbean (Bean 1967) and green gram (Ho 1974) in support of this conclusion. These pulse crops have received relatively greater attention from the standpoint of their genetic improvement. Table 1 shows the yields of these crops on an absolute basis and on a per day basis. These yields have been compared with those of one of the highest yielding wheat varieties available at present. It will be seen that the per day productivity of these pulse crops compares well with that of the wheat variety. Crops like chickpea and pigeonpea offer similar possibilities of increase in their yield.

BREEDING FOR HIGHER YIELDS

The foremost need in organizing improvement programs for higher yields of pulses is to take into consideration the past selection history of these crops. As far as the developing countries are concerned, there is little doubt that many of these crops continue to retain a number of wild characteristics, such as a bushy and spreading growth habit associated in many cases with excessive vegetative growth, late maturity and toxic or other undesirable constituents in their seeds.

Table 1. Absolute and Per Day Yield of Some High Yielding Varieties of Wheat and Grain Legumes (kg/ha)

Crop	Grain yield	Crop duration (days)	per day yield
*Wheat (Kalyan Sona)	5890	150	39.2
**Soybean (Clark-63)	3799	92	41.3
Green gram (CES 87-17)	2436	80	30.4
Broad bean (Imperial Windsor)	5376	130	45.10

* Source: Report of the Coordinated Agronomic Experiments, 1973-74, All India Wheat Workshop, ICAR.

** Source: Mehta, N.K., IARI (unpublished)

These characteristics serve the crop well under stress conditions.

Indeed, the presently available varieties of pulse crops, even though they have a low yield potential, should not be dismissed lightly for they have incorporated through thousands of years of natural selection attributes which make them adapted to conditions where virtually nothing else will grow. A good example of this is provided by Lathyrus sativus, which is grown in India over an area of nearly five million acres. The grains of this pulse carry a toxic amino acid (Rao et al 1969) which is believed to be the major factor responsible for lathyrism. In spite of this knowledge and many government efforts, it has not been possible to replace the Lathyrus crop in India. The crop is grown in paddy fallows and there is no other crop plant equally hardy which can replace it under these conditions. The development of high yielding varieties in pulses comparable to those in cereals requires breeding for a new level of management. Two kinds of approaches are imperative in this regard.

Breeding for Nonirrigated Conditions

Vast areas of agricultural land in countries like India will continue to be nonirrigated for many years to come. Pulse crops will continue to have an important place in these regions. The foremost need of these regions is to develop a new kind of agronomic management for pulses as well as for other crops. It is now well recognized that response to fertilizer application is possible even in the case of nonirrigated crops. In wheat, for example, varieties have been developed which show such a response (Bhardwaj 1973).

The availability of a new package of agronomic practices based on more efficient techniques of soil and water conservation, use of limited amounts of chemical fertilizers, and chemical control of insect pests should make it possible to develop varieties with a higher yield potential than those available at present.

The widely prevailing concept that a nonirrigated crop cannot take full advantage of an improved level of management has to be discarded. There is evidence to show that the present set of varieties can be replaced by relatively high yielding types under these conditions, following the kind of agronomic improvement described above. The newly developed pigeonpea varieties, Pusa Ageti, Sharda and Mukta and the Kanpur type-21 have generally given higher yields even under nonirrigated conditions.

Breeding Varieties for Intensive Cultivation

For a major production advance comparable to that in cereals, the pulse crops must be fitted into an intensive kind of agriculture. The limited evidence which we have at present shows that this is not only possible but that it can be achieved without a great deal of competition with the cereal crops. The foremost need is to develop varieties with a reduced maturity duration which can be fitted in a series of multiple cropping patterns. Also, these varieties have to be bred for an improvement in their plant type, particularly in respect of a higher harvest index. The harvest index in a crop provides a measure of the proportion of grains relative to the total plant weight. It is useful to estimate harvest index by pooling all the plants from a large plot as this minimizes the role of environmental factors in modifying it. In theory, the contribution of roots to total dry matter production should be taken into consideration while estimating harvest index, but in practice this is rarely done.

HARVEST INDEX IN PULSES

The scientific basis for the improvement of plant type in pulses can be readily seen. The stress conditions under which pulses have been cultivated for centuries has meant selection for characteristics which contribute to the establishment of the crop under these conditions. One of the most important of these characteristics is a profuse vegetative growth. In no other grain legume can this growth be seen more clearly than in plgeonpea. The traditional, long duration varieties of plgeonpea grown in India often show a total dry matter production of nearly 15 tons per hectare. This amount exceeds the total dry matter production in the best of the spring wheat varieties available in the world. Some of the highest yielding wheat varieties today are the dwarf types developed in Mexico and more recently in India. These give a grain yield of nearly 6 tons per hectare over a period of five months. These varieties are comparable with the early maturing pigeonpea varieties like Pusa Ageti and Type-21. Table 2 shows the dry matter production, grain yield and harvest Index of some of these pigeonpea varieties and those of chickpea and wheat. It is clear that the main factor responsible for the lower grain yields of pigeonpea relative to wheat is their poor harvest Index and not their photosynthetic capacity.

A similar situation can be seen in the case of chickpea. The total dry matter production in the chickpea varieties is somewhat less than that of the highest yielding varieties of wheat. The difference, however, is not as great as might be expected considering the fact that the former is grown as a nonirrigated crop. The lower grain yields of chickpea varieties must again be attributed primarily to their lower harvest index.

The above analysis shows clearly that the most important component of an improved plant type in pulses must be a high harvest index. The morphological frame of the plant must be reconstructed in such a way that the total dry matter produced is more efficiently partitioned between grains and the vegetative parts.

BREEDING FOR HIGHER HARVEST INDEX

It may be argued that breeding for a higher harvest Index (combined with high total dry matter production) amounts to breeding for yield. It should be emphasized in this context that selection for a higher harvest index is possible on a phenotypic basis. The recent work on the development of dwarf varieties of wheat and rice has shown that one or a few major gene mutations can bring about extensive reconstruction of the plant type, which is associated with an improvement In the dwarf varieties of wheat, and this contributes in a significant manner to the higher yields of these varieties (Table 3). The other important component is a good tillering capacity. There are no a priori grounds to suggest that a genetic reconstruction of the plant type in favor of a higher harvest Index cannot be achieved in pulses. The improvement may be associated with a more determinate growth habit and relative insensitivity to photoperiodic conditions, but this is not essential. In wheat and rice, apart from dwarfing, relative photoinsensitivity is often associated with an improvement in harvest index. The early maturing relatively photoinsensitive pulse varieties may be found to be associated with a similar increase in their harvest index. This belief is supported by some of the recent work in India on the development of new varieties of pigeonpea.

It should be emphasized, however, that a high harvest index can also be combined with an indeterminate growth habit and late maturity. This is shown by the remarkable progress made in India in recent years in developing high yielding F1 hybrids of upland cotton. The Hybrid-4 strain of <u>Gossypium hirsutum</u> developed by Dr. C.T. Patel of Gujarat shows this kind of plant type. The hybrid has been reported to give a record yield of 40-50 quintals per hectare of seed cotton and already covers thousands of acres in the western and peninsular parts of the country. In selecting for a high harvest index in pulses, the important requirement is to increase the relative proportion of effective pods per plant. This may be possible both with and without photoinsensitivity. Photoinsensitivity, however, is desirable in its own right for it should make it possible to fit the new varieties into multiple cropping patterns.

Harvest Index and Root Growth

It should be emphasized that a genetic reconstruction of the plant type in favor of a higher index must take into consideration the requirements of the root system in the plant. This would be particularly important in the case of varieties recommended for nonirrigated areas of limited rainfall. Most of the pulse varieties like those of pigeonpea grown under these conditions have been selected for a well developed root system, which can extract moisture from the deeper layers of the soils. Any attempt to repartition the dry matter between the vegetative and reproductive parts should not be at the expense of the root system in such cases. Fortunately, there is evidence to show that possibilities exist to combine a high harvest index with a well developed root system. One of the best examples is provided by dwarf varieties of wheat like Kalyansona. The variety gives high yields both under irrigated and nonirrigated conditions and is particularly remarkable for its capacity to show good tillering and root formation under conditions of moisture stress.

Table 2. Yield and Harvest Index in Wheat, Pifeonpea and Chickpea (Quintals/Hectare)				
Crop	Varieties	Biological yield (harvested dry matter)	Harvest index	Economic yield (grains)
* Wheat	P4-2	142.82	38.57	55.12
	P29-1	151.63	38.81	58.81
	P77-1	141.38	39.61	55.73
** Pigeonpea	Pusa Ageti	133.33	15.00	20.00
	Sharda	139.99	13.50	18.75
***Chickpea	Pusa 53	99.72	20.00	19.34
	Sel 539.1	94.24	25.30	23.87
	C235	121.66	30.00	36.66

* Based on Kulshreshtra and Jain (unpublished)

** Based on Singh, Pahuja and Jain (unpublished)

***Based on Bahl, Raju and Jain (unpublished)

Table 3. Yield and Harvest Index in Bread Wheat* (Quintals/Hectare)			
Varieties	Biological yield	Harvest index	Economic yield (grains)
Tall (NP 824)	172.12	30.65	53.27
Semi-dwarf (Sonalika)	180.73	35.37	63.93
Dwarf (Moti)	164.95	40.48	66.59

* Based on Jain and Kulshreshtra (unpublished)

Experimental Evidence in Root Development

More important is the recent evidence on the pattern of root development in different varieties of cotton and other crops (Wakhaloo et al. 1973, Katyal and Subbiah 1971). The main finding is that there is considerable intergenotype variation in this regard and it should be possible to select for a deep root system both in the early maturing and late maturing groups of varieties. The early maturing varieties of cotton included in these studies had been bred for a higher harvest index.

Role of Early Maturing Varieties

Also, the widely prevailing concept that early maturing varieties have no role in non-irrigated areas is not valid. The highest yielding varieties in pigeonpea under these conditions in India are not the late maturing traditional types, but some of the newly evolved early and medium maturing varieties.

PHYSIOLOGICAL BASIS OF HARVEST INDEX

The traditional varieties of pulses like pigeonpea and chickpea tend to combine high total dry matter production with a poor harvest index. The physiological basis of this maldistribution of dry matter in the plant is becoming increasingly clear.

Function of Photosynthetic Activity

It has been found that it is largely a function of a highly nonuniform distribution of photosynthetic activity over the growth period of the plant. The photosynthetic activity is more pronounced during the vegetative phase of crop growth contributing to total dry matter production, which may exceed that of the cereals, as we find in the case of pigeonpea. However, the photosynthetic rates register a sharp decline as pods begin to develop. The drop is associated with a fall in total nitrogen content of leaves and loss of RuDP activity. This appears to be a general phenomenon in pulses as shown by the work of Sinha (1973, 1974) on the basis of his studies on chickpea, cowpea, pigeonpea and green gram. This decline in photosynthetic activity is found to be associated with the disintegration of nodules, with the result that supply of nitrogen becomes limited and the plant has to depend on the nitrogen already accumulated in the leaves. Support for this conclusion has also come from the work of Hardy (1974) on soybean in the course of his CO_2 enrichment experiments during fruit development.

Influence of Sink Capacity

We must, therefore, conclude that the harvest index in pulses is poor not because of a poor sink capacity. Indeed, the sink in many of the pulses appears to be unusually large when one considers the flowering potential of these crops. Crops like pigeonpea and chickpea are very profuse in their flowering. Many of the flowers, however, are lost due to shedding and the pods which do develop are only partially filled.

Conclusions on Photosynthetic Activity

The conclusion that photosynthetic activity in pulse crops declines as pod formation starts has important implications. Selection for a high harvest index can be expected to be associated with a more uniform distribution of photosynthetic activity during the life of the plant. There are good reasons why natural selection should favor high photosynthetic activity in the preflowering stages of plant growth. As explained earlier, under the stress conditions in which pulses have been traditionally grown, the most important requirement is the establishment of a good stand. In the absence of this, the plant is not expected to survive and hence the selection,for excessive vegetative growth in the preflowering stages.

EXPERIMENTAL APPROACHES FOR HIGH HARVEST INDEX

In crops like pigeonpea and chickpea,

major gains in yields can be expected, as we have seen, if selection is practiced for an improvement in plant type in terms of a high harvest index, response to increased plant populations per unit of land, and early maturity. The total dry matter production in these crops is already quite high. It can be further increased through agronomic manipulations.

Cropping Patterns

Another direction which the improvement program can be expected to take in the future is in the breeding of varieties for cropping patterns different from the traditional cropping schemes, which have evolved largely in response to the needs of a maintenance kind of agriculture. This point can be best illustrated with reference to the chickpea crop in India. The chickpea crop in northern India is sown in the month of October and harvested in April, taking a total period of nearly six months in the field. If we study the pattern of crop growth during this period, we find that there is very little during the first three months and it is only towards the end of January that production of dry matter picks up, followed by pod formation in March. For the first two and one-half months, the crop virtually sits in the field showing hardly any growth. Sinha (1974) has made a study of leaf area development during different stages of crop growth in chickpea and his main observation 1s that following *very* slow development, the area shoots up during the period between the last week of January and first week of March.

The main reason chickpea is planted in October and not in January or February is that the crop is raised entirely under nonirrigated conditions and sowing is done on moisture conserved from the preceding monsoon rains. With manipulation of agronomic conditions, chickpea can be fitted into new cropping patterns, which would help to reduce the maturity duration of this crop and fit it into more productive crop sequences. Breeding of varieties of the following kind deserves consideration for these new cropping schemes.

(a) Varieties which would respond to sowings in the middle of September in the northern belt. These will have to combine a day neutral condition with early flowering so that the crop can be harvested by end of December.

(b) Varieties which can be sown in October, as at present, but show early growth and day neutrality, combined with early flowering so that they can be harvested in January.

(c) Varieties which can be sown in the month of January. They will be selected for a long day response and would be expected to vacate the field by the end of April. Unlike the first two groups, these varieties will be developed for conditions where presowing irrigation is available.

Breeding for Fertilizer Response

Nitrogen

Most pulse crops under Indian conditions respond to a starter dose of nitrogen as 1t takes time for the nodules to develop and start fixing atmospheric nitrogen. The physiological analysis of Sinha, as explained earlier, indicates that nitrogen also becomes a limiting factor during pod formation, when the nodules begin to disintegrate, following a decline in the photosynthetic activity of the plants. This would suggest that it should be possible to breed varieties of pigeonpea, chickpea and cowpea which will respond to larger doses of nitrogen than the 20 kg per hectare, which is generally recommended as a basal dose. The wisdom of breeding such varieties, however, appears questionable at the present time. Grain legumes have a unique capacity to extract nitrogen from the atmosphere and it is obviously desirable to exploit this capacity to the fullest possible extent. We have already seen that the major limitation with regard to the yield of crops like pigeonpea and chickpea is not with regard to the total production of dry matter, but an unbalanced distribution of this dry matter between the pods and the vegetative parts of the plant. It should be possible to develop varieties which would make more efficient use of the fixed nitrogen by making available more of it for the developing pods. The breeding programs in crops like pigeonpea and chickpea should, therefore, be planned not so much for response to externally applied nitrogen but to a more uniform fixation of nitrogen during crop growth.

Phosphorus

As regards phosphorus, there is over whelming evidence that most of the grain legumes show a good response to P_2O_5 application. The response has been found to be particularly good in crops like pigeonpea. It should, however, be emphasized that most of the existing varieties of pulses in India have been selected for conditions of poor soil fertility. Once we accept the principle that the pulse crops should receive an improved agronomic management 1n the same way as cereals, it would be possible to select varieties which show a greater response to phosphorus than the existing varieties. In the past, breeders have preferred to make their selection under conditions of average rather than high fertility. Breeding for fertilizer response, thus, has a definite place in pulse improvement programs as far as nutrients like P_2O_5 are concerned.

RECENT PROGRESS

Based on the concepts outlined above, new varieties of pulses have been developed at the IARI and other centers during the last eight years. None of them shows the efficiency of the plant types which are available in wheat and rice where a harvest Index of more than 40% has already been achieved. The new varieties of pulses, however, show that progress is possible in this direction. The rate of this progress should increase enormously as more and more genetic variability is injected Into the breeding programs. Most pulse breeders 1n India continue to work with a limited number of genetic stocks. This represents a far more serious limitation to the progress of pulse improvement programs than anything inherent in the genetic potential of these crops.

New Varieties

The studies have been particularly successful in the case of pigeonpea, green gram, cowpea and lentil. A number of new varieties of pigeonpea have already been released and a number of others are 1n advanced stages of testing (Jeswani 1970; Jain 1974). •The released varieties include Pusa Ageti, Sharda and Mukta whose seeds have been multiplied by the National Seeds Corporation. Some of these varieties respond to a plant population of 100,000 plants per hectare as against 45,000 of the older types. The maturity duration of these varieties has been reduced to five to six months which is nearly half of that of many of the older varieties. The new varieties have given yield of nearly 25 quintals per hectare, which is more than double the yield of many of the older varieties, when the per day productivity of the two groups of varieties is compared.

A part of the Improvement in the yields of these varieties has come from their improved harvest Index. They are relatively less bushy and more compact with a harvest index of nearly 15%, while the corresponding figure for many of the older varieties is nearly 10%. It is clear, however, that the harvest index of the new pigeonpea varieties is still very low compared to that of the high yielding varieties of wheat and rice. Some of the varieties now being tested show a higher harvest index of nearly 25%.

ACKNOWLEDGEMENT

I am grateful to a number of my colleagues for permitting me to quote their unpublished work. The ideas developed in this paper are based on the work of a large number of scientists in this Institute.

DISCUSSION

A.K. Auckland:	I have reservations on harvest index. I think more yield should be the objective.
H.K. Jain:	We are all Interested in yield. To get that we have to use criteria like harvest Index.
K.J. Frey:	In small grains It has been possible to make improvement through eye selection on harvest index. Grain yield per se has certain limitations because we always make restricted selection by stratifying the population. Therefore harvest index 1s very valuable particularly when single plant selections are made. To facilitate assessing harvest Index, the plants should be grown under stress. This is a standard procedure in Iowa.

A.K. Auckland: I agree with the point about putting plants under stress for calculating harvest index.

W.V. Royes: I agree with Dr. Jain's observations. We need to change plant design suited to local conditions.

S. Chandra: I think selection pressures must be broad based.

J.C. Davies: We must not forget the peasant situation. For example, farmers grow indeterminate, long duration pigeonpeas obviously because the Insect damage does not result in total losses since the plant keeps on producing flowers to compensate for insect damage.

LITERATURE CITED

Bean, K.W. (ed) 1967. World Crops: The J. of Int. agric., 19, pp. 84.

Bhardwaj, R.B.L. 1973. Ten years of research on dwarf wheat. Proceedings of 12th All India Wheat Research Workers' Workshop, pp. 68-98.

Hardy, R. 1974. Photosynthetic as a factor limiting yield in grain legumes. Proceedings of FAO Technical Advisory Group Meeting on pulses, New Delhi (in press).

Harlan, H.V. and M.L. Martini. 1938. Jour. Agr1. Res. 57, 189-199.

Ho, L. 1974. Yield trials of elite mung bean varieties. AVRDC Seminar, Taiwan.

Jain, H.K. 1974. Genetic improvement and production prospects of food legumes. Tropical Agricultural Research Series. No.6 Tropical Agricultural Research Center, Tokyo.

Jeswani, L.M. 1970. New pulse varieties for dry areas. A new Technology for Dry Land Farming. Bull, IARI pp. 84-87.

Katyal, J.G. and B.V. Subbiah. 1971. Root distribution patterns of some wheat varieties. Indian J. Agri. Sci. 41, 786-790.

Milner, M.M, (ed.) 1973. *Nutritional Improvement of food legumes by breeding.* Milner, ed. pp. 389. Protein Advisory Group of the United Nations System.

Rao, S.L.N., I. Malathi and P.S. Sarma. 1969. Lathyrism. World Rev. Nutr. Diet. 10, 214.

Sinha, S.K. 1974. Improvement in the yield of pulses: A physiological and biochemical approach. Recent Advances in Plant Science (in press).

Sinha, S.K. 1973. Yield of grain legumes: problems and prospects. Proc. I I SABRAO Congress. Indian J. Genet, (in press).

Swamlnathan, M.S. 1973. Basic research needed for further improvement of pulse crops in Southeast Asia. *Nutritional improvement of food legumes by breeding* Milner ed. pp. 61-68.

Swamlnathan, M.S. and H.K. Jain. 1973. Food Legumes in Indian Agriculture. *Nutritional improvement of food legumes by breeding* Milner ed. pp. 69-82.

Wakhaloo, S., A.M. Oza and M. Singh, 1973. Root activity and soil feeding zones of cotton. Preliminary studies with three *G. hirsutum* varieties. ISNA Newsletter 2, 24-26.

FOURTH

SESSION

PROBLEMS OF NUTRITIONAL QUALITY OF PIGEONPEA AND CHICKPEA AND PROSPECTS OF RESEARCH

J. H. Hulse[1]

INTRODUCTION

Because of the extent of the relevant published literature the principal difficulty in preparing this paper has been to decide what to omit rather than what to include. Many worthy papers are missing from the list of references because of the limits of space and time. However copies of all those cited are available at IDRC and can be made available to anyone seriously interested.

Though the two food legumes under discussion appear under a variety of names, throughout this paper "Cicer arietinum" will be referred to as chickpea and "Cajanus cajan" as pigeonpea.

Since the volume of published scientific literature which describes chickpea appears much larger than that on pigeonpea, the subsequent text may appear somewhat unbalanced in relative content.

ORIGINS AND EARLY USE OF LEGUMES

Food legumes can be described as potentially the most valuable yet probably the least developed of the naturally occurring sources of food protein. The nutritional value of legumes was recognized by the author of the book of Daniel (Dan. I: 12) who wrote:

> "Prove thy servants I beseech thee ten days; and let them give us pulse to eat and water to drink then let our countenances be looked upon before thee and the countenances of the children that eat of the portion of the King's meat... At the end of 10 days their countenances appeared fairer and fatter in flesh than all the children which did eat the portion of the King's meat. Thus Melzar took away the portion of their meat and the wine that they should drink and gave them pulse."

Chickpea appears to have originated in the fertile crescent of the Mediterranean. Though Arnon (1972) suggests the crop had its earliest origins in the Himalayas, recipes including chickpea are to be found in De Re Coquinaria one of the earliest known cookbooks which was written by the Roman gourmet Apicius, in The Deipnosophists by Athenaeus and by PIiny the Elder in his Historia Naturalis. Athenaeus describes dishes containing boiled and roasted chickpeas and the use of the tender and mature seeds in several desserts. Pliny recommends chickpea as a diuretic, to stimulate lactation and also to prevent skin diseases.

While the results of archaeological excavations around the Mediterranean appear to have firmly established the origin of chickpea, the birthplace of the pigeonpea, so called becauce it is said to be a favorite of the wild pigeon, appears less certain. In 1908 Watts (The_ Commercial Products of India) reported that pigeonpea grew wild in China and in the countries of Indochina. In 1904 De Candole (The Origin of Cultivated Plants) reported that pigeonpea was to be found in Africa from Zanzibar to the coast of Guinea

---

[1] International Development Rerearch Center, Ottawa, Canada

and at about the same time pigeonpea was said to be growing wild in the region of the Upper Nile.

From the earliest times the food legumes in general and chickpea in particular have been stigmatized as the food of the poor and even today in Latin America it is descriptive of a poor man to state that he is "counting his garbanzos".

PRESENT PRODUCTION AND CONSUMPTION OF LEGUMES

One could write a major work on the various ways in which chickpea and pigeonpea are cooked and eaten in different parts of the world. They may be eaten raw as immature green seeds, or as cooked or milled dried pulses. The seeds may be parched, or roasted over open fires, in metal pans or on hot sand.

In India probably more than 75% of the chickpeas produced are milled to produce dhal. In several Middle Eastern countries milled chickpeas are mixed with wheat and other cereal flours to make a variety of fermented breads and sweet breads, in addition to being combined with meat, vegetables and/or spices in many very delicious dishes.

The total world production of the major legumes is given in Table 1. If we exclude soybeans and groundnuts, chickpea falls third and pigeonpea fifth in order of production. Table 2 presents production data for 1972 by major regions and it can be seen that Asia and the Far East provide roughly 90% of both the world's chickpea and pigeonpea production. Mauritania (24g/person/day) is the largest per capita producer of chickpea with Togo and India (20g/person/day) in second place. The Dominican Republic (15g/person/day) is the largest and India (8g/person/day) the second largest per capita producer of pigeonpea.

In terms of total production, India is the largest producer of both pigeonpea and chickpea. According to Swaminathan and Jain (1972), chickpea represented 51.0% and pigeonpea 11.2% of India's total pulse production of approximately 11.7 million tons in 1969-70.

Table 3 presents the percentage change in (a) population, (b) total food production (c) food per capita and (d) chickpea production for the world as a whole and for the principal developing regions of the world.

Table 1. World Production of Major Legumes, 1972

	'000 M.T.
Soybeans	52712
Groundnuts	16532
Phaseolus Vulg.	11010
Pisum. Sat.	10731
Chickpea	7415
Vicia Faba	5286
Pigeonpea	1648
Cowpea	1146
World Total	106480

Source: UN PAG Bulletin 3 (2) 1973

Table 2. Chickpea and Pigeonpea Production, 1972

	'000 M.T.		
	Chickpea	Pigeonpea	All Major Pulses[1]
Developed Countries	132		8713
Latin America	186	34	4345
Near East	235		788
Asia and Far East	6530	1548	19854
Africa	332	66	3536
All LDCs	7283	1648	28523
World	7415	1648	37236

[1] Phaseolus vulgaris; Vicia faba, Pisum sativum; Cicer arietinum; Cajanus cajan; Vigna spp.

Table 3. Percent Change in Population and Legume Production, 1952-1972

	Population	Total Food	Food Per Cap	Chickpea
Developed Countries	+22	+60	+32	-42
Latin America	+62	+65	+ 2	+78
Near East	+57	+65	+ 2	+64
Asia and Far East	+51	+65	+ 9	+40
Africa	+52	+47	- 3	+55
All LDCs	+53	+62	+ 6	+42
World	+40	+61	+15	+38

Source: FAO Statistics of Production and Population 1972

In the world as a whole, the population has increased by roughly 40% while chickpea production has increased by 38%. In Latin America and the Near East chickpea production has risen faster than the population. In Asia legume production in general, and chickpea production in particular, have fallen markedly behind the rate of population increase and are grown at a noticeably lower rate than the percentage increase in total food production.

CEREAL - LEGUME NUTRITIONAL PROTEIN RATIO

Cereal protein and legume protein are nutritionally complementary; those amino acids which are deficient in the one being generally adequate in the other. As a broad generalization, a diet in which protein derived from cereals and protein derived from food legumes are 1n approximately a 70-30 ratio comes very close to nutritional adequacy.

According to FAO (1972) based on total production statistics, only 1n Latin America does the ratio of cereal protein to legume protein approach a 70:30 ratio. In Africa and the Near East the ratio is 75 cereal to 25 legume, whereas in Southeast Asia it is closer to a 90:10 ratio. World cereal production is increasing at a much faster rate than world legume production, consequently the need to increase legume production on a worldwide basis and in particular in South and Southeast Asia must be regarded as a matter of vital urgency.

PROTEIN CONTENT OF CHICKPEA AND PIGEONPEA

In the FAO (1970) Publication "Amino Acid Content of Foods" the average protein content of chickpea (Nx6.25) 1s quoted as 20.1 and of pigeonpea (Nx6.25) as 20.9%.

Swaminathan and Jain (1973) give the results from 16 varieties of chickpea grown at 12 locations and 11 varieties of pigeonpea grown at 5 locations. They state the range of protein in chickpea from 12.4% to 28.1% with a mean of 19.5% and 1n pigeonpea from 18.5% to 26.3% with a mean of 21.5%.

Since many of the protein contents quoted in the literature are based on a wide variety of sources and various methods of analysis, they are not all readily comparable. Many may prove to be of little practical value to the plant breeder, since in comparatively few instances are the identity and origin of the samples analyzed clearly defined.

Variation in Protein Content

In The Pulse Crops of India, Argikar reports protein contents (Nx6.25 on a moisture free basis) from 17.5 to 27.9, the results being from different strains grown at different localities. Also in the same publication the author quotes analytical results from a range of eight different strains of chickpea (Table 4).

Soil Influence on Protein Content

In the same publication it is suggested

Table 4. Analyses of Whole and Dehusked Chickpea

	Whole	Dehusked
Ether Extract (%)	3.9-6.2	4.6-6.9
Nx6.25%	20.8-25.9	25.3-28.9
Soluble carbohydrate %	60-63	63-65
Crude fiber %	8.0-8.7	1.0-1.5
Ash%	3.0-3.3	2.5-2.9

Source: G.P. Argikar Pulse Crops of India ICAR 1970

that soil conditions may influence protein content of chickpea which ranged from 17.5% to 27.9%, the highest tended to be those strains grown on alluvial soils. Protein contents of those grown on black cotton soils were 17.5%, 17.9%, 19.7%, 20.0%, 22.0% and 26.3%. Those grown on alluvial soils were 22.7%, 26.3%, 27.7% and 27.9%. However, since in this case the strains were all different it is not possible to isolate environmental from genetic influences.

Variation in Protein in Chickpea Strains

Lal et al. (1963) analyzed 47 pure strains of chickpea, 24 of which were described as Common and 23 Kabuli. Common strains varied in protein content from a low of 17.38% (strain BR17 from Bihar) to a high of 23.8% (strain G2 from Madhya Pradesh). The Kabuli strains ranged from a low of 19.65% (strain NP7 - IARI) to a high of 25.41% (strain Rabat from the Punjab). The authors believe that Kabuli strains are genuinely and significantly higher in protein, ether extract and iron content. They claim the Common strains are higher in crude fiber and calcium.

Chandra and Arora (1968) analyzed 40 varieties of chickpea all of which were grown in the Punjab. They identified four high protein varieties (Nx6.25 = 29.8%). The names and sources of origin of the four high protein varieties were: (a) Algeria 3444-Algeria; (b) Frontier 8A-Pakistan; (c) Gram Cross A- India: (d) Gadag S2-India. The low protein varieties (Nx6.25 =18.4%) were (a) Tehran 29 and (b) Ahmedabad SI.

Dr. Hugh Doggett kindly supplied us with the results of protein nitrogen analyses * carried out at ICRISAT by (a) Microkjeldahl and (b) the Udy dye binding method on 29 samples of chickpea, 85 samples of pigeonpea and 14 dehusked samples of pigeonpea. The results are given in Table 5.

Table 5. Analyses of Chickpea and Pigeonpea by Microkjeldahl and UDY (ICRISAT Results)

	Mean	Variance	Range
Chickpea			
Udy	23.77	0.79	22.58-26.56
Microkjeldahl	23.47	0.78	21.5-25.13
Pigeonpea			
Udy	21.44	0.61	19.26-23.17
Microkjeldahl	21.04	1.02	18.1-23.31
Pigeonpea with seed coat removed			
Udy	24.87	0.89	23.64-26.24
Microkjeldahl	25.25	1.52	23.52-27.58

In "New <u>Vistas</u> in. <u>Pulse Production"</u> (IARI 1971) the yields and protein contents of "high yielding" varieties of chickpea and pigeonpea are quoted. The chickpea varieties range in protein content from 22.4% to 24.7%, the yields from 917 to 1053 kg/ha, and the protein yields from 215.5 to 260 kg/ha. Pigeonpea ranges were: protein 20.7%-21.1%; yield 1250 to 1682 kg/ha, protein yield 259 to 340 hg/ha.

Zimmerman et al. (1967) fractionated, by hand scalping, the cotyledons of random samples Of chickpea into an inner and outer portion and analyzed for protein, lysine and methionine (Table 6).

The weight(%) represent the proportions of the whole seed. The balance of 10.2% represents the combined weight of hulls and embryo.

Many authors have published the results

Table 6. Protein, Lysine and Methionine Activity and Antitryptic Activity of Chickpea

	Part of Cotyledon	
Percent	Inner	Outer
Weight	25.1	64.7
Crude Protein	19.4	25.7
Lysine	1.23	1.79
Methionine	0.21	0.29

Table 6a. Composition of Various Fractions of Chickpea

	Percent			
	Seed Coat	Cotyledon	Embryo	Whole Seed
Proportion	14.5	84	1.5	100
Protein (Nx6.25)	3	25	37	22
Ether Extract	0.2	5	13	4.5
Ash	2.8	2.6	5	2.7
Crude Fiber	48	2	3	8
Cho	46	66	42	63
Phosphorus (mg/lOOg)	24	290	740	260
Iron (mg/lOOg)	8	5	11	6
Calcium (mg/lOOg)	1000	70	110	200

of their analyses for essential amino acids in chickpea and pigeonpea. A selection of these results are presented in Tables 7 and 8.

Inconsistency in Data on Protein Content

Hanumantha and Subramanian (1970) (See Column A of Tables 7 and 8) quote the range of results from 15 different papers. They also quote (Column G) results which they determined using paper chromatography. Later in Column E and F respectively are (E) the range of results from various sources reviewed by FAO and (F) the average of the same FAO data. The variability of results among different authors is readily apparent. To what extent the variation reflects genuine differences among samples and to what extent it is attributable to inconsistencies in methodology and experimental error 1s difficult to say. In any event, *very* few of the results quoted will be of great help to plant breeders since rarely do the authors state precisely the nature, biological history and source of the materials analyzed. The columns labeled "WHO" in both Tables quote the World Health Organization's recommended reference amino acid pattern: what might loosely be described as "an ideal proportion of essential amino acids".

AMINO ACID SCORES

Table 9 presents the author's (J.H. Hulse 1974) calculated amino acid scores for chickpea and pigeonpea based upon (a) the FAO average values and (b) Hanumantha Rao and Subramanian's analyses.

The amino acid score is the quotient of the amount of each amino acid reportedly present divided by the WHO reference pattern level for the same amino acid. The first and second limiting amino acids are those with the lowest and second lowest score respectively. According to the FAO results, the sulphur amino acids, methionine plus cystine, are first limiting in both chickpea and pigeonpea. Tryptophan or valine is the second limiting in the case of chickpea and tryptophan second limiting in pigeonpea. From Hanumantha Rao and Subramanian's results, tryptophan appears clearly as first limiting and methionine plus cystine as second limiting in both cases. Braham et al, (1965) claim that in autoclaved pigeonpea meal "methionine and tryptophan were equally deficient."

METHIONINE ANALYSES

In New Vistas in Pulse Production the results of methionine analyses on a large number of pulse crop samples are quoted. The data for chickpea and pigeonpea are given in Table 10. Unfortunately, the results are quoted as mg methionine per gram of sample

Table 7. Amino Acid Composition of Pigeonpea

	(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	WHO*
Isoleucine	51-66	57	66	38	30-33	31	50	46	40
Leucine	61-87	70	88	72	60-66	63	59	80	70
Lysine	62-74	64	70	68	72-83	77	59	58	55
Methionine	3-34	9	9	12	4-6	5	14	7	35
Cystine	4-18	8	—	—	7-12	10	11	.6	
Phenylalanine	78-91	91	82	10	78-93	83	57	72)	60
Tyrosine	33-40	—	—	31	19-21	20	32	22)	
Threonine	31-40	38	41	36	28-31	29	47	40	40
Tryptophan	2-9	2	2	—	4-8	6	3	—	10
Valine	43-57	51	57	45	34-40	36	59	54	50
Histidine	—	34	22	34	35-40	37	—	36	

(A) Hanuraantha and Subramanlan (1970) (15 papers)

(B) Rao S.V. et al. (1964)

(C) Banerjee (1960)

(D) Van Etten et al. (1967)

(E) FAO (1970) - Range

(F) FAO (1970) - Average

(G) Hanumantha and Subramanlan (1970)
by paper chromatography

(H) Royes W.V. (1972)

*WHO - Recommended "Ideal" amino acid composition energy and protein requirements WHO (1973)

Table 8. Amino Acid Composition of Chickpea

	(A)	(B)	(C)	(D)	(E)	(F)	(G)	MHO*
Isoleucine	44-60	60	57	44	42-47	44	50	40
Leucine	49-80	86	67	76	71-80	75	50	70
Lysine	45-79	64	54	72	65-74	68	46	55
Methionine	7-31	17	9	14	5-17	10	9)	35
Cystine	7-18	8	—	—	8-15	12	8)	
Phenylalanine	30-68	50	37	66	39-78	57	53))	60
Tyrosine	20-35	—	—	33	19-34	29	) 23)	
Threonine	28-48	48	32	35	35-42	38	45	40
Tryptophan	2-12	6	4	—	4-15	9	3	10
Valine	38-63	54	45	46	34-57	45	48	50
H1st1d1ne	—	23	14	23	24-30	26	—	

(A) Hanumantha and Subramanian (1970) (15 papers)

(B) Rao S.V. et al. (1964)

(C) Banerjee (1960)

(0) Van Etten et al. (1967)

(E) FAO (1970) - Range

(F) FAO (1970) - Average

(G) Hanumantha and Subramanian (1970)
by paper chromatography

*WHO - Recommended "ideal" amino acid composition energy and protein requirements MHO (1973)

Table 9. Amino Acid Scores

	Chickpea (a)	Chickpea (b)	Pigeonpea (a)	Pigeonpea (b)
Isoleucine	no	125	78	125
Leucine	107	71	90	84
Lysine	123	84	140	107
Methionine & Cystine	63	49	43	71
Phenylalanine & Tyrosine	143	126	172	148
Threonine	95	112	73	118
Tryptophan	90	30	60	30
Valine	90	96	72	118

Source: (a) FAO Average (b) Hanumantha and Subramanian (1970)

Table 10. Methionine Content of Chickpea and Pigeonpea

	No. of Samples	Mean Methionine mg/g sample	S.D.	Range
Chickpea	84	2.08	0.334	1.10-3.00
Pigeonpea	295	1.54	0.334	0.80-3.00

Source: New Vistas in Pulse Production IARI 1971

and hence cannot be compared with the amino add results presented in other tables.

To what extent the variation in methionine is Influenced by variability in protein content is not indicated. In any event, the range of results suggests that variability 1n methionine content may exist in significant degree and may be genetically Influenced.

Other Nutrients

The total lipid (ether extract) content of chickpea appears 1n general to lie between *3%* and 6% and in pigeonpea between *]%* and *2%.* The fatty acid composition of both legume lipids is nutritionally favorable with more than 50% of the lipid consisting of polyunsaturated fatty acids.

The carbohydrate concent which consists mainly of starch is variously reported between 50% and 65% in both legumes.

VITAMIN CONTENT

In common with most other legumes, chickpea and pigeonpea contain only modest amounts of vitamin A, approximately 300 International Units per 100 g in chickpea and 150 IU in pigeonpea. Thiamine content in both legumes 1s approximately 0.5 mg/100g. Both contain comparatively little riboflavin (approximately 0.15 mg/100g) but both are fair sources of niacin (1.5 to 2.5 mg/IOOg). All three vitamins are present in roughly the amounts found in whole cereal grains. Both chickpea and pigeonpea are comparatively good sources of iron (6-9 mg/IOOg) and contain five to ten times the concentration of calcium found 1n the major cereals. (Daniel and Norris 1945; Aykroyd and Doughty 1964).

Influence of Sprouting on Essential Nutrients

Since in a number of countries chickpea and pigeonpea are allowed to germinate before being eaten, a number of authors have reported on the influence of sprouting on a number of essential nutrients [De and Barai (1949), Bannerjee and Bannerjee (1950), Chattapadhyay and Bannerjee (1951),De and Datta (1951), Chattapadhyay and Bannerjee (1952), Belavady and Bannerjee (1953), Chattopadhyay and Bannerjee (1953), Bannerjee et al. (1954), Bannerjee et al. (1955), Singh and Bannerjee (1955)], Ascorbic acid, niacin,available Iron, choline, tocopherol, pantothenic acid, biotin,pyridoxine. Inositol and vitamin K all reportedly Increase in both chickpea and pigeonpea during germination.

Other Studies

Patwardhan (1962) states that the Biological Value (BV) (an estimation of the proportion of absorbed nitrogen that is retained in the body for maintenance and/or growth) ranges in chickpea from 52% to 78% and in pigeonpea from 47% to 74%; that the coefficient of digestibility ranges from 76% to 92% in chickpea and 59% to 90% in pigeonpea; that the Protein Efficiency Ratio (PER) ranges from 1.3 to 2.1 in chickpea and from 1.3 to 1.6 in pigeonpea (Table 11). Elsewhere Patwardhan (1961) quotes a PER of 1.1 for chickpea and 0.7 for pigeonpea.

Table 11. Biological Efficiency of Chickpea and Pigeonpea

Source	Biological Value %	Coefficient of digestibility %	Protein Efficiency	Level of Feeding %
Chickpea	52-78	76-92	1.3-2.1	12
Pigeonpea	47-74	59-90	1.3-1.6	12

Source: Patwardhan, V.N. Am. S. Clinical Nutrition, Vol. II (July-Dec 1962) p.12 "Pulses and Beans in Human Nutrition".

Variation in Results of Studies

The variance cited by Patwardhan (1962) is illustrated in other results from various authors. It is probable that these variable results reflect a combination of (a) differences in methodology, (b) intrinsic differences and, (c) differences in methods of processing the various samples reported on.

The comparatively low values of the various PERs quoted reflect the lack of balance in the amino acid content of these legumes. At the same time, in rat feeding studies used to evaluate nutritional value, the results tend to be based upon isonitrogenous rather than isocaloric diets.

INFLUENCE OF COOKING AND AUTOCLAVING ON NUTRITIVE VALUE

Some authors claim that cooking or autoclaving raises the nutritive value of both chickpea and pigeonpea [Gaitonde and Sohoniek (1952); Hirwe and Magar (1951)]. Graham et al. (1965) claim that after autoclaving for 20 minutes the PER of chickpea meal was increased from 0.46 to 1.52.

Kande (1967) states that normal cooking does not alter either the digestibility or the nutritive value of chickpea.

Chitre and Vallury (1956b) compared the plasma protein levels of rats fed both raw and autoclaved chickpea and pigeonpea. There was no significant difference between raw and autoclaved chickpea but the plasmaprotein levels were lower in rats fed autoclaved than rats fed raw pigeonpeas. They concluded that chickpea was one of the most efficient sources of protein in maintaining blood protein plasma levels.

OTHER CHARACTERISTICS

Ochse (1931) claims that raw seeds of pigeonpea contain an unidentified narcotic which if eaten in quantity induces sleepiness. Ochse concludes that pigeonpea seeds are a harmless soporific. No one else to the author's knowledge has pursued this subject.

Kuppuswamy et al., (1958) report findings in Central America which indicate that chickpea when fed as the sole source of protein to experimental animals produced toxic symptoms attributable to "cicerism". It is claimed that the "toxicity" could be ameliorated by the addition of methionine or choline. No toxin was however identified and interest in "cicerism" seems to have died since 1951.

Three other undesirable characteristics associated with some food legumes are: a) the presence of substances which agglutinate red blood cells, b) trypsin inhibitors and c) a tendency to induce flatulence. The first two factors have been studied by Liener (1973). Liener's results are given in Tables 12 and 13. Haemagglutinating activity appears to be zero in chickpea and pigeonpea and, compared

Table 12. Hemagglutinating and Antitryptic Activities of Crude Extracts* of Raw Legumes

Legume	Hemagglutinating Activity	Antitryptic Activity
Phaseolus vulgaris	HU/ml	TIU/ml
Black Bean	2450	2050
Kidney Bean	3560	1552
Cicer arietinum	0	220
Cajanus cajan	0	418
Phaseolus aureus	0	260

*A 10% suspension of the finely ground meal In 1% Nacl clarified by centrifugation.

Table 13. Effect of Heat on Nutritive Value of Some Legumes

Source of Protein	Gain in Weight	
	g/day	
	Raw*	Heated
Phaseolus vulgaris		
Black Bean	-1.94 (4-5)	+1.61
Kidney Bean	-1.04 (11-13)	+1.48
Cicer arietinum		
Bengal Gram	+1.25	+1.16
Cajanus cajan		
Red Gram	+1.33	+1.74

*100% mortality observed during period (in days) shown in parentheses.

with black bean and kidney bean, the antitryptic value in chickpea and pigeonpea appears to be of little consequence.

It is perhaps worth pointing out that most of the comparative work on trypsin inhibitors has been done with bovine trypsin. It is well known that bovine trypsin is more significantly affected by antitrypsins than is human trypsin and since most of the trypsin inhibitors present in legumes appear to be comparatively thermolabile it is doubtful if they are of any great importance in, human diets. Certainly they appear to be of little consequence in cooked chickpea and pigeonpea.

FLATUS PRODUCTION IN LEGUMES

Though in adults, flatus production is probably more of social than clinical importance, severe flatulence can give rise to acute discomfort in infants. Narayana Rao et al. (1973) produce evidence to indicate that the following legumes induce flatus in the decreasing order indicated; chickpea being highest and green gram lowest: chickpea; black gram (Phaseolus mungo); pigeonpea; green gram (Phaseolus radiatus). Though the substance (s) in chickpea and other legumes which leads to flatus has not been positively identified, it does appear that the effect is reduced by cooking. Srikantia (1973) describes experiments in which groups of children received 50% of their total protein from pigeonpea while another group received the same amount from milk. The growth of the children in the two groups was identical suggesting that the legume protein was a satisfactory replacement for milk.

The author goes on to state "legumes could be used safely in amounts to provide as much as 50%-60% of the total protein in the diet (of children)."

Phytic Levels

Hulse and Laing (1974) and Urie and Hulse (1952) have reported upon the importance of phytic acid in human nutrition which depends upon its property of forming insoluble compounds with essential minerals such as calcium, iron, magnesium and zinc. Phytic phosphorus appears to be present in chickpea at levels in excess of 200 mg/100g. It is also present in significant levels in pigeonpea. The level in chickpea approximates that present in whole wheat. Since the calcium content of chickpea and pigeonpea is significantly higher than the calcium in cereals the phytic phosphorus may not seriously interfere with calcium absorption in human diets. The phytin levels may, however, be sufficiency high to interfere with iron, magnesium and zinc absorption.

Polyphenols

Though the polyphenols (often described as "tannins") are known to be widely distributed among the leguminoseae, little appears to be known about the polyphenol content of chickpea or pigeonpea. It seems highly probable however that, particularly in chickpea possessing near black, purple, brown or maroon seed coats and chickpeas with brown and orange testas, that polyphenols are present. The biochemical mechanism whereby polyphenols interfere with protein metabolism in humans and animals has yet to be determined but there is evidence to suggest that polyphenols can be correctly described as antinutrients. It would be worth discovering whether there is a significant difference in biological value between the dark and light seed coated pigeonpea and chickpea varieties.

PROBLEMS OF DATA REPORTING

Hulse and Laing (1974) have commented upon the shortcomings in the manner in which analytical results related to the cereal grains are reported in the literature, and the need for a universally standardized methodology by which the biochemical composition and the biological value of the cereal grains are determined and rationally presented.

Similar criticisms might be advanced concerning the published analytical and nutritional data relevant to the food legumes. The Protein Caloric Advisory Group (PAG) of the United Nations System has recently prepared, in PAG Guideline 16, Protein Methods for Cereal Breeders Related to Human Nutritional^Riquirements. While many of the recommendations in this publication are applicable to legumes, 1t 1s hoped in the not too distant future a similar PAG Guideline will be prepared for legume breeders. Some of the inherent difficulties and approaches to the subject are discussed in another PAG Publication (1972), The Nutritional Improvement of Food Legumes by Breeding.

Sources of Error in Analysis

It is possible that chemical analysis is a less precise science than plant breeding. Williams (1974) lists 27 sources of error 1n the Kjeldahl testing procedure for protein content and 18 sources of error in the Udy dye binding system of protein testing. It 1s worthy of note that a significant error can result from dye binding analyses carried out on immature grains since the dye stuffs used are readily absorbed by chlorophyll and thus immature grains tend to give an exaggeratedly high value for protein content. In addition, grains high in cellulose may also present exaggeratedly high protein values. One of the greatest sources of error in amino acid analysis results from a lack of care and careful standardization of the method of hydrolysis.

Daniels (private communication 1974) carried out analysis of variation on the protein contents of various chickpea and pigeonpea samples analyzed by Microkjeldahl and Udy (dye binding) methods at ICRISAT. The results are given in Table 14. Though significant, the coefficients of correlation are comparatively low. This, at least in part, may be attributable to the narrow range of resuIts over which the analyses were made. Since Udy is intended as a comparatively rough screening test, it would be useful to repeat the comparison over a much wider protein range. In any event, it is suggested that in selecting for increased protein, differences of less than one full percent in percent protein (0.16%N) between the test and the standard can be discarded for all practical purposes.

Suggested Laboratory Procedure

As suggested in PAG Guideline 16, it is urged that all analytical laboratories in plant improvement research centers establish collaborative protein and amino acid testing programs with other laboratories and retain homogeneous reference samples stored below freezing in sealed containers by which to check equipment calibrations from time to time.

PROTEIN EVALUATION METHODS

The biological methods of protein evaluation include those which depend upon body weight gain and those which depend upon nitrogen retention in the test animals. Most recommended test methods are based upon an isonitrogenous diet. It is readily

Table 14. Analysis of Variation on Protein Analyses by Microkjeldaht and UDY Method

	No. of Samples	Range (Protein X)	SD	Coefficient of Correlation
Chickpea (Whole)	29	21.5-25.13 (MK) 22.58-26.56 (Udy)	0.88 0.89	.6171
Pigeonpea (Whole)	85	18.1-23.31 (MK) 19.26-23.17 (Udy)	1.006 0.78	.4152
Pigeonpea (Seed coats removed)	14	23.52-27.58 (MK) 23.64-26.24 (Udy)	1.23 0.94	.7912

demonstrable that the results with rats and other animals may be highly dependent upon the proportion of protein in the test diet. For example, proteins generally considered nutritionally inferior such as wheat gluten, will appear more satisfactory at low levels of intake than at high levels of intake when compared with a standard protein such as casein. The PAG Guideline 16 therefore recommends a slope growth method in which all proteins are tested at a minimum of three different levels against a standard, the rat being recommended as the preferable test animal. The Relative Protein Value (RPV) is then expressed as:

$$\frac{\text{Slope of the test protein}}{\text{Slope of the standard protein}} \times 100$$

Standardization

A brief word on the standardization of conventions by which results are recorded is perhaps in order. It is recommended that "protein" values be quoted as total nitrogen on a dry weight basis. If it is considered desirable to quote the results as "protein" these results should also be expressed on a dry weight basis and the conversion factor from "nitrogen" to "protein" clearly stated.

Data Reporting of Cereals

In the case of cereals it is recommended to breeders looking for "high protein" lines that they express their results as mg nitrogen/seed rather than as nitrogen or protein on a total dry weight basis. In the cereal grains, protein content and composition vary among different fractions of the seed and protein as percent dry matter 1s influenced by seed weight, and the relative proportion of the various seed fractions present. These in turn are influenced by environment and agronomic conditions. Similarly, the protein nitrogen present in the legumes is not uniformly distributed throughout the seed (Zimmerman et al. 1967) and therefore results expressed as mg nitrogen/seed is again recommended when selecting for higher protein breeding lines.

Data Reporting of Amino Acids

Amino acids have also been expressed in a variety of ways. It is recommended that no matter what the method of determination the results should be expressed as mgAA/per gram nitrogen. Minerals and vitamins are best expressed as mg or g/100 g of material with the exception of vitamins A and 0 which are customarily expressed in International Units.

Cooperation Between Disciplines

It would appear that if resources are to be used with greatest effect a great deal more cooperation between plant breeders on the one hand and analytical chemists and nutritional biochemists on the other hand is essential. It is my view that the latter have served the breeders *very* poorly in their attempts to develop plants of superior nutritional values. Perhaps an elementary course in botany would prove valuable for food chemists and biochemists.

Duration of Nitrogenase Activity

In seeking genotypes capable of synthesizing higher than average levels of protein nitrogen some attention might be given to the duration of nitrogenase activity. Hardy et al. (1968) and (1971) and LaRue and Kurz (1972) have described a method for determining the duration of nitrogenase activity which depends upon the ability of the nitrogenase present in the legume root nodule to reduce acetylene to ethylene. The results of the workers at the Prairie Regional Laboratory in Saskatoon indicate significant variations among different Pisum sativum lines in the length of time during which the nitrogenase is active. It is their belief that those lines of longer nitrogenase activity possess a higher potential capacity for synthesizing seed protein.

RECOMMENDATIONS FOR PLANT BREEDERS

In its publication "Nutritional Improvement of Food Legumes by Breeding" (1973) a PAG Working Group recommends a long list of considerations to which the plant breeder should give attention.

Time will not permit a detailed commentary upon the individual recommendations within the PAG document but suffice it to say that, since pigeonpea and chickpea appear to be comparatively free from major toxic factors and nutritional inhibitors, the plant breeder's primary concern should be to increase the yield potential of these crops and to explore the range of genetic variability related to seed nitrogen content and perhaps amino acid composition. What is required is a significant increase in protein production per unit area of land per unit of time.

As a secondary objective, and when time and facilities permit, it would be useful to determine whether the proportions of sulfur containing amino acids and tryptophan are genetically controlled. If either of these limiting amino acids is increased it should not be at the expense of lysine. The cereal grains are first limiting in lysine and since cereals and legumes are in many diets eaten together, the lysine contribution by the legume 1s of primary importance. Where the legumes are eaten with maize there may be a good case for attempting to raise the tryptophan content though this may be more readily achieved by genetic manipulation of the maize than of the legumes.

Where chickpeas and pigeonpea are the principal source of protein nitrogen calories in the diets of people who subsist largely on root crops, the sulfur amino add content is of significant importance since the cyanogenic glycosides present in cassava combine with and reduce the absorption of methionine and other sulfur amino acids.

PROCESSING OF LEGUMES

It is my opinion that a great deal more attention could be given to the processing of legumes. As stated earlier, food legumes tend to be regarded as poor man's meat but this image could be significantly changed by imaginative technological research and development.

Particularly to be recommended are technological systems which permit the processing of cereals and legumes using the same equipment. Such technology has been developed in Canada and is now installed in a small rural mill in Northern Nigeria. It consists of simple abrasive decortication using rotary carborundum discs in a rubber case followed by hammer mills or mosaic grinders, screening and packaging facilities. Technology of this kind permits inexpensive foods in which the optimum ratio of cereal and legume protein is combined together. Such foods are particularly advantageous for infants and young children, nursing mothers and other nutritionally vulnerable groups.

The techniques of protein concentration in cereals by fine grinding and air classification have been known for many years. The principle is that in a finely ground flour the carbohydrate preponderates in the heavier particles. Consequently, protein fractionation can take place by applying a centrifugal force to the fine flour particles opposed by a centripetal drag. The heavier particles of higher effective mass will move in one direction and the finer protein rich particles in the other direction.

In theory air classification is easier to achieve with legume flours than with cereal flours since legume flours contain, in general, significantly larger starch granules. That this theory is sound has been demonstrated at the Prairie Regional Laboratories in Canada (private communication) where field pea flour (Pisum sativum) has been thus converted to significantly higher protein contents than occur naturally in the cotyledon. While this technology is not as inexpensive as simple milling, it is simpler, less expensive, and less hazardous in tropical countries to operate than the "wet" systems of producing protein concentrates.

SUMMARY

In summary, it can be said that the chickpea particularly and also the pigeonpea, represent valuable but considerably under-exploited sources of edible protein. Greater attention needs to be given to their genetic diversity to determine the range of variability related to their biochemical composition. However, as stated at the outset, breeding for improved nutritional quality should not be undertaken at the expense of all those factors which contribute to improved yield.

Footnote: In the interests of brevity only a comparatively few relevant references have been cited in the text. An additional longer bibliography is provided and copies of all of the publications quoted are available at IDRC in Ottawa.

DISCUSSION

A.K. Auckland: Could you give the range of methionine content in chickpea?

J.H. Hulse: Not much information is available. Some data have been reported from IARI which is presented in Table 10.

A.K. Auckland: Could methionine be more important than tryptophan? In Uganda where sesame production decreased as groundnut production increased, this was said to be correlated with an increase in beri-beri disease. Sesame has a higher methionine content than groundnut.

J.H. Hulse: Probably this relates to vitamin deficiency but I need more Information before I can comment on this observation.

P. Pushpamma: Are polyphenols located in the whole seed or primarily located in the seed coat? Since the consumption in India is mainly in the form of dhal in which the seed coat is removed, is it important to study the effect of polyphenols on the nutritional quality of legumes?

J.H. Hulse: Polyphenols are widely distributed among the leguminosae and it is probable that they are in highest concentration in the seed coats. However, I have not come across reports of research on polyphenols in chickpea and pigeonpea. In Latin America it has been demonstrated that black seed coated varieties of Phasconlus are inferior in digestibility to the white seed coated varieties. Study should be carried out to ascertain what if any polyphenols are present in the seed coat of chickpea and pigeonpea, particularly those varieties with dark colored seed coats.

H.K. Jain: In my view protein should be screened as the amount per seed rather than as percent of seed weight, since a higher protein percent is obtained in shrivelled seeds. Also the heritability of protein per seed in wheat is three times higher when it is scored as the absolute amount per seed than that of protein expressed on percent basis.

J.H. Hulse: In the PAG guidelines to cereal breeders it is recommended in selecting for protein inheritability that breeding lines be scored on the basis of mg nitrogen per seed. Even where nitrogen as percent of dry matter appears to be a useful parameter, the condition of the seed, i.e., plump or shrivelled, should be described.

R. Jambunathan: In Table 6 of your paper you have given that the seed coat in chickpea constitutes 14.5% of total weight of the seed. We have some preliminary evidence from our laboratory which indicates that pigeonpea seed coat accounts for 15% (average) of the total weight. Since we lose the seed coat in the preparation of dhal, this constitutes a considerable loss in yield. I would like to pose the question whether we could do something in the way of breeding to minimize this loss?

J.H. Hulse: This would appear to be a problem both for the breeder and the food technologists. The technologists could develop more efficient methods of dehulling to ensure that the losses during milling are reduced to minimum. IDRC is supporting a project in Nigeria in which a successful method of dehulling cowpeas has been developed.

LITERATURE CITED

Acharya, B.N., S.P. Niyogi, and V.N. Patwardhan. 1942. The effect of parching on the biological value of the proteins of some cereals and pulses. Indian J. Med. Res., 30, 73-81.

Adolph, W.H., E.I. Shammas, and S.H. Halaby. 1955. The nutritive value of legume proteins and legume-wheat mixed proteins in Near East diets. J. Am. Diet. Assoc, 20: 31-34.

Argikar, G.P. 1970. Pulse crops of India. ICAR, New Delhi.

Arnon, I. 1972. Septematic treatment of the principal crops. Crop production in dry regions. 2, pp. 217-260. London, Leonard Hill.

Ashur, S.S., H.E. Clark, W.H. Moon, and J.L. Malzer. 1973. Nitrogen retention of adult human subjects who consumed wheat and rice supplemented with chickpea, sesame, milk or whey. The Am. J. of Clin. Nutr., 26: 1195-1201.

Aykroyd, W.R. and J. Doughty. 1964. Legumes in Human Nutrition. FAO, Rome (FAO Nutritional Study No.19).

Bannerjee, S. and R. Bannerjee. 1950. Studies on the biosynthesis of nicotinic acid - Part I, Indian J. Med. Res., 38(2): 153-160.

Bannerjee, S., K. Rohatgi, and S. Lahin. 1954. Pantothenic acid, folic acid, biotin and niacin contents of germinated pulses. Food Res. 19: 134.

Bannerjee, S., K. Rahotgi, M. Bannerjee, O. Chattopadhyay and H. Chattopadhyay. 1955. Pyridoxine, Inositol and vitamin K contents of germinated pulses. Food Res. 20: 545.

Bannerjee, S. 1960. Biological value and essential amino acid composition of the proteins and some pulses. Proceedings of symposium on proteins, CFTRI, Mysore, pp. 355-356.

Barja, I., P. Munoz, G. Solimano, E. Vallejos, O. Undurraga, M.A. Tagle. 1971. Formula de garbanzo (Cicer arietinum) en la alimentacion del lactante sano. Nutricion, Vol.XXI, No.4, 485-492.

Belavady, S. and S. Bannerjee. 1953. Studies on the effect of germination on the phosphorus values of some common Indian pulses. Food Res. 18: 223.

Bhagwat, K. and K.K.P. Narasinga Rao. 1942. Vitamin C content of dry bengal gram (C1cer arientinum). Indian J. Med. Res. 30(4): 505-5)].

Braham, J.E., L.G. Elias, and R. Bressani. 1965A. Factors affecting the nutritional quality of cottonseed meals. J. of Food Sci., 30: 531-537.

Butt, J.M., A. Hamid and F.H. Shah. 1965. Changes in vitamic C contents of germinating seeds. Black Bengal grams (Cicer arietinum) Part 1. Pakis. J. Scient. Res., 17(3-4): 164-168.

Chandra, S. and S.K. Arora. 1968. Protein ascorbic acid and mineral content of Cicer arietinum. Curr. Sci., 37: 237.

Chitre, R.G. and S.M. Vallury. 1956a. Studies on the protein value of cereals and pulses, Part 1. Indian J. Med. Res., 44: 555-563.

Chitre, R.G. and S.M. Vallury. 1956b. Studies on the protein value of cereals and pulses, Part II. Indian J. Med. Res., 44, 565-571.

Chattopadhyay, H. and S. Bannerjee. 1951. Studies on the choline content of some common Indian pulses and cereals both before and during the course of germination. J. Food Sci., 16: 230-232.

Chattopadhyay, H. and S. Bannerjee. 1952. Effect of germination on the total tocopherol content on pulses and cereals. J. Food Sci., 17: 402-403.

Chattopadhyay, H. and S. Bannerjee. 1953. Effect of germination on the biological value of proteins and the trypsin-inhibitor activity of some common Indian pulses. Indian J. Med. Res., 41: 185-189.

Daniel, L. and L.C. Norris. 1945. The riboflavin, niacin and thiamine content of dried leguminous seeds. J. Nutr. 30: 31-36.

Daniel, V.A., T.S. Subramanya Raj Urs, B.L.M. Desai, S. Venkat Rao, D. Rajalakshmi, M. Swaminathan and H.A.B. Parpia. 1967. Studies on low balanced foods suitable for feeding weaned infants in developing countries. The protein efficiency ratio of low cost balanced foods based on ragi or maize, groundnut, bengal gram, soya and sesame flours and fortified with limited amino acids". J. Nutr. & Diet. 4, 183-291.

Daniel, V.A., B.L.M. Desai, R.S. Subrahmanya Raj Urs, S. Venkat Rao, M. Swaminathan, and H.A.B. Parpia (with statistical analysis by D. Rajalakshmi). 1968. The supplementary value of bengal gram, red gram, soya bean as compared with skim milk powder to poor Indian diets based on ragi, kaffir corn and pearl millet. J. Nutr. Diet. 5(4):283-291.

Daniel, V.A., D. Narayanaswamy, B.L.M. Desai, Soma Kurien, M. Swaminathan, and H.A.B. Parpia (with statistical analysis of results by D. Rajalakshmi). 1970. Supplementary value of varying levels of red gram (Cajanus cajan) to poor diets on rice and ragi. J. Nutr. Diet., 7: 358-362.

Daniel, V.A., B.L.M. Desai, S. Venkat Rao, M. Swaminathan, and H.A.B. Parpia. 1970. The effect of supplementing with limiting amino acids on the nutritive value of the proteins of low cost balanced foods based on blends of cottonseed, peanut and chickpea flours and kaffir corn (Sorghum vulgare) or ragi (Eleusine coracana) or wheat. PI. Fds. Hum. Nutr., 2: 1-6.

De, H.N., and S.C. Barai. 1949. Study of the mechanism of biosynthesis of ascorbic acid during germination. Indian 0. of Med. Res., 37: 101-110.

De, H.N. and S.C. Datta. 1951. Studies on the mechanism of biosynthesis of nicotinic acid during germination of cereals and pulses. Indian J. Agri. Sc1., 31(4): 16.

De, H.N. and S.C. Datta. 1952. Studies on the mechanism of biosynthesis of nicotinic acid during germination of cereals and pulses. Indian J, Agri. Sci. 21: 375-394.

Eashwaran, P.P.,S. Gopinath, S. Jamala and R.P. Devadass. 1972. Evaluation of the protein quality of two selected vegetable protein mixtures using albino rats. J. Nutr. Diet. 9: 327-330.

Esh, G.C. and T.S. De. 1960. High and low protein bengal gram:nitrogen distribution and nutritional assessment. Proceedings of symposium on proteins, CFTRI, Mysore, pp. 357-362.

Food and Agricultural Organization of the United Nations. FAO Production Yearbook. 1972.

Food and Agricultural Organization of the United Nations. 1970. FAO "Amino Acid Content of Foods".

Gaitonde, M.K. and K. Sohonie. 1952. Occurrence of a trypsin inhibitor in field bean. J. Scient. Ind. Res., 11B: 339-341.

Goyco, J.A. and C.F. Asenjo. 1965. The lactation value, a new index of protein evaluation. J. Nutr. 85: 52-56,

Grande, F., J.T. Anderson and A. Keys. 1965. Effect of carbohydrates of leguminous seeds, wheat and potatoes on serum cholesterol concentration in man. J. Nutr. 86: 313-317.

Hallab, A.H., H.A. Khatchadourian and I.Jabr. 1974. The nutritive value and organoleptic properties of white Arabic bread supplemented with soybean and chickpea. Cereal Chem. 51(1): 106-112.

Hanafy, M.M., Y. Seddik and M.K. Aref. 1970. Formulation of a protein-rich vegetable mixture for prevention of protein-calorie malnutrition. J. of the Sci. of Food and Agr., 21(1): 8-18.

Hanumantha, K. Rao and N. Subramanian. 1970. Essential amino acid composition of commonly used Indian pulses by paper chromatography. J. of Food Sci. and Tech. 7: 31-34.

Hardy, R.W.F., R.D. Holsten, E.K. Jackson and Burns. 1968. The acetylene-ethylene assay for N2 fixation:laboratory and field evaluation. Plant Physiol., 43: 1185-1207.

H1rwe, S.N. and N.G. Magar. 1951. Effect of autoclaving. Curr. Sc1., 20: 40-41.

Holl, F.B. and T.A. LaRue. 1967. Genetics of legume plant hosts. J. Food Sci., 32: 1-17.

Hulse. J.H. and E.M. Laing. 1974. "Nutritive Value of Triticale Protein". Ottawa, international Development Research Centre.

Indian Agricultural Research Institute. 1971. "New Vistas in Pulse Production".

Kande, J. 1967. Valeur nutrionnelle de deux graines de legumineuses. Annls. Nutr. Aliment., 21: 45-67.

Kuppuswamy, S. and M. Srinivasan. 1958. Proteins in foods. Indian Council of Medical Research, 26: 35-56.

Kurien, P.P. and H.A.B. Parpia. 1968. Pulse milling in India-1 Processing and milling of tur, arhar (Cajanus cajan Linn). J. of Food Sci., 5: 203-207.

Kurlen, S., D. Narayanaswamy, V.A. Daniel, M. Swaminathan and H.A.B. Parpia. 1971. Supplementary value of pigeon pea (Cajanus cajan) and chickpea to poor diets based on kaffir corn and wheat. Nutrition Reports International, 4(4): 229-236.

Lal, B.M., V. Prakash and S.C. Verma. 1963. The distribution of nutrients 1n the seed parts of Bengal gram (Chick-pea) experientia 19:154. Annls of Biochem. and Exper. Med., 23.

Larue, T.A.G., ana W.G.W. Kurz. 1972. Estimation of nitrogenase in intact legumes. Can. J. Microbiol., 19: 304-305.

Liener, I.E. 1973. Toxic factors associated with legume proteins. J. Nutr. Diet., 10:303.

Mathur, K.S., P.N. Wahi, D.S. Gahlaut, R.D. Sharma, and S.K. Srivastava. 1961. Prevalence of coronary heart disease in general population at Agra. Indian J. Med. Res., 49: 605-611.

Mathur, K.S., S.S. Singhal and R.D. Sharma. 1964. Effect of Bengal gram on experimentally induced high levels of cholesterol in tissues and serum in albino rats. J. Nutr., 84: 201-204.

Narayanaswamy, D., T.R. Doraiswamy, V.A. Daniel, M. Swaminathan and H.A.B. Parpia. 1972. Effect of supplementing poor rice diet with low cost protein food, chick pea or skim milk powder on nitrogen retention and net protein utilization in children. Nutrition Reports International, 5(2): 171-181.

Ochse, J.J. "Vegetables of the Dutch East Indies". 1931. Martinus Nijhoff, The Hague.

Parpia, H.A.B. 1972. Utilization problems in food legumes. "Nutritional Improvement of Food Legumes by Breeding", PAG Symposium, Rome.

Patwardhan, V.N. 1961. "Nutritive Value of Cereal and Pulse Proteins". National Academy J. Sciences, National Research Council, Washington, D.C. Publication 843.

Patwardhan, V.N. 1962. Pulses and beans 1n human nutrition. Amer. J. of Clin. Nutr., 2: 12,

Phansalkar, S.V., M. Ramachandran and V.N. Patwardhan. 1957. Nutritive value of vegetable proteins. Part I, Indian J. Med. Res., 45: 610-621.

Ramakrishna, M., D.B. Wankhede and M.R. Raghavendra Rao. 1973. Incorporation of (U-14C) aspartate into lysine, threonine and other amino acids in Bengal gram (Cicer arietinum). Indian J. Biochem., 10(4): 285-286.

Rao, P.V., T.K. Ananthachar and H.S.R. Desikachar. 1964. Effect of certain chemicals & pressure on cookability of pulses. Indian J. Technol., 2.

Rao K.H. and N. Subramanian. 1970. Essential amino acid composition of commonly used Indian pulses by paper chromatography. J. of Food Sc1. and Tech., 7: 31-34.

Rao, N.N., T.N. Ramachandra Rao and M.S. Shanthamma. 1972. Development of predigested protein-rich food based on Indian oilseed meals and pulses II. J. of Food Sci. and Tech., 9.

Rao, M.N., K.S. Shurpalekar, E.E. Sundaravalli and T.R. Doralswamy. 1973. Flatus production 1n children fed legume diets. PAG Bull. 3(2): 53.

Shehata, N.A. and B.A. Fryer. 1970. Effect on protein quality of supplementing wheat flour with chickpea flour. Cer. Chem. 47(6).

Singh, H.D. and S. Bannerjee. 1955. Studies on the effect of germination on the availability of iron in some common Indian pulses. Indian J. Med. Res., 43: 497-501.

Singh, L. and S.K. Maheshwari and D. Sharma. 1971. Effect of date of planting and plant population on growth, yield, yield components and protein content of pigeon-pea (Cajanus cajan (L.) Millsp.). Indian J. Agri. Sci. 41(6): 535-538.

Singh, S., H.D. Singh and K.C. Sikka. 1968. Distribution of nutrients in the anatomical parts of common Indian pulses. Cer. Chem., 45: 12-19.

Sinha, S.K. 1973. Green revolution and break-through in food production in India. Indian J. of Agr. Econ., 28(2): 26-42.

Srikantia, S.G. 1973. Use of legumes and green leafy vegetables in the feeding of children: A review of experience. PAG Bull. 3(2): 30.

Srinivasa Rao P. 1969. Studies on the digestibility of carbohydrates in pulses. Indian J. Med. Res., 57, 2151-2157.

Swaminathan, M.S. and H.K. Jain.1972. Food legumes in Indian Agriculture. "Nutritional Improvement of Food Legumes by Breeding". PAG Symposium, Rome.

Tara, M.R., T.N. Rawal and M.V. Rama Rao. 1972. Effect of processing on the proteins of arhar dal. J. Nutr. Diet., 9: 208-212.

Tara, M.R. and M.V. Rama Rao. 1972. Changes in the essential amino acid content of arhar dhal (Cajanus cajan) on dehydration. J. of Food Sci. and Tech., 9.

Tasker, P.K., M. Narayanarao, M. Swaminathan, A.N. Sankaran, A.P. Jayaraj and V. Subrahmanyan. 1961. The supplementary value of low-cost protein food based on a blend of peanut, coconut, and chickpea (Cicer arietinum) flours to a maize-tapioca diet. Agr. Food Chem., 9(5): 413-416.

Tomar, G.S., L. Singh, D. Sharma and A.D. Deodhar. 1973. Phenotypic stability of yield and some seed characteristics in Bengal gram (Cicer arietinum L.) varieties. JNKVV Rs. J., 7(1): 35-39.

Urie, A. and J.H. Hulse. 1952. "The Science, Raw Materials and Hygiene of Baking". MacDonald & Evans Ltd.

Van Etten, C.H., W.F. Kwolek, J.E. Peters and A.S. Barclay. 1967. Plant seeds as protein sources for food or feed. Evaluation based on amino acid composition of 379 species. O. Agric. Food Chem. 15(6): 1077-1089.

Vankat Rao, $., R. Leela, M. Swaminathan and H.A.B. Parpia. 1964. The nutritive value of the proteins of leguminous seeds. J. Nutr. Diet. 1: 304-321.

Vijaraghavan, P.K. and P.R. Srinivasan. 1953. Essential amino acid composition of some common Indian pulses. J. of Nutr., 51: 261-271.

Williams, P.C. 1974. Errors 1n protein testing. Cer. Sci. Today, 19(7): 281-286.

Zimmerman, G., S. Weissmann and S. Yannai. 1967. The distribution of protein, lysine and methionine, and antitryptic activity in the cotyledons of some leguminous seeds. J. Food Sci., 32: 129-130.

GRAIN QUALITY IN
CAJANUS AND CICER

W. V. Royes and A. G. Fincham[1]

MEANS FOR ESTIMATING PROTEIN QUALITY

The role of legumes in the nutrition of humans and other monogastric animals is largely that of supplying protein. Thus grain quality in legumes may be ragarded as mainly a matter of protein quality and quantity. A widely used means of estimating protein content is that of estimating nitrogen by the Kjeldahl method and calculating the protein as 6.25 times the nitrogen. For efficiency 1n time, technique, total applicability and cost, it has no equal. However, the Information it gives is limited and may often defy correct interpretation.

The inadequacies of this method led to the determination of digestibilities and protein efficiency ratios and the formation of the concept of available nitrogen or that portion of the nitrogen that becomes tissue protein. Numerous species of experimental animals and methods of estimating the nitrogen available have been used. In general, time, cost, and technique complexity vary directly with the amount and quality of the information obtained.

Amino Acid Profile

The picture that has emerged is that whereas cereals tend to have protein in which lysine is the limiting amino add, legume protein is short of the sulphur bearing amino adds. Studies on the supplementation of legume protein with the limiting amino adds have shown that protein availability and thus effective protein quantity can be considerably improved by improvement in the amino add profile. There have been considerable advances in the technology of quantitative amino acid analysis in the last twelve years and breeding for improved amino acid profile is now feasible. There are, however, a number of constraints that must be considered.

BREEDING FOR AMINO ACID CONTENT

The demonstration that single gene substitution can result in marked increases 1n the content of limiting amino acids raises the question of the extent of our ability to manipulate the amino acid content of food crops (Mertz, Bates, and Nelson 1964; Munck 1972; Nelson, Mertz, and Bates 1965). It has been convincingly argued by Nelson (1973) that marked changes in the over-all amino acid composition of a seed arise from a shift 1n the proportion of the normally synthesized proteins without changes in the primary amino add sequences of these proteins. Such shifts can be genetically manipulated in seeds where large quantities of storage protein are synthesized. Amino acid composition may also be altered by changing the relative proportion of tissue which contain protein populations that are significantly different 1n their amino acid composition.

PROBLEMS

Consideration of the constraints which exist within the system has led us to formulate a plan for practical problem solving. For legumes the first problem is analytical. The relevant amino acids are nearly always methionine and cystine. They are both present at low concentration and are both prone to

---

[1] Ministry of Agriculture, Kingston, Jamaica, West Indies

oxidation during hydrolysis. Solutions exist but they take their toll in time, cost, sample size and number. We are actively seeking the most efficient solution for our situation. The second limiting amino acid, namely tryptophan, is destroyed by acid hydrolysis and requires separate analysis causing an added burden.

The second problem is that of the nature and extent of environmental variation. Luxury consumption of nitrogen and other inorganic nutrients in plants is well-known. The effect on the amino acid profiles of the protein appears to have escaped attention so far. Our unsuccessful attempts to grow *Cicer arietinum* confirmed previous reports of its unsuitability for the Caribbean. Flowering has just been recorded at 1,200 meters in Jamaica. Our extended experiments on *Cajanus* have confirmed our previous conclusions that gross variation in nitrogen and sulphur nutrition does not give a significant increase in the variation observed in amino acid profiles of a highly inbred line, CH 11, 33, 34 which is the same as Code I or UQ50.

Our work on the estimation of heritabilities for the amount of various amino acids in the seed protein of *Cajanus* is as yet incomplete. So far we have found that some amino acids have high, about 0.7, and some have negligible, 0.01 heritabilities. We view this work as a prerequisite for the consideration of genetic selection for amino acid content.

A further problem is the nature and extent of the variation in amino acid profiles in the various solubility fractions of the seed protein and the various parts of the seed.

We envisage that when we have obtained suitable solutions to these preliminary problems it may be possible to interpret the analyses which are currently in progress on the range of material available to us for *Cajanus*. The result of this survey may then be used in conjunction with the heritability estimates to project feasibilities for breeding programs.

OTHER CONSIDERATIONS

The over-all aim is the production of a diet that supplies sufficient quantities of all the essential amino acids at minimum cost. The method considered here is one of many possible solutions that may be tried. It has the aim common to all breeding research of requiring, in theory a single research input and a single change, in theory, in farm practice: namely a new variety, and no increased costs for extra material.

It is interesting to note that the ordinary people of the Caribbean, *very* few of whom are indigenous, have found another solution. To their diets of root crops, cereals, legumes and scarce indigenous animal protein they have added animal protein imports. These are the portions of the carcass which are least sought after, and thus cheap, because they contain a high proportion of structural as opposed to muscle protein.

It is possible that competition for scarce resources may prevent the mounting of breeding programs aimed at procuring higher concentrations of amino acids so cheaply available in an acceptable alternative form in the Caribbean.

DISCUSSION

J.S. Kanwar:	Could you elaborate on the result obtained by the nitrogen and sulphur application on the amino acid composition of the grain?
W.V. Royes:	Using Code I (CH 11, 33, 34) which has been inbred for ten generations, there was no significant increase in the variation of amino acid profile between four treatments which were the application of one kilogram of ammonium sulphate, sodium sulphate, urea and no fertilizer per plant.
O. Sharma:	Have you studied the application of zinc sulphate as this was found to be useful in peas?
W.V. Royes:	No, we have not studied its effect.

LITERATURE CITED

Mertz, E.T., L.S. Bates and O.E. Nelson. 1964. Mutant gene that changes protein composition and increases lysine content of maize endosperm. Science 145:279-280.

Munck, L. 1972. Barley seed proteins. In Proceeding of the American Chemical Soc. Symp. on Seed Proteins, Los Angeles, March 19, 1971 (In press).

Nelson, O.E., E.T. Mertz and L.S. Bates. 1965. Second mutant gene affecting the amino acid pattern of maize endosperm proteins. Science 150:1469-1470.

Nelson, O.E. 1973. In Genes, Enzymes and Populations, A.M. Sub (Ed) Plenum Press, New York.

EVALUATION OF NUTRITIONAL VALUE, COOKING QUALITY AND CONSUMER PREFERENCES OF GRAIN LEGUMES

P. Pushpamma[1]

INTRODUCTION

It is a well-known fact that Indian diet is primarily vegetarian with heavy dependence on cereals and pulses. With increase in price of animal products (milk, meat, eggs), there 1s rapid shift from nonvegetarianism to vegetarianism. The protein requirement of the Indian population, Including vulnerable segments, has to be met invariably through legumes. Very fortunately, the cereal which in one or other form is the main dish and the pulse which is usually found in the accompanying dish of the common Indian diet contains proteins which complement each other in their amino acid pattern. Though the quality of the protein depends mainly on the essential amino acid composition, the actual utilization in the living organism depends on the availability of amino acids. Since legumes are used in the diet primarily for their protein content, 1t 1s essential to examine the factors affecting the protein quality which are as follows:

(1) Amino acid content and their availability

(2) Amino add imbalances

(3) Interference of antinutritional factors usually found in legumes

(4) The accompanying constituents of protein in the seed which may interfere in the digestion and absorption

AMINO ACID AVAILABILITY

The availability of amino adds, which is otherwise called digestibility of proteins, is reported to be very low in vegetable proteins compared to animal proteins. It has been suggested low digestibility of cereal and legume proteins is due to crude fiber concentration. However, the contribution of crude fiber to the low digestibility of legume protein is doubtful since most of these contain crude fiber below 8%. Another opinion expressed by several writers (Bressani et al. 1963; Patwardhan 1962; NAS–NRC 1963) is that the low digestibility is due to lack of complete hydrolysis of protein. However, the knowledge available for the cause of low digestibility and amino add availability of legume proteins is scanty. Two reasons recognized are (1) the factor inherent in the nature of seed and seed protein, and (2) the unavoidable decreases resulting from processing. Less well explained are the reasons for difference in the availability of amino acids of native vegetable proteins. A great variation was reported in the digestibility of pulses. Table 1 shows the values for pigeonpea and the chickpea.

Solubility as a Factor in Digestibility

It has been suggested that the low solu-

---

[1] College of Home Science, A.P. Agricultural University, Hyderabad, India

bility of cereal protein reduces their susceptibility to enzymatic attack accounting for the low digestibility of some proteins. Bressani and Elias (1968) in their review on vegetable protein suggested the possibility of a certain insoluble fraction in plant protein which may be resistant to the enzymes in the digestive tract. The probability of an important role of cell structure and location of the protein in the seed in determining the digestibility and amino acid pattern of seed proteins is also stressed by the above authors. However, studies conducted in the nutrition department of Home Science College on the protein fraction of pigeonpea and chickpea (Table 2)indicates that about 97% to 98% of proteins are in soluble fraction compared to 20%-25% soluble protein fraction found in cereals. If poor digestibility of cereal proteins can be attributed to the large fraction of insoluble proteins, the pulse protein should rate higher than cereal protein in digestibility since they have a relatively high proportion of soluble protein fraction.

Cereal-Pulse Digestibility

This prediction seems to be far from the truth since digestibility of pulses or legumes is reported to be not better than cereal, in fact even poorer than cereal protein. Much work has been done on cereal protein fractions, their amino acid composition and the influence of genetic engineering on the alteration of these fractions. However, our knowledge about specific characters of pulse proteins and their reactions with the accompanying constituents in the seed, which *are* essential in understanding the difference in digestibility, 1s very limited.

Seed Location of Protein

Altschul et al. (1961) did pioneering work on seed proteins and reported the need for deriving the classification of seed protein factors based on their location in the seed and function rather than solubility. The major portion of seed protein will be usually located in the aleurola. The recent electron microscope studies, however,revealed the presence of osmophillic bodies, which are called protein bodies, in parenchyma cells of groundnut cotyledons. Table 3 shows the subcellular fractions of groundnut cotyledons.

There is now evidence that these osmophillic bodies are proteinacious and a significant portion of protein of a seed is present in these bodies amounting to about 50%-75% of total available proteins. One of the expectations is that the difference between the seed of high and low protein content may be due to the population of protein bodies and the relative proportion of these bodies per cell. Some studies on proteins of particulates, with emphasis on separation of various types and in the properties of the fractions, will throw more light on the understanding of seed proteins and the factors responsible for differences in the nature and quality of legumes and seed proteins.

Other Factors in Amino Acid Availability

The other factor which Influences the availability of amino acids from legume protein is the presence of antinutritional factors which are usually found in most of the legumes. It was shown in many studies (Bressani and Elias 1962; Altschul, et al. 1961) that not only soybean but most of the other legumes contain some kind of antinutritional factors. However, since these factors are mostly water soluble or heat labile, they will usually be destroyed in the conventional method of cooking pulses.

INFLUENCE OF COOKING

Since most of these legumes are not consumed in a native state but are subjected to some degree of heat treatment, it is essential to consider the processing or cooking commonly used in order to determine the nutritive value. Apparently excessive heat reduces the nutritive value of the protein due to the destruction of some essential amino acids like lysine and sulphur containing amino acids. The nutritive value of a protein may be affected by such factors as temperature, duration of heating and moisture in a manner which varies according to protein, carbohydrates and other components in the food. Heat is most damaging to plant protein when it is applied under conditions of low

Table 1. Digestibility Co-efficient, Biological Value, PER of Redgram Dhal and Bengalgram Dhal

Legumes	Method of preparation	Biological value	Digestibility co-efficient	Protein efficiency ratio
Pigeonpea	---	46-74	59-90	-VE*to 1.7
Pigeonpea	Cooked or autoclaved	—	—	1.3 to 1.6
Chickpea	...	52-78	76-92	0.7 to 2.0
Chickpea	Cooked or autoclaved	—	—	1.3 to 2.1

Source: PATWARDHAN - (1962)

Table 2. Percentage Distribution of Protein in Different Fractions of Local and Improved Strains of Pulses (Conventional Method)

Variety	Crude protein GM%	True protein GM%	Total soluble proteins	Prolamine	Glutel - line	Total proteins extracted
Pigeonpea						
S5	22.36	20.75	90.43	1.09	6.78	98.30
T.21	22.52	20.74	90.65	1.71	5.28	97.64
Local	20.47	18.43	92.92	0.72	4.30	97.94
Chickpea						
Chaffa	20.37	18.27	89.74	1.23	6.40	97.37
	18.87	17.82	94.88		3.70	98.58

Source: Rafathunnissa and Umakumari (1972)

Table 3. Yield and Composition of Sub-cellular Fractions of the Groundnut Cotyledon Obtained in Nonaqueous Media

Class of particle	Yield in gm/500 gms	N %	P %	Moisture %
Protein bodies	18.6	13.3	0.32	9.0
Aleurone grains	30.7	11.4	1.87	9.7
Starch grains	8.6	1.5	0.37	7.9
Reticulum	3.5	6.7	0.71	8.0
Cell wall	3.5	2.7	0.09	12.9
Vascular tissue	15.7	7.7	0.78	10.4
Fat free cotyledons	265	9.0	0.90	10.0

Source: Dieckert et al. (1962)

moisture in the presence of carbohydrate. It is essential to consider cooking or processing conditions in determining amino acid availability.

At present, available information indicates that moderate heat treatment improves the nutritive value of most legumes by inactivation of deleterious heat labile compounds. Some preliminary work carried out in the College of Home Science (Table 4) indicates the effect of different methods of cooking on protein quality of pigeonpea, chickpea and groundnut. It can be also observed that excessive heat causes a decrease in their nutritive value.

Table 4. Results of Biological Experiments With Raw and Cooked Chickpea, Pigeonpea and Groundnut

Particulars	P.E.R. value	Average total weight gain
Raw chickpea	1.0413	37.25
Chickpea, baked	1.1760	45.82
Chickpea, deep-fried	0.0016	0.75
Groundnut, raw	0.8248	25.83
Roasted groundnut	1.0436	38.99
Fried groundnut	0.7817	31.66
Raw pigeonpea	1.0	26.7
Boiled pigeonpea dhal	0.76	20.6
Pigeonpea dhal (pressure cooked)	1.02	27.0
Roasted pigeonpea dhal	1.34	39.6

Source: Sudershan and Pushpamma (1972)

Conclusions on Effects of Cooking

The beneficial effect of heat treatment on pigeonpea, chickpea and groundnut, as in the case of soybean and cotton seed proteins, can be seen from the data in Table 4. It is evident that a controlled heat treatment improves nutritive value significantly due to destruction or inactivation of toxic substances which are sensitive to heat. At the same time, the danger of overheating resulting in a rapid decrease in the protein quality is observed. The critical role of processing or cooking in improving the quality of legume proteins and the danger of damage from overdoing or incomplete removal of toxic compounds is one of the important factors to be considered in conducting biological experiments for assessing the nutritive value of legume proteins. By overlooking this factor there is a danger of underestimating the nutritive value of legume proteins if conducted only on raw foods.

The primary objective of developing the quality and quantity of protein in legumes is mainly to augment the protein content of the human diets where these are consumed only after cooking in one form or other. In the case of cereals, considering the quality after cooking may not be essential as the situation is less complicated and changes in the availability of the amino acids are not that significant.

DIETARY CONSIDERATIONS

Neither cereals nor legumes alone will be sole contributors of protein in any mixed diet. It is more important to evaluate the supplementary value of these legumes to the cereal which is usually consumed in the normal dietary pattern. In this regard, the results of an experiment on the supplementary value of different legumes to sorghum which is in progress may be interesting. The experiment tests whether all legumes will have the same effect or if there is any particular legume which is better for supplementing sorghum based diets. This experiment is in progress in the Nutrition Department of Home Science College. The available data at the time of symposium will be presented.

CONSUMER PREFERENCE

Though it is very gratifying to note the concern of agriculturist and nutritionist in Improving the quality of legumes and other agricultural products, market value *of* these grains and legumes will not be based upon the protein quality or quantity. Some improved varieties in the past have failed in the market in spite of their high nutritive value as they could not meet other requirements of the consumer.

Consumer preference for legumes, especially for pigeonpea and chickpea, depends upon several factors other than nutritional considerations. The nutritional consideration for food is influenced by the level of education of consumer, nutritional awareness regarding the physiological needs of the body and also dietary knowledge. In most of the developing countries where the major portion of the consumers are illiterate and Ignorant about the nutritional needs, preference for pulses 1s based on (a) storage capacity, (b) yield of dhal after milling from the whole grain, (c) cooking time, (d) texture and consistency of cooked product, (e) color, (f) taste and flavor and (g) cost.

Yield

Legumes are used both as whole seed and in the split form after removing the seed coat. This split pulse is popularly known as dhal in India. Pigeonpea is rarely used whole in India whereas chickpea is used as whole seed, dhal and also as flour. As a consequence of food habits, much plgeonpea as well as chickpea are being milled in India. The preference for the yield capacity becomes Inevitable for the consumer, producer and retailer. The yield of dhal mainly depends upon the percentage of losses in the process of milling, which in turn depends upon the size of seed, thickness of seed coat as well as the grade of milling. The bigger seed with a thinner seed coat, and a lower milling grade will yield more dhal. Not only for higher yield but also for easier cooking, a seed with thinner coat is preferred by the consumer. It is also preferred for its better digestibility due to lower percentage of crude fiber compared to a seed with thick coat.

Storage Capacity

The producer, retailer as well as the consumer prefer a grain with better storage capacity. They know by experience which grain keeps for a longer time; when they want to store for a long period they go for such a quality. The storage capacity of a grain is Influenced by the Inherent biological qualities of the grain. It is felt that a grain with thick seed coat can be stored for a longer period without being attacked by Insects than seed with a thinner seed coat. It is, therefore, a challenge to agriculturists to develop a grain with better keeping quality but with a thin seed coat.

Cooking Time

Cooking time is Important in consumer preference for dhals because of time and fuel. Legumes take considerably longer for cooking than any other vegetable products. This is especially true with whole pulses. There also is a difference in cooking time required for different legumes. Cooking time depends to some extent upon the thickness of the seed coat and its composition. In addition to seed coat, the composition of the seed itself has some influence on cooking time. This is evidenced by observations on the different cooking times required for cooking different dhals and legumes.

Relation of Water Absorption to Cooking Time

Water absorption and cooking time required for some local and improved varieties of chickpea and pigeonpea in the experiment carrled out in the College of Home Science are presented in Table 5. Though there is no difference in the cooking time of local and improved varieties, the difference between chickpea and plgeonpea is quite evident.

Those grains which absorb water quickly will take less time for cooking. In case of dhals, it is water absorbing capacity that makes the difference in cooking time. This capacity of dhal may be dependent on cell wall structure, nature of the constituents 1n the seeds and the compactness of the cells in the seed, etc. Soaking may reduce the cooking time. Unless the soaked water is used for cooking, which is generally not the practice 1n most of the families, there will be nutrient losses, especially minerals and water soluble vitamins. Cooking time outrates all other preferences in the case of legumes. It would not be rash to state that one of the drawbacks in popularizing the soybean is the long cooking time it takes.

Texture and Consistency

Consumer preference for any particular food is Influenced to a large extent by the methods of cooking and the form 1n which it is consumed. For example, plgeonpea is used mostly as dhal in the form of a thick gravy (sambar) along with rotis, chapatis or rice. A variety which gives a thick and uniform consistency along with short cooking time is preferred by any consumer. The reason lentils cannot replace plgeonpea is that they cannot give such a texture after being cooked.

Table 5. Cooking Quality of Local and Improved Strains of Pulses

Sl. No.	Variety	Raw		Soaked			Soaked and Cooked				Cooked without soaking			
		Wt. gm.	Vol. ml.	Wt. gm.	Vol. ml.	H_2O Absorbed ml.	Time mts.	Wt. gm.	Vol. ml.	H_2O Absorbed ml.	Time mts.	Wt. gm.	Vol. ml.	H_2O Absorbed ml.
I.	<u>Pigeonpea</u>													
	S5	20	25	41	69	30	25	45	70	165	46	46	89	320
	T.21	20	25	40	67	30	25	44	70	160	46	48	86	295
	Local	20	25	41	67	28	30	44	71	180	49	48	88	345
II.	<u>Chickpea</u>													
	Chaffa	20	25	45	65	29	25	46	70	110	59	36	55	387
	Local	20	26	46	65	30	25	46	71	108	60	40	60	400

Source: Rafathunnisa & Umakumari - (1972)

In the case of chickpea such a quality does not play an Important role as it is used mostly whole or as flour.

Color

Color plays an Important role in consumer preference, especially at a higher income level. As a consequence of this many dhals, especially pigeonpea, are synthetically colored. This confirms the consumer preference in color. A dhal with deep color is much preferred over a dull color.

Taste and Flavor

These dhals have natural flavors. Dhal which gives good flavor after it is cooked is preferred by the consumer. This is also one of the important factors to be considered.

Cost

Whereas the color, taste and flavor play important roles in consumer preference when the consumer is in a position to spend a little more, cost plays a very important role in the case of the consumer who can barely afford that commodity. The production of legumes on a large scale must be increased to make them available to the needy low income group who constitute the majority of our population. When they are not in position to buy pulses, the question of preference does not arise. If they buy at all, they buy a dhal which costs the least.

DISCUSSION

J.H. Hulse:	All plant breeding programs in the international centers place a primary emphasis on yield improvement. If starch production is the main objective, one should grow cassava, not legumes. Forecasts of protein or any other nutritional requirement which are based on estimates of food consumption are to be treated with extreme caution. Averages based upon estimates of production divided by estimates of population are notoriously imprecise and large variations from the mean are to be found within populations among families and even within families. I agree that many unwise and ill Informed statements may have been made concerning the protein gap and some of the solutions proposed are unrealistic. This, however, should not be taken as an exercise to swing the pendulum to the other extreme and to state that only calories are important.
A.K. Auckland:	I agree with Dr. Hulse. We should try to maintain the present level of protein and at the same time try to improve the yield.
P. Pushpamma:	The survey analyses do not take into consideration the variability in protein consumption, digestibility of protein, etc.
L.R. House:	In maize, increase in protein concentration results primarily from an increase in the prolamine fraction. This fraction is very low in lysine; also, increase in protein is negatively correlated with yield. In the early days of corn improvement little effort was made to Increase protein content or change composition. Interest in the improvement of protein quality was stimulated with the finding that the single recessive gene, opaque-2, in corn resulted in a change in concentration of protein fractions resulting in higher lysine concentration. This single factor inheritance is useful to breeders in backcrossing elite agronomic lines to the high lysine source. A search for simple recessive genes for quality Improvement in legumes may be worthwhile. Recently at Purdue, a high lysine line (P721) was obtained by treating seed with a chemical mutagen.

J.S. Kanwar: I would like to pose the following questions and invite comments from this distinguished audience. How much protein should we aim for in legumes? For example, in Australia, the average protein reported is 26% with 30% as the highest value while in India the range of protein content in chickpea we obtain is reported to range between 18 - 24%. I also would like to know how much effort we should put into the analysis of deficient amino acids and attempts to improve this content in protein.

J.H. Hulse: I stated earlier that research to modify the amino acid content of legumes should be given a secondary priority. Grow legumes as a protein crop and calories can be obtained from cereals. However, the cereal and legume balance should ensure an adequate protein quality. Express the result as protein/acre/unit time. Although less emphasis should be placed on the screening for sulphur amino acids and tryptophan, all possibilities should be tried dut, such as whether these amino acids are genetically controlled or not and the influence of environment on the content of these amino acids. Very little information is available in this regard and ICRISAT will need to start from scratch. At some point ICRISAT should explore the range of genetic variability in legumes as it affects protein content and amino add composition since ICRISAT has the responsibility to serve the whole world on chickpea and pigeonpea.

H.K. Jain: If we stress the result on protein/acre of land, yield takes care of itself.

K.O. Rachie: I would like to add that the result should be expressed as protein/acre/day.

H. Doggett: Cooking quality should also be Included in the program.

LITERATURE CITED

Altschul, A.M. et al. 1961. Intracellular distribution of seed proteins. Arch. Biochem, Biophys. 95:402-404.

Bressani, R. and L.G. Elias. 1962. Processed vegetable protein mixtures for human consumption in developing countries. J. Food Sci. 31:626-631.

Bressani, R., L.G. Ellas and A.T. Valiente. 1963. Effects of cooking and of amino add supplementation on the nutritive value of black beans (Phaseolus vulgaris, L) Brit. J. Nutr. 17:69-78.

Dleckert, J.W., J.E. Snowden, Jr., A.T. Moore, D.C. Heinzelman and A.N. Altschul. 1962. Composition of some subcellular fractions from seeds of Arachis hypogaea. J. Food Sd. 27:321-325.

National Academy of Sciences - National Research Council. 1963. Evaluation of protein quality. Washington, D.C. 1963. NRC Publication 1100.

Patwardhan, V.N. 1962. Pulses and beans in human nutrition. Am. J. CIin. Nutr. 11:12-30.

Rafathunnissa, O. and K. Umakumarl. 1972. A comparative study on protein quantity and quality of local and improved strains of pulses, (unpublished).

Sudershan. M. and P. Pushpamma. 1972. The effect of cooking on the protein quality of jowar, bengalgram and groundnut, (unpublished).

CHICKPEA AND PIGEONPEA: SOME NUTRITIONAL ASPECTS

S. G. Srikantia[1]

PRODUCTION

Legumes constitute an article of food all over the world, but their use is particularly widespread in the tropics and the subtropics, constituting as they do important sources of protein in habitual diets. Of about eighteen legumes extensively cultivated today, the two most commonly used in India are the chickpea (Cicer arietinum) and the pigeonpea (Cajanus cajan). The production and per capita availability of these two legumes in India during the last three years are indicated below:

Year	Area: Hectares: 10°		Production: Tons: 10^6		Availability q/per capita/day	
	Chickpea	Pigeonpea	Chickpea	Pigeonpea	Chickpea	Pigeonpea
1970-71	7.84	2.66	5.20	1.88	22.7	8.2
1971-72	7.91	2.35	5.08	1.68	22.6	7.5
1972-73	6.94	2.33	4.47	1.75	20.4	7.9

Source: Agricultural Situation in India

There are, however, wide variations in the use of these legumes from one region to another; income levels and urban and rural conditions modify the consumption.

NUTRITIONAL QUALITY

There are considerable data in the literature relating to the chemical composition and nutritive value of the chickpea and pigeonpea. The significance of some recent data obtained in our country is briefly discussed here.

Attempts to improve the nutritional quality of these legumes have mainly centered around their protein content and amino acid makeup. Under Indian conditions, chickpea and pigeonpea supplement cereal based diets.

Limiting Amino Acids

Since lysine is the limiting amino acid in most cereals, this nutrient has come in for special consideration. Notwithstanding the fact that cereals are low in lysine, examination of the amino acid content and profile of diets of the poor sections of the population in India shows that the limiting amino acid in these diets is not lysine, but methionine.

One needs to take a close look at the all too common emphasis on the so-called limiting essential amino acid concept of a single food before attempts are concentrated on increasing the lysine content of chickpea and pigeonpea. One of the major thrusts in the improvement of cereal protein quality is in the area of increasing both the protein content of the cereal and the lysine content of its protein. There would perhaps be not too much to be gained by

---

National Institute of Nutrition, Hyderabad, India trying to increase the lysine content of all foods commonly used, particularly in situations like our own.

There are adequate data to show that when existing cereal based diets are consumed in amounts sufficient to meet the calorie needs, the protein and amino acids needs are also met. There are also data which indicate that in situations wherein the calorie needs are not met because of inadequate food intake, the mere improvement in the quality of protein ingested is not associated with substantial benefits. Both chickpea and pigeonpea have relatively low amounts of methionine and attempts to improve the content of this amino acid are worth considering.

Examination of over 1300 varieties of chickpea in India for their methionine content has shown a range of values from 1.0 mg to 3.5 mg/g of the pulse. Since yield potential must be considered a crucial factor in breeding, it is necessary to select from among high yielders varieties that have the highest methionine concentrations.

Often the protein quality is judged by a look at its amino acid makeup. While this is undoubtedly a quick method of screening for biological value, it is necessary to remember that often protein quality, as measured by standard biological procedures like growth, PER and NPU, is at variance with that expected from the amino acid makeup. It becomes essential that the most promising varieties be evaluated by biological testing.

Variation in Protein and Amino Acids

Another aspect which plant breeders are fully aware of is the wide variation that can occur in protein content and sometimes in amino acid makeup of the same variety grown in different locations. The protein content of several varieties of chickpea grown in different areas in India has shown a variation of sometimes over 70%, indicating the extent to which environmental and scil conditions Influence nutrient composition.

Such an observation has also been made with respect to lysine and methionine content of pigeonpea. The mean levels of lysine in pigeonpea grown 1n New Delhi have been found to be about 15% higher and of methionine 25% higher than pigeonpeas grown in Akola and Rajendranagar. It must be pointed out, however, that the varieties grown in the three areas were not all Identical. These data, however, point out that the full expression of genetic potential does not always occur.

Other Nutrients

In discussing the nutritive value of legumes from the point of view of protein, it should not be forgotten that they provide several other essential nutrients—carbohydrates, trace elements and vitamins. It 1s necessary to ensure that newer varieties of these pulses bred for higher yields and better amino acid profiles do not suffer a reduction in the concentration of these essential micronutrients.

Trypsin Inhibitors

Of special interest from the point of view of nutritive value is the reported presence of trypsin inhibitors in the pigeonpea. Since pigeonpea is never eaten raw, but is always subjected to some form or other of heat treatment which inactivates such inhibitors, Its presence appears to be of little consequence. Special efforts to breed varieties with low or no trypsin Inhibitors, therefore, may not be considered as having a high priority.

Flatus Formation

Of some concern, however, is the flatus producing property of both chickpea and pigeonpea. The inclusion of either of these pulses in diets in amounts which provide 20%-25% of calories can lead to a four to ten fold rise in gas formation.in the Intestines. Many pulses are known to lead to flatulence, but there are wide variations in their potency. From the point of view of acceptability particularly for older infants and young children, both the chickpea and the pigeonpea suffer from this drawback, since in many communities flatulence is associated with low digestibility.

The mechanism of increased flatus formation is not as yet known. Studies in man have shown that much of the gas formed is carbon dioxide and hydrogen, and that heated legumes produce less gas than do unheated legumes, suggesting that there may be a heat labile flatulence factor. Recent studies on the carbohydrate makeup of chickpea, pigeonpea, green gram and black gram, and the in vitro rate of amylosis have shown that the rate of amylosis is lowest in chickpea, followed by pigeonpea, green gram and black gram.

It has been suggested that these differences may be related to differences in the capacity of these four pulses to produce gas. There is thus an immediate need to investigate into the factor or factors which leads to flatulence and if possible, eliminate it. Such a procedure will go a long way in improving the acceptance of these pulses in the diets of young children.

Summary

The nutritive value of the chickpea and pigeonpea has been demonstrated both in normal subjects and in those who are malnourished. In fact, several clinical investigations have shown that even severely ill young children can accept and tolerate relatively large amounts of chickpea. However, legumes today are used primarily as supplementary sources of protein to balance protein quality of the staple. Legumes in general take a long time to cook. Though this may not be a crucial factor in their acceptance, it is desirable to develop varieties that reduce cooking time. High priority obviously has to be given to increasing production and availability of legumes. Attempts at improving their quality must be considered in the context of the total diet of population groups who consume fair amounts of legumes.

LITERATURE CITED

Kapoor, V.P. et al. 1971. Chemical analyses of seeds from 40 leguminous species., Sci. Cul. 37:349.

Kaul, A.K. and G. Gassi. 1971. Survey for a high methionine variety in the world collection of chickpea. Curr. Sci. 40:652.

Ramasastri, B.V. and P. Srinivasa Rao. 1969. Some studies on the nutritive value of rice varieties and pulses. Proc. Nutr. Soc. India. 7:13.

Srikantia, S.G. and C. Gopaian. 1960. Clinical trials with vegetable protein foods in kwashiorkor. Indian J. Med. Res. 48:637.

Steggarda, F.R. and J.F. Dimmick. 1966. Effects of bean diets on concentration of carbondioxide in flatus. Am. J. Clin. Nutr. 19:120.

Venkatachalam, P.S., S.G. Srikantia, Geeta Mehta and C. Gopaian. 1956. Treatment of nutritional oedema syndrome (kwashiorkor) with vegetable protein diets. Indian J. Med. Res. 44:539.

SESSION REVIEW

A. R. Sheldrake[1]

INTRODUCTION

For at least fifteen years we have grown accustomed to hearing that the major nutritional problem facing the world 1s a shortage of protein, and the so-called protein gap has become a common cliche in politicians' speeches, newspapers and in general discussions. However, within the last year or so an increasing number of criticisms have been raised against the protein gap philosophy; and the utility and potential effectiveness of many of the research and action programs Initiated under its sway have been searchingly questioned. For example, it has recently been argued 1n the columns of Nature that the amino acid supplementation of foods has no effect on the nutritional status of those consuming the foods. Articles with titles like 'The Great Protein Fiasco' have appeared in other scientific journals. Such criticisms have even been reported quite extensively 1n the more serious newspapers. The primary importance of the protein gap which for years has been accepted as an unquestioned truth has now become a matter of considerable controversy.

In the light of this controversy, Dr. Ryan, Dr. Yadav and I undertook a survey of all the relevant literature and information we could obtain on the nutritional situation in the semiarid tropics, since this is clearly of interest and importance to the work of ICRISAT. We have produced two papers entitled "Human Nutritional Needs" and "Crop Breeding Objectives in the Semiarid Tropics", copies of which we can supply to anyone who is interested.

IMPORTANCE OF CALORIE DEFICIENCIES

In summary, what we found reinforced and confirmed the sort of conclusions that have recently been put forward in some of the controversial publications I have alluded to. Although in the semiarid tropics in the lower income groups there is a deficit of protein in the diet, the deficit of calories is far greater. And as one moves up the income scale, the maximum recommended protein requirements are much sooner reached than the minimum calorie requirements. In short, people are simply not getting enough food. In this situation simply increasing the amount of protein in the diet, or increasing the percentage of selected amino acids, is unlikely to have a significant beneficial effect because the protein and amino adds cannot be used effectively if calories are deficient–they tend to be burnt up as fuel.

Real protein deficiencies–where diets contain sufficient calories but insufficient protein–do occur to some extent in the humid tropics when starchy roots and tubers form the basis of the diet, but seem to be very far from common in the semlarld tropics. Of course protein is necessary in the diet, but so are calories, and the protein gap philosophy has led to a distorted and one-sided view of the problem. In this connection 1t is interesting to note that the Protein Advisory Group of the U.N. has recently changed its name to the Protein-Calorie Advisory Group.

Importance of Starch

In the legumes the starch, which makes up the majority of the pulse grains, has been more or less completely ignored. For example, in the Protein Advisory Group Publication "Nutritional Improvement of Food Legumes by Breeding" (1972) 1n over 320 pages, less than one is devoted to starch. It may be argued that legumes are primarily a protein crop and that we should concentrate on the protein 1n the legumes; the starch will come from the cereals. But in the cereal field we find that the nutritional emphasis is once again almost entirely on protein and amino acids such as lysine. Here too starch has been

---

[1] International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, India

more or less completely ignored. This is a natural consequence of thinking that the major nutritional problem is not one of calorie supply but primarily of protein as a limiting factor. But it seems that we must now change our basic assumptions.

REORIENTATION OF NUTRITIONAL RESEARCH

In much of the "quality" work on proteins and amino acids, emphasis has been placed on percentage levels, and aims of percentage increases 1n protein and selected amino acid levels have been much discussed. The attempt to increase percentages may stem partly from an assumption that people eat a fixed quantity of food and that to increase their Intake of a given nutrient that percentage of the nutrient within a plate of food must be increased. However, for the undernourished with whom we are concerned, this is not the case. If their effective income rises, they eat more food. For example, in the lower income brackets in India a doubling of Income per capita is associated with an approximate doubling of consumption per capita of chickpeas.

"Quality" may be more or less synonymous with amino acid composition for a number of scientists. However, as Dr. Pushpamma has stressed, this is not what it means in the market when prices are determined by consumer preferences for things like larger seed size, cooking quality and seed color. Fortunately we have an economics team at ICRISAT and Dr. M. von Oppen of our economics department is Investigating these preferences by means of market surveys, etc. In breeding new varieties we cannot afford to ignore these factors since if we breed a variety with, for example, a 25% higher yield but with a 30% lower market price, the farmers will make more profit by growing higher priced but lower yielding varieties and will therefore be unlikely to adopt the new variety. Dr. von Oppen has already found that market prices of different types of pigeonpea needs can vary by at least 25%.

CONCLUSIONS

It seems that our best possible strategy is to breed for higher yields of economically acceptable varieties of both cereals and pulses and not to worry about attempting to change amino acid profiles by a positive breeding strategy. In the pulses perhaps the best thing to do would be to test promising high yielding material in the breeding program for protein, sulphur amino acids and starch to make sure that we do not produce a variety abnormally defective in these constituents. This would be a negative screening procedure, not a positive attempt to change protein percentage on amino acid levels by screening thousands of samples and attempting to breed for such factors as high methionine levels. In any case we know too little about the heritabilities and environmental effects on such percentages for this to be feasible at present.

But on this point, though perhaps for different reasons, there seems to be general agreement. Mr. Hulse has said he would not give high priority to work on amino acid composition; Dr. Royes has remarked that instead of trying to improve the percentage of sulphur amino adds in the pulses we should perhaps think of these amino adds being supplied by other components in the diet such as cereals. Dr. Pushpamma has also pointed out that the methionine levels of pulses should not be seen in isolation but in the context of diets containing cereals when the problem ceases to seem so important.
Dr. Srikantia has emphasized that if sufficient cereal based diets are eaten to meet caloric needs, the amino add needs will be met automatically.

FIFTH

SESSION

GERMPLASM COLLECTION AND EVALUATION IN CICER AND CAJANUS

L. J. G. van der Maesen[1]

INTRODUCTION

With the general awareness of genetic erosion in crop plants accompanying the rapid introduction of improved cultivars, attempts are at last being made on a worldwide scale to preserve the available and precious material. With Cicer and Cajanus we are still in a better position than is the case with wheat even if preservation for wheat were initiated now. More than 70% of both pulse crops are still grown from landrace material, at least in India where the majority is grown. On the other hand, in Turkey only a minority of the 29 so-called chickpea varieties as described by Popova and Pavlova (1933) could be secured by expeditions of the Crop Research and Introduction Center at Menemen, Izmir. In 1958, their existence was indicated by Genckan who also described these forms. The bold seeded Mediterranean chickpea gradually replaced smaller seeded cultivars with colored seed coat. By contrast in Ethiopia the Mediterranean form Kabuli has not yet spread over large areas. Westphal (1974) never found it at markets, but only near an agricultural research center. He designated the material as cv Italian Wonder.

Aside from improvement in agriculture, extinction of primitive forms or particular landraces is hastened by repeated droughts, when people eat their sowing seed and have to rely on relief seed sources from elsewhere. Further population pressure brings a higher density of browsing animals and those form a threat to weedy and wild relatives of both chickpea and pigeonpea, as well as to other crop species. Civil and guerilla warfare is likely to destroy certain habitats where valuable material might occur.

Presently the international institutes have committed themselves to the task of preserving germplasm. International cooperation and coordination was recently started with the establishment of the International Board for Plant Genetic Resources, with headquarters at FAO in Rome. Three points in handling germplasm are considered Important and inseparable:

1. Exploration and collection
2. Documentation
3. Evaluation

These points will be reviewed in some of the following paragraphs.

The word germplasm was used for the first time (cf. Rieger et al. 1968) by Weissmann in 1883 (Keimplasma) and stands, in strict sense, for the chromatine material in the cell nucleus. The genetic material forms the physical basis of inheritance which is transmitted from generation to generation by the generative cells. In a broad sense, breeders have used the word germplasm for a long time to indicate the collection or assembly of populations, lines, clones, cultivars, landraces, etc., from as many different sources as possible which are to be used in combining specific properties into a final product they can release as a cultivar.

ASSEMBLING INFORMATION ON THE CONCERNED SPECIES

Taxonomists provide us with the necessary data about the species and their occurrence. At the infraspecific level they often provide useful information, but this has been ignored by breeders or proved to be of limited practical use. The breeders and the different plant introduction services hitherto produced little recent classification in Cicer and Cajanus into which all germplasm could be fitted, although considerable artificial grouping has been carried out.

---

[1] International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, India

Classification of Cicer and Cajanus

In 1972, the author presented a full revision of the genus Cicer as a part of his monograph on the crop. The Infraspecific classification he could not tackle, but at ICRISAT he will have a good opportunity to do so. In Cicer, 39 species exist: Cicer arietinum L., the chickpea, seven other annual wild or weedy species and 31 perennial ones. The last ones especially are very difficult to obtain and to grow. Their geographical distribution 1s known, but sometimes from very old sources only. Two species have been found only once. The herbarium, original descriptions, old and new maps, travel guides and literature study are the basis for those searches.

For Cajanus such a recent treatment does not exist. It is a genus with three to four species and ten or more synonyms can be found for the species Cajanus cajan (L.) Millspaugh. References are much less abundant than for Cicer and are still scattered. In Cicer the morphological' species concept works very well, whereas Cajanus is a treat for biosystematicists since it crosses *very* well with several Atylosia species. The two related genera should perhaps be united into one genus since the 'biological' species concept features genetical barriers to delineate species. Reddy (1973) and De (1974) advocate this standpoint after genetical and cytological research 1n both genera. The statement has been made several times since 1900.

Collection of Primitive Species

Neither of our pulse crops possess enough accessions which are completely resistant against diseases, such as wilt or blight (Fusarium orthoceras var. cicer! resp. F. udum and Ascochyta rabieT). As wild species generally possess more resistance, the breeders need wild species and germplasm collections which contain those for use and storage. No certainty exists that we will be forever able to replenish our sources of wild material because of, among other things, goat population, and political inaccessibility. The efforts to obtain them are too complicated to enable frequent trips.

Knowledge of the existence of other collections, procuring the material, exchange of personal experience and data prove to be most useful. Priorities can be postulated with respect to the areas where primitive forms are in danger of replacement or where valuable additional germplasm material may be found.

ORIGIN AND DISTRIBUTION OF CICER

Cicer arietinum has not been found in a wild state, though escapes occur. Vavilov (1951) indicated the Hindustan, Central Asian, Near Eastern and Mediterranean centers as primary sources of origin, and the Ethiopian center as secondary. These diverse centers form the nuclei of the area inhabited by wild Cicer species. Recently a few annual species have been described which are closely related to the cultivated chickpea: C. bijugum K.H. Rech. and C. echinospermum, P.H. Davis, both occurring in Turkish Mesopotamia and Iraqi Kurdistan. Both are favored by human influence on the ecosystem: they inhabit fallow fields and orchards. C. pinnatifidum Jaub & Spach and C. judaicum Boiss, both annual Mediterranean species, were formerly believed to be predecessory material for chickpea. In Afghanistan the annual relatives of the chickpea are C. chorassanicum (Bge)M. Pop and C. yamashitae Kitam. In Ethiopia, C. cuneatum Hocnst ex Rich is found. The last three species are more different from the chickpea. These species have never been deliberately collected for germplasm except C. cuneatum. C. pinnatifidum was present in some seed collections of botanical institutes.

For all perennial species the occurrence is known although not all localities are traceable. In Iran and Central Asia this proved to be difficult. Very old or single finds are source for pessimism over hopes of tracing these species again. For example, C. subaphyllum Boiss found on a mountain Isolated in the plains near Persepolis in Iran in 1841, could not be found when the author made an attempt in June 1974. However, this species seems one of the least useful to the breeders. Annual species are the first to be collected, are easier to grow and more logical to use 1n breeding, although no successes have been reported yet from interspecific crosses.

Detailed information on distribution is found in the monograph by van der Maesen (1972). The areas where chickpeas are in the course of replacement by improved cultivars, as superImposed on the areas of wild and cultivated chickpeas, are presented, together with a list of suggestions for collections (van der Maesen, 1973). In general, India and Iran are well represented in the present ICRISAT collections, comprising about 8500 accessions.

The chickpea moved from its ecological optimum — foothills with high light Intensity, long days, moderately high temperatures, well-drained soils — to the plains of India and has adapted quite well there. Man is mainly responsible for the wide distribution which started at a very early age. Archaeological proofs were found of cultivated chickpeas in Hacilar, Turkey, dated 5450 B.C. Also early finds were obtained in Jericho and Mesopotamia. Old Sanskrit names as well as carbonized names point to a presence of chickpeas in India since 2000 B.C. White seeded Kabuli chickpeas apparently arrived in India only about 250 years ago, as indicated by its name. More detailed accounts can be found in the monograph.

ORIGIN AND DISTRIBUTION OF CAJANUS

De (1974) reviewed the history and distribution of Cajanus. African origin for the genus is noted by de Candolle (1882) because pigeonpeas were not found wild in India but occurred in the wild state in several locations in Africa. Zhukovsky (1962) favored African origin without giving evidence or reference to Vavilov, (1951), who regarded India as the center of origin because of the wide variability in pigeonpeas. He did not mention Atylosia. Most authors repeat that Cajanus is a monotypic genus, although C., kerstingii Harms is a truly wild species found in West Africa (Gillett et al. 1971, Hepper 1958), which could be an indication for the origin of the genus. More clarification is still needed regarding nomenclature and species concept. Etymological basis for African origin only applies for the West Indies where the pigeonpea was brought with the slave trade.

Both the variability in Cajanus cajan as well as the occurrence of 22 species of the closely related genus Atylosia in the Indian subcontinent clearly point to Indian origin. Several authors (cf De 1974) described the distribution from India to Africa, and from there to America, and from India eastwards to the Malay Archipelago, Indochina and Australia as backed by historical and etymological evidence. This process probably took place in the last centuries B.C. China received Cajanus in the 6th century A.D.

A preliminary search in the Index Kewensis alone, leaves us with eight spp. in Cajanus, of which four are not yet withdrawn as synonyms for Atylosia species in Australia. At present, two to four species remain validly described. Many synonyms (not species as quoted by De, 1974) were listed. In Atylosia, 34 species are listed: 22 in India, Sri Lanka and Burma, one on Mauritius, seven in Australia, one in Malaysia, two in China, one in Thailand, without counting the widely spread A. scarabaeoides Benth and a few species of India also found elsewhere. A. scarabaeoides was undoubtedly introduced into Africa (Gillett et al. 1971). The Indian A. volubilis Gamble, A. goensis (Dalz) Dalz as well as A. scarabaeoides are found in Java. A. mollis Benth is also found in Malaysia and the Philippines, but the majority of species can be found in India. Mainly the Western Ghats and other hilly regions, such as the Malabar coastal mountains, form the center of variability. From the distribution as given by De (1974), no species appears to be endemic in the Himalayas.

Homology between Cajanus cajan and Atylosia lineata Wight & Am was proven by Reddy (thesis 1973). Less relationship was found to A. sericea Benth ex Baker and the twining species A.scarabaecides, but still hybrids were obtained. Seven pairs of chromosomes, out of 11, are common to both the genera. To look for a wild progenitor of pigeonpea, or at least for a common predecessor, the erect Atylosia species are a natural source. The separation of the genera on the narrow basis of the aril has repeatedly been brought to attention. Atylosia has a well-developed aril, Cajanus has a small rim aril, although considerable variability exists. A revision of these and related genera in the tride Phaseoleae appears badly needed. More floristic information is also necessary, since the Flora of British India still appears to be one of the major sources.

OBTAINING GERMPLASM

So far only a few attempts have been made elsewhere to acquire and keep large germplasm collections of Cicer and Cajanus. The collections of Vavilov and his collaborators are classical, but much of this material was lost during the war. Several small collections existed at the regional national breeding centers in India. A large sized collection was obtained by the Regional Pulse Improvement Project, initiated by USDA/USAID, and this forms the bulk of the chickpea and pigeonpea accessions at ICRISAT. RPIP made extensive collections of most pulses grown in India and

Iran for which we should give them full credit Cooperation with the IARI and the Karaj Agricultural College was Initially Intensive. When financial and other resources dried up, the program was handed over to the national agricultural authorities (IARI and All India Coordinated Pulse Improvement Project) before ICRISAT started Its operations. Many RPIP accessions were obtained through these channels, and they have been used and are being used 1n several centers as well. However, a considerable number have been lost. Cooperation with Indian and other Institutes is gratefully acknowledged and will continue.

From the Arid Land Agricultural Development Program, working since 1972, much material has been received and still will flow to the ICRISAT collections. The International nature of ICRISAT permits an attempt to obtain all available germplasm material for the two pulses for which the Institute assumed responsibility.

The two important ways of obtaining accessions are to get other collections by correspondence or personal contacts, and collecting of material on expeditions in the areas where chickpeas or pigeonpeas are grown and wild relatives occur. The first method thus far yielded most of the lines; the second approach may yield more specifically wanted material.

EXPLORATION AND COLLECTION

A good preparation is of utmost importance for collection trips, and not only because of limited time and resources. From the standpoint of economy, however, collection trips often cost only a fraction of the expense of institutes and government and private breeders to develop a cultivar.

The morphology of the crop species will be well-known by our collectors. If special characteristics occur, these should be detected in the field or in markets. The markets, preferably of small regional centers or villages where farmers sell their own products, are good sources for grain legume cultivars. All members of the team should also have a fair knowledge of the wild species' habit. Of course collections will not have to be restricted to Cicer, Cajanus and Atylosia only.

Methods of Collection

Methods and techniques adopted for collection of germplasm are given by Bennett (1970). She describes the limitations of the amount of material which can be collected in a certain time. In Turkey, the Izmir Center could not average 50 samples a day with four teams. In Afghanistan, where only wheat was collected by the FAO mission, the maximum was 15 samples a day. Market samples can be collected more rapidly, but knowledge of market days is necessary. In Ethiopian markets it proved easiest to procure a sample of 100-200 g, the variable amount being sold for 5 Ethiopian dollars. For our needs a larger amount can be procured.

The size of samples varies with the population variance. Zagaja (1968) gives a minimum number of 20,000 seeds in order to gather the existing variation in a crop. This is completely infeasible in wild Cicer and extremely difficult in Atylosia, but in the first case we have self-pollinating plants which makes homozygosity more probable. A sample of 20,000 seeds of chickpeas or pigeonpea would vary between one and ten kilograms, and is obtainable from farmers.

In the field, random sampling is the most applied technique, perhaps supplemented by a biased sampling to select all rare phenotypes. These are not necessarily genetically distinct, and perhaps only indicate a small local fertile spot.

It is also necessary to collect at least five herbarium specimens along with the seeds, if possible. Often the plants will have dried up when ripe seeds of Cicer spp. are collected. Especially for rare and wild species, better reference storage is required since many of them are rarely available in the world's herbarium institutes.

Bennett (1970) also gave an extensive list of observations to be taken at the collection site. For convenience these are coded. All planning procedures such as arrangements for visa and approvals, guides and interpreters, technical equipment, are discussed.

Political Inaccessibility

One of the problems encountered 1s political inaccessibility, in some regard even more than topographical inaccessibility. A proposal, accompanying the Cicer monograph (van der Maesen 1972) reads as follows: International agreements should enable scientific botanical exploration in border areas or politically disputed areas for qualified scientists of all nationalities. Even in nondisputed areas, however, a team of foreigners, squatting on the ground here and there, taking crop samples or apparent worthless weeds, scribbling notes and kilometer readings, looks suspicious. Knowledge of the language facilitates contacts with local authorities and farmers. In the case of Cicer many Interesting border areas are prohibited or difficult to enter, such as Eritrea, Mount Hermon in Lebanon, Iraqi Kurdistan, the Afghani panhandle and Kashmir. Recently a plant collector was detained for five months in Somali prisons when he accidentally crossed the ill-delineated border with his Land Rover. Incessant diplomatic efforts were needed to release him, and his Ethiopian companions were released only after 17 months of prison.

DOCUMENTATION

Documentation before collection concerns mainly literature research. It may be done by computer retrieval, but backdated literature is not traceable yet. The classical way of the snowball system proved to be adequate for Cicer, and for Cajanus it will be even more manageable since fewer references exist.

Documentation after obtaining the collections is more cumbersome and concerns observations about the plants and seeds. It should aim at usefulness for the breeder and the classifier. The RPIP has already provided a number of characteristics for many accessions of their collections on computer outprints. At present FAO is in the course of the preparation of a basic program to enable data retrieval in the TAXIR (TAXonomic Information Retrieval) language which proved to be suitable for the purpose (Rogers 1974). Careful use of the involved terminology is necessary to avoid errors made by the computer.

The plant breeder as well as the taxonomist may thus obtain more easily selected information, as the computer easily picks out wanted data, and storage of data is provided. The base for the data is the field book, kept carefully every year a collection is grown. Obviously, per crop the observations will differ and classes will be arbitrary. Easily distinguishable and measurable characteristics as used by the breeders appear to be most practical.

MAINTENANCE OF GERMPLASM

The preservation of seeds, the best way germplasm can be stored where short duration crops are concerned, should be done in such a way that renewal of the germplasm should be carried out as seldom as possible. Genetic erosion may occur at *every* renewal. However, with Cicer this is less of a problem than in Cajanus. Chickpeas are self-pollinated, pigeonpeas show 3% to 40% outcrossing; the contamination is and has already been enormous, especially in collections. Laborious selfing, reportedly very difficult under Hyderabad conditions, is needed to arrive at more stabilized accessions than a kind of mini-populations. It is still under discussion, as what exactly has to be regarded as a germplasm line in pigeonpea.

Bulking and Selfing Methods

Allard (1970) suggested bulking of material similar in appearance and environmental descent into 'race reservoirs' as almost Inevitable in cross-fertilized plants. Large bulk populations retain enormous stores of variability and few genes are completely lost despite environmental pressures. Cultivation of the reservoir in different environments, switching of places combined with cold storage would reduce further genetic loss. A disadvantage is that opportunity to discover and scrutinize properties of individual lines is lost, so the lumping should be postponed as long as possible. For a collection of lima beans (Phaseolus lunatus) of more than 2000 items, a number of 200 were judged to be interesting enough to be maintained separately, the rest was combined into 30 populations, later on reduced to 100 Items and 15 populations. Therefore, a combination of bulking and selfing, apparently an opportune method for preserving lima bean genetic resources, might be valid for pigeonpea. Before lumping, several years of careful studies are needed.

In pigeonpea, selections on seed character already doubled the number of accessions and the collection in the field shows a lot of variation within the row. Formerly the seeds from each row were simply bulked, so whatever we have at hand now will not be similar to the originally introduced material. Selection within the rows is done, or plants different from the average are selfed and tagged separately to avoid confusion.

Longevity

Research on seed longevity is scarce,

since it involves very long-term trials. Bennett (1974), proposal of FAO Genetic Resources Unit suggests ideal storage facilities, such as -18°C, seed at 5 + 1% moisture in sealed containers. Minimum standards are storage at 4°C, seed below 8% moisture. Each accession should have 30 samples of 400 seeds each, with a replicate collection of 5 samples, in laminated foil packets or any reliable moisture proof container. Regeneration is necessary if 5%-10% loss in germination occurs. Every five years a routine germination test should be carried out. When the stock falls below 2000 seeds, renewal should be arranged.

Storage

Cultivars differ in their storage habits under ordinary conditions. Under room temperatures, Kabuli chickpeas retain proper germination capacity for one to two years only, because of their soft seed coat. Deshi chickpeas keep well for three to four years. In closed glass jars, after nine years, 90% was found to germinate. In cold storage in Menemen, Izmir, the seeds are routinely renovated after ten years. Presently plans worked out to build cold storage for ICRISAT providing about 5°C and 40% relative humidity as a minimum. Separate compartments offer different possibilities for each crop.

EVALUATION

Evaluation starts with morphological description, elimination of duplicates and establishing of workable classification systems. Depending upon the circumstances, this may be a special purpose or a natural one. At ICRISAT now at least the situation exists 1n which all major collections of chickpea and pigeonpea are joined, and, as stated before (van der Maesen, 1972) it should be possible to initiate work on proper infraspecific taxonomy. This cannot be done for the purpose of classification as such, but it has to provide a tool to the users of the germplasm.

Yield is a combination of most of the factors mentioned, although some morphological observations only serve classification purposes. More detailed observations may be added if useful. The importance of observations is different for various conditions and flower periods, and 1t will not be necessary to screen all the accessions for all the factors.

The following qualitative and quantitative characters will have to be evaluated, in order to find out yield potentials:

1. Days to flower
2. Maturity group
3. Flower color
4. Plant height
5. Plant width
6. Growth habit
7. Number of primary branches
8. Number of secondary branches
9. Pod number per plant
10. Pod size
11. Pod color
12. Number of seeds per pod
13. 100 seed weight
14. Seed color
15. Testa structure
16. Seed form
17. Cotyledon color
18. Seed yield per plant
19. Straw yield per plant
20. Reaction to major pests and diseases (flower duration, escape and resistance)
21. Protein content and amino acid pattern
22. Other biochemical relationships
23. Tolerance to drought, waterlogging and alkalinity
24. Response to high fertility and irrigation
25. Plant architecture and leaf angle, leaf size and number
26. Seedling vigor
27. Nodulation capacity
28. Male sterility

29. Cytogenetic relationships

CONCLUSIONS

Cooperation with the different disciplines will make possible the evaluation. Along with the maintenance comes the distribution of genetic material among the interested workers all over the world, and if possible the documentation of the results then obtained elsewhere. A government quarantine section serves ICRISAT which minimizes likelihood of fatal mistakes in transportation of non-present pests, etc.

Luckily the remarks of Westphal (1974) in a theorem become irrelevant for ICRISAT at least. He made the statement on account of Hawkes' (1970) paper on taxonomy of cultivated plants: The historically understandable incompatibility of moods between plant breeders and plant taxonomists poses a barrier for close cooperation between their areas of specialization in order to improve the systematics of cultivated crops.

Therefore, the different

will cooperate not for benefit of system in itself, but for improved practical use and conservation of the heritage nature gave to us.

DISCUSSION

E.E. Hartwig: Is it unnecessary to explore the possibilities of the use of chemicals to control the bees to check the cross-pollination in pigeonpea?

L.J.G. van der Maesen: There, is a complete lack of knowledge about the pollinating bees. Entomologists could help us. Moreover, there are a few difficulties in this regard, like very long flowering period spread over several months especially in late types. As many as 17 sprays were required to control the pod borers in the previous season and the presence of many kinds of bees on the other crops.

K.J. Frey: The importance of utilizing the available germplasm for quantum jump in yield hardly needs to be emphasized. Future collection can be more profitable in the areas where evolutionary changes are taking place.

L.J.G. van der Maesen: I agree that we may make efforts to collect and utilize the wild and cultivated species from the center of origin, like Turkey.

H. Doggett: There is urgent need to create race reservoirs of germplasm collections from which one can draw material for utilization in the breeding program.

L.R. House: ALAO has been involved in collecting legumes in Afghanistan. It was appreciated in Afghanistan that the Ford Foundation was a non-governmental agency and that the collector would be Lebanese rather than American.

Further collection work would require travel into isolated areas. It is important to select wild species; and maintenance of seeds in areas of adaptation is Important.

All collections should be maintained at at least two places in the world and germplasm pools might be made in addition to this collection.

A.K. Auckland: In my opinion, the material for photosensitivity can be evaluated in high altitude areas of the U.S.S.R. and the Lahaul Valley in North India. I think "germplasm collector" is a wrong word; some other terminology may be chosen.

B.P. Pandya: I feel that while evaluating the germplasm, the material should also be explored for extra early seedling vigor.

since it involves *very* long-term trials. Bennett (1974), proposal of FAO Genetic Resources Unit suggests ideal storage facilities, such as -18°C, seed at 5 ± *1%* moisture in sealed containers. Minimum standards are storage at 4°C, seed below 8% moisture. Each accession should have 30 samples of 400 seeds each, with a replicate collection of 5 samples, in laminated foil packets or any reliable moisture proof container. Regeneration is necessary if 5%-10% loss in germination occurs. Every five years a routine germination test should be carried out. When the stock falls below 2000 seeds, renewal should be arranged.

Storage

Cultivars differ in their storage habits under ordinary conditions. Under room temperatures, Kabuli chickpeas retain proper germination capacity for one to two years only, because of their soft seed coat. Deshi chickpeas keep well for three to four years. In closed glass jars, after nine years, 90% was found to germinate. In cold storage in Menemen, Izmir, the seeds are routinely renovated after ten years. Presently plans worked out to build cold storage for ICRISAT providing about 5°C and 40% relative humidity as a minimum. Separate compartments offer different possibilities for each crop.

EVALUATION

Evaluation starts with morphological description, elimination of duplicates and establishing of workable classification systems. Depending upon the circumstances, this may be a special purpose or a natural one. At ICRISAT now at least the situation exists in which all major collections of chickpea and pigeonpea are joined, and, as stated before (van der Maesen, 1972) it should be possible to initiate work on proper infraspecific taxonomy. This cannot be done for the purpose of classification as such, but it has to provide a tool to the users of the germplasm.

Yield is a combination of most of the factors mentioned, although some morphological observations only serve classification purposes. More detailed observations may be added if useful. The importance of observations is different for various conditions and flower periods, and it will not be necessary to screen all the accessions for all the factors.

The following qualitative and quantitative characters will have to be evaluated, 1n order to find out yield potentials:

1. Days to flower
2. Maturity group
3. Flower color
4. Plant height
5. Plant width
6. Growth habit
7. Number of primary branches
8. Number of secondary branches
9. Pod number per plant
10. Pod size
11. Pod color
12. Number of seeds per pod
13. 100 seed weight
14. Seed color
15. Testa structure
16. Seed form
17. Cotyledon color
18. Seed yield per plant
19. Straw yield per plant
20. Reaction to major pests and diseases (flower duration, escape and resistance)
21. Protein content and amino acid pattern
22. Other biochemical relationships
23. Tolerance to drought, waterlogging and alkalinity
24. Response to high fertility and irrigation
25. Plant architecture and leaf angle, leaf size and number
26. Seedling vigor
27. Modulation capacity
28. Male sterility

29. Cytogenetic relationships

CONCLUSIONS

Cooperation with the different disciplines will make possible the evaluation. Along with the maintenance comes the distribution of genetic material among the interested workers all over the world, and if possible the documentation of the results then obtained elsewhere. A government quarantine section serves ICRISAT which minimizes likelihood of fatal mistakes in transportation of non-present pests, etc.

Luckily the remarks of Westphal (1974) in a theorem become irrelevant for ICRISAT at least. He made the statement on account of Hawkes' (1970) paper on taxonomy of cultivated plants: The historically understandable incompatibility of moods between plant breeders and plant taxonomists poses a barrier for close cooperation between their areas of specialization in order to improve the systematics of cultivated crops.

Therefore, the different disciplines will cooperate not for benefit of system in itself, but for improved practical use and conservation of the heritage nature gave to us.

DISCUSSION

E.E. Hartwig:	Is it unnecessary to explore the possibilities of the use of chemicals to control the bees to check the cross-pollination in pigeonpea?
L.J.G. van der Maesen:	There, is a complete lack of knowledge about the pollinating bees. Entomologists could help us. Moreover, there are a few difficulties in this regard, like *very* long flowering period spread 'over several months especially in late types. As many as 17 sprays were required to control the pod borers in the previous season and the presence of many kinds of bees on the other crops.
K.J. Frey:	The importance of utilizing the available germplasm for quantum jump in yield hardly needs to be emphasized. Future collection can be more profitable in the areas where evolutionary changes are taking place.
L.J.G. van der Maesen:	I agree that we may make efforts to collect and utilize the wild and cultivated species from the center of origin, like Turkey.
H. Doggett:	There is urgent need to create race reservoirs of germplasm collections from which one can draw material for utilization in the breeding program.
L.R. House:	ALAD has been involved in collecting legumes in Afghanistan. it was appreciated in Afghanistan that the Ford Foundation was a non-governmental agency and that the collector would be Lebanese rather than American. Further collection work would require travel into isolated areas. It is important to select wild species; and maintenance of seeds in areas of adaptation is important. All collections should be maintained at at least two places in the world and germplasm pools might be made in addition to this collection.
A.K. Auckland:	In my opinion, the material for photosensitivity can be evaluated in high altitude areas of the U.S.S.R. and the Lahaul Valley in North India. I think "germplasm collector" is a wrong word; some other terminology may be chosen.
B.P. Pandya:	I feel that while evaluating the germplasm, the material should also be explored for extra early seedling vigor.

K.O. Rachie: There are certain physical problems in collecting the germplasm. But In my opinion the evaluation and utilization of germplasm are still unresolved problems, which should receive top priority.

T. Bezuneh: I prefer that the grouping of germplasm according to nations or to regions would be used. The evaluation of the entire germplasm may be done at least at two sites.

Appendix 1. Chickpea Germplasm at ICRISAT (October 1974)

Country	No. of Entries
India	3862
Iran	3504
Turkey	131
Ethiopia	105
U.S.A.	81
Spain	71
Pakistan	69
Egypt	46
Morocco	44
U.S.S.R.	36
Tunisia	29
Israel	26
Afghanistan	25
Jordan	23
Cyprus	21
Mexico	21
Lebanon	17
Iraq	15
Algeria	12
Syria	11
Italy	10
Greece	4
Sudan	4
Nigeria	3
Burma	3
Portugal	3
Hungary	3
Bulgaria	3
Yugoslavia	2
Germany	2
Sri Lanka	2
France	1
Kenya	1
Peru	1
Unknown	169
Information pending	145
Total	8505

Appendix II. Pigeonpea Germplasm Collection at ICRISAT (December 1974) (excluding subaccessions)

Country of origin	Number of entries	
India		3486
Andhra Pradesh	(1124)	
Uttar Pradesh	(808)	
Madhya Pradesh	(329)	
Bihar	190	
Maharashtra	168)	
Tamil Nadu	(156)	
Karnataka	(139)	
West Bengal.	(67)	
Delhi	67)	
Orissa	(39)	
Gujarat	(7)	
Rajasthan	(4)	
Others (State of origin not known)	(259)	
Puerto Rico		38
Sri Lanka		53
Surma		21
Trinidad		13
Jamaica		12
Nigeria		10
Bangladesh		8
Brazil		7
British Guyana		4
Australia		3
U.S.A.		2
Thailand		2

LITERATURE CITED

Allard, R.W. 1970. Problems of maintenance. Genetic resources in plants - Their exploration and conservation, Frankel, O.H. and E. Bennett, eds. IBP Handbook No.11, Blackwell Sci. Publ. Oxford & Edinburgh: 491-494.

Bennett, E. 1970. Tactics of plant exploration. Genetic Resources in Plants, etc. 157-1799.

Candolle, A.de 1882. l'Origine des plantes cultivees. Paris: 258.

De, D.N. 1974. Pigeon Pea. Evolutionary studies in world crops, diversity and change in the Indian subcontinent. Sir J. Hutchinson, ed. Cambridge Univ. Press, Cambridge: 79-87.

Genckan, S. 1958. Turkiye'nin onemli nohut cesitlerinin Baslica vasiflari uzerinde arastirmalar. Ege Univer. Matbaasi, pp. 107.

Gillett, J.B., R.M. Pollhill and P. Verdcourt. 1971. Atylosia, Cajanus. Flora of tropical East Africa, Leguminosae Part 4: 707-711.

Hawkes, J.G. 1970. The taxonomy of cultivated plants. Genetic Resources in Plants, etc.:69-85.

Hepper, F.N. 1958. Cajanus, Atylosia. Flora of west tropical Africa. Hutchinson, J. and J.M. Dalziel, 2nd ed. Keay, R.W.J, ed. 1-2:559.

Popova, G.M. and A.M. Pavlova. 1933. Nut turtsii. In: La Turquie agricole, Zhukovsky, P., ed.: 340-347.

Reddy, L.J. 1973. Interrelationships of Cajanus and Atylosia species as revealed by hybridization and pachytene analysis. Unpublished Ph.D. thesis. Indian Institute of Technology, Kharagpur, India.

Rieger, R., A Michaelis and M.M. Green. 1968. A glossary of genetics and cytogenetics. Springerverlag Berlin, Heidelberg, New York.

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. Commun. Agric. Univ. Wageningen 72(10) pp. 742.

Van der Maesen, L.J.G. 1973. Chickpea: distribution of variability. In: Survey of crop genetic resources in their centers of diversity. FAO/IBP: 30-34.

Vavilov, N.I. 1951. The origin, variation. immunity and breeding of cultivated plants. Chronica Bot. 13-1/6: 26-38.

Westphal, E. 1974. Pulses in Ethiopia, their taxonomy and agricultural significance. Pudoc, Wageningen. 47-56.

Zagaja, S.W. 1968. Report on the UNDP/SF Project. Crop Research and Introduction Center, Izmir. 30-42.

Zhukovsky. P.M. 1964. Cultivated plants and their wild relatives (Systematics, geography, cytogenetics, origin). Leningrad: 364-365.

BIOLOGY OF ADAPTATION IN CHICKPEA

B. R. Murty'

INTRODUCTION

With the introduction and spread of high yielding varieties in some crops, several genotypes of semiwild and primitive chickpea cultivars of actual or potential use are becoming extinct. Therefore in the UM section of International Biological Program, emphasis has been made on conservation and utilization of these genetic resources useful to man. The nature of their adaptation, which is a major component of productivity as stated by Frankel and Bennett (1970) is the basis for analysis. While some of them can only give high yield in specific environments, others are able to perform well in different situations. The project on biology of adaptation is designed to obtain fundamental scientific information about the processes concerned in such adaptation. The evaluation of these plant resources to improve adaptability and productivity of these genotypes and for the incorporation of this capacity of wide adaptation into high yielding genotypes is the basis of these studies.

Cicer has been chosen as a representative of the grain legumes by the working group of SCIBP since it is a plant of economic importance and a major source of protein in many developing countries. It has shown a wide range of adaptation with little human selection, and is therefore eminently suited for examining the process influencing adaptation.

The Protein Advisory Group (1972) has emphasized that priority in legume breeding shall be (a) improvement of productivity by higher yield and adaptability and yield stability along with nutritional balance, (b) fundamental studies on the presence of undesirable linkages and physiological associations and modes of overcoming them and (c) study of growth and development processes for identifying efficient genotypes in terms of plant architecture, response to stress and inherent photosynthetic ano respirational efficiencies.

For such studies, the analysis of the cultivars in terms of their adaptation, particularly for yield, maturity, and protein stability, will permit identification of a diversity of genetic mechanisms that are involved, since natural selection may have fixed different constellations of genes in different environments.

The present studies consist of such an analysis of the interaction of a world collection of genotypes with environment, and analysis of productivity and adaptability in genetic terms carried out during the past five years in cooperation with other countries producing chickpea.

MATERIALS AND METHODS

The major areas of cultivation of chickpea are Spain, Portugal and Italy in Europe, Mexico in the Western Hemisphere; India, Iran, Pakistan, Burma, Turkey and Syria in Asia; Morocco and Ethiopia in Africa. The Near and the Far East account for over 85% of the total world area and an equal proportion of total production of 12 m tons. These are also the areas of very limited human selection with a variety of environmental conditions including season and soil type. A majority of these landraces have high local adaptation even within the same country, accentuated by natural selection for resistance against drought and Ascochyta and Fusarium. Local consumer preference for appearance, particularly for seed size and color, seed filling, and easy separation of seed coat is also a factor.

In the first phase of the program, a collection of 250 locally adapted cultivars included whitish yellow, brown and black seeded types was made by the author in 1969 from Iran, Turkey, Syria, Jordan, Lebanon, Greece, Italy, Spain, Cyprus, Morocco, Nigeria, U.A.R., Ghana and East Africa to augment a

---

[1] Indian Agricultural Research Institute, New Delhi, India

similar collection in India. This collection was evaluated in India after 1970.

A total of 27 characters were found: spreading habit, vegetative growth, days to 50 percent flowering, flower color, chlorophyll depth, leaf size, leaflet size, reproductive growth, flower shedding, wilt resistance, visual score of productivity, leaf drying, length of primary branch, spread 1n cm, number of primary branches, number of secondary branches, seeds per ten pods, pods per secondary branch, number of pods per plant, pod size, days to maturity and yield per meter, etc. These were scored with emphasis on developmental traits in addition to seed and agronomic characters. The relative distribution of lines resistant to Ascochyta, a major disease of this crop, was also examined. The association of seed color and seed size with resistance to this disease was also analyzed.

In the second phase, these collections along with additional Indian and exotic lines, were further evaluated during the October to March season in the years 1971 to 1974. A total of 459 entries were raised at the Indian Agricultural Research Institute, New Delhi, in an augmented randomized complete block design using ten Indian varieties from different parts as checks. The plot size was two rows of three meter length. The spacing was kept at 75 cm between rows and 15 cm within rows.

Visual scores ranging from one to ten were given on plot basis for most of the characters related to development, vegetative growth, productivity and disease resistance. Except for wilt resistance, where lower scores were given to cultures showing a high degree of resistance, a higher score was considered desirable.

Regression analysis of G x E interaction was carried out using the methodology of Eberhart and Russell (1966). Factor analysis was done using the Centrold Method of Holzinger and Harman (1941) and D^2-analysis after transformation to uncorrelated variable, as described by Rao (1952, 1972). Genotype-environmental interactions were also examined by the technique of Perkins and Jinks (1968). A larger world collection of 5474 accessions consisting mostly of advanced cultivars was also analyzed using multivariate analysis.

One hundred representatives of the above collection of primitive cultivars from different geographical areas were grown in an international trial of biology of adaptation. The trial was conducted from 1971 to 1974 in seven countries, India, Turkey, Morocco, Greece, Ethiopia, Spain and Mexico, in a randomized complete block design with three replications. An additional set along with new collections (580 collections in all) was also maintained at IARI, New Delhi.

RESULTS AND DISCUSSION

Nature of Variation and Adaptation

The performance of entries exhibited considerable range of variability within and among countries for 22 of the 27 characters examined. From a preliminary assessment of variation and other information on the ecological conditions of their cultivation, the major factors of local adaptation appear to be grain size, resistance to Ascochyta, wilt, drought and frost.

The maximum spreading habit was found in cultures from the South Asian region and from Iran and Israel. The Mediterranean material was vigorous but narrow in variation for maturity, but it was considerably early.

The variation for chlorophyll depth, flower shedding and length of reproductive period, seeds per pod and pods per branch was narrow (Table 1, 2 and 2a). The varieties from Jordan, Morocco and Cyprus had larger leaves and leaflet length. Considerable amount of variation was observed within and among different geographic regions for leaf and leaflet size, number of primary and secondary branches, growth habit and resistance to wilt. A considerable range of variation was recorded within each geographic region. A high degree of resistance was shown by cultures from U.A.R. and American lines of Spanish origin.

The overall comparison of mean performance of collections from different geographic regions, among themselves and with those of ten checks, revealed that the entries from Iran, India, Pakistan, Cyprus, Spain, U.S.A. and Israel were superior in their productivity, pod number, pod size and earliness with a moderate degree of resistance to wilt. Differ ences between the collection of primitive cultivars and the larger world collection were observed 1n the means and ranges of variation for days to flower, growth habit, seed size and pods/plant (Table 2a).

Table 1. Effect of Environment on the Expression of Some Characters in Representatives of Primitive Cultivars of Chickpea in 1971-72

S.No.	Characters	Turkey		Greece		Ethiopia		India	
		$\overline{X}$	Range	$\overline{X}$	Range	$\overline{X}$	Range	$\overline{X}$	Range
1.	Habit	6.1	4.0-8.0	6.8	5.0-8.0	4.5	1.0-6.0	5.6	3.0-9.0
2.	Chlorophyll depth	6.3	3.0-8.0	7.6	7.0-9.0	5.3	5.0-6.0	6.2	4.2-9.0
3.	Leaf size	5.0	4.0-8.0	4.2	3.0-8.0	NA		4.3	1.0-8.0
4.	Leaf drying	5.2	1.0-9.0	NA		5.6	4.0-7.0	5.6	2.0-8.0
5.	Plant height (cms)	18.1	12.5-31.1	24.2	19.3-34.0	63.7	33.0-91.0	46.4	30.0-54.7
6.	Primary branches	2.3	1.6-3.1	3.8	2.9-6.7	NA		5.7	3.3-11.7
7.	Days to flower	64.3	61.0-85.0	67.4	65.0-73.0	NA		94.7	83.0-118.0
8.	Days to maturity	113.2	109.0-122.0	122.9	119.0-134.0	NA		155.5	145.0-166.0
9.	Seeds/10 pods	15.7	5.6-22.6	16.4	10.0-21.0	NA		14.5	10.0-19.0
10.	Seed size	1.9	1.0-9.0	NA		4.8	3.0-9.0	4.6	3.0-9.0
11.	Disease score	4.7	2.0-9.0	NA		6.5	3.0-8.0	5.4	4.0-9.0
12.	Yield/plant in gms.	8.7	3.2-16.2	16.8	8.6-52.0	38.8^{++}	2.0-72.0	14.4	6.3-27.3

Items 2 to 4, 9 & 10 = Scores of 1 to 10 in favorable direction

Item 11 = 1 is resistant, 10 highly susceptible; Item 1 = 1 erect, 10 spreading

++ Grain number per plant

Table 2. Pooled Means of Eleven Characters in Chickpea from Diverse Geographical Groups Grown in a Common Environment (New Delhi 1969-1973)

Region	Flowering time (days)	Leaf size (cms)	Leaflet size (mm)	Leaf drying (score)	Maturity (days)	Pri Br. No.	Pods/ plant No.	Seed/10 pod No.	100-seed wt.(gms)	Yield/ meter (gms)	Disease score
India	87.22 ±9.71	4.37 ±1.01	4.11 ±1.26	5.67 ±2.48	158.33 ±7.13	9.47 ±4.90	111.44 ±85.40	14.76 ±3.43	15.45 ±9.48	320.68 ±153.41	4.55 ±1.97
Iran	88.22 ±7.15	4.58 ±1.21	4.42 ±1.55	4.26 ±2.84	156.04 ±23.58	8.60 ±6.54	100.05 ±64.38	14.12 ±3.76	14.91 ±19.81	269.45 ±153.45	5.33 ±3.81
Morocco	91.87 ±1.99	4.94 ±1.91	4.81 ±2.07	4.08 ±3.38	152.91 ±3.81	8.86 ±9.21	91.92 ±104.04	11.69 ±2.63	26.19 ±14.19	92.00 ±88.03	6.75 ±2.05
Spain	97.59 ±2.48	6.82 ±1.14	7.04 ±1.00	2.31 ±2.11	148.71 ±2.65	6.00 ±5.92	28.67 ±25.92	9.43 ±1.40	39.91 ±12.63	43.00 ±39.01	7.68 ±1.73
Ethiopia	88.54 ±9.29	4.91 ±0.70	4.82 ±1.17	2.45 ±1.03	150.45 ±2.21	4.82 ±3.87	69.73 ±46.30	11.91 ±2.12	46.82 ±17.62	126.10 ±98.84	6.36 ±2.86
Mexico	100.50 ±2.12	7.00 ±1.73	6.67 ±2.31	3.67 ±1.53	155.33 ±2.52	14.67 ±13.32	84.67 ±61.33	13.33 ±3.05	14.00 ±9.54	48.33 ±6.35	6.33 ±2.08
Turkey	98-	3.67-	4.60-	3.00-	148-	3.13-	42.67-	11.30-	NA	26.00-	3.00-
U.S.S.R.	118	7.33	6.67	4.14	164	7.00	51.25	17.50		69.09	4.51
Rumania	±1.53	±2.08	±1.45	±1.44	±3.46	±1.15	±5.69	±3.20		±71.09	±0.58

Table 2a. Range of Variation of Means of a World Collection of 5474 Accessions of Chickpea*

Character	South Asia (1619)	Near East & Caucasian (3765)	Mediterranean (36)	Other African (8)	USA & Mexico (19)
Plant Type	5.4-6.3 (5.9)	4.5-6.3 (5.6)	4.5-6.0 (5.0)	3.3-7.2 (5.6)	5.7-6.0 (5.9)
Days to Flower	100-113 (106.2)	104-128 (114.3)	101-110 (106.5)	91-113 (103.3)	104-107 (105.6)
Days to Maturity	176-179 (177.6)	175-181 (178.7)	175-187 (178.7)	179-186 (181.3)	177-179 (178)
Seeds/10 Pods	13-15 (13.8)	13-14 (13.7)	11-17 (14.4)	11-14 (12.5)	15-16 (15.5)
100-Seed Wt. (gms)	11.8-17.4 (14.7)	11.7-18.1 (15.4)	12.0-19.6 (15.5)	12.5-27.8 (16.9)	12.9-17.7 (15.3)
Flowers/Plant	183-452 (297.8)	242-300 (270.8)	159-379 (268.9)	194-310 (267.9)	255-421 (337.9)
Pods/Plant	163-404 (263.3)	214-265 (239.4)	133-368 (250.4)	173-290 (232.8)	218-383 (300.6)
Disease Score	3.8-9.0 (6.0)	3.0-9.0 (6.2)	4.5-6.6 (5.8)	6.0-9.0 (8.4)	7.2-8.1 (7.5)

* The data for 27 accessions of unknown origin is not included.

Source: Jayaprakash, R.K. (Unpublished).

Nature of Association Between Productivity and Other Traits

From the interrelationships among various characters related to wide adaptation, it was found that productivity does not appear to be directly related to wilt resistance. Wilt resistant types were found in medium and low yielding groups. Productivity was not related to maturity or the period of vegetative growth. It was found that better yielding groups had lower flower shedding. Productivity was related to depth of chlorophyll and semierect habit, larger leaf size and the number of secondary branches. It was also related to pod size in the medium and high yielding groups.

When the amount of variability and mean performance over other environments was compared among different geographic regions, cultures belonging to South Asia and the Mediterranean and Caucasian regions were better than others. The varieties which received a high score for productivity were from Iran, India, Pakistan, Cyprus, Spain, U.S.A. and Israel. The characters related to wide adaptation were chlorophyll depth, leaf and leaflet size, pod size, spreading habit and pod number.

Variability in the Semiprimitive Cultivars for Specific Characters Related to Adaptation

The collections exhibited considerable range of variability within and among countries for most of the characters examined. The pattern of the variation in the semiprimitive types is likely to be different from that in the advanced cultivars and is therefore summarized below. The highest degrees of variation for spreading habit which is associated with susceptibility to soil borne diseases was found 1n cultures belonging to the South Asian region and from Iran and Israel in the Near East Region. Varieties from Iran, India, Pakistan, U.S.A., Spain and Israel were found to have a large number of primary and secondary branches. Entries from Iran, India, U.S.A., Spain, Pakistan, Israel and U.A.R. had more pods per plant.

Variation for flowering time was 61 to 118 days (Table 1). Many of the varieties from Iran, India and Pakistan and two from Ethiopia were early (85 days). Most of the varieties from U.S.S.R., Spain, Syria and Libya were late in flowering as well as in maturity.

Considerable range of variability was noted for disease resistance, although only a few lines were highly resistant to Ascochyta. The maximum variation for disease resistance was noted among lines from Jordan, Cyprus, Spain, Ethiopia, Syria and Libya. The varieties which showed a high degree of resistance along with a reasonable level of adaptation were: P.620, 827, 1819, 3459, 4081, 4087, 4088, 4089, 4117, 5030, IBP-58 and 66 P. 1528, 1137, EC.26414 and EC.26435.

The entries from countries belonging to the Near East, Mediterranean and African highlands were marked for their low productivity mainly bicause of their high susceptibility to Ascochyta, poor pod setting and pod filling. The distribution of favorable and unfavorable alleles for pod number and seed number were of equal magnitude in collections from different countries.

The relative stability of performance of varieties from Iran, U.S.S.R., India, Pakistan and Burma was better than from other countries. The varieties from Rumania, U.A.R., Morocco, Cyprus, Lebanon, Spain, Ethiopia, appeared to be highly locally adapted.

From the regional means and ranges of variation for the characters mentioned earlier the Iranian material appeared to be a collection assembled from several other countries and cannot be considered as of local origin. The Turkish and Moroccan accessions with good seed size were also the best sources of disease resistance, a major factor limiting adaptation in chickpea.

Regression Analysis of Flowering Time and Yield Stability

While flowering time is important for local adaptation, there is flexibility in this material in its response to environment. Even within the range of flowering (61 to 118 days) there was a wide range of genotypic response over environments. The lines with good yield potential (400 gms/meter) were spread over the entire range of variation for flowering time except in extreme late types which did not set seed at all. The proportion of the linear component of interaction was not related to the mean or size of regression coefficient for yield (Table 2b).

Mean yield and stability for yield did not appear to be related to flowering time. From the other data available, it was not related to either the corresponding means and regression coefficients for growth habit, leaf and leaflet size, plant spread, number of branches and seed number per pod, but appeared to be related to early vigor, chlorophyll depth, moderate resistance to wilt, slow senescence, and small to intermediate seed size.

Comparative Variation in the International Trial

Among the trials conducted with the same material in seven countries, complete data are available from four countries for 14 characters (Table 1). There is considerable change both 1n means and the ranges of the same entries for different characters over the environments. It is particularly noticeable for height, number of primary branches, days to flower and maturity, seed size.and yield per plant. It was the least for wilt, pod size, leaf drying and habit. This can be compared with the performance of dlfferent geographical groups in a common environment (Table 2) which indicates that different constellations of genes have been fixed over long periods of local selection in different environments, although the variation within each geographical group is considerably limited by intense local adaptation.

On the other hand, the variability in the Trans-Caucasian region particularly Turkey, U.S.S.R. and Rumania is quite diverse compared to that of adjacent Iran. Even in the

Table 2b. Pooled Regression Analysis of Days to Flower and Yield/meter during 1969-1972

	Days to Flower			Yield/Meter		
	Mean	b	0^2	Mean	b	O^2
Checks	102-112	0.65-1.35	3.1-82.2	91-418	-0.09 to 2.48	92-75348
Other entries	97-111	0.33-1.77	1.6-592.4	62-511	-0.11 to 2.21	34-160056

Mediterranean material, which is predominantly selected for large yellow seeds, the Spanish material is distinctly different than that from Morocco and Turkey, particularly for leaf and leaflet size, leaf drying, pods per plant, seed weight, yield and susceptibility to Ascochyta. Data available on other characteristics but not presented in this paper, indicate that the black seed coat associated with wilt resistance is due to surface color which is water soluble. These black seeded resistant types are invariably small sized in Iran, Turkey and adjoining U.S.S.R. (11 gms/100 seeds) while the Moroccan material is very large (24-43 gms).

Thus, resistance to Ascochyta may not be related to seed size or even maturity, and any association between these characters may be due to fixation of some gene combinations rather than strong linkage. The period between flowering time and maturity has shown considerable variation even in adjacent regions such as Morocco and Spain and in similar highland regions of Ethiopia and Mexico (Table 2). Yield and seed size are not adversely related in a comparable maturity period of 175-190 days among lines moderately resistant to Ascochyta. Their yield varied from 5 to 20 g/ha with 100-seed weight ranging from 11 to 43 gms.

Association Between Yield and Other Characters

It is particularly relevant to summarize genetic association between characters in sufficiently large material subject to human genetic selection in the light of the preceding paragraphs. Four major geographical groups representing different ecological regions have been examined separately and collectively for correlation of yield with other characters associated with human and local adaptation (Table 3). Both phenotypic and genetic correlations are parallel in this study. The overall association is different from the association within each geographical group. Both the magnitude and the direction of association between yield and flowering time has changed in the Mexican material as compared to the others.

Similar is the case with days to maturity. Pronounced changes in association among geographical groups is found between yield and chlorophyll depth, leaf drying, days to flower, days to maturity, pod size, seed size, seed color and disease resistance. Out of 13 characters, nine have shown differential association in different geographical regions. This can only be interpreted in terms of local adaptation and fixation of adaptive gene blocks favored by the local forces of selection. Any improvement involving limited hybridization restricted within a region may not change these associations. Even if these associations are productive under local conditions, their incorporation in superior but widely adapted types may permit the exploitation of diverse genetic mechanisms towards stability of production.

Genotype-Environment Interactions

In spite of the erosion of genetic variability due to local adaptation, there is considerable variation in the nature and magnitude of genotype-environmental interaction both among and within geographical groups. A regression analysis of fifteen characters for a sample of 239 entries out of 567 entries in four environments has shown that the response as measured by the regression coefficient varied from 2 to 15 times depending upon

Table 3. Phenotypic Correlation Between Yield per Plant and 13 Other Characters in Collections From Different Geographical Regions

Geographical Regions	Habit	Chlorophyll depth	Leaf size	Leaf drying	Plant Ht.	No. of Pr. Br.	Days to flower	Days to maturity	Pod size	Seeds/ 10 pods	Seed size	Seed color	Disease score
India (83)	-0.14	0.19	≃0	-0.14	-0.10	-0.04	-0.02	≃0	-0.10	0.17	-0.27	0.36**	-0.11
Near East (325)	-0.40**	0.07	-0.14	-0.22*	0.04	0.15	-0.34**	0.04	-0.26**	0.33**	-0.19	0.07	-0.06
Mediterranean (91)	-0.57**	-0.04	-0.30**	-0.37**	-0.25	0.04	-0.20	≃0	-0.53**	0.26	-0.51**	0.38**	-0.28*
Mexican (7)	-0.22	0.27*	-0.17	-0.56**	-0.13	≃0	0.42**	0.39*	0.06	0.22	-0.35	0.12	-0.40**
Ethiopia (21)	-0.44**	0.09	-0.16*	-0.31**	-0.01	-0.01	-0.26**	0.29**	-0.27**	0.21**	-0.30*	0.31**	-0.17

Total countries - 22; Total accessions - 527 + Checks

Figures in brackets are the number of entries the character (Table 4). The range of means of the individual entries for the same characters was also large. The Interaction component in six of the seven characters, which are directly related to local adaptation and productivity, accounted for more than 50% of the total variation except for flowering time. In spite of this variation, the linear component is only around 30% in all the cases.

Thus the non-linear component which is less predictable appears to be crucial in the adaptation in chickpea. Similar results are also found in other crops like sorghum and millets which are normally grown in stress environments and are also subjected to selection for local adaptation (Murty 1970). Another interesting feature is the absence of any strong adverse relation between stability of yield and stability of flowering time as given earlier 1n the pooled regression analysis. Therefore, it would appear possible to combine stability for flowering with substantial response in yield with improved environment. Stability of 1000-grain weight which is yet to be completed in this study will Indicate if a reasonable degree of stability for this character can permit wider adaptation without sacrificing yield.

Factor Analysis

An earlier study of the world collection of sorghum and millet has shown considerable change 1n the factors for divergence in the semiprimitive cultivars as compared to those 1n highly selected material with substantial changes in the factor loadings (Murty et al 1970). A limited study in chickpea in this investigation has shown that the factor loadings and the proportion of the communality accounted for by each factor are different in the genotypic and the environmental matrix separately (Table 5). This can be explained on the basis of non-normality of the genotypic matrix. A minimum of four factors are necessary for the 20 characters to account for over 90% of the total variability. The first two factors have accounted for only 60% to 66% of the total variability indicating that there are mutually compensating factors in the divergence within this material in spite of the limited human selection.

The first factor is predominantly a growth factor including seedling establishment and photosynthetic activity. The loading in the second factor is related to seed development with substantial influence on leaf and leaflet size and reproductive potential. The crucial role of the reproductive period in the second and third factor in the genotypic matrix indicates that in addition to flowering time the duration of maturity from flowering is an important component for adaptation. Its influence on the degree of flower shedding needs further study. The factor loadings and the proportion of communality were different in the large world collection, indicating differences in the forces of divergence from those of the collection of primitive cultivars (Table 5a).

Genetic Divergence Using Generalized Distance

A classification of the same material for 21 characters using D2-stat1stic has resulted in eight clusters with a variety P.2415 from Iran being different from the rest. It is extremely late in flowering with the maximum lateral spread and the smallest leaflets. The cluster means reveal that among high yield groups, compact plant type and number of secondary branches and pods per plant are the major components of the divergence (Table 6). The composition of the clusters has revealed clear divergence between black and pink seeded types from the rest. It is likely that seed color is related to some other characters important for fitness. Black seeded types are invariably small while the pink types are quite large.

The analysis using generalized distance has shown that yield per plant is not adversely related with maturity, seed size and color and is in confirmation of the regression analysis mentioned earlier. The characters important for divergence from the distance analysis would appear to be seed size, lateral spread, leaflet size, pods per plant, and to some extent days to flower, the diversity among clusters was also substantial (7.36 to 77.29 units) and the intra-cluster divergence varied from 3.58 to 11.51. Earliness, limited lateral spread and more secondary branches and the length of reproductive branch and limited flower shedding and slow leaf drying would appear to be related to yield.

Recently, a similar analysis of nearly 5000 accessions of a world collection of chickpea by Dr. R.K. Jayaprakash of the University of Wales, Aberystwyth, in collaboration with the author has produced more data. Some other interesting features of divergences as measured by D^2-statistic among the advanced cultivars as compared to the primitive

Table 4. Pooled Estimates of Stability Parameters for Some Characters in 239 Chickpea Cuitivars During 1969-73

	Range of estimates			
	u	B	% SS due to Interaction	Linear Total.... Interaction
Leaf size	2.75-6.75	-1.59-5.23	57.72	36.46
Spread (cms)	34-69	-1.0-4.13	66.22	35.20
Leaf drying	3.0 -8.0	-3.1-4.5	73.12	37.69
Primary branches	2.25-12.0	-0.22-3.48	55.50	32.52
Pods/Sec. branches	3.5-10.0	-2.9-4.69	66.24	31.22
Seeds/10 pods	8.5-23.7	-1.97-4.87	58.10	28.13
Days to 50% flowering	80.75-115.75	0.23-3.04	25.16	38.28

Table 5. Factor Analysis of Divergence in Chickpea for 21 Characters

	Genetic			Environmental		
	I	II	III	I	II	III
1. Vigor	0.67	-0.12	0.47	0.57	-0.40	0.20
2. Chlorophyll	0.56	0.34	-0.41	0.29	-0.25	0.19
3. Leaf size	0.65	0.41	-0.39	-0.13	-0.19	0.17
4. Leaf drying	-0.66	-0.12	-0.78	-0.45	0.30	-0.23
5. Height	0.71	0.15	0.37	0.62	-0.45	0.22
6. Days to 50% flower	0.38	-0.96	0.03	0.32	-0.06	-0.29
7. Maturity	0.73	-0.32	0.37	0.55	-0.27	0.31
8. Primary branches	0.99	-0.08	-0.17	0.11	0.45	0.14
9. Reproduct. Length	0.17	0.77	0.61	0.29	-0.07	0.08
10. Pod No.	0.12	0.30	0.35	0.14	0.62	0.56
11. Seeds/Pod	-0.38	0.18	0.60	0.25	0.17	0.06
12. Seed Size	0.69	-0.11	-0.60	0.20	0.14	-0.32
13. Proportion to total communility	47.7	17.9	22.0	34,0	26.4	14.8
	I-IV - 98.7			I-IV -85.3		

Table 5a. Factor and Canonical Analyses of Diversity for 8 Characters in 5474 Accessions of Chickpea

Variable	Factor Loadings		Canonical Vectors	
	I	II	Z_1	Z_2
Plant Type	0.361	-0.219	-0.652	0.193
Flower Color	0.598	-0.504	0.076	0.495
Days to Flower	0.132	0.396	0.009	0.015
Days to Maturity	0.249	0.505	-0.009	-0.043
Pod Size	-0.250	0.176	0.337	0.093
Seeds/Pod	0.442	-0.109	0.286	0.448
100-Wt.	-0.322	0.402	0.467	0.363
Seed Color	0.416	0.647	0.394	-0.612
% Contribution	38.9	47.2	45.5	23.8
Residual	13.9			

$\lambda_1 + \lambda_2 = 69.3, \quad \sum_{1}^{3} \lambda_i = 86.2$

Rest (λ_4 To λ_8) = 13.8

Source: Jayaprakash, R.K. (Unpublished)

Table 6. Cluster Means for Chickpea Collection Classified by D_2 statistic

Cluster	Leaflet size	Days to 50% flower	Lateral spread cms.	Sec. Br.	Pods/ plant	Seeds/ pod	Seed size	Seed yield per plant
I	5.0	93.6	78.5	17.4	68.5	1.4	3.3	16.7
II	4.5	94.5	86.0	13.9	49.3	1.8	2.2	13.4(BL)
III	6.0	96.0	71.9	17.1	63.8	1.5	3.2	17.4
IV	7.6	100.2	90.6	18.1	42.3	1.1	6.9	9.9(P)
V	6.7	96.5	82.5	16.2	46.9	1.2	5.1	4.2
VI	7.6	98.4	88.2	15.7	56.9	1.6	3.5	15.5
VII	4.5	97.8	71.4	17.2	41.1	1.4	3.1	9.8
VIII	4.0	107.7	91.3	14.2	44.5	1.3	3.0	5.7(LP)

BL= Black; P = Pink; LP = Light Pink; Rest are yellow & brown cultivars particularly on the limited role of flowering time in the divergence among the advanced cultivars has been noted. (Table 6a).

CONCLUSION

The present study has been concentrated only on stability for yield and flowering. Limited information is available on protein content of this material in different environments which suggest that it is possible to combine stability of yield with moderate stability for protein content. More studies in this direction including relative stability of amino acid levels need to be undertaken. The results have also shown that the so-called adverse association between yield, resistance and grain size in chickpea are more due to genetic erosion rather than physiological limitation. Fifteen varieties of chickpea 'have been selected on the basis of their productivity for further work: P.4257, 4307, 4334 4420, 4426, 4549, 4560, 4713, 4954, 4989, IVP-113, ICP-117 and ICP-118.

Acceptability as described by PAG is greater for large seeded types which are presently highly susceptible to Ascochyta, while the small seeded, highly wrinkled, brown types which are resistant to Ascochyta but are not favored except for some limited preparations. The present study has indicated that it is possible to combine seed size with yield and disease resistance. It would also appear possible to improve productivity by superimposing the plant structure to improve the harvest index simultaneously with resistance to Ascochyta and large seed size. This may be possible by broadening the genetic base with wide crossing at intraspecific level utilizing the locally adapted cultivars as donors of adaptive genetic blocks into the otherwise better yielding genotypes. Studies on the relationship between wide adaptation with inherent photosynthetic and respiration efficiency and rhizobial nitrogen fixing processes and photosynthetic source-sink manipulation as was done in soybean by Lawn and Brun (1974) will be useful. Mutational rectification specifically for resistance to Ascochyta would be possible as a short-term measure in the large seeded, yellow colored chickpea varieties which already have a high yield potential particularly in the Near East and South Asia.

Table 6a. Cluster Means for 8-Characters in World Chickpea Collection Using D'statistic

Cluster Character	I	II	III	IV	V	VI
Plant Type	1.58	1.95	2.40	2.03	2.13	1.95
Flower Color	1.55	2.33	1.65	2.83	2.00	1.96
Days to Flower	108.00	104.60	103.90	104.20	104.00	106.50
Days to Mature	179.80	178.00	178.70	177.30	175.20	180.60
Pod Size	2.35	2.20	2.09	2.40	2.31	2.38
Seeds/10 Pods	13.50	14.10	12.30	16.10	14.30	13.00
100 Seed Wt. (gms)	19.03	15.60	13.80	17.76	16.57	18.53
Seed Color	2.75	1.57	3.25	3.06	4.28	3.08

Source: Jayaprakash, R.K. (Unpublished)

DISCUSSION

K.B. Singh: I wish to know from Dr. Murty how after selecting widely adapted varieties and making crosses with high yielding ones, one should select plants in the segregating populations for wide adaptation.

B.R. Murty: There are several possibilities but in my opinion the most practical way would be to grow and select the material at two locations. This should be followed by multilocation tests to identify widely adapted genotypes.

H.K. Jain: The concept of coadapted gene complex is an idea of population genetics. If this is so, the germplasm from different parts of the world could be presumed as genetically diverse and utilized accordingly. This may facilitate avoiding the arduous analysis of the germplasm based on Mahalnobis' D-square statistics.

S. Chandra: Some of the varieties which are not widely adapted when crossed produce widely adapted offspring. This wide adaptation was achieved by multilocation tests.

LITERATURE CITED

Anonymous. 1972. *Report on legume breeding by protein advisory group*, 21st meeting, New York, June 1973.

Eberhart, S.A. and W.A. Russell, 1966. Stability parameters for comparing varieties. *Crop Sci*. 6: 36-40.

Frankel, O.H. and E. Bennett. 1970. Genetic resources in plants - their exploration and conservation. Blackwell Sci. Publ. Oxford and Edinburgh. L-544.

Holzinger, K.J. and H.H. Harman. 1941. *Factor analysis.* Univ. of Chicago Press, Chicago.

Lawn, R.J. and W.A. Brun. 1974. Symbiotic nitrogen fixation and soybeans. I. Effect of photosynthetic source-sink manipulations. *Crop Sci*. 14: 11-16.

Murty, B.R. 1970. Analysis of adaptation of world collections and new hybrids of sorghum and Pennisetum. *Afr. Soils* 15: 707-719.

Murty, B.R., V. Arunachalam and O.P. Jain. 1970. Factor analysis in relation to breeding system. *Genetica* 41: 179-189.

Perkins, J.N. and J.L. Jinks. 1968. Environmental and genotype-environmental components of variability. *Heredity* 23:339-356

Rao, C.R. 1952. *Advanced statistical methods in biometric research*. John Wiley & Sons, New York.

Rao, C.R. 1972, Recent trends of research work in multivariate analysis. Biometrics 22: 3-22.

SESSION REVIEW

G. C. Hawtin[1]

Both the papers presented in this session have stressed the importance and urgency of collecting germplasm. Dr. van der Maesen has pointed out that over 70% of both crops are still growing from local landraces, but we cannot afford to be complacent as this situation could change very quickly if new very high yielding varieties are released. Mention was made of the work of the International Board for Plant Genetic Resources and I would urge close cooperation with this organization in the collecting and evaluation of germplasm. At least two of the proposed centers have a direct relevance in the preservation of chickpea germplasm, the one at Izmir in Turkey and the one proposed for Ethiopia.

Dr. van der Maesen put great emphasis on the collection of related wild species in addition to the local cultivars. From the few attempts which have been made so far at interspecific hybridization within the genus Cicer, no successes have been reported. It is suggested that more research be devoted to this as the potential benefits are considerable both with regard to disease resistance and other factors such as the perennial habit, and drought tolerance.

It was said that political inaccessibility frequently poses a greater problem than topographical inaccessibility, and whereas this may be true for certain key regions, the problem of topographical inaccessibility certainly should not be overlooked. From recent experience of collecting pulses in Afghanistan it was found that the region in which collecting was possible, even using four wheel drive vehicles, was relatively small and it is now felt that If we undertake future collection in that country much of the travelling will have to be on horseback, by donkey or on foot. The area which can be covered in this manner is obviously very limited and the only realistic way to get around this problem is to train local nationals in the relevant taxonomy and techniques of collection. Problems of language, as mentioned by Dr. van der Maesen, would also largely be overcome by the use of such personnel.

Some interesting comments were made regarding the maintenance of collections and I think more thought must be given to this aspect. Several approaches are currently being used at different institutes. I am aware of one program which has been maintaining its collections by a process of single plant selection. The method used at ALAD is to try and keep the genetic constitution of a sample exactly as it was received, and working collections are obtained from this by a process of single plant selection.

I feel that it is very important that world germplasm collections be maintained at more than one location, as an insurance against loss, however caused.

I was interested in the reported low number of samples which can be collected per day. From our experience in Afghanistan I would suggest that one useful way of increasing this is to obtain seed at the local markets, where one can often buy samples directly from farmers. From discussion with the farmer, many of the required details as to the exact location, and environment of origin can be ascertained.

Dr. van der Maesen has stressed the need for further work on the intraspecific taxonomy of Cicer arietinum and rightly, I feel, pointed out that any such classification should be of relevance to a breeder. The paper given by Dr. Murty goes some way towards this, and he has demonstrated a number of important groupings within the material studied. Nearly all the plant characters mentioned were of potential use to a breeder and he has gone a long way towards characterizing the divergence.

The concept of gene constellations is an important one and I think Dr. Murty has made some very valid comments regarding the breaking up of these adaptive gene groups.

The next stage has to be a genetic analysis to determine just what will be the significance of breaking these constellations, and to determine the extent of the gene linkages involved.

---

[1] Arid Lands Agricultural Development Program, Ford Foundation, Beirut, Lebanon

One final comment I would like to make is on the question of photoperiodicity. With the exception of one publication, all the findings to date have suggested that chickpea is a quantitative long day plant. We heard this morning from Dr. Corbin that he has been able to find three different reactions to photo-period in the material he has studied. I feel that further work must be done on this and the effects of other environmental factors, since it is of very great importance in the understanding of such data as was presented to us by Dr. Murty.

SIXTH

SESSION

BREEDING CONCEPTS AND TECHNIQUES FOR SELF-POLLINATED CROPS[1]

K. J. Frey[2]

Basically, the breeding of any species of crop plants, regardless of its natural breeding system, involves two phases: (a) the creation of a reservoir of genotypic variation and (b) selection among the genotypes.

METHODS FOR CREATING GENOTYPIC VARIATION

Review of Experimentation

After the original genotypic variation available from introduction and/or natural sources has been exploited, a breeder is confronted with the need to "create" a new reservoir of genotypic variation upon which to practice selection. It was at this point that breeders of self-fertilizing small grain species found themselves 1n the 1920's and 1930's.

Hybridization

To create the new reservoirs of genotypic variation that they needed, these plant breeders began to use hybridization to enhance recombination among genes from different genetic strains. An alternative method for creating reservoirs of genotypic variation, of course, is via induced mutations. The background research for this breeding methodology was being done by Stadler (1928, 1932), Muller (1932) and Gustafsson (1947) during the same period when use of hybridization became popular. More will be said about mutation breeding later in this paper.

During the years of the Twenties and early Thirties, hybridization in self-fertilizing species involved biparental crosses almost exclusively; and even today, a half century later, most hybridizations in these species are still biparental. The recombination possible from blparental crosses are too restrictive to permit rapid improvement in selfing species.

Multiple Crosses

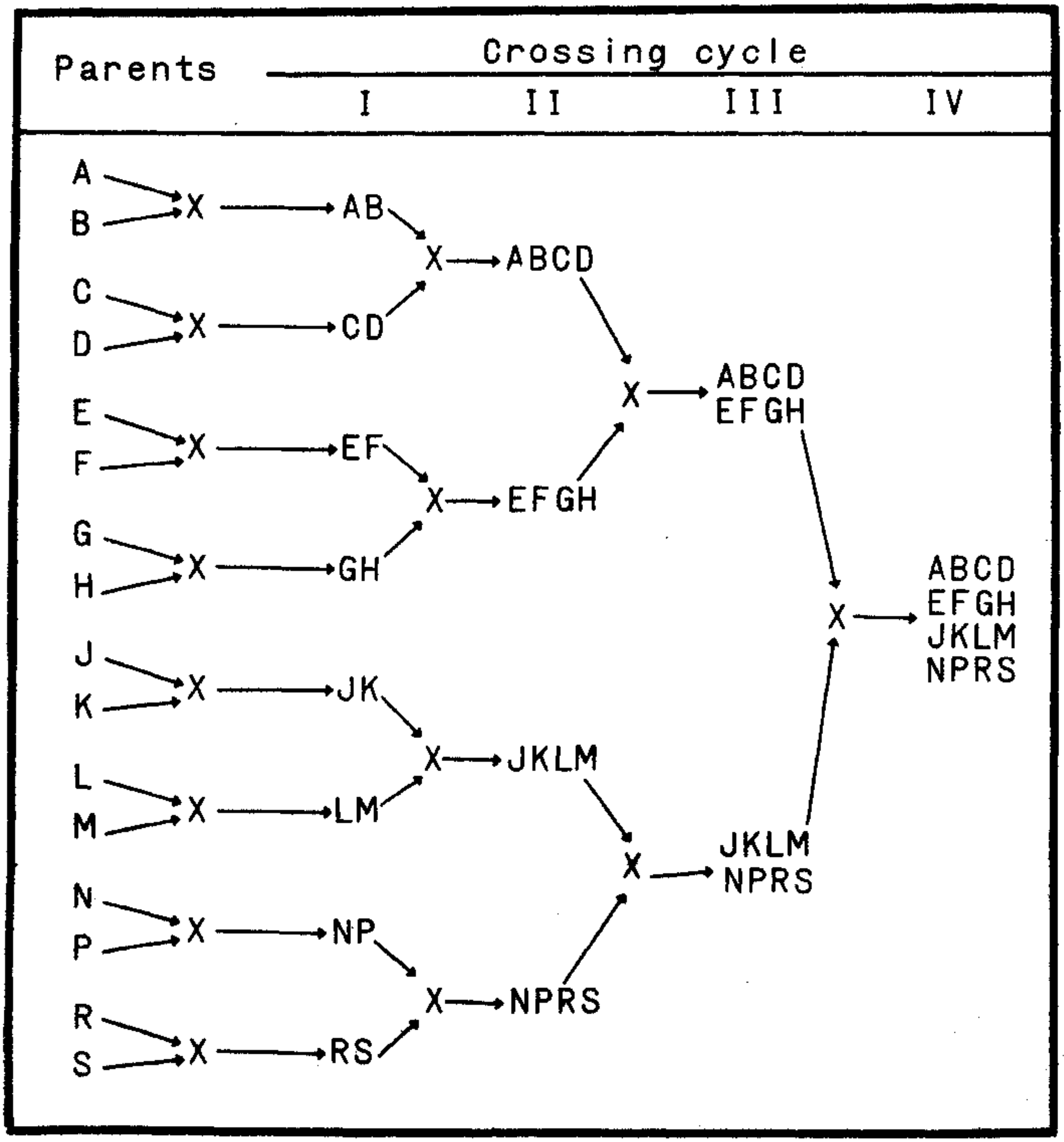
To overcome this limitation, Harlan et al. (1940) proposed the use of multiple crosses. This was a mating scheme whereby 16 or 32 parents are crossed 1n successive generations into single crosses, double crosses, octuple crosses, etc., (Figure 1) until the final hybrid involves all parents. Theoretically, the multiple cross provided opportunity for recombination among genes from many parental strains. However, there were two practical limitations relative to multiple crosses. First, it was not practically feasible in the later generations of the mating scheme to obtain enough F1 seeds to retain all parental genes in the final crossing generation. Akerman (1946), assuming a multiple cross with 16 parents each of which carried one unique, desirable gene, calculated the number of hybrid seeds needed in each generation of the crossing program to insure a 50:50 chance of retaining all 16 genes 1n one plant 1n the final generation. The numbers of crosses were 8, 64, 131,000, and 64.000[4] 1n the first, second, third, and final crossing generations,

---

[1] Journal Paper No.J-8072 from the Iowa Agriculture and Home Economics Experiment Station, Ames, lowa 50010. Project 17S2.

[2] lowa State University, Ames, Iowa, U.S.A.

Figure 1. Diagram of a Multiple Cross Involving 16 Parents (Harlan et al, 1940)



respectively. Obviously, even with a male sterility system to aid in making crosses, these numbers of hybrid seeds would never be attained. Nevertheless, the multiple cross does provide a genetic matrix for simultaneous recombination of genes from several sources.

The second practical limitation with the multiple cross system was suggested by MacKey (1954). He commented that using 16 to 32 parents in a multiple cross would force the inclusion of an unduly large number of unadapted strains. These would tend to undo the good genetic background that it took plant breeders many years and even decades to assemble.

Modified Backcrossing

MacKey suggested using a modified backcrossing program to obtain optimum parental materials with which to carry out the multiple crossing scheme. With this modification, each unadapted parent would be crossed and perhaps backcrossed to an adapted strain of the species before it was used in the multiple cross (Figure 2). In this diagram, U1 to U8 represent 8 unadapted strains and A represents an adapted variety. Of course, more than one adapted variety could be used in this scheme. As illustrated in Figure 1, the materials to be used to initiate the multiple cross would consist of 75% germplasm from the A source and 25% from the U1 to U8 sources. Without any backcrossing, the ratio of A to U_x germplasm would be 50:50, and with two backcrosses, 1t would be 87.5:12.5. The proportion of U_x germplasm that would be desirable in a population resulting from a multiple cross, obviously would depend upon the degree of "unadaptedness" or "exoticness" that the U_x strains represented. If the U_x strains were merely introductions of the same cultivated species adapted to other environments 1n the same latitude, perhaps simple single crosses of the type U_xxA would be adequate. On the other hand, Lawrence (1974), who introgressed germplasm of <u>Avena sterilis</u> L., a weedy oat from the Mediterranean area, into the cultivated oat, A. <u>sativa</u>. found it necessary to backcross two to four times before the base of "adapted germplasm" was appropriate for a practical breeding program. With these levels of backcrossing, the expected proportions of A. <u>sativa</u> germplasm ranged from 87.5% to 96.6%. ALSO, the backcross could be substituted by 3-way or 4-way crosses of the general type Ux x A1 2x A2 or Ux x A1 2x A2 3x A3, where A1 to A3 represent different adapted varieties or the species.

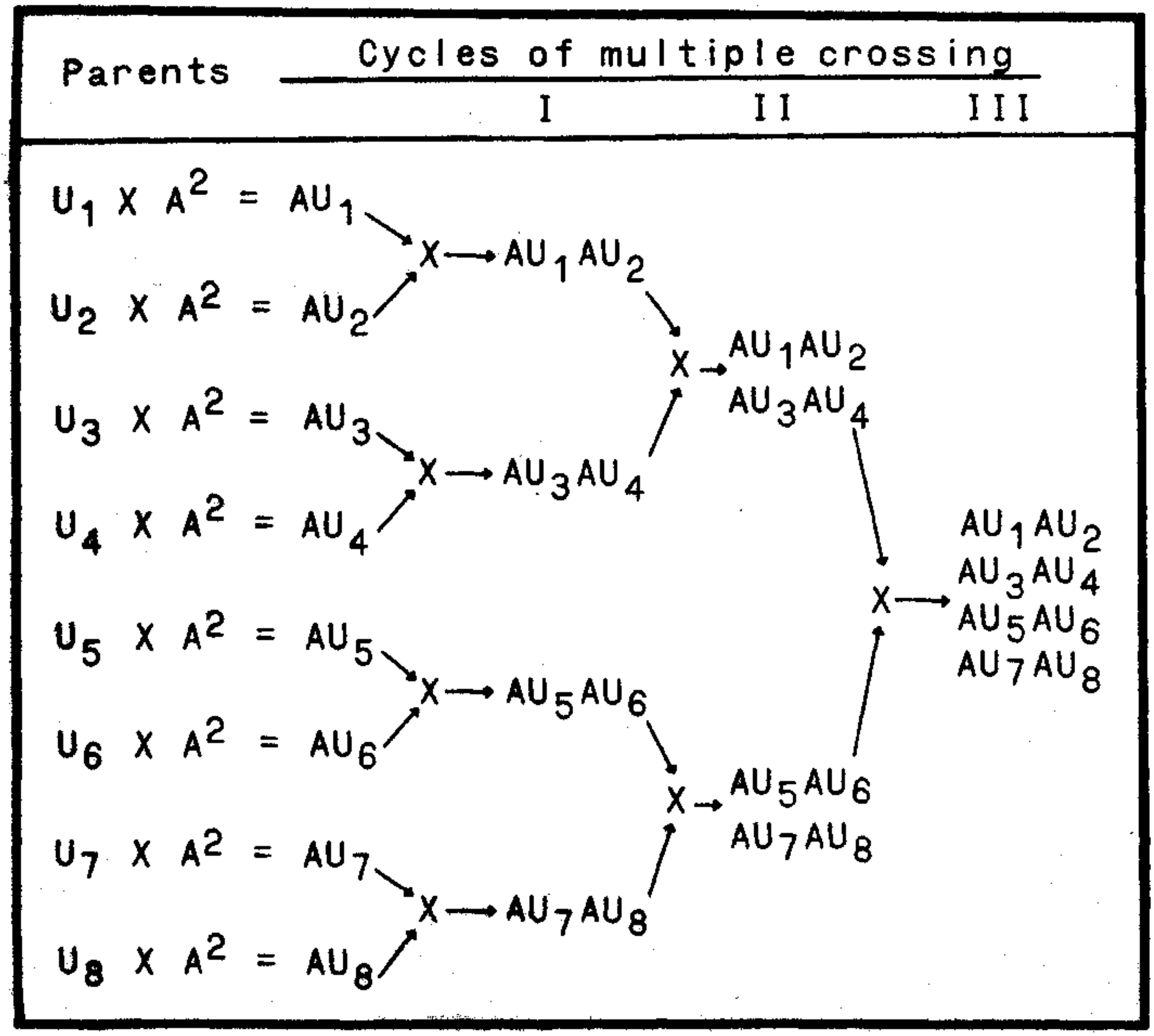
Mutations

Another method by which plant breeders can create genotypic variation is via induced mutations. The basic research on this subject was done by Muller (1932) and Stadler (1928a, 1932) who showed that X-ray treatment of Drosophila and cereal seeds, respectively, would induce mutations. Stadler (1932) was discouraging in his assessment of the value of mutation induction to plant breeding, but the massive experiments conducted by Gustaffson (1947) in Sweden showed its real usefulness. Evidently, the array of mutations induced by mutagen treatment of plant tissues is more or less identical to that which occurs spontaneously, but the rate of mutation occurrence is increased manifold. Space and time will not permit a thorough review here of the mutation research related to plant breeding. It suffices to say that mutations have been induced 1n every plant species tested, both by radiations and by chemical mutagens. As shown by Chandhanamutta and Frey (1975) and Hagberg et al. (1958), genotypic differences occur 1n susceptibility to induced mutation, and there 1s some evidence for a relationship between mutagen used and mutations induced (McKelvie, 1963; Lundqvist and Wettstein, 1962).

The mutation process still is obscure, however, and methods for mutagen treatment are sufficiently crude that the best advice for the breeder who creates genotypic variation by mutagenic treatment is to treat the best adapted strain of his species with a mutagen that is most convenient for him to use. The value of induced genotypic variation for plant improvement was summarized by Sigurbjornsson and Micke (1974). Their summary shows that 98 varieties of field crops and 47 varieties of ornamental plants have been developed through induced mutations. Practically all the improved field crop varieties belong to self-fertilizing species.

With the multiple cross method and by using MacKey's modification to retain good gene combinations, a whole new dimension occurred for obtaining genotypic recombinants that *never* existed before in breeding populations of self-fertilizing species. The obstacle to recombination among alleles at linked loci, however, still remained as a significant barrier to making improvements in self-fertilizing species. With selfing, heterozygosity, which is necessary for effective crossing over and recombination among alleles at linked loci, decreases very rapidly to an ineffective level. Two methods have been tried for increasing recombination among alleles at linked loci.

Figure 2. Diagram of Modified Backcrossing Program Proposed by Mackey (1954) to Obtain Parental Materials for a Multiple Cross Involving 8 Unadapted Parents. (U, to U, represent 8 unadopted strains and A represents an adapted strain:)



Male Sterility

Suneson (1945) introduced a male sterility (ms) gene into a barley bulk population to promote outcrossing. It was effective in promoting outcrossing and heterozygosity in the bulk population, but the ms allele had a decided selection disadvantage in the population, and its frequency decreased to a very low value within several generations. Its effectiveness for increasing heterozygosity in the bulk population was soon lost. Use of a combination of cytoplasmic male sterility and fertility restoration genes in the bulk population has been proposed by Jensen (1970), and it could be an effective way to retain a high degree of outcrossing for those species that have such a mechanism available e.g., wheat. Probably there would be a selective advantage for plants that carried the fertility-restoration alleles, and the effectiveness of this mechanism for promoting heterozygosity would be ephemeral. There is some evidence that too much crossing over in the selfing species, e.g. barley, can be detrimental to fitness.

Other Methods

Attempts have been made to modify the crossing over percentage 1n heterozygous plants by treatment with extrinsic factors, such as actinomycin-D, heat shock, and deficiency of calcium. Mock (1973) summarized this research area and concluded that, although some treatments have seemed to show promise for increasing crossing over between loci on the chromosomes of plants and animals, no consistently effective treatment has been found yet. Grindeland and Frohberg (1966), using radiation treatment of oat seeds to cause male sterility, showed that outcrossing among the resultant plants was increased from 0.8% to over 5.0%. This degree of outcrossing was effective In promoting heterozygosity (Fatunla and Frey 1974).

METHODS OF SELECTION

Bulk Methods

With the very large genotypic variation available from applying the multiple cross method to selfing species, segregating populations no longer could be managed via pedigree selection. Plant breeders, therefore, turned to "bulk" methods for carrying the segregating populations (Harlan et al. 1946).

Much original data on the destiny of genotypes in a bulk population were gained from mixtures of four to ten pure line varieties, propagated for several generations, and then analyzed for varietal survival in the composite. Typical experiments of this type were reported by Suneson (1949) and Mumaw and Weber (1957) for barley and soybeans, respectively. After 16 years of propagation, the dominant barley bariety was Atlas (Table 1), the variety which 1n pure stand was the lowest yielding of the four included in the mixture and, additionally, was susceptible to all major barley diseases present in California. Mumaw and Weber (1957) mixed three soybean varieties 1n equal proportions and after five generations of propagation at Ames, Iowa, the percentages were 75, 25, and 0 for Bavender Special, Hawkeye, and Adams varieties, respectively. The dominant variety was an unadapted and heavily branching type. From the available data on varietal mixtures in self-fertilizing species, it seemed that any relationship (i.e. positive, none, or negative) could exist between ability of a genotype to survive in a mixture and its productiveness 1n pure stands.

Natural Selection in Bulking

As data became available from survival value in bulk populations of segregates from multiple crosses, an entirely different picture began to appear. Suneson (1956) showed that natural selection caused bulk populations from multiple crosses of barley to become higher yielding (Figure 3). In 28 generations of propagation, the yield of CC II increased from77%to 103% of Atlas variety. CC V, CC XII, and CC XIV all began at a higher yield level in the first generation (about 85% of Atlas), and within 14 generations, all had evolved to a bulk yield equivalent to Atlas. Jain (1961) proved that the CC II bulk yield increased because there was a selective advantage within the population for high yielding plants (Table 2). Yield Increases of lines within CC II were due to the selective advantage for genotypes that produced large numbers of seeds. Frey (1967) found that the means of random oat lines from successive generations of Bulk oat populations showed no significant changes for 100-seed weight, heeding date, and plant height over a period of seven years of propagation (Table 3). Likewise, Reyes and Fray (1967) found no change for grain yield means of eat lines from successive generations of bulk populations, and Tiyawalee and Frey (1970) shewed that the frequency of en allele for crown rust resistance remained constant at 0.2 over 10 generations of bulk propagation.

Figure 3. Yield Trends of Bulk Populations of Composito Crosses of Barley with Advancing Genotttions of Propagation in California (Suneson, 1956)

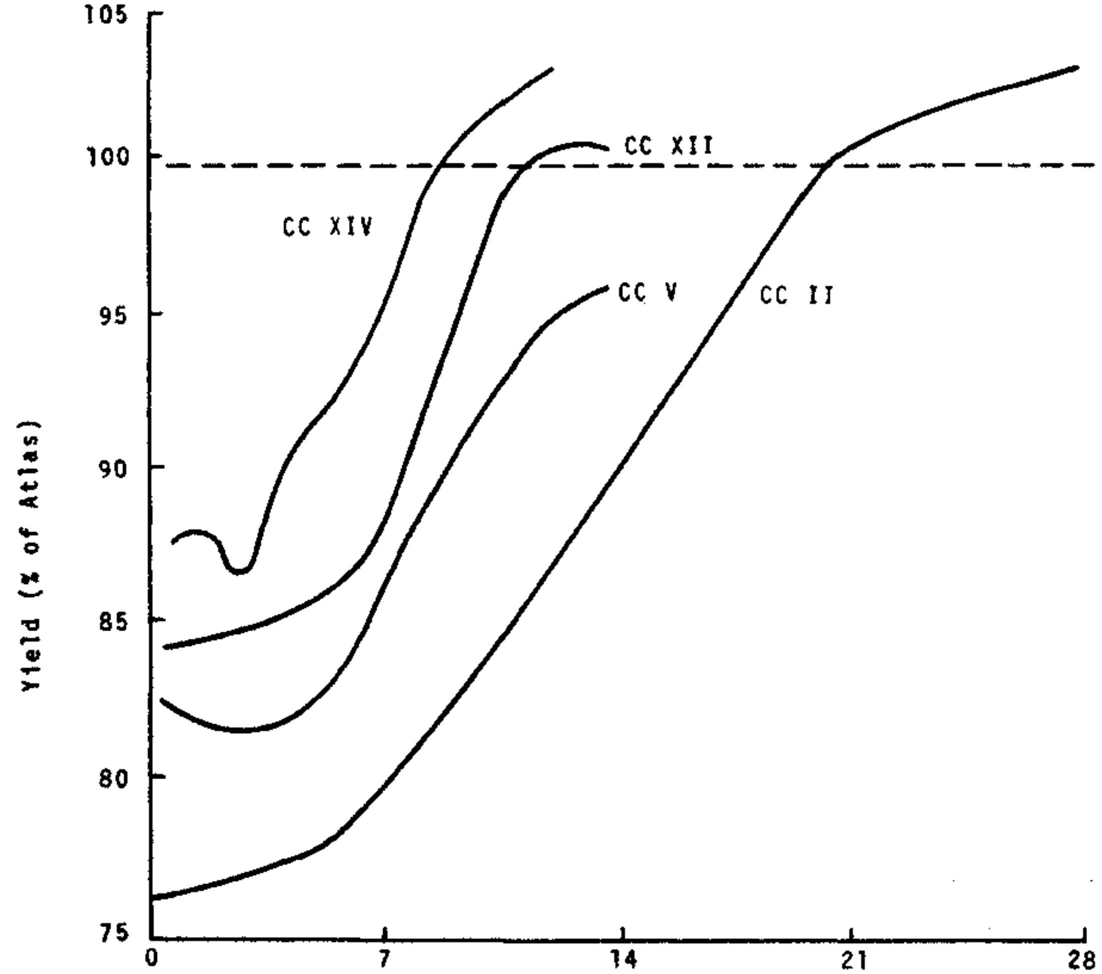


Table 1. Percentages of Four Barley Varieties Surviving in a Mixture After Different Numbers of Generations of Propagation. Suneson 1949

Variety	Number of generations of propagation				
	0	4	8	12	16
Atlas	25	43	63	75	88
Club Mariout	25	23	17	16	11
Hero	25	13	8	4	1
Vaughn	25	21	12	3	0

Table 2. Grain Yields and Numbers of Seeds Produced by Progenies from Various Generations of Barley CCII. Jain 1961

Generation	Yield (gm)	No. of seeds per line (1000s)
F_4	307	7.94
F_7	305	7.90
F_{14}	353	8.52
F_{19}	395	9.44

Table 3. Regression Coefficients for Means of 100-Seed Weight, Heading Date, and Plant Height from Random Oat Lines from Bulk Populations Propagated for 7 Generations

Trait	Regression coefficient[1]
100-seed weight	0.00
Heading date	0.24
Plant height	0.58

[1] No regression was statistically significant

Natural selection may cause evolutionary changes for mean expression of a trait in a bulk population of segregates in a selfing species, but the evidence to date suggests that natural selection will cause either no change or change in a desirable direction from the viewpoint of plant breeding objectives.

Survival in genotypic mixtures and in bulk populations of segregates from crosses can lead to very different conclusions relative to the usefulness of bulk population breeding. Probably the differential results are because mixtures of varieties represent relatively simple systems of competition at the plant level, whereas bulk populations of segregates represent very complex systems of competition at the trait or gene level. Experience gained with bulk populations over the past two decades has led to Its rather wide adoption as a propagation method in many breeding programs with self-fertilizing species.

Single-Seed Descent

Grafius (1965) and Brim (1966) proposed a modification of the bulk population method which has become known as "single-seed descent'. With this procedure, one or two random seeds are harvested from each plant in the bulk planting to form the seed source for the next generation. It is designed to preserve the total range of variation throughout the propagation period and to minimize the effects of natural selection in changing the genotypic *array in* the original population.

Pedigree Selection Procedure

To this point, I have laid stress on concepts and methods for creating genotypic variation and allelic recombination. Most fundamental research emphasis in plant breeding has been placed *on* the other phase, namely, selection. Before the rediscovery of Mendel's Laws, most assuredly, the primary technique of selection used was mass selection. The rediscovery of Mendel's Laws placed emphasis on the particulate nature of inheritance, and this led to the adoption by plant breeders of the pedigree selection procedure for selfing species. This method was highly effective for selecting simply inherited traits and pure line varieties. The growing of individual plants, as required with the pedigree method, was expensive in time and money, so it was not possible to utilize large numbers of segregates in a breeding program. And, when attempting to improve a quantitatively inherited trait and/or to select several traits simultaneously, very large numbers of plants and progenies had to be evaluated.

Mass Selection

As already noted, Harlan et al. (1940) devised the bulk method to propagate large numbers of plants and progenies inexpensively. This method as proposed, fortunately and unfortunately, proved to be an inexpensive propagation method only, with no a priori effect on population improvement. Under some environmental conditions, natural selection caused improvement in the bulk population, but the most effective technique for upgrading a trait mean in a population was mass selection. Work on bulk populations of the selfing species oats (A. sativa) and soybeans (Glycine max) has shown that very crude mechanical mass selection techniques can be highly effective for changing trait means in populations. For example (see Table 4), Romero and Frey (1966) clipped populations of oat plants to a uniform height for four successive generations and caused a mean reduction of 1.2 cm in mean plant height per generation. Tlyawalee and Frey (1970) subjected a bulk oat population to artificially induced epiphytotics of crown rust and winnowed the seed produced on the resultant plants. Heavy seeds, supposedly produced on resistant plants, were saved to propagate the next generation. In seven cycles of this type of mass selection, the frequency of the resistance gene was increased from 0.21 to 0.35.

Table 4. Changes in Means of Random Lines from Bulk Oat Populations Caused by Mechanical Mass Selection

	Trait		
	Plant[1] height	Rust[2] resistance	Seed[3] weight
	(cm)	(gene frequency)	(gm/100)
Generations of mass selection	4	7	5
Mean in -			
first generation	101	0.21	2.55
last generation	96	0.35	3.03

1 From Romero and Frey (1966)
2 From Tlyawalee and Frey (1970)
3 From Frey (1967)

Indirect Mass Selection

Indirect mass selection has also been used effectively. Frey (1967) reported that a screening technique for wide seeds increased seed weight by 0.1 g/100 seeds (about 3%) per generation. Several cases have been reported where indirect mass selection (i.e., selection for trait 1 is practiced by selection for trait 2) has been successful. For example, when Frey (1967) selected for increased seed weight of oats, the grain yield was increased 9.0% after four cycles. Hartwig and Collins (1962) classified seed from F_4 soybean plants according to density, and the mean seed-protein percentage was 44% for heavy progenies and 41% for light progenies. On the other hand, heavy progenies contained 19% oil, whereas light ones averaged 22%.

Problems of Mass Selection

Mass selection is a *very* effective and inexpensive technique for increasing the proportions of desired genotypes in bulk populations of self-fertilizing plants. This technique applied to bulk population of selfing species has some disadvantages also, First, it tends to be a relatively slow method for changing gene and/or genotypic frequencies when compared to pedigree and pureline methods. Secondly, Frey and his coworkers [Tiyawalee and Frey (1970); Frey (1967); Romero and *Frey* (1966)] have shown that selection for a desired expression of one trait may result in undesirable changes in other traits due to repulsion-phase linkages. For example, Frey (1967) and Chandhanamutta and Frey (1973) showed that selection for wide seeds and heavy panicles, respectively, in bulk oat populations, resulted in sizeable increases in mean yield, but simultaneously, plants in the populations became later and taller. Both of the latter traits are undesirable in Midwestern USA because late oat varieties are susceptible to heat damage and tall oat varieties are lodging susceptible. Third, mass selection only Increases the frequency of genotypes already present in the population because it provides no opportunity for recombination among genes carried by selected genotypes.

METHODS FOR SIMULTANEOUSLY CREATING GENOTYPIC VARIATION AND SELECTION

Recurrent Selection

All other selection procedures used in breeding of self-fertilizing crop plants involve simultaneous or concomitant selection and recombination. Intuitively, recurrent selection should be an effective breeding procedure for improving self-fertilizing species. Khadr and Frey (1965) have used it successfully to increase seed weight in oats. As these authors point out, however, the greatest deterrent to using recurrent selection with selfing species is the difficulty in making the large numbers of intercrosses among selected lines required with this method. Because crossing of oats was so tedious and time consuming, they proposed alternating pedigree and recurrent selection cycles, in contrast to repeated recurrent selection, to insure that the selected parents were indeed elite for the selected trait (Table 5). The total predicted gain for continuous recurrent selection was 25% of the population mean accomplished in six years, whereas the total predicted gain from alternating pedigree and recurrent selection was 20% of the population mean accomplished in five years. Therefore, the gain per year was 4% with both methods, but the alternating system was done with half the cost of crossing.

Recurrent selection can be carried out in bi- or multiparental populations. Genetic

Table 5. Schedules for Continuous Cycles of Recurrent Selection and for Alternating Cycles of Recurrent and Pedigreed Selection Using Variability Induced by Irradiation. Khadr and Frey 1965

Year	Season*	Stage with	
		Continuous recurrent selection	Alternating recurrent and pedigreed selection
1-2	Winter	M_1[+] plants	M_1 plants
2	Summer	M2 plants	M2 plants
3	Summer	M_3 test	M_3 test
3-4	Winter	Intercross and grow R_1F_1 plants	Grow plants within selected lines (P)
4	Summer	R_1F_2 plants	P1 test
4-5	Winter		Intercross and grow R_1F_1. plants
5	Summer	R_1F_3 test	R_1F_2 plants
5-6	Winter	Intercross and grow R_2F_1 plants	
6	Summer	R_2F_2 plants etc.	etc.

* Winter and summer season crops would be grown 1n the greenhouse and field, respectively.

[+] M, R and P refer to mutation, recurrent selection and pedigreed generations, respectively.

and/or cytoplasmic male sterility could be used as aids to make the large numbers of crosses required in a recurrent selection program, but the more or less perfect tool for use here woula be a chemical male sterilant. Ethrel (Rowell and Miller, 1971) has been reported as an effective male sterilant for small grains, but the results of these re-, searchers cannot be verified. Therefore, to date, no effective male sterilant is available to aid the use of recurrent selection for any selfing species.

Diallel Selective Mating System

A breeding method for self-fertilizing crops called "a diallel selective mating system" has been proposed by Jensen (1970) (Figure 4). This procedure provides (a) for using a selected group of parents, (b) continual Introgression of new germplasm as desired, (c) opportunity for multiparental gene recombination, (d) continual upgrading of the desired gene frequencies in the bulk population, and (e) continued recombination among selected genotypes. Additionally, it provides an instant genotypic pool for selection of varieties. With this method, all possible biparental combinations are made among n selected parents, and depending upon the number of F_1's, a diallel or partial diallel set of crosses would be made among the F_1's. The set of crosses among F_1's would be trie material for Initiation of a breeding population.

The population would be propagated into the F_2, when some forms of mass and visual selection would be applied, and subsequently, many random crosses would be made among selected F_2 plants. Mass and visual selection with intercrossing among selected plants could be continued 1n every generation or every second generation to maximize heterozygosity, crossing over, and recombination among alleles at linked loci from the multiparental matrix. Of course, resources and personnel available to the breeder would determine the amount of hybridizing that could be done in such a program. This method has not yet been tested for its efficiency or efficacy. It provides an ever present pool from which to select pure line varieties, and opportunity exists to adjust the germplasm base by introgression at any time.

Experiments with Cereals

Over time, a number of very significant changes have occurred 1n plant breeding methodologies for self-fertilizing species as exemplified by studies with cereal grains. For highly heritable (and usually simple-inherited) traits, pedigree selection and biparental recombination were adequate to meet the improvement needs. Experience soon dictated, however, the needs for multiparental recombination of genes and the availability of very large numbers of segregates. Multiple crossing with its modifications and bulk-population propagation answered these needs. Ultimately, it became obvious that the greatest gain could be had in plant breeding if recombination, instead of being random, occurred among selected genes, and recurrent selection was the obvious answer to this need. This procedure, of course, amalgamated the two phases of plant breeding (i.e., creation of genetic variation and selection) into a cyclic continuum. The diallel selective mating system amalgamates all phases in plant breeding into a dynamic system in which the breeding population is fluid with respect to germplasm quality and there is ample opportunity for selection. Remaining, however, are two problems: (a) how to obtain mass crossing, and (b) how to obtain more recombination among alleles at linked loci.

Backcrossing and Multiline Varieties

Backcrossing is a special technique that has been applied extensively for breeding self-fertilizing crops. This technique, first proposed by Harlan and Pope (1922), usually 1s used to replace an allele at a locus that conditions the qualitative inheritance of a trait. It has been used most extensively to add genes that condition resistance to a disease to an already elite variety. Briggs and Allard (1953) list the following requisites for a successful backcrossing program:

(a) existence of a satisfactory recurrent parent variety,

(b) high expressivity by the allele being added,

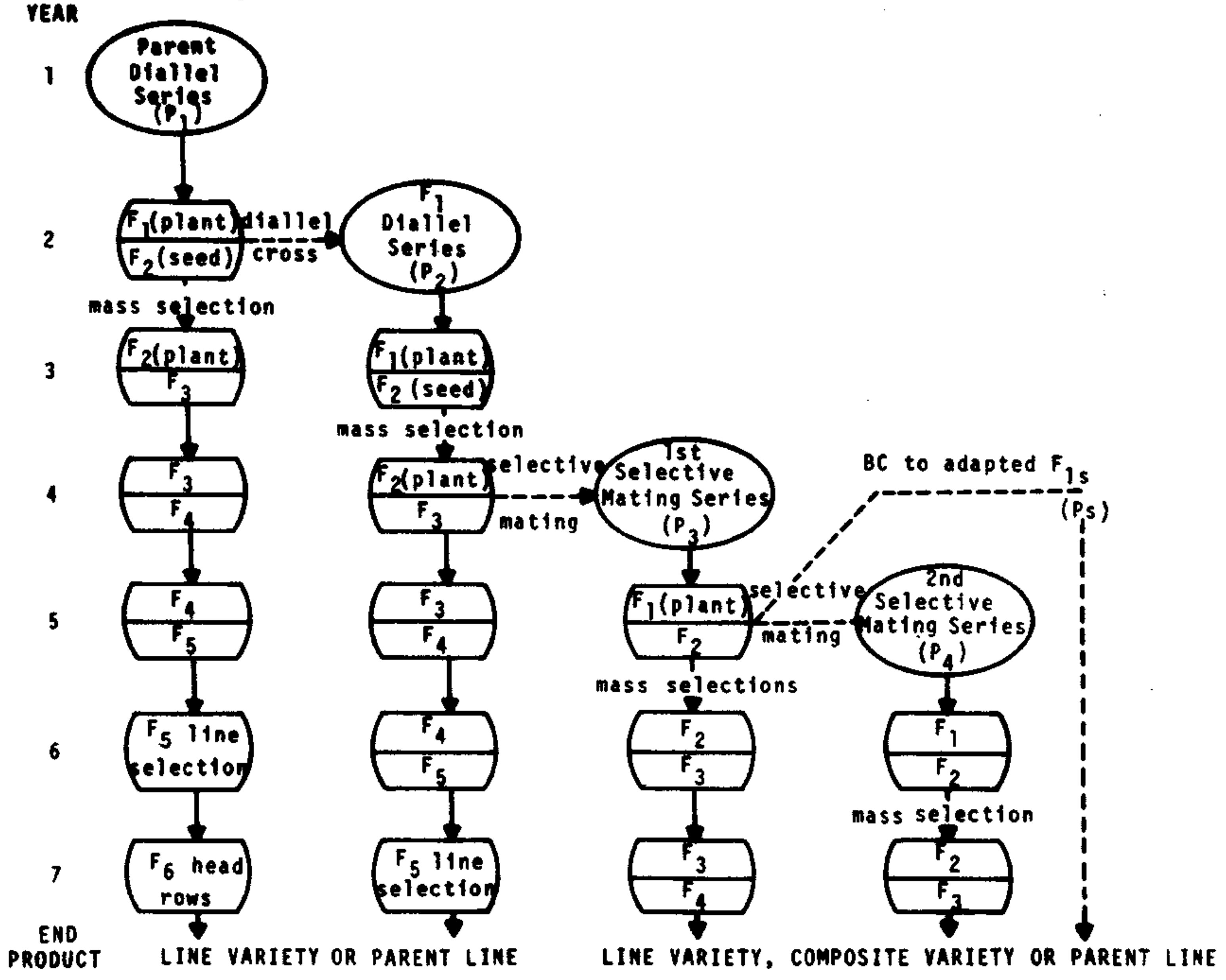
(c) a simple testing technique for detecting the added allele,

(d) recovery of the recurrent genotype 1n a reasonable number of generations.

Experiments with Cereals

At the California Experiment Station.

Figure 4. Flow Chart for the Diallel Selective Mating System (Jensen, 1970)



U.S.A., the wheat breeding program was based exclusively on backcrossing for several decades. The California backcrossing program to improve Bartt variety of wheat is shown in Table 6. The basic varietal genotype was not changed over a period of more than two decades. During this period, all wheat improvement was devoted to removing a few genotypic lesions (e.g., bunt susceptibility, stem rust susceptibility, etc.) from Bartt and to changing the awnedness and grain color. A similar story existed for barley improvement in California. Unless a breeder has a very exceptional recurrent genotype, however, it is questionable whether backcrossing alone is an adequate breeding procedure for keeping varieties of a crop species sufficiently current for the ever-changing situation in agricultural production.

Backcrossing with Small Grains

Backcrossing is being used currently in the breeding of multiline varieties of self-fertilizing small grains (Frey et al., 1973). A multiline variety is a prescribed mixture of isolines, all of which are agronomically similar but each of which carries a unique and different allele for resistance to a specific disease. The isolines are created by backcrossing resistance genes individually into one recurrent parent variety. In the Iowa multiline breeding project with oats, we backcross five times (see Table 7) to the recurrent parent to create an isoline with a specific gene for vertical resistance to crown rust (caused by Puccinia coronata Cda. var. avenae Fraser and Led).

Multiline Breeding

Breeding multiline varieties of self-fertilizing crops is several decades old in concept, but *very* recent in practical application. A multiline variety is bred to meet the specific hazards from a "crowd" disease; i.e., a disease caused by a pathogen that contains physiologic races and that can be explosive in its buildup. Crown rust disease of oats is caused by such a pathogen. Several hundred physiologic races of Puccinia coronata avenae have been discovered. The organism has a generation time of eight to ten days, and pustule numbers on a susceptible field of oats increase at the rate of *50%* per day.

Because the vertical resistance genes of oats give near immunity to some races of the pathogen and complete susceptibility to others, use of a pure line oat cultivar with one resistance gene causes intense selection among races. Soon, the population of crown rust spores becomes uniform for that race or set of races that is virulent on the variety being grown. This causes the once resistant variety to lose its usefulness for agricultural production in crown rust environments. Stevens and Scott (1950) estimated that the crown rust resistance of a pure line oat variety would last for only two to five years in the corn belt of U.S.A.

Multiline Efficiency for Crown Rust

Multiline varieties have several advantages over pure line varieties in combatting crown rust. The multiline variety is heterogeneous for crown rust resistance genes, so the plant population provides a degree of susceptibility to every race in the pathogen population. Every plant is susceptible to one or a small proportion of the races, but no plant is susceptible to all races of the pathogen population. The practical results with a multiline variety are twofold: (a) the useful life of a multiline variety (i.e., relative to crown rust) should be much longer than the two to five years Stevens and Scott (1950) found for pure line varieties, and (b) the buildup of the pathogen and the disease it causes is much lower in a multiline than in a susceptible oat variety.

With respect to point (a), multiline varieties of oats have not been in agricultural production sufficiently long to provide an estimate of how many years their rust resistance will be useful. Multiline E and Multiline M varieties of oats were released to corn belt farmers in 1968, and to date (i.e., through 1974) there is no observable decrease in their levels of resistance to naturally occurring crown rust disease.

Multiline - Rust Experiments

We do.have rather definitive Information, however, about the effect that multiline varieties have upon the pathogen buildup in a growing crop of oats. Results from a typical experiment conducted by Cournoyer (1970) to measure pathogen increase in fields of oats sown to susceptible and multiline varieties are shown in Figure 5. In this experiment.

Table 6. Outline of Backcross Program to Improve Bartt Variety of Wheat. Briggs and Allard 1953

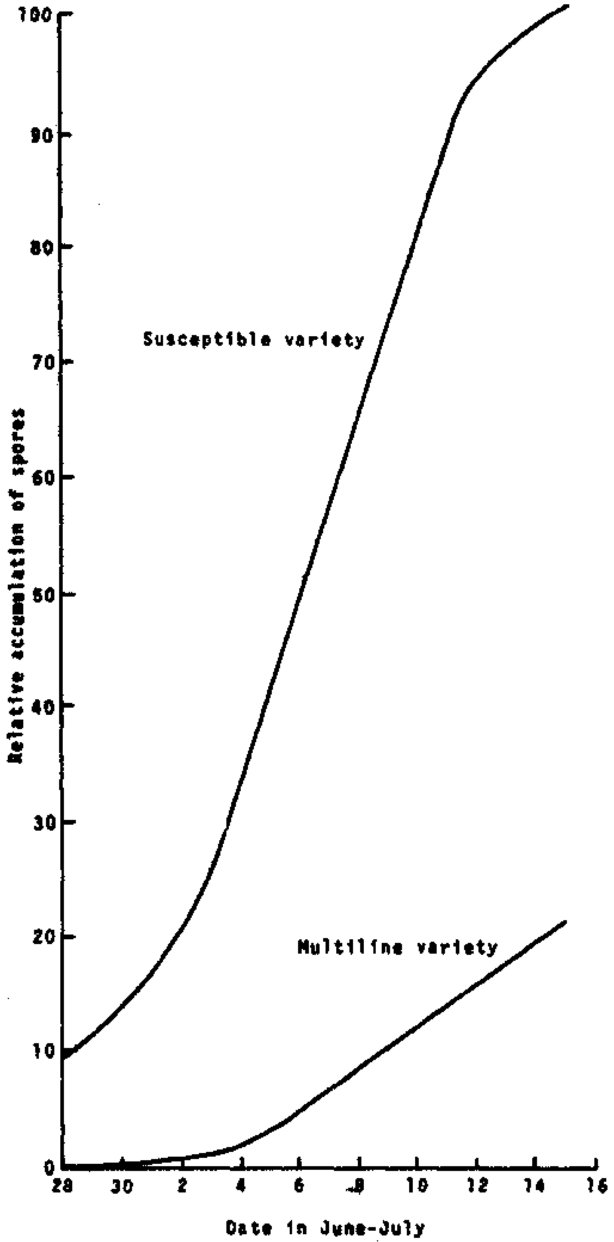
Variety designation	Pedigree	Purpose
Bartt 35*	Martin x Bartt^7	Loose-smut resistance
Bartt 38	Hope x Bartt^7 2 x Bartt 35	Stem-rust resistance
Bartt 46	Bartt 38 x Bartt^2	More stem-rust resistance
Awnless Bartt	Onas x Bartt^{11}	Awnlessness
Bartt 52	Red Seln from Bartt 38 x Bartt 38^2 2 x Bartt 46	Red kernel color
Bartt 54	Bartt 46 x Bartt^2	Intensify Bartt traits

*Designates year of release of improved Bartt.

Table 7. Accession and C.I. Numbers and Parentage of Isolines Used in Multiline M Varieties of Oats. Frey and Browning 1973

Isoline accession no.	Isoline CI no.	Parentage
X104C-7	9182	CI 7555^6 x Ceirch du Bach
X270I	9183	CI 7555^6 x CI 8079
X421I	9184	CI 7555^6 x CI 8001
X422	9185	CI 7555^6 x Victorgrain 48-93
X423	9186	CI 7555° x Ascencao
X424III	9187	CI 7555^6 x Ascencao
X447	9188	CI 7555^4 3 x Bonkee 2 x CI 7154 x CI 7171
X499I	9189	CI 7555^6 x CI 6665
X475II	9190	CI 7555^6 x CI 8078
X765	9191	CI 7555^5 2 x Clinton x CI 8081

Figure 6: Relative Cumulative Counts of Crown Rust Spores Collected Outside of Plots Sown to Susceptible and Multiline Varieties of Oats that had been Inoculated with Four Races (Coumoyer, 1970)



four crown rust races were used, the plot size was 16 x 16 m, and profusely sporulating plants were transplanted at four sites (three m from each corner) in each plot. The technique resulted in an extremely heavy epiphytotic that killed the susceptible variety more prematurely than the cumulative spore yield would indicate. The multiline cultivar yielded 25% as many spores as the susceptible one, and when spore collections were terminated by crop maturity on July 15, there was no suggestion that spore yield from the multiline cultlvar had reached a plateau. Furthermore, all four of the races released into the multiline plots were still present at the end of the season.

Multiline varieties for self-fertilizing species are desirable only for certain agricultural production situations. They are designed specifically to combat pathogens with variable virulence and their development and release is justified only for production areas where a given disease is the major factor that limits crop production. Because backcrossing 1s used to develop the isolines for a multiline variety, the recurrent parent may not be "up-to-date" for agronomic traits.

USE OF EXOTIC GERMPLASM

Another timely topic for discussion in this report is germplasm introgression. This topic, of course, applies to both crossing and selfing species. To date, really exotic germplasm, especially from weedy species, has been used nearly exclusively as a source of genes for improving qualitatively inherited traits, such as disease resistance. Recent data suggest that quantitatively inherited traits can be improved *by* this method, also. Several years ago, during a routine backcrossing program to develop isolines of oats that varied by genes conditioning resistance to crown rust disease, Frey and Browning (1971) discovered that some isolines with rust resistance alleles from A. *sterilis* gave significantly increased yields when grown in rust free environments. *Avena sterilis* is a weedy species of oats collected from the Mediterranean area. It is hexaploid, and it crosses readily with cultivated oats. This initial "yield gene" was discovered in two genetic backgrounds of cultivated oats, but the gene has since been transferred to four additional backgrounds.

Experimental Evidence

These observations led to a study done by

Peter Lawrence currently on the ICRISAT staff (Lawrence 1974). He built 48 populations representing six levels of introgression of A. sterilis germplasm, by backcrossing into eight biparental combinations. The parental combinations represented all crosses between two A. sativa and four A. sterilis parents. He then tested 80 random lines from each population in a field grown experiment and found a decided degree of transgressive segregation for grain yield in all generations of Introgression and for each parental combination (Figures 6 and 7). As one might expect, however, the transgressive segregates for yield Improvement were not necessarily desirable for agronomic traits, so Lawrence practiced selection first for good levels of agronomic traits such as maturity, plant height, harvest index, etc., and then assayed the yielding ability of lines that survived the selection for agronomic traits. The yields of the surviving lines are shown 1n Figures 8 and 9. Note that, even though many F_2 and BC_1F_2 segregates had superior yields, few to none of them survived the selection for agronomic traits. The result was that the likelihood of recovering good A. sativa lines with improved yield from A. sterilis sources was most easily accomplished by selecting in Bc_2 to Bc_4, at which stages the expected proportion of A. sterilis germplasm was between *12%* and *3%*.

This particular model using A. sativa and A. sterilis seems to illustrate several significant points: (a) genes for improving quantitatively inherited traits in cultivated species may be found in strains of their weedy, and perhaps wild, relatives; (b) as suggested by MacKey in his essay on multiple crosses, it is necessary to introgress less than 50% of weedy or wild germplasm into the breeding population to recover the already present background of desirable genes in the agronomic varieties; and (c) some evidence suggests that specific combining ability exists among A. sativa x A. sterilis lines.

Our situation with oats may be unique. I believe that the distance of genetic divergence between cultivated and weedy species may sometimes be either too great or too "little to fit the model Lawrence researched. The oat species he used have been geographically isolated for 2000 years, with little opportunity for gene flow between them. However, chromosomal evolution (i.e., structural rearrangements of chromosomes) seemingly has not been great 1n either species. I do not know whether pigeonpeas or chickpeas have exotic relatives that might form similar models. For a weedy or wild species to have value for improving a relative cultivated species, it would have evolved neither too close nor too distant in relatedness. Probably maize and teosinte represent a situation similar to the one with A. sterilis x A. sativa.

OTHER BREEDING CONCEPTS

Time will not permit me to go into detail about breeding for mixing abilities, or for ideotypes in self-fertilizing crop species, but these are two new techniques on which data are accumulating. Perhaps these can be made the theme of a paper or two for some future symposium and workshop on breeding self-fertilizing species.

Figure 6. Frequency Distributions for Grain Yield, for All Generations and All Crosses Involving the C.I. 7463 A. sativa Recurrent Parent and Four A. sterilis Accessions: 1 = B442, 2 = B443, 3 = B444, and 4 = B445. [[Black areas denote transgressive segregates (Lawrence and Frey, 1974)]

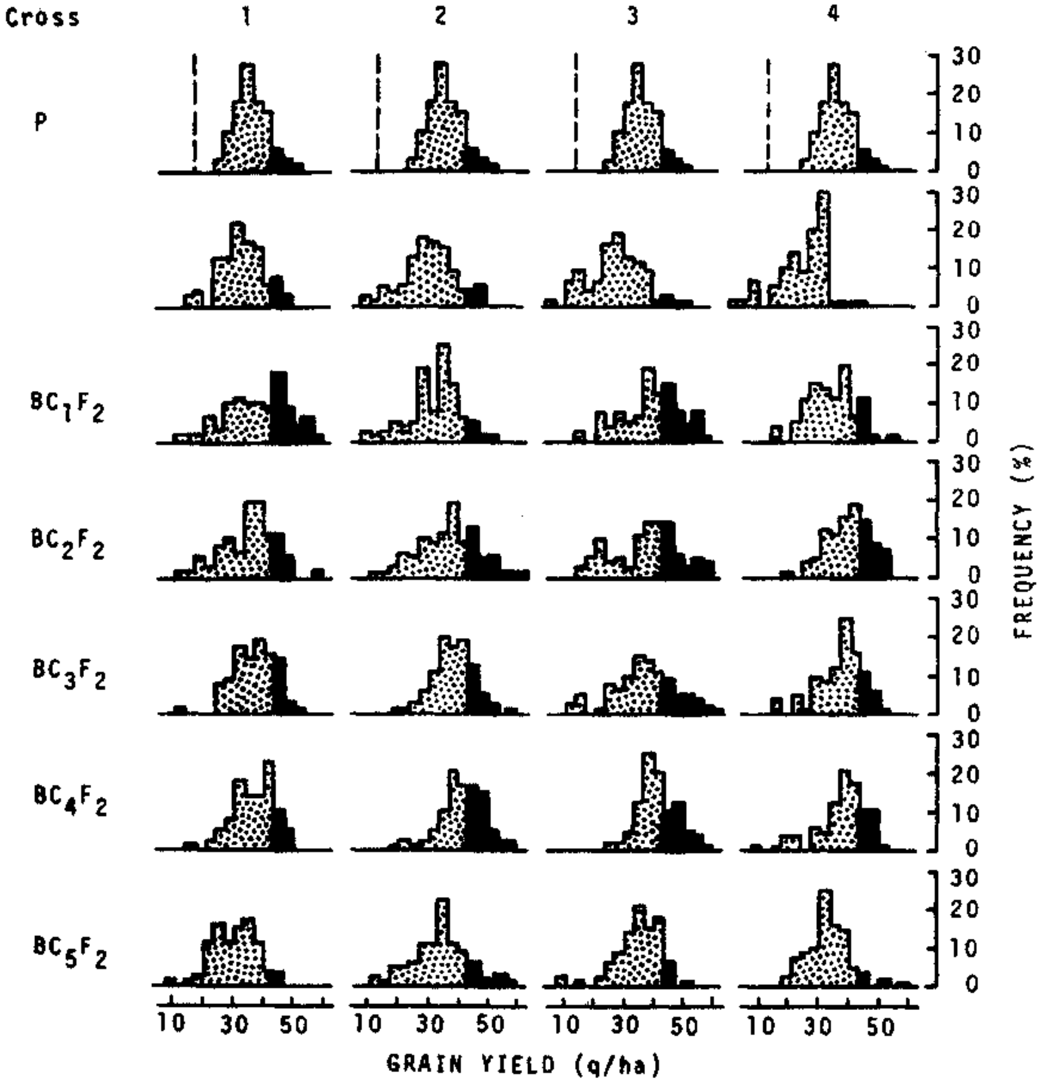


Figure 7. Frequency Distributions for Grain Yiald, for All Generations and All Crosses Involvingthe C.I.8044 *A.* sativa Recurrent Parent and Four A. steriiis Accessions: 1 = B442, 2 = B443, 3 = B444, and 4 - B44S. [Black areas denote transgressive segregates (Lawrence and Frey, 1974)]

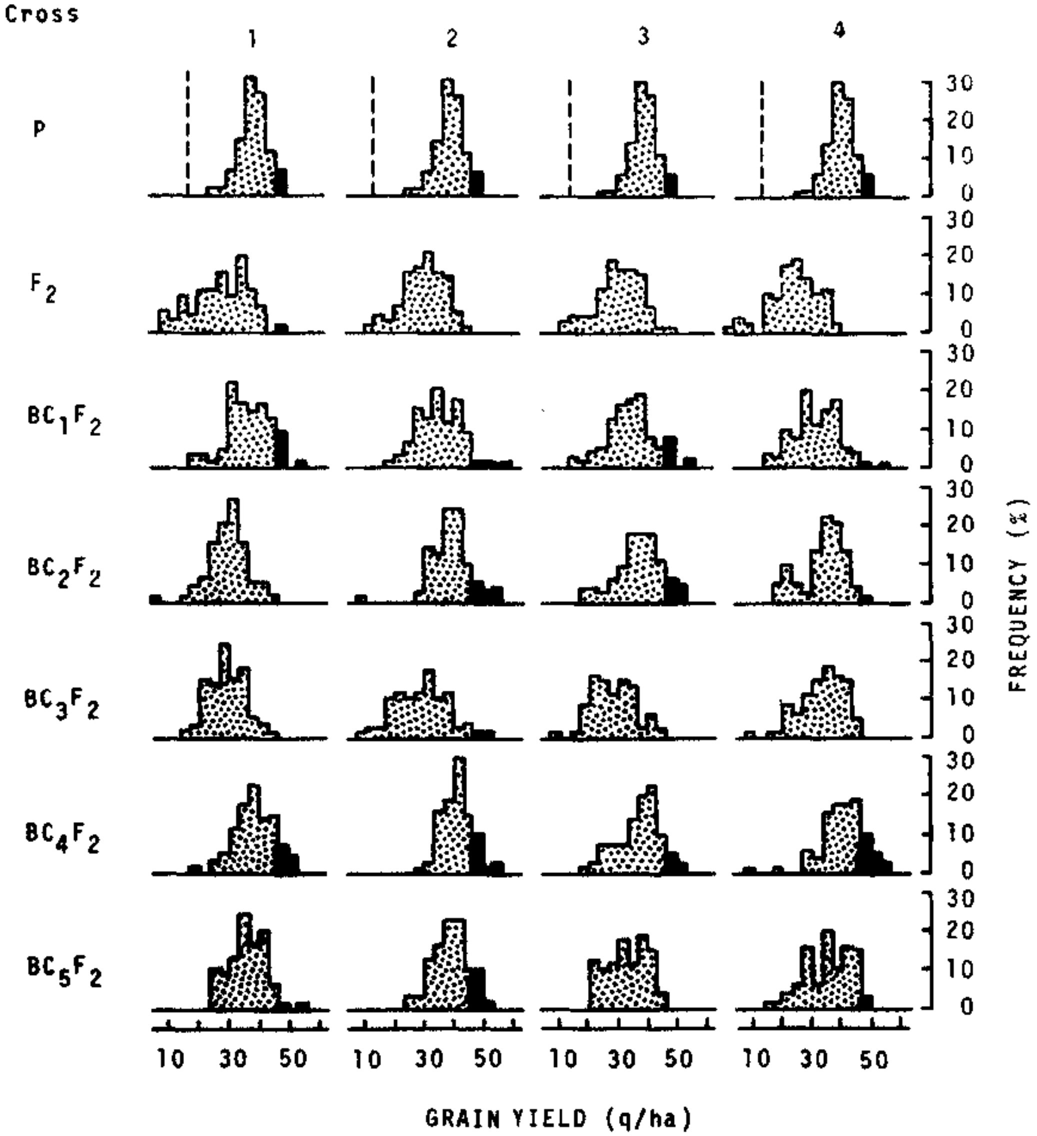


Figure 8. Frequency Distributions for Grain Yields of Lines that have Suitable Agronomic Traits, for All Generations and All Crosses Involving the C. I. 7-63 A. sativa Recurrent Parent and Four A. sterilis Accessions: 1 = 8442. 2 = 8443. 3 = 8444, and 4 = B445. [Black areas denote transgressive segregates (Lawrence, 1974) 1

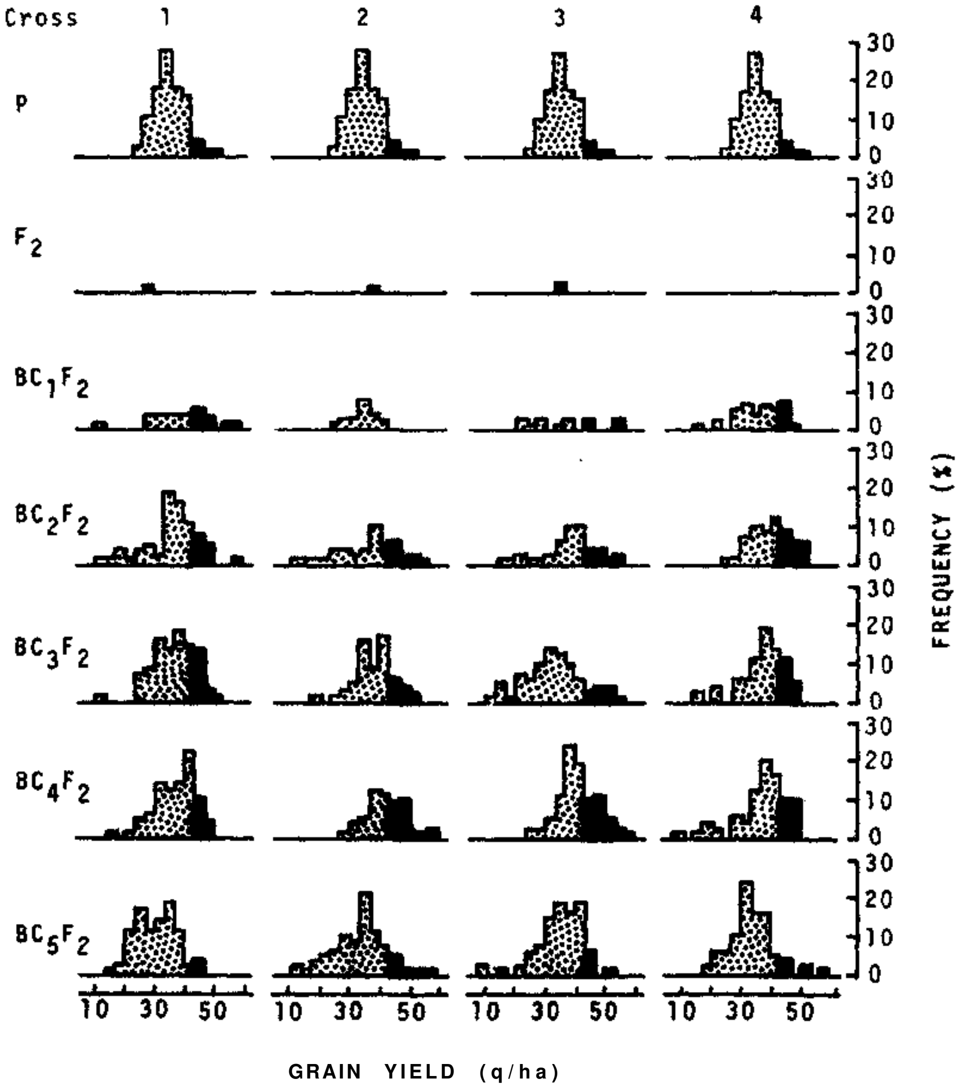
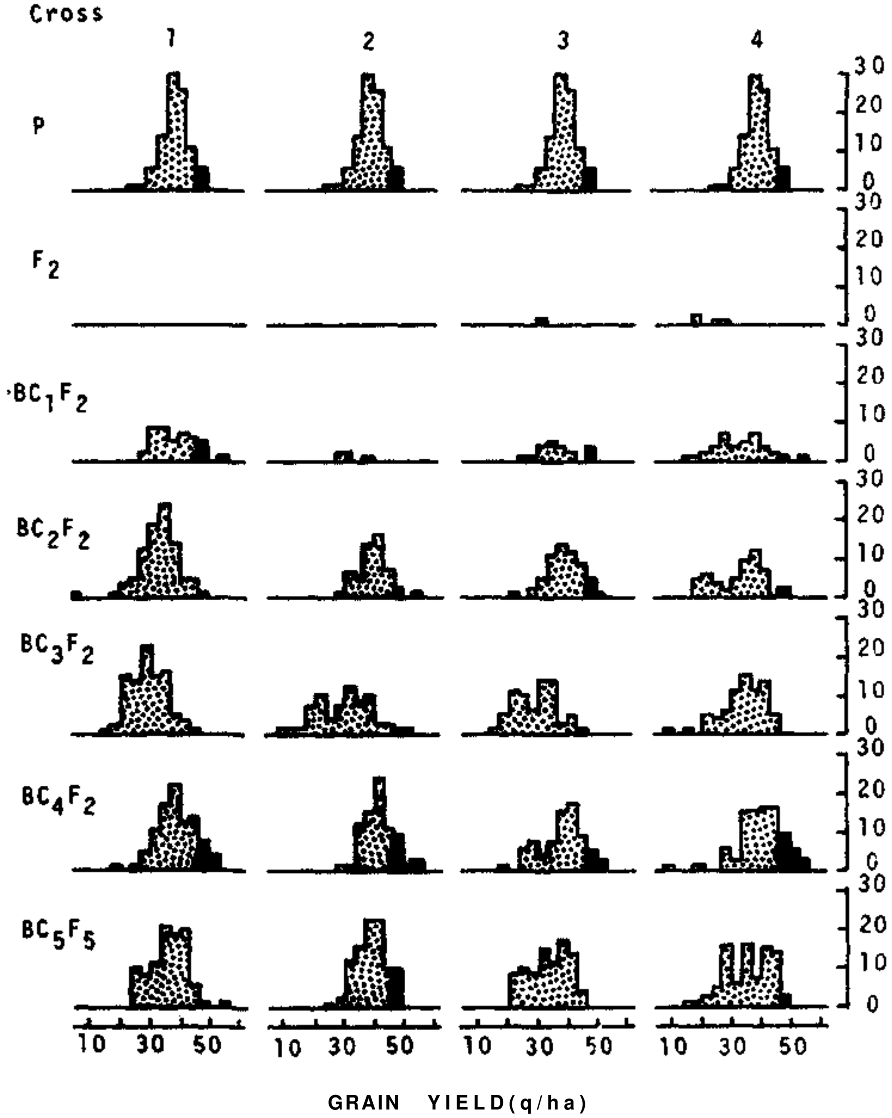


Figure 9. Frequency Distributions for Grain Yields of Lines that have Suitable Agronomic Traits, for All Generations and All Crosses Involving the C. I. 8044 A. sativa Recurrent Parent and Four A. sterilis Accessions: 1 = B442, 2 = B443, 3 = B444, and 4 = B445. [Black areas denote transgressive segregates (Lawrence, 1974).]



DISCUSSION

A.K. Auckland: I would be interested to see the introgression of exotic germplasm tried in chickpea.

L.R. House: I feel there is a tendency in breeders to work in self-pollinated crops from a narrow germplasm base. It will be desirable that ICRISAT adopts a comprehensive scheme of germplasm distribution to all chickpea workers. Then only with local material the local x exotic crosses could be made.

K.J. Frey: I tend to agree with Jain and Murty that scope for yield advances in the pulses is great, that we should concentrate in using simply inherited gene blocks to take the big jumps available for improvement.

LITERATURE CITED

Akerman, A. 1946. Plant breeding, Svalof, 1896-1946. K. Bloms Boktr, Lund.

Briggs, F.N. and R.W. Allard. 1953. The current status of the backcross method of plant breeding. Agron. J. 45:131-138.

Brim, C.A. 1966. A modified pedigree method of selection in soybeans. Crop. Sci. 6:20.

Chandhanamutta, P. and K.J. Frey. 1973. Indirect mass selection for grain yield in oat populations. Crop Sci. 13:470-473.

Chandhanamutta, P. and K.J. Frey. 1975. Spontaneous and induced mutation rates in di, tetra-, and hexaploit oats (<u>Avena</u> sp.). Submitted to Radiation Botany.

Cournoyer, B.M. 1970. Crown rust epiphytology with emphasis on the quantity and periodicity of spore dispersal from heterogeneous oat cultivar-rust race populations. Ph.D. Thesis. Iowa State University, Ames, Iowa, 191 pp. (Diss. Abstr. 31; 3104b, 1970).

Fatunla, T. and K.J. Frey. 1974. Changes in quantitatively inherited traits in radiated and nonradiated bulk oat (<u>Avena sativa</u> L.) populations. Egypt J. Genet. Cytol. 3:259-277.

Frey, K.J. 1967. Mass selection for seed width in oat populations. Euphytica 16:341-349.

Frey, K.J. and J.A. Browning. 1971. Association between genetic factors for crown rust resistance and yield in oats. Crop. Sci. 11:757-760.

Frey, K.J. and J.A. Browning. 1973. Registration of M (midseason) series of isolines of oats as parental lines. Crop Sci 13:291.

Frey, K.J., J.A. Browning, and M.D. Simons. 1973. Management of host resistance genes to control diseases. Z. Pflanzenk. und Pflanzenschutz 80:160-180.

Grafius, J.E. 1965. Short cuts in plant breeding. Crop Sci. 5:377.

Grindeiand, R.L. and R.C. Frohberg. 1966. Outcrossing of oat plants (*Avena sativa* L) grown from mutagen derived seeds. Crop Sci. 6:381.

Gustaffson, A. 1947. Mutations in agricultural plants. Hereditas 33:1-100.

Hagberg, A., A. Gustafsson, and L. Ehrenberg. 1958. Sparsely contradensely ionizing radiations and the origin of erectoid mutations in barley. Hereditas 44:523-530.

Harlan, H.V. and M.N. Pope. 1922. The use and value of backcrosses in small grain breeding. J. Hered. 13:319-322.

Harlan, H.V., M.L. Martini, and Harland Stevens. 1940. A study of methods in barley breeding. US Dept. Agric. Tech. Bull. 720 pp. 26.

Hartwig, E.E. and F.I. Collins. 1962. Evaluation of density classification as a selection technique in breeding soybeans for protein or oil. Crop Sci. 2:159-162.

Jain, S.K. 1961. Studies on the breeding of self-pollinating cereals. The composite cross bulk population method. Euphytica 10:315-324.

Jensen, N.F. 1970. Adiallelselective mating system for cereal breeding. Crop Sci. 10:629-635.

Khadr, F.H. and K.J. Frey. 1965. Effectiveness of recurrent selection in oat breeding (*Avenc sativa* L.). Crop Sci. 5:349-354.

Lawrence, P. 1974. Introgression of exotic germplasm into oat breeding populations. Ph.D. thesis. Iowa State University, Ames, Iowa. 120 pp.

Lawrence, P. and K.J. Frey. 1974. Backcross variability for grain yield in oat species crosses (*Avena sativa* L. x A. *sterilis* L.). Euphytica 23:In press.

Lundqvist, E. and D. Wettstein. 1962. Eceriferum mutants in barley. Hereditas 48:342-362.

MacKey, J. 1954. Breeding of oats. Handbuch fur Pflanzenzuchtung 2:512-517.

McKelvie, A.D. 1963. Studies in the induction of mutation in *Arabidopsis thaliana* L. Radiat. Bot. 3:105-123.

Mock, J.J. 1973. Manipulation of crossing over with intrinsic and extrinsic factors. Egypt J. Genet. Cytol. 2:158-175.

Muller, H.J. 1932. Further studies on the nature and cause of gene mutations. Proc 6th Int. Congr. Genet. 1:213-255.

Mumaw, C.R. and C.R. Weber. 1957. Competition in natural selection in soybean varietal composites. Agron. J. 49:154-160.

Reyes, R. and K.J. Frey. 1967. Effect of seeding rate on survival of genotypes in oat populations. Iowa State J. Sci. 41:433-445.

Romero, G.E. and K.J. Frey. 1966. Mass selection for plant height in oat populations. Crop Sci. 6:283-287.

Rowell, T.L. and D.G. Miller. 1971. Induction of male sterility in wheat with 2-chloroethylphosph1c acid (Ethrel). Crop Sci. 11:629-631.

Sigurbjornsson, B. and A. Micke. 1974. Philosophy and accomplishments of mutation breeding. IAEA Publ. PL503/40. pp. 303-342.

Stadler, L.J. 1928. Mutations in barley induced by X-rays and radium. Science 68:186-187.

Stadler, L.J. 1932. On the genetic nature of induced mutations in plants. Proceedings of 6th Int. Congr. Genet. 1:274-294.

Stevens, N.E. and W.O. Scott. 1950. How long will present spring oat varieties last in the Central Corn Belt? Agron. J. 42:307-309.

Suneson, C.A. 1945. The use of male sterile in barley improvement. J. Am. Soc. Agron. 37:72-73.

Suneson, C.A. 1949. Survival of four barley varieties in a mixture. Agron. J. 41:459-461.

Suneson, C.A. 1956. An evolutionary plant breeding method. Agron. J. 48:188-191.

Tiyawalee, D. and K.J. Frey. 1970. Mass selection for crown rust resistance in an oat population. Iowa State J. Sc1. 45:217-231.

SESSION REVIEW

S. Chandra[1]

INTRODUCTION

Dr. Frey's paper is a comprehensive one and covers most of the modern plant breeding concepts and has convincingly shown the successful applications of these methods in self-pollinated crops, particularly oats. I propose to discuss the various aspects of Dr. Frey's presentation with particular reference to chickpea and also briefly to pigeonpea.

EXPERIMENTS IN INDIA

First, it may be worthwhile to examine briefly the plant breeding efforts so far made in India.

To start with, a few varieties were evolved in different parts of the country as single plant selections from local bulks. Intervarietal hybridization, as a means to create new variation was begun in the 1940's, resulting in development of a few important varieties like C 1234 and C 235 which were resistant to Ascochyta blight, T 87, C 214 and G 130 which were relatively higher yielding and C 104 and Barachana which were special purpose types, meant for culinary preparation as whole seed – the former being Kabuli and the latter green seeded. The above list of varieties need not create the impression of significant advances particularly as some of these existed for about 30 years and also because they are specifically adapted to different regions in India.

Even today most of the breeders try to utilize in a conventional manner products of single crosses. However they have the advantage that selection of parents in these crosses was not based on eye selection or the per se performance but on more solid genetic foundations, viz., the g.c.a. estimates in respect of these lines. Yet also, the advance over existing yield levels of improved varieties has been rather small in relation to time spent, except in few cases. It is nevertheless encouraging that the chickpea varieties H 208, L 550 and H 355 emerged in the All-India trials as stable genotypes though they represent only a small advantage for yield.

OBSERVATIONS ON CHICKPEA AND PIGEONPEA

The background information presented above should *serve* to show how imperative it is to intensify purposeful breeding efforts with a view to obtain significant yield advance and also to stabilize it. Dr. Frey's paper focuses attention on a number of excellent schemes which can be advantageously applied to chickpea and pigeonpea. The emphasis on multiple crosses with a view to creating genetic variability is noteworthy. There is in fact evidence with us to show that in chickpea, use of double crosses yielded a higher estimate of expected genetic gain than single crosses and it was attributed to greater yield of genotypic variation in the double cross population. However, the limitation of achieving high population size required in quadruple and later generations become rather difficult in chickpeas, where in spite of very intensive efforts, realization of crossed seeds is extremely limited. In pigeonpea, however, the identification of male steriles offers a more hopeful avenue for utilizing the technique. The multiple cross bulk population will offer strong possibilities of identifying useful genotypes in different ecogeographic areas.

It is very interesting that Dr. Frey has given a good illustration of the indirect gain in yield by selecting for higher seed size in oats. In doing so he has effectively re-emphasized the importance of augmenting selection criteria in the endeavor for yield improvement.

---

[1] Division of Genetics and Plant Physiology, Central Soil Salinity Research Institute, Karnal, Haryana, India

Selection/Variation in Chickpea and Pigeonpea

It is very important to lay special emphasis on selection simultaneous with creating the variation in both chickpea and pigeonpea. There is a serious problem of adaptation especially of the exotic chickpea germplasm, particularly the Kabuli ones. At the same time, Kabuli types are genetically diverse relative to Deshi ones. It is therefore proposed that Kabuli x Deshi crosses may first be handled by Mackey's modified backcrossing program before being employed in multiple cross system. At this point, however, I should state that there is no basis to assume any crossability barriers between Deshi and Kabuli ones.

Diallel Selective Mating System

Jensen's scheme of diallel selective mating system has been greatly emphasized by Dr. Frey and I have no doubt that this system, possibly with some modifications would be beneficial to both chickpea and pigeonpea. What is significant in this scheme is the crossing of selected F_2 plants resulting from F1 diallel matings. I may as well mention here that in 1968 and 1969, we conducted large scale crossing of F2 plants in several chickpea crosses and discovered a multifold increase in genotypic variation in these progenies as compared to their selfed progenies. It was also found that among progenies of F2 plants crossed, those flowing from selected plants had greater mean performance and also as much genetic variation as those from randomly crossed plants.

Results

It may be of interest that this technique resulted in breaking the undesirable negative association of seed size and yield. Progenies of certain F2 matings have yielded as high a positive correlation between these characters as 0.89. This also illustrates the point made by Dr. Frey, that greatest gains could be made if recombination occurred among selected genes rather than being random. I have therefore no doubt about the utility of Jensen's procedure in its application particularly to chickpea. I might also mention that chromosome size of chickpea is very small and its average chiasmata frequency, perhaps among the lowest in crop plants. Thus, intensive as well as extensive efforts would have to be made to overcome linkage barriers.

Backcrossing

I agree with Dr. Frey that backcrossing should form an important phase of improvement program in self-pollinated crops. I further agree with the multiline concept particularly when composite resistance tends to be difficult to achieve. In chickpeas only one donor seems to exist at present for composite resistance to <u>Ascochyta</u> blight. This variety (P 1528-1) originated in Israel. However, resistance to some races of this disease happens to be present in at least two other varieties: C 727 (Pakistan) and C 235 (India). Even if composite resistance from the Israel source 1s transferred to a given agronomic base, it would be still desirable to impart ability for multiple resistance (horizontal) to the populations.

Wilt in Chickpea

It is unfortunate that very little is known about wilt disease of chickpea. However it is not difficult to visualize that pathogen would play a leading role even when some agroclimatic factors are known to predispose chickpea to higher incidence of wilt disease. Inadequacy of soil moisture and high temperatures at planting or fruit formation are important to wilt infection. These facts have to be accounted for in a wilt resistance program of chickpea.

Specific Problems for <u>Cicer</u>

Dr. Frey's illustration of A. <u>sativa</u> x A. <u>sterilis</u> cross yielding transgressive segregates for yield is very impressive indeed. In this case too, emphasis on backcrossing to cultivated race is significant. He has rightly pointed out use of this approach in <u>Cicer</u> of which the cultivated species <u>arietinum</u> may benefit from its closest ones <u>pinnatifidum</u> or <u>microfillum</u>. I may add again in this regard that even though there is great similarity in the chromosome complements of these species, a chemical inhibitor, which is a protein in nature, presents a crossabillty barrier. However, our studies have shown that the protein barrier is quantitatively more effective at higher temperatures, so that crosses attempted at lower temperature or in high mountains of Himalayas are likely to prove successful. Of course physical or artificial means to overcome crossabillty barriers would constitute another approach in realizing interspecific crosses of Cicer.

CONCLUSIONS

I think that 1n the end I would specifically emphasize the application of Mackey's and Jensen's schemes to improvement in chickpea and pigeonpea and to mention that the kind of facilities available at ICRISAT present a strong case for development of populations which can be used further as sources of variation and hopefully too for selection of superior genotypes in different parts of the world.

SEVENTH

SESSION

INCREASING EFFICIENCY IN BREEDING PARTIALLY OUTCROSSING GRAIN LEGUMES

K. O. Rachie[1] and C. O. Gardner[2]

INTRODUCTION

Plant improvement in self-pollinating species like the grain legumes has been largely confined to varietal improvement methods based on pedigree, bulk pedigree, backcross and multiple crossing techniques. These methods have been *very* useful in recombining simply inherited characters affecting disease and pest susceptibility and various morphological characters into improved strains and lines. More recently crossing at the F_1 level and single seed descent (Brim 1966) have been stressed to increase the rate of recombination and reduce the load of record-keeping thereby allowing the breeder to make and retain larger numbers of recombinations. Nevertheless, even with these refinements, traditional varietal improvement methods have not been very efficient for improving quantitatively inherited characters like seed yield, oil content, tolerance of stresses and horizontal resistance to diseases and insects. Moreover, the crossing and record-keeping procedures are often both cumbersome and time consuming for the rate of progress attained.

There is considerable interest among present day breeders in applying more efficient breeding methods to self-pollinated species like the grain legumes and cereals to Improve productivity potentials of these crops (Jennings 1974). One possibility is through population improvement utilizing recurrent selection to accumulate desirable genes and facilitate breaking of linkages. This method is substantially more efficient in breeding for quantitatively inherited characters than conventional varietal improvement. However, because of the necessity for recombination each cycle, this system has been utilized principally in outcrossing species. More recently--within the past five years—some recurrent selection schemes designed for self-pollinated crops and utilizing both hand crossing and outcrossing mechanisms like male sterility have been proposed [Doggett and Eberhart (1968) Jensen (1970) Compton (1970)]. Even mass selection has been demonstrated to be useful in self-pollinated species with a low level of outcrossing provided that the additive component of genetic variance is important (Redden and Jensen 1974).

PREVIOUS INVESTIGATIONS

Population improvement has been defined and described by Sprague (1966) as a form of breeding designed for utilization of additive gene effects, and includes all operations within a system in which the end product is an improved, sexually propagated pure line *or* random mating population. The general formula for expected gain per cycle (G) from selection is 6 = CHD where C is a function of the breeding system used and is one when only selected parents are involved in the mating system and $^1/_2$ when pollen 1s random and selection is on the female plant only; H is heritability on an individual plant or family mean basis depending on the system used and is the proportion of phenotypic variance among individuals or families (C^2) attributable to additive genetic variance (0^2_g), i.e. H = 0^2_g; and 0_ is the selection differential or the mean of the selected group (Xs) minus the mean of all the individuals or families tested *(X)*, which in a

---

[1] The International Institute of Tropical Agriculture, Ibadan, Nigeria.

[2] University of Nebraska, Lincoln, Nebraska, U.S.A.

normally distributed population is expected to be equal to $k\,\sigma^2_{ph}$; where k is the standardized selection differential and is a function of population size and proportion selected. Phenotypic variance (σ^2_{ph}) is dependent on the breeding system used. In individual plant selection, it is the total variance among individual plants evaluated. In family selection it is dependent upon the data unit analyzed and the number of plants per plot, replications per location, and the number of locations used in the evaluation. If total yield per plot is the data unit analyzed,

$$\sigma^2_{ph} = \frac{\sigma^2}{rm} + \frac{\sigma^2_{ge}}{m} + \sigma^2_g,$$ where σ^2_g is the genetic component of variance among families, σ^2_{ge} is the family (genotype) and environmental interaction component, σ^2 is the experiment error, m is the number of location and r is the number of replication at each location. If mean yield per plant is analyzed

$$\sigma^2_{ph} = \frac{1}{rm}\left(\sigma^2_p + \frac{\sigma^2_w}{n}\right) + \frac{\sigma^2_{ge}}{m} + \sigma^2_g,$$ where σ^2_p is the plot component of variance, σ^2_w is the within plot component and n is the number of plants per plot. In the latter case, the experimental error is $\sigma^2 = (\sigma^2_p + \frac{\sigma^2_w}{n})$. It is not necessary to calculate the variance among plants within plots unless estimates of σ^2_p and σ^2_w are desired. They are not needed to predict expected progress from family selection but they are needed to predict progress from individual plant (mass) selection.

Other Selection Methods

Sprague (1966) has also described five selection methods designed primarily for naturally outcrossing species or where artificial random mating can be imposed. Several modifications of these schemes can be employed depending on the crop, generations obtainable per year, and facilities available, but only a few of these *are* practical for partially outcrossing crops which are listed by Empig, et al. (1972) in Table 1.

Eberhart (1970) has pointed out ways to increase efficiency. First, the additive genetic variance among families under evaluation (σ^2_g) can be increased by broadening the genetic base of elite genetic stocks in the base population—i.e., using elite materials from breeding programs in the major . centers of diversity for the crop. After developing the population, the method of selection directly influences the magnitude of the coefficient of σ^2_g in mass selection and S1 selection where $\sigma^2_{g'} = \sigma^2_A$; whereas for S2 selections $\sigma^2_{g'} = \frac{3}{2}\sigma^2_A$.

S2 Testing

Theoretically, the most efficient scheme on a per cycle basis is S2 testing because the coefficient of the additive genetic component of variance in the numerator of the expected gain equation is larger although the phenotypic variance in the denominator could also be somewhat larger since increasing homozygosity tends to raise the genotype x environment interaction. Mass selection does not readily permit precision testing of individuals under high population stress and the phenotypic variance in this method is likely to be high. Also individual plants cannot be replicated, but their S1 and S2 progenies can be for better evaluation. S1 and S2 testing offer better precision for estimating family means than half-sib or full-sib methods with consequent rapid genetic gain if three or four generations can be obtained in a single year.

Constraints

Adapting population improvement to self-pollinated crops like grain legumes involves several difficulties—especially during the recombination generation. These include:

1. Tediousness in making handcrosses
2. Few numbers of seeds produced per cross (2-15)
3. Low rate of natural outcrossing
4. Dependency on insects for transmitting pollen
5. Difficulties in assessing field performance

These constraints impose severe limitations on the number of lines that can be included, the range of genetic diversity that can be sampled and the extent of outside participation that is possible. However,

Table 1. Selection Method for Population Improvement Schemes as Described by Sprague (1966) and Empig et al. (1972)

Selection Scheme	Generations per Cycle	Numerator
1. Mass selection based on female only	1	$k\ (\frac{1}{2})\ \sigma^2_A$
2. S1 family testing and selection	3	$k\ \sigma^{2*}_A$
3. S2 family testing and selection	4	$k\ (\frac{3}{2})\ \sigma^{2*}_A$
4. Full-sib family testing and selection	2[1]	$k\ (\frac{1}{2})\ \sigma^2_A$
5. Half-sib family testing and selection	2[1]	$k\ (\frac{1}{4})\ \sigma^2_A$
6. Testcross family testing and S1 family selection	3	$k\ (\frac{1}{2})\ \sigma^{2**}_A$

k = standardized selection differential.

6^2_A = additive genetic variance in the parent population assumed to be mating at random and at linkage equilibrium.

[1] Assumes no independent recombination phases. Selected families are recombined in such a way as to make new full-sib or half-sib families for testing. With an independent recombination phase, three generations are required.

* In the two-allele per locus model $\sigma^{2*}_A = \sigma^2_A$ only when gene frequencies are 0.5 or when there is no dominance. Biases when dominance exists or when gene frequencies are not 0.5 may not be large.

** $\sigma^{2**}_A = \sigma^2_A$ only when gene frequencies in the tester population are identical to those in the population being tested.

modifications in recurrent selection methods coupled with improvements in hand crossing techniques or breakthroughs in mating habits (outcrossing mechanisms) can provide a range of options in population improvement schemes. Moreover, plant breeding in the tropics offers year round field growing conditions with uniformly short days. This helps synchronize flowering—a tremendous advantage in implementing these schemes. In practical terms, from two to four successive generations per year are feasible for most grain legumes.

RECOMBINATION METHODS

The problem of obtaining an adequate number of crosses in the recombination phase of population improvement in self-pollinating species like the grain legumes is a major barrier to adopting these more efficient breeding systems. There are two methods of crossing: by hand or by pollinating insects. Outcrossing mechanisms like male sterility, delayed dehiscence, and constricted petal or protogyny can prove a great boon to either pollinating system. Hand crossing is tedious and some form of fractional or partial diallel crossing system may be required. On the other hand, insect pollination, while extensive, is random and may be skewed toward certain maturities, greater nectar secretion, position of the flower and other factors. However, techniques have been developed or proposed that may help overcome most of these drawbacks. These can be applied to easily crossed species with a high degree of self-pollination like cowpeas as well as to species that are difficult to cross, but with a reasonable degree of natural outcrossing (10%-30%) like pigeonpeas and lima beans.

Utilizing Male Sterility

The discovery of a highly stable form of male sterility in cowpeas (Rachie, et al. 1974) has made it possible to develop a large number of new gene combinations which cannot be easily produced any other way. It eliminates the need for emasculation and the chance of accidental selfing. However, the major advantages of male sterility lies in increasing the rate of effective fertilization. For example, crossing fertiles x fertiles utilizing a rapid and efficient hand method (Rachie.et al. 1975) results in a maximum 20% success under greenhouse conditions, whereas an 82% effective fertilization rate in crosses on ms_2 ms_2 plants was attained in the field during June-July 1974, During this same period it was found possible to make about 50 hand crosses per man hour for a total of 5,764 hand crosses; but meanwhile the bees had made 13,827 random crosses on the same group of ms plants.

Genetic male sterility (ms_2 ms_2) found originally in Prima in 1972 was transferred on to twelve elite lines and the resulting F_2 population has been classified broadly into three basic plant types: A = erect strains (plant type 1-2); B = semi-upright plants (type 3-4); and C = more prostrate, viney strains (type 5-7). These are being used as a Spectrally Diverse Genotypes (SDG) series in a modified fractional diallel crossing procedure in the recombination phase. During recombination, each of the 100 to 200 selected fertile lines is crossed on to five or more sterile plants in each of the SDG series (A, B and C). The resulting F_1's are then advanced two generations during which both negative and positive selection for desirable characters is practiced before quantitatively testing at the S_2 level.

Description of Experiment

Recombination can be done in any season at Ibadan, but would be most convenient during the dry-irrigated season (November-February) for the S2 testing procedure. Pollinating insects may not be as highly effective then as in June and July, but massive hand crossing is both rapid and convenient. Moreover, it permits selecting pollinators based on pre-fruiting criteria. For example, more than 5000 hand crosses were made at IITA during a three weeks period in February/March 1975 by a team of 4—5 field assistants working an average 2-3 hours per day. The decision to handcross may be delayed until fruiting has started on fertiles to establish whether insect pollination is effective. There will still be time to do hand crossing so long as growing conditions—especially moisture— remain favorable.

Two types of crossing blocks can be established to serve both insect and hand crossing procedures. The first is simpler consisting of a population of about 5-10 thousand plants grown from a blend of equal numbers of seeds selected from the ten percent elite lines in the S2 testing phase, and seeds are space planted (two seeds every 30-50 cm x 150 cm). These plantings should be made in alternate rows interspersed on at least two dates 10-14 days apart to facilitate random mating. On flowering, the sterile plants on which the crossed seeds are produced must be labelled with pegs or tags to permit identifying at harvest. Alternatively, equivalent representation of the original components can be preserved through the seed parent by planting the crossed progeny of the original elite strains interspersed with a blend of equal numbers of all retained lines to serve as pollinators. Fertiles are identified and removed in seed parent rows at the beginning of flowering. Effective control of harmful insects was achieved during flowering without inhibiting bee activity by spraying weekly with Azodrin in the afternoon when the cowpea flowers had closed and pollination ceased for the day.

This scheme proposes introducing new materials into the main stream population on a continuing basis through a two step procedure in which specialized subpopulations are first merged with a "backup population" wherein elite lines are subsequently fused with the mainstream. Elite lines from the mainstream would be merged reciprocally with backup and subpopulations to perpetuate raising of their agronomic bases.

Experimental Results

The sequence of operations for one cycle of population improvement in cowpeas utilizing genetic male sterility is graphically illustrated in Figure 1, while two alternative methods of recombination - Modified Fractional Diallel/S_2 Testing and Modified Half Sib/S_2 Testing are outlined in Figure 2. The relationships between sub-, backup and mainstream populations as applied to the IITA cowpea improvement program are shown in Figure 3.

Dual Population System

This method of recombination is proposed for species like pigeonpeas and lima beans with a reasonable degree of outcrossing (10% to 40%) and where hand crossing is particularly difficult and time consuming. It may also be used where it is desirable to maintain two distinct populations for different purposes, especially when each contributes significantly to the other.

Both parental types would be "resurrected" during generation advance by reselecting the distinctive recessive condition in each population. Simply inherited characters affecting seedling coloration, plant growth habit, leaf shape, pubescence, plant pigmentation, pod shape and colors, seed shape and size, testa color and pattern, and other attributes can be used to quickly and easily detect F1 plants. The recessive conditions of these characters are used as the seed parent in plantings timed to synchronize flowering between the two populations. These plantings would be made in alternate rows or hills to maximize outcrossing. Some roguing may be necessary in the seed parent population.

Lima Beans

It is not necessary to establish different plant types in the two populations, but each should have a distinctive recessive character for which the other population is dominant. In the case of lima beans, which parallels the inheritance in many other grain legume species, four sets of genes controlling seedling (hypocotyl) pigmentation, cotyledon color, determinancy and testa color are *very* convenient for this purpose. The seedling and mature seed markers are especially useful since indeterminate viney plants tend to intertwine making it impossible to separate single plants at harvest. Determinate growth (dd) is recessive to indeterminancy (D-) which can usually be detected early in growth by developing a viney leader. Cotyledon color is controlled by a single gene (3 - producing white cotyledons and gg giving rise to green cotyledons. Two manifestations of testa color - white and green - are desirable from the quality point of view. Both are recessive to other testa colors and eye patterns, but white occurs as W- , whereas green testa requires ww. Seedling (hypocotyl) pigmentation has been studied by Allard (1952) and found to be genically controlled as follows:

cc, R-, P- = green hypocotyl

C-, rr, pp = green hypocotyl

C-, R-, pp = red hypocotyl

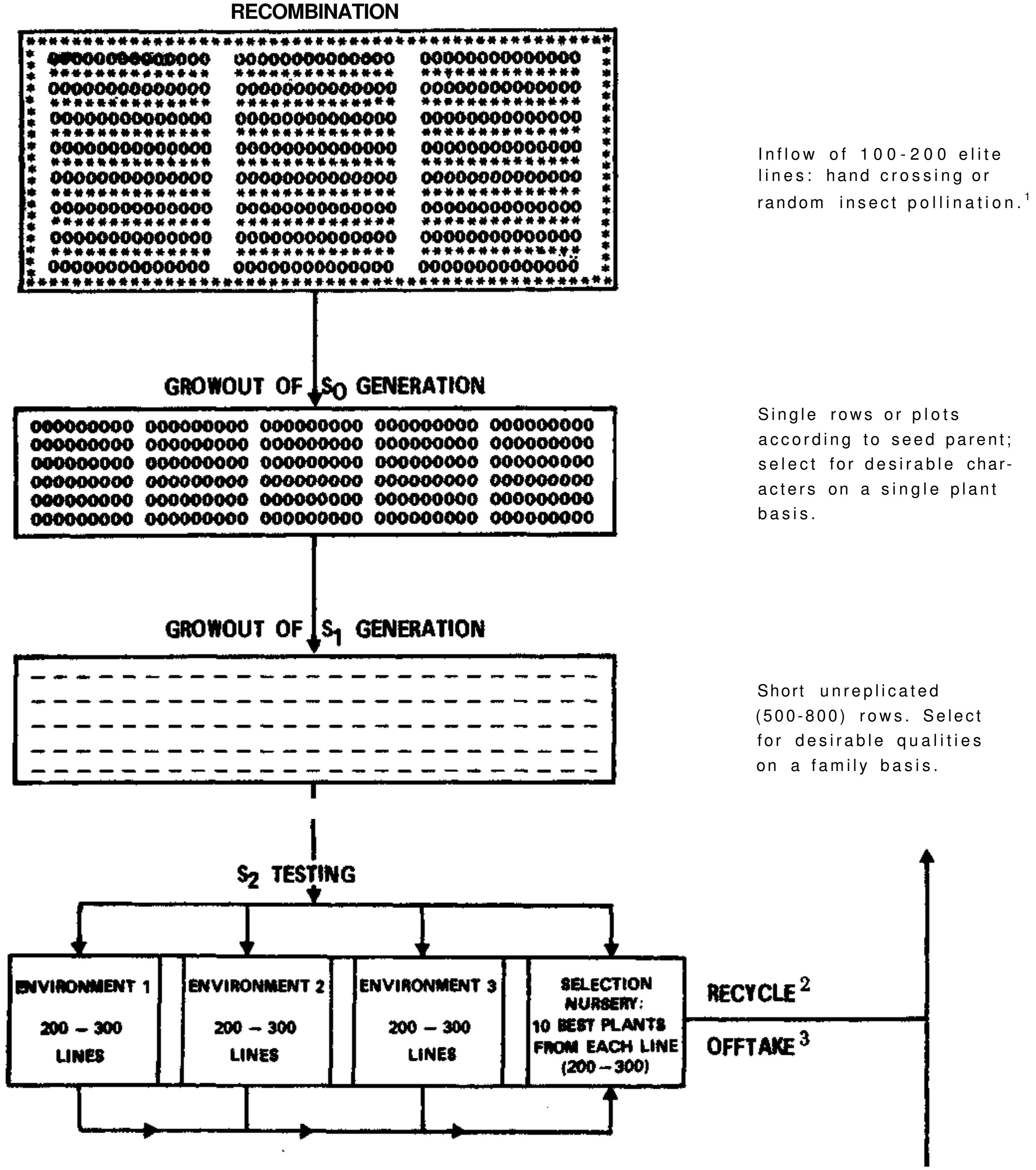
C-, rr, P- = purple hypocotyl (also purple flowers)

C-, R-, P- = red purple hypocotyl (also purple flowers)

Results of Crosses of Lima Beans

Random assortment of gametes from a nonspecific pollen source and fertilizing green

Figure 1. RECOMBINATION AND SELECTION PROCEDURE FOR POPULATION IMPROVEMENT IN COWPEAS *(Vigna unguiculata Walp)* UTILIZING GENETIC MALE STERILITY



Inflow of 100-200 elite lines: hand crossing or random insect pollination.[1]

Single rows or plots according to seed parent; select for desirable characters on a single plant basis.

Short unreplicated (500-800) rows. Select for desirable qualities on a family basis.

---

[1] Several subpopulations for pest and disease resistance, special plant characters and improved qualities can be established.

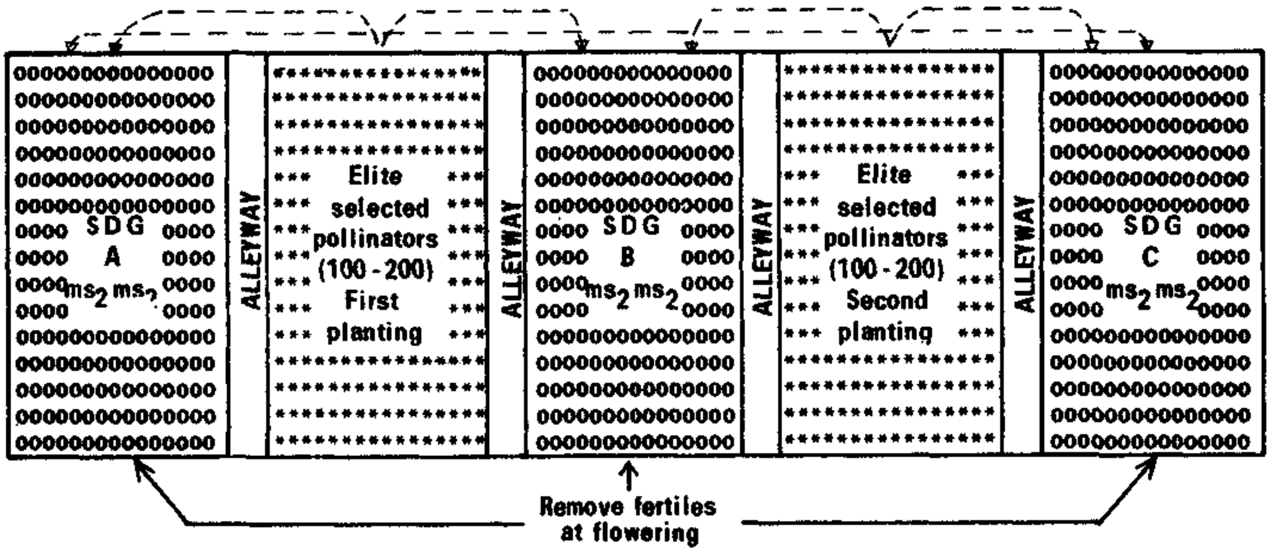
[2] Only the ten selections in each of the ten percent best performing lines over all ecologies are recycled.

[3] Offtake for pedigree selection and other breeding purposes can be done at all stages.

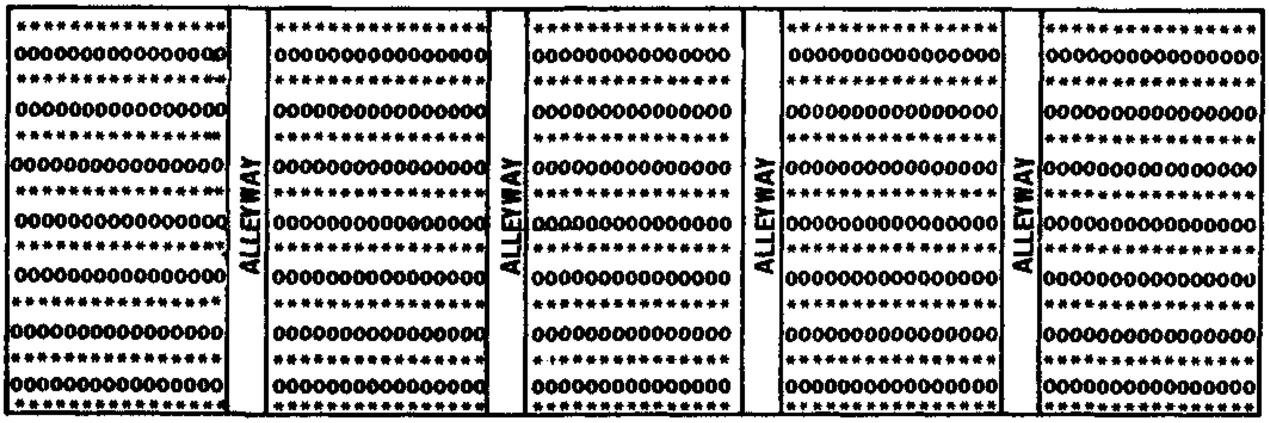
Figure 2. **ALTERNATIVE RECOMBINATION PROCEDURES FOR POPULATION IMPROVEMENT IN COWPEAS UTILIZING GENETIC MALE STERILITY.**

A UODIFIED FRACTIONAL DIALLEL/S2 TESTING (Hand Crossing)

Hand pollinate 10-20 male steriles in each SDG population (A,B,C)



B *MODIFIED HALF - SIB/S_2 TESTING (Insect Pollination)*

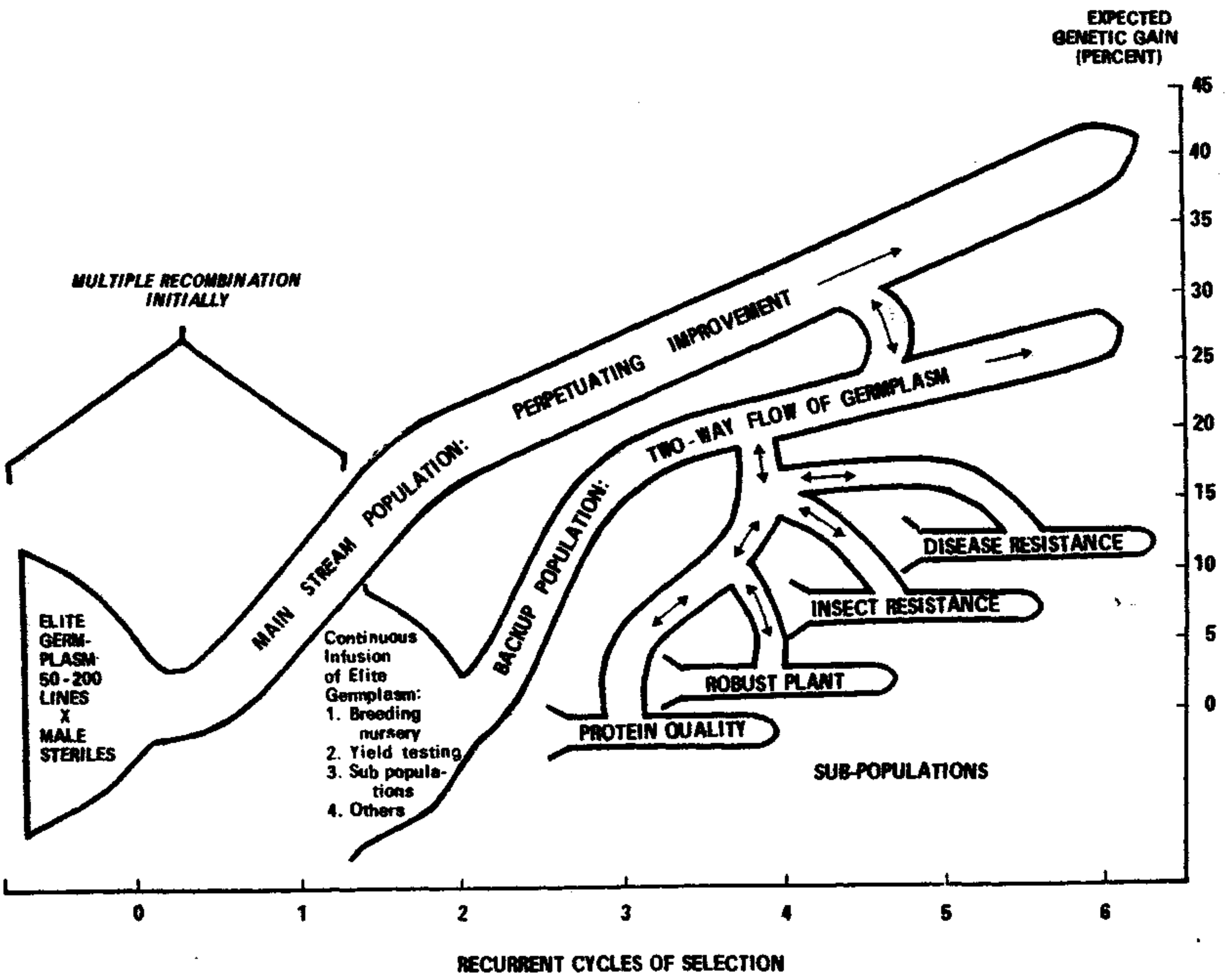


* = Pollinators-a blend of equal numbers of seeds of all elite selected lines (100-200).

o = Individual elite lines (100 - 200) from which fertiles have been removed at beginning of flowering.

NOTE: Pest protection - Spray azodrin every 7-10 days in the afternoon.

Figure 3. INTEGRATION OF MAIN STREAM, BACKUP AND SUB POPULATIONS IN GRAIN LEGUME IMPROVEMENT AT IITA.



seedling plants would result in nearly 50% green seedlings, but utilizing only red purple seedling plants could increase the proportion of colored F, seedlings to around 75% thereby Increasing the efficiency of hybrid detection. Similarly, utilizing two unrelated simple recessive genes in a population would increase the proportion of readily detectable F1's. For example, it should be possible to detect more than 80% of the nonparental types(nearly all F1's) from a growout of a lima bean crossing block utilizing two determinancy and testa color factors when the following assumptions are made:

1. Two populations are grown in close proximity to each other and planted as to maximize "natural" outcrossing;
2. The two populations are limited to two alleles each for determinancy (D, d) and seed testa color (W, w);
3. A random source of pollen is supplied by an indeterminate population (D-) producing three times as many white (W-) seeds and indeterminate (D-) garnets as green seed (ww) and determinate (dd) gametes, respectively;
4. Only determinate plants in a population containing twice as many white as green seeded plants are harvested as the putative outcrossed seed parent;
5. White seeded and green seeded plants are planted separately and nonparental types are identified during the growout - as indeterminate plants, or with testa color different from that of the mother plants.

Of course, a lower yield of crosses can be obtained even more simply by utilizing only one recessive character in each population: a determinate population with white colored testae (A) and an indeterminate population with green testae (B). Thus, only indeterminate plants are selected in the putative F1 growout of determinate plant types in population (A); and only white or colored testa plants are selected in population (B). Since many hundreds or thousands of crosses may be required, only single seeds from the topmost pods (the ones most likely to be visited by pollinators) need be retained for growing out the putative F1 generation. Discovery of male sterility in limas would simplify the problem further, but it is not essential owing to the high natural outcrossing (15%-30%) in this species. Moreover, male sterility must eventually be eliminated in commercial varieties.

Planting Arrangements

Several planting arrangements may be adopted depending on the genotypes involved and environmental conditions prevailing. These usually involve alternating rows or hills or varying numbers of rows or hills planted to assure synchronizing of flowering dates between the two parents (Figure 4). Perhaps the most convenient system is utilizing the longer duration, less determinate population (like viney limas) as the pollen donor and planting it first. The more determinate seed parent would be planted appropriately later and on two or more successive dates about 10-14 days apart to better sample genetic diversity in the pollinator population. However, it is important to have pollen available by the time the seed parent begins flowering, and over a long period of time. Timely irrigation helps extend the flowering period in indeterminate plant types. Planting must be done during the period of shortening days to allow daylength sensitive ecotypes to flower. Most photoperiod sensitive cowpeas planted after mid-February do not flower normally at Ibadan.

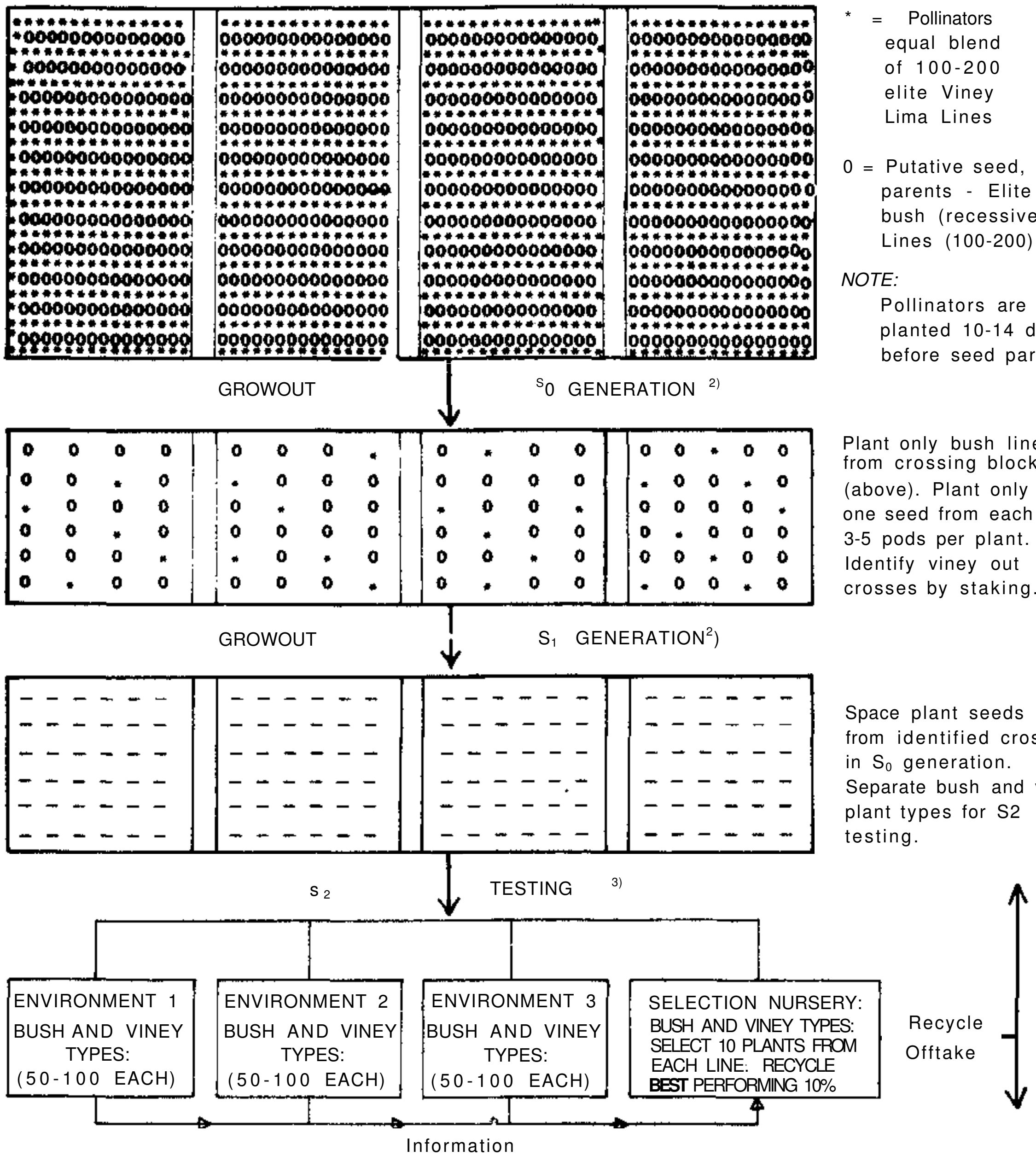
SELECTION PROCEDURE

It is usually desirable to complete one cycle of recurrent selection within a twelve month span of time to allow testing during the main season the crop would be grown. With medium and short duration lima beans, pigeonpeas and soybeans, three generations per year are possible in the tropics and, therefore, S1 testing may be the desired selection method. However, S2 selection is more efficient and easier to manage owing to greater uniformity of lines being tested and availability of many seeds for replicated testing. Thus, it may be preferable and more efficient to adopt S2 testing even when two years per cycle are required, but it is especially appropriate for cowpeas since four generations per year are possible. Since nearly all grain legumes produce the best quality seeds when they mature during bright, sunny weather at the beginning of the dry season, the Second Rains is the best season for testing at Ibadan. This means the recombination generation must be grown during the irrigated dry season with the S_0 grown out during the First Rains.

S_2 Testing

Cowpeas provide an excellent subject for

Figure 4. RECOMBINATION AND SELECTION PROCEDURE FOR DUAL POPULATION IMPROVEMENT UTILIZING HALF Sib/S2 TESTING IN LIMA BEANS *(Phaseolus Lunatus L.)* RECOMBINATION[1])



* = Pollinators equal blend of 100-200 elite Viney Lima Lines

0 = Putative seed, parents - Elite bush (recessive) Lines (100-200)

NOTE:
Pollinators are planted 10-14 days before seed parents.

Plant only bush lines from crossing block (above). Plant only one seed from each of 3-5 pods per plant. Identify viney out crosses by staking.

Space plant seeds from identified crosses in S_0 generation. Separate bush and viney plant types for S2 testing.

1. A separate block for viney x viney limas can be established if major emphasis is to be given to this plant type. Similarly, a bush x bush crossing block can be established if major emphasis is given to this plant type .

2 . Since bush type plants will be segregating one bush to three viney types, it is not possible to yield test bush selections until the S, generation . However, the occurrence of 25 percent bush plants should not have any effect on the performance of viney selections - either in the S_1 or S_2 generations - owing to the vigorous, spreading growth of viney plants .

3. Separate yield tests must be conducted for bush and viney plant types.

population improvement since four generations per year are possible with supplementary irrigation at IITA thereby allowing use of the S2 testing method. A modification of the method presently under development can be completed with a 12-month span:

Generation	Season	Operation
1	Dry-Irrigated (Nov-Feb)	Recombination by hand or naturally by insects utilizing genetic male sterility.
2	Early First Season (March-May)	Grow out F1's; discard weak, diseased plants.
3	Between Rains (June-Aug)	Grow out S1's; select 200-300 families discarding inferior plants for S2 testing.
4	Second Rain (Sept-Nov)	Replicated tests of 200-300 S2's in three environments. Select best 102 on yield tests for recombination.

S, Testing

The operational aspects of the selection procedure appropriate for S1 testing (also Half Sib/S_2 or Full Sib/S2 testing) employing Dual Population recombination for one cycle at Ibadan are outlined below:

Generation	Season	. Operation
1	Nov-March	Recombination utilizing the Dual Population System described above. Parent populations are constituted by blending equal numbers of seeds in both plant types classified in the previous harvest.
2	April-July	Grow out 600-800 presumed F1's in single rows 10-20 m in length; Identify true crosses and selfs. Use seeds of best F1 plants in each of 200-300 best lines.
3	Aug-Nov	Yield test the 200-300 best lines replicated at least twice under three environments. Simultaneously, grow out a separate nursery and select the ten best in all 200-300 lines being tested. Retain for next cycle of recombination only those lines selected within the best performing 2-30 lines. Reclassify selections as to parental type for recombination.

This system is designed to restore the original number of lines, but it is important to retain reasonable equivalence in both parental types. Since the frequency of the seed parent type with multiple recessive factors is likely to remain low—especially during the first one or two cycles—it may not be possible to recover an equivalent number of elite lines in this type. Therefore, it would be reasonable to retain only about a third or fourth the number of pollinators compared with seed parent types. It is further suggested that a more inclusive germplasm pool be merged with both parental types at appropriate types intervals (every 2-3 cycles) through a gradual infusion process to broaden the genetic base and maintain a high rate of advancement (Figure 4).

The end product of this process can be pure breeding strains utilized as commercial varieties, parental lines and genetic stocks, or composite varieties with wide adaptation and a high level of tolerance to stress. In fact, for some of these crops—especially the partially outcrossing lima beans and pigeonpeas—a reasonable level of heterozygosity would be advantageous since some heterotic vigor would occur and the variety would better fit a broader range of environments. However, composite varieties should be uniform for growth habit, plant height, maturity, pest and disease resistance and seed qualities.

Yield Testing

A major constraint in testing grain legumes is the large numbers of seeds required — especially when yield testing a broad range of plant types ranging from indeterminate to erect, prostrate and climbing types. Four row plots 3-4 meters long separated from adjacent plots by 1.2 to 1.5 m are presently used for cowpeas at IITA to provide an adequate yield sample. Minimum seed requirements (2 good seeds/hill) is 520-672 seeds per trial. Moreover, land requirements are considerable-from 16-23m^2 per plot.

Recognizing the importance of expanding the environmental component of population improvement, the feasibility of utilizing smaller plots, perhaps with more replicates, is being studied at IITA. Short (2.5 m) three row, circular and "diamond" hill plots are being tried in an attempt to reduce seed requirements to 10-20 seeds and area to 2.2-4.0 m^2 per plot. Such plots could maximize intraplant competitive stress while reducing inter-genotype competition as well as seed and land area requirements by several fold. If such testing proves reliable, a single, spaced plant could provide enough seeds for replicated testing at one or two locations.

IMPLICATIONS FOR OUTREACH

Adoption of population improvement schemes will have profound effects on the kind of outreach activities an international crop improvement program becomes involved in. New opportunities will unfold, and seemingly impossible problems may become amenable to solution. This is particularly applicable to viruses on annual crops, blast disease of rice, Cercospora leaf spots, stem borers and several sucking insect pests. Added to these are opportunities to reach new dimensions of adaptation and productivity levels.

Recurrent selection schemes provide the means for developing an infinite range of genetic variability. This variability is exploitable over an extraordinary range of conditions. It also proviaes much broader opportunities for collaborating national programs–particularly in situations with limited resources and facilities. However, exploiting the potential of this new technology will require able and perceptive crop researchers at the national and regional levels. Therefore, there will be an urgent need for research training of young scientists in new breeding technology broad enough in scope to cater to different levels of participation as envisaged below:

1. Field selection and testing stations. These programs would select and test advanced lines from populations and composite varieties from various sources–especially from intermediate centers.

2. Intermediate crop improvement programs. These would have limited staff ana- resources to carry on recycling activities, but would require an understanding of how to use genetic male sterility or dual population systems with limited but elite germplasm in solving local or regional problems, while simultaneously raising productivity levels. They would serve as direct links between advanced and selecting or testing stations.

3. Advanced crop improvement programs. These would have a full team of scientists to generate new populations and varieties in serving national and regional collaborators. They would be essentially independent programs, with direct linkages into international centers.

The major distinction between the "intermediate" and "advanced" levels described above would depend on national priorities and availability of resources. Many countries could not afford an "advanced program" or may not deem the economic importance of the crop worthy of larger investment.

The first prerogative of training at all levels will be teaching good crop husbandry and maximizing returns for specific environments and management inputs. Only then will it be possible to exploit the constant flow of new genetic variability which will become available from international and national/regional crop improvement centers.

CONCLUSIONS AND SUMMARY

Population improvement, defined as a form of breeding for the utilization of additive gene effects, is highly effective in improving outcrossing species. Recently there has been considerable interest in applying recurrent selection principles toward the improvement of self-pollinated crops. The requirements for successfully implementing population improvement are:

1. Developing populations from a broad base of elite genetic stocks.

2. Effecting massive geneflow through

extensively random or systematically diverse recombination.

3. Selecting for desired simply inherited (qualitative) characters.

4. Evaluating performance of S_1's to S_2's for complex, quantitatively inherited characters like yield and horizontal resistance under a range of environments.

5. Providing a continuing offtake of elite genotypes into "pedigree" advancement and infusing new genetic materials into the system.

The major constraint in adapting population improvement in self-pollinated crops like grain legumes has been the difficulty in effecting massive geneflow during the recombination phase and limitation of seeds for testing in several environments. These problems can be overcome through:

1. Increasing the rapidity and efficiency of hand crossing;

2. Introducing some form of outcrossing like genetic male sterility, delayed dehiscence or protogyny into the population;

3. Enhancing directed natural outcrossing in partially outcrossing species.

4. Reducing seed numbers and plot size required for testing.

Introducing male sterility into cowpea populations has been highly successful in increasing the rate and success of hand crossing; and has facilitated extensive, partially directed outcrossing by pollinating insects - primarily bees. Delayed dehiscence linked with (puberulence) might be utilized similarly in soybeans; except that only three generations are feasible in a 12-month span. For partially outcrossing species like lima beans and pigeonpeas, extensive crossing can be achieved through the Dual Population System in which two populations are developed simultaneously. One of these carrying easily recognized recessive genes is utilized as the seed parent while the population carrying more dominant genes and having a more indeterminate growth habit can be used as the pollen donor.

The end product of this process is an improved seed propagated pure line or a random mating population. It is suggested that the rate of genetic gain within an established plant type could be quite high during the first 2–3 cycles, and that improvement would be sustained at a lower but satisfactory rate thereafter.

Outreach and training will be profoundly affected by the new breeding technology. There will be expanded needs for training of crop improvement researchers at different levels of technology to serve in the linkage between international and advanced national centers and the extension/farmer level. Three levels are envisaged: (1) Field selection-testing stations, (2) Intermediate centers (limited resources), and (3) Advanced centers, directly linked with international crop improvement centers, but themselves generating new populations and serving or directing lower echelon stations.

ACKNOWLEDGEMENTS

The writers are especially grateful to Dr. S.A. Eberhart, Research Scientist – USDA/ARS, Iowa State University, Ames 50010 for his valuable suggestions on the statistical portions of the manuscript; and they are also indebted to Dr. S.K. Hahn, Geneticist and Program Leader for Roots and Tuber Improvement - IITA, and to Dr. K. Rawal, Botanist and Plant Explorer - IITA, for their helpful comments and demonstrating the workability of the systems described.

DISCUSSION

K.J. Frey: I would like to point out that Or. Rachie has given three types of plant population division: (a) according to plant growth habit, (b) the dual population system and (c) the flow chart system. In the latter one, how would the flow back into the base population work?

K.O. Rachie: The intention of having subpopulations is to allow maximum progress for specific objectives, and then attempt to raise the agronomic levels of these subpopulations. The three plant types we have talked about are true agronomic types, i.e., three points on the spectrum of genetic diversity.

P. Lawrence: Could you explain the dual populations system better?

K.O. Rachie: I have been using it to achieve recombination, e.g., in lima beans. These are two distinct types and a tremendous increase comes from intercrossing them. Each can contribute to the other.

P. Lawrence: Is the end product a hybrid?

K.O. Rachie: I envisage pulling out pure lines.

P. Lawrence: What do you achieve by growing populations separately?

K.O. Rachie: I don't see the point in leaving them mixed. We will cross between viney and bushy types within groups too.

L.R. House: My grandmother said don't put all your eggs in one basket. Line and cross material are better than composites in sorghum in the Middle East but are also carrying along composites.

K.O. Rachie: I said at the outset the methods I am proposing were an adjunct to conventional methods. I did not mention the word composite in my paper. The diagram shows that offtake goes into a pedigree system.

J.M. Green: Dr. Rachie was asked to speak about the application of methods of breeding cross-pollinated crops to self-pollinated crops, which would account for his emphasis.

0. Sharma: We have started a dual population program using obtuse leaf as a single gene recessive character to identify crosses. We have some material like Dr. Rachie's with very limited branching.

K.O. Rachie: I plan to offer the new type pigeonpeas to anyone interested in having them.

B.V.S. Reddy: We have some pigeonpea plants with anthers without pollen and others with stigmas well above anthers.

K.O. Rachie: Congratulations.

K.B. Singh: Could there be a single factor like the dwarfing gene in wheat and maize that we should look for in grain legumes?

K.O. Rachie: I am selecting for the biggest, tallest and most rugged cowpeas I can find.

W.V. Royes: How do you know the male parents from which bees are bringing pollen?

When I cross, I know what I want. You cannot allow bees to do this. Secondly, you do not talk about selection indices. Do you not know what you want to get? For selection there must be objectives.

K.O. Rachie: Only part of our program is devoted to population improvement. However, this is likely to Increase in importance.

K.J. Frey: I think Dr. Royes is talking about recurrent selection and by growing composites we are trying to break up linkage systems.

G.C. Hawtin: Have you done any research on gametocides?

K.O. Rachie: I have not used them.

K.J. Frey: One was used on cotton and other crops but this was the first and was not very good. Ethrel has been used in wheat but it does not work on oats. We now have a Du Pont chemical which gives poor seed set but 90% outcrossing.

L.J.G. van der Maesen: I did some work with clover, immersing the head in 10% alcohol solution and this seemed workable.

K.J. Frey: Hot water is an effective male gametocide but cannot be used on a mass basis.

H.K. Jain: Dr. Rachie's scheme has the merit of generating more variability in a self-pollinated crop than is possible by conventional methods. In India there is an F1 cotton cultivated on over one million acres and each seed has been produced by hand pollination.

J.M. Green; Hybrid cotton shows that Indian farmers will adopt a viable technology. With pigeonpeas we have not overlooked the possibility of producing hybrids.

K.O. Rachie: We do quite a bit of vegetative propagation of F1 plants for increasing F2 seed production.

L.J.G. van der Naesen: Doesn't it cost a lot of sowing seed for a dense population of pigeonpea?

K.O. Rachie: A range of 50-100 kgs of seed is not too much. I envisage broadcasting seed in some situations, or having very close rows. But our plants are prototypes, mainly for use as parental stocks.

K.B. Singh: Cowpea has a very low productivity in the world. In India, they are little used because of low productivity. How much jump can be made so this crop could become useful? In India there is scope for short duration grain legume crops in the summer. Cowpeas took too long. Are your varieties short duration varieties?

K.O. Rachie: The low yields of cowpeas are a great challenge. Cowpeas are interplanted with cereals and the low yields may be partly explained by this. Cowpea seeds have excellent quality. Cowpeas may be more easily improved than mung beans.

K.B. Singh: How will your short duration varieties perform in India?

K.O. Rachie: I think there is potential for cowpeas and that our initial gains will be rapid. We have recently identified a variety with considerable disease and pest resistance.

LITERATURE CITED

Allard, R.W. 1952. Inheritance of hypocotyl color in lima beans. Proceedings of Amer. Soc. Hort. Sc1. 60; 387-390.

Brim, C.A. 1966. A modified pedigree method of selection in soybean. Crop Sci. 6: 220.

Brim, C.A. and M.F. Young. 1971. Inheritance of a male sterile character in soybeans. Crop Sci. 11(4): 564-566.

Compton, W.A. Recurrent selection in self-pollinated crops without extensive crossing. Crop Sc1. 10(6):773.

Doggett, H. and S.A. Eberhart. 1968. Recurrent selection in sorghum. Crop Sc1. 8: 119-121.

Eberhart, S.A. 1970. Techniques and methods for more efficient population improvement in sorghum, pp. 197-213. Sorghum in the Seventies. Journal Paper No.7088 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa.

Empig, L.T., CO. Gardner and W.A. Compton. 1972. Theoretical gains for different population improvement procedures. Lincoln, Univer of Nebraska, College of Agriculture Bulletin MP26 Revised.

Jennings, P.R. 1974. R1ce breeding and world food production. Science 186: 1085-1088.

Jensen, N.F. 1970. A diallel selective mating system for cereal breeding. Crop Sci. 10(6): 629-635.

Rachie, K.O., K. Rawal and J.D. Franckowiak. 1947a. An efficient method of hand crossing cowpeas, Vigna unguiculata (L.) Walp. IITA Technical Bulletin No.2, Ibadan, Nigeria.

Rachle, K.O., K. Rawal, J.D. Franckowlak and M.A. Akinpelu. 1974. Two outcrossing mechanisms in cowpeas, Vigna unguiculata (L.) Walp. Euphytica, 35:1-5.

Redden, R.J. and N.F. Jensen. 1974. Mass selection and mating systems in cereals. Crop Sc1. 14(3):345-350.

Sprague, G.F. 1966. Quantitative genetics in plant improvement, pp. 315-354 in Plant Breeding. K.J. Frey Ed. Ames, Iowa State Unlver Press.

SESSION REVIEW

B. P. Pandya[1]

OBSERVATIONS ON SELECTION

Population improvement is essentially a genetic tool to concentrate favorable genes in a population and is almost a thoroughfare in the genetic improvement of unselected populations in field crops. Broadly speaking this technique aims at increasing the level of performance of a trait or number of traits in crop species from generation to generation and cycle to cycle. However, in practice it has become more or less a synonym for selection in population with considerable amount of fixable and additive type of gene actions. In this technique, selection work has been predominantly based on function of the parameters, extent of heritability, selection differential and the type of variances.

In practice, mass selection, full sib family selection, half sib family selection, S1 family selection and recurrent selection have been frequently followed for capitalizing additive type of gene actions and advancing the performance of the populations especially on outcrossing species like maize, pearl millet,etc.

POTENTIAL OF OUTCROSSING

The partially outcrossing crop species provide a good opportunity for concentrating and funneling out favorable genes in a population. The extent of outcrossing in some of these potentially outcrossing species could be enhanced for better exploitation of non-additive type of gene actions than what is usually expected under a partial outcrossing genetic mechanism. Therefore, for getting a fuller exploitation of the advance under recurrent selection, it would be a worthwhile genetic enquiry to look for morphological and physiological mechanisms for upgrading the extent of outcrossing in these economically important crop species. This could be accomplished by incorporating male sterility mechanisms or some sort of modification in the structure of the flower facilitating easy outcrossing through the visiting insects.

Recurrent Selection in Partially Outcrossing Species

Utilization of the recurrent selection method could be a good potential technique for improving the performance of partially outcrossing species like pigeonpea and lima beans. The paper provided by Dr. Rachie embraces the theoretical background and the operation procedure for raising the recurrent selection cycles and testing their performances, with 200-300 best F1 plants obtained from dual population system. The level of genetic progress with selection in these crop species could be facilitated much more quickly *by* the incorporation of seedling marker (color) or leaf shape for early rogueing of the selfs. However, for the genetic improvement in grain yield possibility it may be more desirable to begin with much larger number of F1 plants than 200 to 300, providing enough chances for breaking up the undesirable linkages.

Further, because of the partial outcrossing in each of the generations within each cycle of selection i.e., in S0, S1, etc., selfing of the selected plants/progenies in S0, S1 and selection nursery may be worth considering.

Other Considerations in Recurrent Selection

Also certain other considerations will have to be taken into account from the point of view of the practicability of such types

---

[1] G.B. Pant University of Agriculture and Technology, Pantnagar, Uttar Pradesh, India

of recurrent selection programs. These are:

1. Parents used must be purified through selfing for plant type, maturity, seed coat color, etc.
2. Separate programs for determinate and indeterminate types should be undertaken.
3. Selection programs should be taken up in isolations in order to avoid contamination of pollen from other sources.
4. It may be desirable to choose the parents from diverse sources. Sufficient amount of locally adapted materials should also be represented among the parents.
5. Survey of the locations to determine the extent of outcrossing in pigeonpeas before carrying out such programs in those areas will be desirable.

EIGHTH

SESSION

BREEDING SOYBEANS RESISTANT TO DISEASES

E. E. Hartwig'

INTRODUCTION

In 1973, soybeans were grown on approximately 23 million hectares in the U.S., producing an average yield of 1887 kg/ha. Soybean production in the U.S. for grain is of relatively recent origin, as 1941 was the first year in which the area planted to be harvested for grain equalled the area planted for forage. At present, soybeans are the number one cash crop grown in the U.S. Maize has a higher value, but much of this crop is fed on the farm and marketed in the form of livestock.

In my own research, I have been concerned primarily with soybean production in the southern states. Here we are concerned primarily with a region lying between latitudes 30 and 38 degrees. Nearly all soybean producing areas are at an elevation of below 250 meters. Annual rainfall varies from 80 to 130 cm. Soils cover a range from loamy sands of the coastal plains to the heavy clays of the Mississippi alluvium.

Research leading to the development of improved cultural practices and better adapted disease resistant and nematode resistant cultivars has contributed appreciably toward the increased'production of soybeans in the South. In 1953, we grew slightly more than 1 million hectares with a'yield of 880 kg/ha. By 1963, the planted area had increased to 3.5 million hectares with a yield of 1300 kg/ha, and in 1973, the area had increased to nearly 7.9 million hectares and a yield of 1700 kg/ha.

The cultivar 'Lee', released to farmers for production in 1954, made a significant contribution toward reducing risks for the soybean grower, because of its seed holding characteristics in addition to its resistance to several diseases. Most soybean cultivars moderately adapted for production in the South prior to the availability of Lee were likely to shatter as soon as they reached maturity. Shatter resistance is of considerable importance where large areas are to be harvested with mechanical harvesters, so as to permit the machine to be used over a longer period. The development of additional cultivars having a range in maturity has eliminated losses from shattering prior to harvest.

At Stoneville, Mississippi, we maintain a germplasm collection of slightly over 1,000 entries, while at Urbana, Illinois, a collection of over 2,500 entries is maintained. The entire collection, primarily from eastern Asia, represents material from a range of 0° to 60° latitude. This germplasm collection has provided a reservoir of material to investigate whenever a new problem was identified.

DISEASES

Several diseases and nematodes have been identified as causing reductions in yield for soybeans growing in the southern U.S. Some that we have given consideration in our treedlng program are: bacterial pustule (Xanthomonas phaseoli var. sojensis), wildfire (Pseudomonas tabaci), target spot (Corynespora cassiicola), phytophthora rot (Phytophthora megasperma var. sojae), frogeye leaf spot (Cercospora sojina), downy mildew (Percnospora manshurica), root knot nematode (meloidogyne incognita, and M. arenaria), cyst nematode (Heterodera glycines), and soybean mosaic virus. Soybean strains having a high level of resistance to each of these problems have been identified. In most cases highly productive cultivars having a high level of resistance have been developed and released for production, and are being grown by farmers.

Bacterial Pustule

One of the first diseases of soybeans to

---

[1] Selta Branch Experiment Station, ARS/USOA, Stoneville, Mississippi, U.S.A.

be given attention when research on the crop expanded in 1943 was bacterial pustule. Although the area planted to soybeans was small, all areas observed were heavily infected with bacterial pustule and wildfire. Two very similar cultivars, 'Nanking' and 'CNS'.were observed to be free of both diseases. Later studies proved both to be resistant to bacterial pustule, and this resistance to bacterial pustule was effective in preventing development of wildfire. Nanking and CNS were selections from seed lots introduced from Nanking, China, in 1927.

Development of Resistance to Bacterial Pustule

Genetic studies conducted by Hartwig and Lehman (1951) showed that resistance to bacterial pustule was inherited as a simple recessive character. Studies conducted by Hartwig and Johnson (1953) using closely related lines showed that reductions in seed yield of 8% to 11% could be measured following a moderate development of bacterial pustule. Additional studies conducted at Stoneville, Mississippi, have shown yield reductions of 15%. Feaster (1951) conducted studies inoculating soybeans at different times of the day to determine the optimum time of inoculating breeding material. He concluded that most severe infections were obtained when the inoculations were made at the time of day when stomatal openings were the greatest. At this time, leaves were most readily water soaked.

A simplified method for field inoculation with bacterial pustule was developed by Jones and Hartwig (1959). Fresh infected leaflets were used as a source of inoculum by first running them through a food chopper and then comminuting this material in a food blender with tap water. This suspension is allowed to stand for about 2 hours before filtering, and then used to inoculate plants. Infected leaflets may be chopped and frozen and *stored for* use the following year. If fresh material is desired, a susceptible cultivar may be planted early, inoculated with frozen material and fresh infected leaves used for inoculating the breeding nursery.

At present, all soybean cultivars grown on the nearly 8 million hectares in the Southern U.S. are resistant to bacterial pustule. Much of our breeding material at Stoneville is resistant. However, whenever we utilize strains from the germpiasm collection to introduce a new character, we again introduce susceptibility to bacterial pustule. Under normal summer conditions at Stoneville we have several wind and rain storms. Rain driven by a heavy wind will move bacterial pustule from an infected leaf for considerable distance. For several years, we have followed a program of planting 2 rows of a bacterial pustule susceptible cultivar at the side of a field,, followed by 20 rows of experimental strains, and then another pair of rows of the susceptible cultivar. When the susceptible cultivar has reached the 3 to 5 trifolilate stage, frozen infected leaflets are used as source of inoculum for inoculating the susceptible borders. Rain with wind is effective for spreading the disease to susceptible breeding lines. We normally make no selection for resistance to bacterial pustule in F2, but attempt to identify all susceptible or segregating lines in F3. Resistant plants may be tagged within segregating rows. Only bacterial pustule resistant lines are retained for yield evaluation.

Target Spot

Leaf spotting of susceptible cultivars and experimental lines caused by target spot has been observed *in* all southeastern states. At Stoneville, yield reductions on susceptible cultivars of 18% to 32% have been measured in five out of ten years (Hartwig 1959). Target spot development is more severe in years having good late season moisture. Although target spot infection can be established each year, development sufficient for measuring differences among breeding lines is obtained only when late season moisture is adequate for supporting disease development. In view of the problems of getting heavy disease development on susceptible lines, no progress has been made in determining the nature of inheritance of resistance to target spot. However, it has been possible to identify susceptible breeding lines and eliminate them before they would be advanced very far in the breeding program. All cultivars released for production have a high level of resistance.

Phytophthora Rot

Phytophthora rot was first recognized as a disease of soybeans in 1948. Since then, the disease has been reported in most soybean producing areas of the U.S. and Canada. The disease is most troublesome on slowly drained clay soils. The disease may cause seed rot, pre- or post-emergence damping off, killing at any time during the season, or merely a reduction in plant vigor. Several sources of resistance are available in the germplasm collection and resistant cultivars are now widely grown. Bernard et al. (1957) determined that a high level of resistance was controlled by a single dominant gene. Another nonallelic gene for resistance has been described by Kilen et al. (1974).

Methods of Control of Phytophthora Rot

Phytophthora rot could be a serious problem in several million hectares of soybean production on the alluvial soils of the lower Mississippi Valley, if cultivars with at least a moderate level of resistance were not grown. Several highly resistant cultivars are in production. It is possible to identify highly susceptible strains in the field plantings on clay every year. However, strains rated as moderately susceptible may survive in some years. At present, we grow F2 populations on a soil where phytophthora rot is not expected to be a problem and all plants are harvested individually. During the winter months, progeny from F2 plants are screened for reaction to phytophthora rot. Ten seeds from each F2 plants are planted in sand in 10 cm pots, and 5 days after emergence each plant is inoculated. A spear pointed needle is dipped into a semisolid Uma bean agar containing mycelia and zoospores. Plants are kept in a moist atmosphere for 24 hours after being inoculated. Susceptible plants should be dead within 4 or 5 days after inoculation. Approximately 3 weeks are required for handling one batch of material. A new planting is made immediately following reading of the previous batch. F3 lines are grown on clay from F2 plants classified as resistant or heterozygous. A pedigree breeding method is utilized. In most cases, uniform appearing F5 lines are harvested for evaluation for seed yield. These lines may be rechecked to assure their resistance to phytophthora rot. Replicated plantings for yield evaluation are made on clay where phytophthora rot is a problem.

Root Knot Nematode

While phytophthora rot is a more serious problem on the slowly drained clay soils, both root knot and cyst nematodes are more likely to be problems on well drained sandy loam soils. The common root knot nematode, Meloidognye incognita, has a wide variety of hosts. In southern U.S., it is commonly referred to as the cotton root knot nematode. The cultivar Laredo, once widely grown for forage, has a high level of resistance, as does also the cultlvar Palmetto. Laredo traces to an introduction from China obtained in 1914, while Palmetto traces to an Introduction received in 1927. Both have been used 1n the breeding program. In each case, it has been necessary to make one or more backcrosses to a productive variety in order to obtain highly productive root knot resistant lines.

Breeding for Root Knot Resistance

Breeding work to develop root knot resistant lines has been conducted primarily in the field. Since nematode populations may be variable in the soil, we consider it important to use frequent checks. We have identified the cultlvar Pine Dell Perfection as being extremely susceptible. This cultivar has seed and plant characteristics readily identifiable In some of our plantings, we have planted 3 seed of Pine Dell Perfection with 8 seed from a single plant selection in hills spaced 50 cm apart in the row. This method permits concentrating a large amount of material in a small heavily infested area. If Plne Dell Perfection remains healthy, we know the nematode population was low. However, when Pine Dell Perfection plants die in midseason and the breeding line remains vigorous, we have confidence that it has a high level of resistance. Late in the season, roots are inspected from thehealthier appearing lines. Several highly resistant cultivars have been released for production.

Soybean Cyst Nematode Control

The soybean cyst nematode was first recognized in the U.S. in 1954. Shortly after it was identified, a search was made to isolate sources of resistance. The cultivar 'Peking', tracing to an introduction from China obtained in 1907, was found to be resistant. Peking is a black seeded type grown for forage purposes. Several other black seeded types were also found to be highly resistant. Resistance is conditioned by 3 recessive gene pairs and a dominant gene. In addition, the gene giving colored seed is closely linked with a gene for resistance. It has been necessary to do all screening in the greenhouae in soil having a high cyst content. F2 seed is planted in infested soil. Approximately 30 days after emergence the roots of each plant are inspected for cyst development. Seedlings free of cysts are repotted and later transplanted to the field. After maturity, progeny are again checked for cyst reaction. Resistant plants are used as parents for crossing with adapted cultivars. It has been necessary to screen *very* large populations in order to have a sufficient number of resistant lines to permit selection for agronomic characters. Resistant cultivars have been developed and are being grown in regions where the soybean cyst nematode is a problem.

Four races of the soybean cyst nematode have now been recognized. The resistance of Peking gave adequate protection against races 1 and 3. Race 2 has been of little consequence, but race 4 has been observed in localized areas 1n major soybean areas once cultivars with resistance to races 1 and 3 were widely grown. Resistance to race 4 has been identified and breeding lines developed with this resistance. In the program to develop productive cultivars having resistance to race 4, cultivars or breeding lines with resistance to races I and 3 were used as recurrent parents. Since production fields will have a mixture of the several races, the cultivar to be grown must be resistant to all. Advanced lines will be evaluated both on infested and noninfested soil.

Soybean Mosaic Virus

Soybean mosaic virus is perhaps the most common virus of soybeans. Infected plants have rather rugose leaves, but the degree of symptoms will vary with the cultivar. Seed from infected plants will be mottled.. This means that color which should be restricted to the hilum is spread to parts of the seedcoat. Ross (1968) measured yield reductions as high as 25% after seedlings of the cultivars Hill and Lee were inoculated with SMV. In studies, at Stoneville, we have made composites of resistant and susceptible F_2 plants. When not inoculated the two composites produced similar yields. After inoculation, the resistant composite produced a seed yield equal to its noninoculated counterpart. The seed yield of the susceptible composite was reduced 24% after inoculation. We have developed near-isogenic lines differing in reaction to SMV which we plan to grow at several locations to determine the frequency of yield reduction from natural infection by SMV.

Breeding for Control of Soybean Mosaic Virus

Several sources of resistance to SMV have been identified and are being utilized 1n the breeding program. Differences have also been noted among strains of SMV. Resistance to SMV appears to be simply inherited with resistance being dominant. A susceptible variety is planted in the field earlier than normal plantings and inoculated with leaf material on plants in the greenhouse. This provides an abundance of fresh inoculum for other breeding material. Normally we inoculate F_2 plants soon after emergence. Susceptible plants can be identified and eliminated in a few weeks. F_3 lines are grown from resistant and heterozygous F_2 plants. In most cases we will subject F_3 and F4 lines to other selection pressures and inoculate F_5 lines from crosses expected to segregate for reaction to SMV.

In our breeding program, we have found 1t possible to locate sources of resistance to disease or nematode problems once the problem was identified. In all cases the source of resistance has been low yielding, susceptible to shattering, susceptible to other diseases, and in general, poor in agronomic qualities. In studies at Stoneville utilizing several strains from the germplasm collection as a parent with an adapted cultivar (Hartwig 1972), the best of the recovered lines yielded only 80% as well as the adapted parent. Thus, 1t appears necessary to make one or more backcrosses to an adapted strain in order to obtain strains which will equal adapted cultivars in yield where the problem does not occur.

BREEDING OBJECTIVES

Breeding for resistance to several pest problems has been discussed individually. Problems do not normally occur in isolated areas. Multiple pest resistance has been our overall objective along with good agronomic qualities, high yield potential, and a product which meets market requirements. Breeding for improvement must be a general building program to incorporate additional characters which will improve the product. As this is being done, care must be taken to see that susceptibility to another problem is not introduced., Evaluating breeding lines in several environments will aid in this regard. Basically-cyst nematodes and phytophthora rot should not be expected to be major problems in the same soil. However, it is possible in a 200 hectare field to have areas where phytophthora rot causes damage to a susceptible cultivar and other areas where cyst nematodes cause injury. Consequently, we have had to incorporate resistance to both phytophthora rot and cyst nematodes into one variety. This task has been accomplished with less difficulty by first having resistance to each in a highly productive cultivar.

Problems such as cyst nematodes and root knot nematodes are more likely to occur in the same soil type. The cultivar Forrest, released for commercial production in 1972, is highly resistant to the more prevalent races of cyst nematode, root knot nematode, and reniform nematode. In addition, it has a moderate level of resistance to phytophthora rot and is highly resistant to the major foliar diseases. Although nematode resistance was the major objective in the development of Forrest, over a 2 year period at over 20 test locations it has produced seed yields 8% superior to the highest yielding variety of similar maturity where nematodes were not a problem. These results illustrate that we can improve efficiency of production along with reducing hazards to production.

The cultivar Forrest is moderately resistant to phytophthora rot but does not have the highest level of resistance. We have developed breeding lines having the same level of nematode resistance as Forrest but having a higher level of resistance to phytophthora rot. Some of these lines have been hybridized with breeding lines having a high level of resistance to another root knot nematode, *Meliodogyne arenaria*. We already have highly productive strains resistant to foliar disease, phytophthora rot, and two root knot nematodes, M. *incognita* and M. *arenaria*, so our objective here is to add resistance to cyst nematodes.

Highly productive cultivars must be at least moderately resistant to pest problems, if they are to produce consistently. Responses to fertility or management cannot be measured successfully without a good disease resistant cultivar.

DISCUSSION

Y.L. Nene: I want to know whether in your opinion the entire breeding material at ICRISAT should pass through the sieve of the disease nursery with particularly important diseases like pigeonpea and chickpea wilt.

T. Bezuneh: In my opinion it may not be very desirable since the pathogen or the diseases at one place may not be the same at another place and in that case if we stress too much a particular disease factor we may lose sight of other important factors. This may turn out to be highly elusive when we are not sure of the causal organisms or the races involved in various regions of the semiarid tropics. This way, some very valuable material may be lost which may have definite use in other areas of the world.

H.K. Jain: Will Dr. Nene suggest to the breeders the technique for selecting for wilt resistance in chickpea which is a great problem at present.

Y.L. Nene: The lack of basic Information on the etiology of the disease and the racial pattern of the organisms involved is the major handicap at present. However, I am quite optimistic about having the needed Information in the near future.

W.J. Kaiser: Screening for wilt resistance should be done in areas where disease incidence was high in addition to establishing wilt sick plots at ICRISAT. However, I would not advise this for virus, particularly for those which do not occur in India. I suggest that the screening against chickpea virus could be done in Iran, where these viruses occur frequently in chickpea growing areas.

LITERATURE CITED

Feaster, Carl V. 1951. Bacterial pustule disease 1n Soybeans: artificial inoculation, varietal resistance and inheritance of resistance. Mo. Agri. Exp. Sta. Res. Bull. 487, 26 p.

Hartwig, E.E., and S.G. Lehman. 1951. Inheritance of resistance to-bacterial pustule disease in soybeans. Agron. J. 43:,226-229.

Hartwig, Edgar E., and H.W. Johnson. 1953. Effect of the bacterial pustule disease on yield and chemical composition of soybeans. Agron. J. 45: 22-23.

Hartwig, Edgar E. 1959. Effect of target spot on yield of soybeans. Plant Dis. Rpr. 43: 504-505.

Hartwig, Edgar E., B.L. Keeling and C.J. Edwards, Jr. 1968. Inheritance of reaction to phytophthora rot 1n the soybean. Crop Sci. 60: 634-635.

Hartwig, Edgar E. 1972. Utilization of soybean germplasm strains 1n a soybean improvement program. Crop Sci. 12: 856-859.

Jones, John P., and E. Hartwig. 1959. A simplified method for field inoculation of soybeans with bacteria. Plant Dis. Rpr. 43: 946.

Kilen, T.C., E.E. Hartwig, and B.L. Keeling. 1974. Inheritance of a second gene for resistance to phytophthora rot in soybeans. Crop Sci. 14: 260-262.

Ross, J.P. 1968. Effects of single and double infection of soybean mosaic and bean pod mottle viruses on soybean yield and seed characters. Plant Dis. Rpr. 52: 344-348.

REVIEW OF E. E. HARTWIG'S PAPER

Y. L. *Nene*[1]

INTRODUCTION

As we know, one of the features of agriculture in the semiarid tropics is the capital-scarce economy. Because of the limited capacity of the farmers for inputs costing cash money, varieties of pigeonpea and chickpea with built-in resistance to major diseases would be most welcome. There can be no two opinions on the point that breeding disease resistant varieties should be a top priority item. The present session is, therefore, a *very* important one.

Dr. Hartwig's paper beautifully and *very* clearly brings out what could be achieved *in* the direction of breeding disease resistant varieties through intensive and sustained efforts. Although his paper deals with the soybeans, there is a great deal we can learn from each and *every* situation he has discussed. We are likely to face similar situations once our chickpea and pigeonpea programs get going.

PATHOGENS OF CHICKPEA AND PIGEONPEA

Before I initiate discussion on Dr. Hartwig's paper, it would be appropriate to take stock of the disease situation in pigeonpea and chickpea. The available literature reveals quite a large number of pathogens reportedly affecting these two crops. The position is summarized in Table 1.

Fortunately not all diseases are serious and hopefully they will not be serious at any one time and at any one location. It is good, however, to know the potential enemies of these two crops. At present the diseases which could be considered relatively more common are:

Pigeonpea:	wilt (*Fusarium oxysporum* f. sp. *udum*), sterility mosaic, leafspots (*Cercospora* spp.), bacterial leafspot and stem canker (*Xanthomonas cajani*) stem anthracnose (*Colletotrichum cajani*), yellow mosaic.
Chickpea:	wilt/root rots by several pathogens, *Ascochyta* blight, *Botrytis* grey mould, and rust (*Uromyces ciceris - arietini*).

Further shortlisting for identifying truly major problems brings us to wilt and sterility mosaic in pigeonpea and the four problems of chickpea listed above. These are the diseases we should worry about at present.

Chickpea and Pigeonpea Resistance

Let us then review what we already know about the sources of resistance against some of these diseases and about the studies on

Table 1. Diseases/Pathogens* Reported on Chickpea and Pigeonpea

	Chickpea	Pigeonpea
Fungi	24	31
Bacteria	1	2
Virus and Mycoplasma	7	4
Nematodes	1	7
Alga		1
Others	2	
Total	35	45

* Some of these are obviously synonyms and therefore the actual number should be somewhat less. Lists have been appended.

---

[1] International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, India

mode of inheritance. In fact the available information is very meager.

The cultivar G-24 of chickpea was claimed resistant/tolerant to Fusarium wilt in Punjab, but was later found susceptible (K.B. Singh 1973). Some 11 lines were found resistant to Fusarium wilt at Kanpur, India and three of these (100, 101, 106) have been used in the hybridization program with T-2 and T-3 cultivars. Also, two selections (32/35-8/7 and 32/35-32/2) obtained from the F5 of the cross between 100 x 106 have been claimed promising (D.V. Singh et al. 1973). The cultivar C 612 from Pakistan (H. Singh 1957) was reported resistant to Ascochyta blight. One black seeded line from Israel (Accession No.12-074-06625) proved highly resistant to Ascochyta (Kaiser 1972). In pigeonpea, more than 30 lines/varieties have been claimed as tolerant, sufficiently resistant and resistant in India. However, their availability is difficult. In some cases it is not certain whether the seed has remained pure. The most commonly claimed resistance source from New Delhi is NP (WR) 15, but 1t has been found susceptible at Parbhani in central India. Against sterility mosaic, several tolerant lines have been identified at Coimbatore, which incidentally include wilt resistant NP (WR) 15 (Ramakrishnan and Kandaswamy 1972).

We know very little about the inheritance of resistance. A single report on the inheritance of chickpea Fusarium wilt resistance tells us that 1t is controlled by a single pair of genes (Ayyar and Iyer 1936). Resistance to pigeonpea wilt is stated to be controlled by a pair of duplicate dominant genes (Joshi 1957) and also by multiple genes (Pal 1934; Shaw 1936).

OBSERVATIONS ON RESISTANCE BREEDING

With this background Information on chickpea and pigeonpea diseases, let me draw upon a few examples Dr. Hartwig has described 1n his paper to point out situations which we might come across 1n our programs of breeding for disease resistance. Dr. Hartwig has described how cultivars resistant to root knot were developed. It is interesting to see the modification made in the screening procedure to increase reliability of the test, by planting in hills the seed of susceptible P1ne Dell Perfection in the same row with selected material. Such a modification is essential in case of a soil inhabiting pathogen. I expect we will have to resort to similar procedures when we screen material for wilt resistance both in chickpea and pigeonpea. Or. Hartwig has also cited the example of soybean cyst nematode. The resistance in black seeded materials like Peking is governed by 3 recessive gene pairs and a dominant gene and the. gene giving colored seed is linked with gene for resistance. The situation is further complicated by the presence of races. All this has necessitated producing and screening a large amount of breeding material and a sustained effort. Once again, we may come across a similar situation in wilts of chickpea and pigeonpea. This is more so because there are indications of the presence of physiologic races of the pigeonpea wilt fungus. Dr. Hartwig has mentioned the cultivar Forrest in his paper which has resistance to various nematodes and major foliar diseases and also a moderate level of resistance to phytophthora rot. This tells us the way and gives us hope of being able to develop pigeonpea and chickpea cultivars possessing resistance to several major diseases.

Resistance Screening Methods

Let me focus attention now to the question of resistance screening. In every situation, Dr. Hartwig has mentioned the screening procedures followed. As we know, the success of any resistance breeding program depends largely on how efficient and reliable the screening has been. The wilt of pigeonpea and the sterility mosaic are found at ICRISAT. Likewise wilt and root rots of chickpea have also been observed. It should therefore be possible to screen the germplasm here itself by having sick plots (for wilts only) where heavy inoculum of the pathogens would be added repeatedly. This I consider necessary to screen large amounts of germplasm and breeding material under otherwise natural conditions. There is always an apprehension that having sick plots on the farm will pose a threat to other plantings. I believe selection of plots in a corner of the farm should minimize such a danger and also the gains we make by having sick plots should outweigh any risks involved. I am glad to say that we are currently busy developing a sick plot for pigeonpea wilt.

Certain pathogens like chickpea Ascochyta and the rust fungus are not observed in climatic conditions of Hyderabad but are commonly prevalent in north India. These diseases are, however, very important and cannot be ignored. I suggest that there should be a location for screening against these two diseases somewhere in north' India. This will support the breeding program which has been planned for cooler regions. I must make mention here that it might be possible to produce these two diseases in the glasshouse. If we succeed, screening in the glasshouse would usefully supplement field screening. Since Ascochyta species are known to produce pathotoxins, investigations should be undertaken to see if we could do screening in the laboratory by using such a toxin.

Other Breeding Problems

Another point which needs attention is whether the entire breeding material should be screened for resistance to major diseases and discarding what is susceptible. I understand that the entire breeding material passes through disease screening nurseries at the CIMMYT and the same is now being done at the IRRI. At ICRISAT, we are not yet ready to do mass screening, say in case of pigeonpea wilt, because it will take at least a year from now to develop a wilt sick plot. I have my own views on this subject but I would like this matter to be discussed by the participants.

Use of Disease Nurseries

Experience at other institutions has revealed that operating international disease nurseries has yielded very useful results. Such nurseries (1) give information on pathogen variability, (2) indicate performance of materials under different agroclimatic conditions, (3) indicate susceptibility/resistance to other diseases of local importance, and (4) give opportunity to other collaborating scientists to observe international material. Operating such nurseries from ICRISAT, I think, would be very useful. In case of soil borne diseases like wilts, it would be highly desirable to have sick plots at the cooperating centers.

Appendix I. Diseases of Chickpea

FUNGAL

Leaf spots, blights, etc.

**	1.	Ascochyta rabiei (Mycosphaerella rablei)	Bulgaria, Canada, E. Africa, Greece, India, Iran, Israel, Italy, Lebanon, Mexico, Morocco, Pakistan, Spain, Turkey, U.S.S.R.
*	2.	Botrytis cinerea	Argentina, Australia, Colombia, India
	3.	Colletotrichum trifolii (artificial 1noc.)	
	4.	Mystrosporium sp.	India
	5.	Stemphylium sarciniforme	India, Iran
	6.	Stemphylium botryosum	India

Stem rots, root rots, damping off, etc.

	1.	Macrophomina phaseoli	Ethiopia, Iran
	2.	Mycosphaerella phaseoli (Dry root rot)	India
	3.	Nigrospora sp.	India
*	4.	Operculella padwickil (Foot rot)	India
	5.	Ozonium taxanum var. parasiticum	India
*	6.	Pellicularia filamentosa (Collar rot, root rot) (Sclerotium rolfsii)	Ethiopia, India
	7.	Phytophthora cryptogaea	?
		P. megasperma	India
		P. parasitica (some isolates)	?
	8.	Pythium aphanidermatum	Argentina, Australia
	9.	Pythium sp.	Iran
*	10.	Rhizoctonia bataticola (wilt)	Australia (?), Ethiopia (?), India
	11.	Sclerotinia sclerotiorum	Australia, India, Iran

---

* Common

** More common

FUNGAL (continued)

	Wilts	
**	1. Fusarium oxysporum f. sp. ciceri	Australia (?), Ethiopia (?), India, Pakistan, Peru, U.S.A.
	2. Verticillium alboatrum	U.S.A.
	Rust	
*	1. Uromyces ciceris - arietini	Afghanistan, Bulgaria, France, India, Iran, Mexico
	Powdery mildew	
	1. Leveillula taurica	Sudan
	2. Erysiphe sp.	Iran

BACTERIAL

	1. Xanthomonas cassiae (Seedling rot)	India

VIRAL (Stunting, chlorosis, wilting, proliferation)

	1. Alfalfa mosaic virus	Iran
	2. Bean yellow mosaic virus	Iran
	3. Cucumber mosaic virus	Colombia, Iran
	4. Lettuce necrotic yellows virus	Australia
	5. Pea leaf roll virus	Iran
	6. Pea enation mosaic virus	U.S.A. (Calif.)
	7. Phyllody (virus ?)	India

NEMATODE

	1. Meloidogyne javanica (Root knot)	India

OTHERS

	1. Leaf yellowing and bronzing due to high salt content (?)	India
**	2. Wilts of unknown etiologies	India

---

* Common

** More common

Appendix II. Diseases of Pigeonpea

FUNGAL

Leaf spots, blights, rots

1. Ascochyta imperfecta (artificial inoculation) - U.S.A.

* 2. Cercospora cajani - Dominican Republic, India, Kenya, Mauritius, Rhodesia, Tanzania, Venezuela

* 3. Cercospora indica - India

* 4. Cercospora instabilis - India

5. Cercoseptoria cajanicola - India

6. Chaetoseptoria wellmani - Guatemala

7. Choanephora cucurbitarum (wet leaf rot) - India

* 8. Colletotrichum cajani (also stem anthracnose) (Glomerella cingulata) - India, Puerto Rico

9. Leptosphaerulina briosiana (brown leaf spot) - India

10. Macrophomina cajanicola - India

11. Macrophomina phaseoli - India

12. Phoma sp. (canker) - Puerto Rico

13. Phyllosticta cajani - Brazil, India

14. Pyrenochaeta cajani - India

Stem rots, cankers, galls, cellar rots, etc.

1. Botryosphaeria xanthocephala - India, Puerto Rico

2. Corticium salmonicolor - New Caledonia

3. Dendrochium gigasporum - Uganda

4. Diplodia cajani - India

5. Macrophoma cajani - India

6. Neocosmospora vasinfecta - India

7. Physalospora SP. - Trinidad

---

* Common

** More common

FUNGAL (continued)

	8.	Phytophthora drechleri	-	India
	9.	Pythium aphanidermatum	-	India
	10.	Rhizoctonia solani	-	India, Sierra Leone, Philippines
	11.	Sclerotinia sclerotiorum (on pods)	-	Bermuda
	12.	Sclerotium rolfsii	-	India
	13.	Synchytrium phaseoli - radiata (also on leaves)	-	India
	14.	Synchytrium unbilicatum (Woroninella umbilicata)	-	India

wilts

**	1.	Fusarium oxysporum f. sp. udum	-	India, Tanzania (?), Uganda (?)

Rust

	1.	Uromyces dolicholi	-	Bermuda, Colombia, Kenya

Powdery mildew

	1.	Leveillula taurica	-	India, Tanzania

BACTERIAL LEAF SPOTS AND STEM CANKERS

	1.	Pseudomonas sp. (from coffee - pathogenic to pigeonpea)	-	Brazil
*	2.	Xanthomonas cajani (also called X. phaseoli f. sp. cajani)		India, Sudan

VIRUS AND MYCOPLASMA (?)

**	1.	Sterility mosaic	-	Burma, India
*	2.	Yellow mosaic	-	India, Puerto Rico, Sr1 Lanka
	3.	Witches' broom (proliferation disease)	-	Dominican Republic, New Guinea, Puerto Rico
	4.	A cowpea mosaic virus (artificially)		Puerto Rico, Trinidad

---

* Common

** More common

NEMATODE

1. *Heterodera avenae* - India
2. *Heterodera cajani* - India
3. *Heterodera vigri* - India
4. *Meloidogyne incognita* - India
5. *Meloidogyne javanica* - India
6. *Rotylenchulus reniformis* - India
7. *Tylenchorhynchus* spp. - India

ALGA

1. Leaf gall alga - India

* Common

** More common

LITERATURE CITED

Ayyar, V.R. and R.R. Iyer. 1936. A preliminary note on the mode of inheritance of reaction to wilt in *Cicer arietinum*. Proceedings Indian Academy of Sciences 3: 438-443.

Joshi, A.B. 1957. Genetics of resistance to diseases and pests. Indian J. Genet. PI. Breed. 17: 305-317.

Kaiser, W.J. 1972. Occurrence of three fungal diseases of chickpea in Iran. FAO Plant Prot. Bull. 20:73-79.

Pal, B.P. 1934. Recent progress in plant breeding at Pusa. Agri. Livestock India 4: 505-515.

Poehlman, J.M. and D.N. Borthakur. 1969. Breeding Asian field crops. New Delhi, Oxford & IBH Publ. Co. pp. 300-307.

Ramakrishnan, K. and T.K. Kandaswamy. 1972. Investigations on virus diseases of pulse crops in Tamil Nadu. Tamil Nadu Agri. Univ. Tech. Rep. pp. 53.

Shaw, F.J.F. 1936. The inheritance of morphological characters and wilt resistance in Rehar (*Cajanus indicus* Spreng). Proceedings Indian Academy of Sciences 3: 491-492.

Singh, K.B. and B.S. Dahia. 1973. Breeding for wilt resistance in chickpea (Abstract). Symposium on wilt problem and breeding for wilt resistance in Bengal gram. IARI, New Delhi.

Singh, D.V., A.N. M1sra, and S.N. Singh. 1973. Sources of resistance to gram wilt and progress of breeding for wilt resistance in Bengal gram in U.P. (Abstract), Symposium on wilt problem and breeding for wilt resistance in Bengal gram. IARI, New Delhi.

INSECT PESTS OF PIGEONPEA AND CHICKPEA IN INDIA AND PROSPECTS FOR CONTROL

J. C. Davies and S. S. Lateef[1]

INTRODUCTION

As has been reported in the resource papers, pigeonpea and chickpea constitute an extremely important part of the diet of the peoples living in the semiarid tropics. They figure conspicuously in the internal markets in many such countries, and undoubtedly a considerable proportion of the production never figures in official statistics, since large quantities are consumed on the homesteads. In spite of these facts, these crops have been largely neglected in a research sense until relatively recently, probably in view of the fact that they did not form important sources of external revenue earnings. In spite of the fact that there has been a considerable stimulus to research on these crops in India in the past six to ten years under the aegis of ICAR, an entomologist coming to the crops 'cold' faces a scattered, often contradictory and sometimes very thin literature. We propose therefore to discuss rather generally some of the problems facing entomologists and breeders with regard to control in the context of the known formidable pest and potential pest list which has been drawn up for India, particularly for the pigeonpea crop.

PRINCIPAL PESTS OF CAJANUS AND CICER

A list of some of the known pest species from the two crops in India is given in Appendices I and II. Many of the pests are of local or occasional importance, and the exact status of others is problematical. We propose therefore to discuss the prospects for control in the light of the three pests which the literature indicates are probably the principal sources of loss in India, and perhaps stimulate discussion on areas where information has yet to be fully documented on them.

In pigeonpea the general consensus of opinion seems to be that the grain pod borer *Heliothis armigera* is the main and most widespread pest, closely followed by the tur pod fly, *Melanagromyza obtusa* while the tur plume moths *Marasmarcna liophanes/Exerlastis atomosa/Sphenarches* complex can be damaging, On chickpea, only H. *armigera* appears to rank as a regular, significant and damaging pest. It must be stressed that periodically pests such as *Amsacta albistriga* on pigeonpeas and *Agrotis* sp. on chickpea can and do cause severe local damage in some seasons.

It is necessary to detail a few of the more significant facts about the life histories of the three main pests, but they are not going to be covered exhaustively.

H. armigera

H. armigera is a medium sized moth which is generally accepted to be a cosmopolitan Old World species. The eggs are laid singly, are small beautifully sculptured, white, and normally laid on young plant tissue or developing fruiting forms. The female moth is generally extremely prolific and well over 1000 eggs are laid making potential population increase considerable. On hatching, the larva feeds for a short time on leaves, flowers or young fruiting forms. Later it tends to devour seed pods. In instances of extremely high population densities it can act as a general leaf defoliator in later instars. On

---

[1] International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, India

the pigeonpea and chickpea crops the larva bores into the pods completely devouring the seed, but rarely completely entering the pod, the hind end of the body projects from the feeding site. The larval stage lasts for about 3 weeks and the fully grown larva pupates in the soil. The pupal stage normally occupies 10-12 days, but periods as long as three months have been recorded.

There is an extremely diverse range of plant hosts. They include opium, tobacco, hemp, pigeonpea, chickpea, mung bean, tepary bean, soybean, groundnuts, pearl millet, sorghum, maize, oats, cotton, okra, lucerne, indigo, sunflower, linseed, safflower, peas, tomato and other Solanacea, onions and dhatura and castor. The moth is positively attracted to flowers and is known to be an active flier and is suspected of being able to migrate on weather fronts.

Melanagromyza Obtusa

The pod fly, *Melanagromyza obtusa*, has been known as a pest of pigeonpea in India since early in the century and has been studied here. It is widely distributed on the subcontinent. The eggs are laid by the female through the wall of the pod and project into the lumen. The wound at the point of insertion usually heals. Data on number of eggs laid are scant — but apparently up to 79 eggs are laid per female. Incubation takes 2-1/2 to 3 days and approximately 70% of the eggs hatch successfully. Initially the larva searches for a soft seed and bores into the epidermis without rupturing the seed coat. In the second and third stage it bores into the cotyledons and in most instances one seed is sufficient for the larva to complete its development. The final instar leaves the seed and prior to pupation "windows" the pod. Larval life occupies about six days. Just before pupation the larva ceases to feed and pupates either in the pod cavity or pod wall tissue, the pupal case being formed from the final larval skin. At temperatures of 22°-24°C and low RH of 20* the pupal period takes up to 14 days, but this is greatly reduced at higher temperatures and higher RHs. Emergence of the adult usually occurs before 10 a.m. in the morning. Records of alternate hosts appear to be lacking in the literature. Several broods are possible in a season, but there is little information on the carry over of the pest in the unfavorable hot season.

Tur Plume Moths

The third major group of pests appear to be the tur plume months. The complex includes *Marasmarcha liophanes, Exelastis atomosa*, and *Sphenarches* sp. all are small delicate moths. They are widely distributed in India. The small round eggs are laid on pods, leaves and flower buds of pigeonpea and 15-56 are laid per female. Most of the eggs are laid per female. Most of the eggs are laid on the developing pods, usually on the lower surface. At a temperature of 30°C the eggs take 2-4 days to hatch, and at 27°C 3-6 days. At temperatures around 28°C the larval period takes 9-15 days with a tendency for a lengthening of the life cycle with increasing temperatures. There is a quiescent period of 1-2 days prior to the pupal period which lasts 3-5 days at 28°C. (These data apply in general to *M. liophanes* and *E. atomosa*).

There appears to be some controversy about when the pest is most prevalent — this may be due to the confused taxonomic situation -- but they are usually first found at flowering. There is also some debate as to whether the insect carries through the hot season as an adult or whether the insect pupates and remains in the soil to survive. It is quite possible that the conflicting evidence on this point is due to species difference.

Storage Losses

No run down of the pest spectrum would be complete without a mention of the serious losses often experienced when these pulses are stored. Losses which occur at this stage are in a sense double losses, since seed which has been successfully harvested has already had to withstand the vicissitudes of weather, field pests and harvest. The main pests in storage are the Bruchids, particularly *Callosobruchus* spp. which often appear in the crop in low numbers just prior to harvest, and reach extremely high numbers in successive generations in the store. Bruchids cause weight loss, lower germination potential and affect quality.

Magnitude of Loss due to Pests

Many papers have been written on this subject, but hard and fast assessment of actual losses by the main pest species are difficult to come by. Methods of assessment are subject to considerable variation. The issue is complicated by the fact that many assessments are made at harvest time when it is difficult to ascribe damage to a particular pest. Estimates of total loss vary from very low ones below 5% to as high as 43% in some varieties,when loss of potential crop is included. This latter point is neglected in many data published. Estimates given by Bindra and Jokhmola (1967) take into account potential crop loss due to pod fly and they note considerable variation in pod damage, which they state exaggerates loss greatly when used as a yardstick for loss assessment since not all seeds in a pod are destroyed in most instances. By detailed work, they calculate actual losses to be in the region of 6.1% to 10.3%. They note losses of 6% due to pod fly, 2.6% due to plume moth and just under 2% due to other causes including Heliothis. On the basis of these and other observations they concluded that the losses in Madhya Pradesh in a normal year could be as high as 20%-25%. They also noted that none of the varieties they tested had noticeable resistance to pests in the field.

It is felt by the authors that this important field of study requires further development in order to establish a reliable method of assessing true loss in the crops and enable breeders to work on a rational basis. Successful screening of varieties is dependent on it.

Prospects for Control

In spite of the importance of these two crops in the dietary pattern of the people and their significance in the farming systems of the semiarid tropics, these crops have been neglected from a control point of view. This is partially due to their relatively low monetary value, 1t is also due to the fact that they occupy a peculiar niche in the agricultural system 1n that they are traditionally grown primarily as intercrop. This applies particularly to pigeonpea. Therefore the plant population is often very low. In considering prospects for control, therefore, the basic realities agronomically and economically must be kept to the fore; if they are not then much research effort is likely to be misdirected.

Chemical Control

There is, entomologically speaking, a considerable difference between growing plgeonpea or chickpea as single stand high population crops and growing them intercropped. This is becoming very obvious 1n the preliminary counts taken on relatively large blocks of land at ICRISAT.

In considering the effectiveness of chemical control of the three main sources of loss their biology is important. Most pests lay their eggs externally and contact insecticides give a good measure of control since the larva is exposed for a shorter or longer period to residual insecticide. In the instance of pod fly however, the whole life cycle takes place within the pod and for full effectiveness a measure of systemic effect is probably necessary.

Successful control of both pod borers and plume moths has been achieved in India with a range of insecticides including DDT, endosuifan, endrin and dieldrin, while DDT and nicotine sulphate have been suggested for pod fly.

There is no doubt that insecticides can keep these crops relatively pest free, but questions must be asked about univeral or set schedule application of insecticides and on how many sprays should be applied. Development of successful and economic regimes requires that more detailed study be carried out on the biology of the pest species involved, particularly their oviposition behavior and times of appearance on the crop. The work must be geared to detailed investigation of losses due to individual pest species and the complex as a whole and to the economics of the disposal of the crop.

Resistance

The work done in India on the biology of the main pest species on pigeonpea indicates that there is considerable hope that some resistance or tolerance will be found in some varieties or lines to both pod fly and plume moths. Both pests appear to prefer and seek tender pods for oviposition, and varieties with rapidly or relatively rapidly hardening pods or seeds would possibly have a strong antibiotic effect. Possibly texture of pod surface may also be important in encouraging oviposition.

It is difficult to be hopeful that resistance to Heliothis will be easy to find in view of the catholic tastes of the pest, its fecundity, and the extremely voracious behavior of later instars. There is a strong possibility also of being misled about apparent resistance to this pest in view of the known and marked seasonal fluctuations in numbers and the attractiveness of flowering to adult moths. Sowing date and maturity period are likely to have a profound effect on Heliothis attack in these circumstances.

In chickpea there have been indications that some lines are more attractive to Heliothis than others. Paradoxically, this gives us some hope that screening, possibly under conditions of high borer numbers, may enable some sorting of the germplasm to be effected. Use of screen house techniques, as currently being carried out at IITA, may reveal useful lines. It is difficult at present at ICRISAT to envisage using such methods with the pigeonpea crop since the plant is much larger and more difficult to handle and facilities are currently limited. With this crop there would appear to be little alternative to painstaking survey and scrutiny of specially sown germplasm blocks in conditions of high pest incidence and observation of growing crops in farmers' fields. At ICRISAT conditions are tending to favor high incidence of Heliothis so we may yet achieve some benefit from this negative factor. Rearing and release of Heliothis moths on a field scale would be rather a complicated and time consuming business and would probably not be effective in any case, for a variety of reasons.

Agronomic

There are conspicuous gaps in the knowledge of carry over of several of the main pests through the dry season in India. This applies particularly in the case of H. anrrigera, Melanagromyza obtusa and Exelastis atmosa and Marasmarcha liophanes. There is also very little information in the case of the three last named on alternative hosts. Such information would be valuable since the possibility of reducing to very low levels the out of season, or resting populations by such methods as deep ploughing,residue destruction etc., is a very real in the context of peasant farmer agriculture.

Preliminary studies on the influence of intercropping of pigeonpeas with cereals and with other legumes have been interesting, if not illuminating. Careful selection of varieties compatible with pest fluctuations may be valid in the context of pest management if not control. It is quite conceivable that build up of large populations of Heliothis available for attacking the pod stage of pigeonpea can be avoided by timing. Similarly, intercropping may have profound influence on parasite build up on both legume crops and judicious management of intercrops may have a profound effect on pest status and parasite transfer.

In the agronomic sense the studies might be stretched to include the possibility of utilization of trap crops –– but far more needs to be known about the biology of the pests, and the instance of several of their host crop range.

Biological

There is ample evidence that at least two of the main pest species, M. obtusa and H. armigera suffer from a high level of parasitism on occasions e.g., Ahmad (1938) indicated that parasitism is low in March on pod fly (5%) but rises rapidly to over 50% by April -- the parasite having an extremely short life cycle of 10-12 days. Ipe (1974) quotes a 20% maximum in February. Counts at ICRISAT tend to support these figures for this pest. Judicious use of insecticides in pest management regimes in intercrops might boost these figures still further.

Rao (1968) has surveyed the parasites of H. armigera in India. Comparison of these data with data from other areas of the vast geographical range covered by H. armigera might reveal conspicuous absentees in the subcontinent, which could be imported and reared for release.

A very promising field in the biological sense, is the use of viruses, several of which have already been typed, for Heliothis sp. control. The introduction of such viruses particualrly in the multiple cropping and intercropping regimes practiced in the semiarid tropics has a *very* real chance of success. An additional attraction of virus is that production is a labor intensive process and calls for little by way of raw material compared to pesticides.

Other possibly more academic and extreme possibilities at the moment are use of pheremones, which to the best of our knowledge have not been isolated from H. armigera (although they have from the closely related species H. 7ea) or the plume moths. It has also been suggested that the male sterility technique might be applicable in India in the instance of Bruchid pests.

FUTURE STRATEGY FOR CONTROL

The foregoing note is written in part

from a genuine naivety of the total situation with regard to pests of these two crops in India. The brief literature survey possible in the time available indicates significant gaps in our knowledge of the pest species themselves, the extent of the damage they do and their interrelationships with each other and the commonly grown varieties of crop, particularly in mixed cropping situations. It is to be hoped that in the next few years we will be able to add to knowledge of the main species while at the same time ensuring that the plant breeders retain useful germplasm in pest *free* conditions while ensuring that they screen for high yielding and good quality lines in the presence of high insect populations. It is important to continue to emphasize the importance of retaining a reasonable measure of pest resistance in any new lines released and the dangers inherent in not testing prospective lines fairly early on in the programs for pest susceptibility over a range of conditions and a number of sites throughout the semiarid tropics. Controlling pests is one thing in situations of 'high farming', either economically or uneconomically — controlling them in the peasant farmer intercropping systems is another. The number of sprays which can be applied to these crops particularly in situations of low plant density is strictly limited by economics. It is most likely that successful control of pests will depend on close cooperation between plant breeders, agronomists and entomologists, and will be based on minimal pesticide input combined with the use of pest management and rotational practices in view of the low inputs possible on these crops. It 1s a goal worth striving for, given the great importance *of* these two crops nutritionally, socially and economically to the people of the semiarid tropics.

DISCUSSION

J.C. Davies: There is a great possibility of the use of viruses for biological control of insects like Hellothis and ICRISAT is seeking assistance in this work from Boyce Thompson Institute in the U.S.A.

K.O. Rachie: In my experience in Nigeria, a few well timed sprays may be able to solve the problem of borers in pigeonpea.

SUGGESTED READING ON PESTS OF PIGEONPEA AND CHICKPEA

It was difficult to obtain all the references on the work published within India on the pests of the two crops in the time available -- though most of them were checked -- a suggested list of reading is therefore given rather than a reference list.

CHICKPEA

Chatterji, S. 1953. On the infestation of bruchids in milled and unmilled pulses. *Bruchus analis*. Sci. Cult. 9(6): 305.

Gangrade, G.A. 1963. A new record of echoropsis parasite of *Heiiothis armigera*, pest of chickpeas. PI. Prot. Bull. FAO 11(1): 20.

Indian Council of Agricultural Research. 1969. Insect pests of crops. Gram (*Cicer arietinum* L.) *Handbook of Agriculture*. New Delhi. 511-512.

Jotwani, M.G., P. Sircar, T.D. Yadav. 1967. Studies on the extent of insect damage and germination of seeds. Germination of some leguminous seeds damaged by developing grubs of *Callosobruchus maculatus* (F.) Indian J. Ent. 29(3): 309-311.

Pingale, S.V., S.B. Kadol, M. Swaminathan. 1963. Effect of insect infestation on stored Bengal gram and green gram. Bull. Cent. Fd. Tech. Res. Inst. Mysore. 5: 211-213.

Pradhan, S. 1963. Pests of rabi crops. Indian Suppl. 12(2): 32-40.

Saxena, H.P. and A.K. Raina. 1970. A bruchid resistant strain of Bengal gram. Curr. Sci. 39(8): 189.

Sharma, S.K., C.K. Kaul, S.R. Betala et al. 1970. Relative efficiency of insecticides against gram pod borer *Heiiothis armigera* Hb. (Lepidoptera: Noctuidae). Annl. Arid Zone 8(1): 43-80.

Thakare, K.R. and S.U. Lande. 1966. Preliminary evaluation of efficacy of *Diadegma* (*Angrtia fenestralis*) in the control of *Heliothis armigera* (Hb.) Dhulla Coll. Agric. Mag. 5(1): 54-65.

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. Mededelingen Landbonwhogeschool, Wageningen. 72(10): 342 pp.

PIGEONPEA

Ahmad, Taskhir. 1937. The tur pod fly. *Agromyza obtusa* Mall. - a pest of *Cajanus* cajan. Indian J. Agri. Sc. Vol. 8 Pt. 1 p. 63-76.

Argikar, C.P. and V.V. Thobbi. 1957. An estimate of the damage caused by tur pod caterpillar, *Exelastis atomosa* W. to pigeon' pea grain. Poona Agri. Coll. Mag. 48(1) p. 25-26.

Ayyar, T.V.R. 1940. Handbook of economic entomology for South India. Govt. Press Madras. 516 pp.

Basu, A.C. and L.M. Pramanik. 1969. Effects of planting dates of grain on the infestation of H. *armigera* Hub and the grain yield. Indian 0. of Entomology Vol. 31 pt. 11.

Bhattacherjee, N.S. 1972. *Heliothis armigera* Huebner, a polytypic species. Ent. News Letter Vol. 2 No. 1 p.3

Bhattacherjee, N.S. and S.I. Gupta. 1972. A new species of *Heliothis* Ochsenheimer (Noct. Lepid) infesting cotton and tur (*Cajanus indicus*) in India with observations on the 3 other common species of the genus! 37 Nat. Hist., Bombay, 6 p. 147-151.

Bindra, O.S. and S.S. Jokhmola. 1967. Incidence of and losses caused by some pod infesting insects in different vars, of pigeon peas (*Cajanus cajan* Millsp. Indian J. of Agri. Sc. 37: 117-186.

Chari, M.S. and H.K. Patel. 1967. The bionomics of tur plume moth, *Marasmarcha liophanes* Mey) on pigeon pea (*Cajanus cajan* Millsp.). The Andhra Agri. J. 14, 5 p. 158-164.

Fletcher, T.B. 1914. Some south Indian insects and other animals of importance.

Gangrade, G.A. 1964. Losses to Tur (*Cajanus cajan*) by *Melanagromyza obtusa* Mall. Indian 0. Ent. 26 p. 364-5.

Hardwick, D.F. 1965. The corn earworm complex. Mem. Ent. Soc. of Canada No. 4 pp. 247.

Kadam, M.V. and G.A. Patel. 1956. Crop pests and how to fight them. D1r. of Publicity, Govt. Bombay, Bombay.

Lal, S.S. and Y.P. Singh. 1973. Efficacy of certain insecticides against *Heliothis armigera* Hub. (Lepid Noctuidae) on grain crop. J. of Research, APAU. Hyd 1(1):

Lefroy, H.M. 1906. Indian Insect Pests. Today and Tomorrow Printers, New Delhi (rep 1971).

Lefroy, H.M. and F.M. Howlett. 1909. Indian insect life. Thaker and Spink Co., Calcutta.

Odak, S.C., B.V. Deshpande and S.V. Dhamdhare. 1967. An estimation of the damage caused by plume moth (Exelastis atomosa) and pod fly (Agromyza obtusa) to tur. J. Agri. Coll. Gwalior 8: 1-3.

Odak, S.C. 1972. Preliminary studies on the estimation of losses caused by pod infesting insects in four varieties of pigeon pea (Cajanus cajan L). Proceedings 8th workshop on pulses, p 227-235.

Pandit, P.V. and R.R. Rawat. 1965. Blo ecological studies on Exelastis atomosa W. Unpublished thesis MSc, Vikram University.

Rajagopalan, C.K. and J. Paul Devakumar. 1965. Preliminary studies on the infestation of Agromyza obtusa Mall in red gram (Cajanus cajan Lin). J. Madras Agri. 52(8): 345-346.

Rao, V.P. 1968. Heliothis spp and their parasites in India. PANS Aug. 1968.

Rawat, R.R. and S.S. Jokhmola. 1967. Estimation of losses in grain yield in different varieties of tur (Cajanus cajan) by pod fly, plume moth pulse beetle and other means. Madras Agri. 54(11): 601-602.

Reddy, K.V.S. 1973. Studies on the grain caterpillar Heliothis armigera (Hub)(Lepid Noct) with special reference to its biology, host preference and estimation of loss 1n red gram. Ph. D. thesis, University of Agri. Science, Bangalore 132 pp.

Rivnay, E. 1962. Field crops in the Near East. Dr. W. Junk, Den Hague.

Saxena, H.P., P. Sircar and A. Phokela. 1970. Results of investigation on pests of pulses conducted during rabi 1969. Proceedings 4th Workshop, Ludhiana p. 193-194.

Sharma, S.K., C.K. Kaul, S.R. Betala, et al. 1970. Relative efficiency of insecticides against grain pod borer, Heliothis armigera. Annl. Arid Zone 8, 1 p. 143-80.

Singh, H. and M.S. Dhooria. 1971. Bionomics of the pea pod borer (Etiella zinckenella (Treitscke.) Indian J. Ent. 33(2): 123-130.

Singh, H., B. Singh, and K.B. Singh. 1972. Screening of germplasm of arhar for resistance to insect pests. Proceedings 7th Workshop Kharif pulses, Bangalore 1972.

Srivastava,A.S. 1964. Entomological Research during the last 10 years in the section of the entomologist to Govt, of U.P., Kanpur (India). Research Memoir III, U.P. Govt., Kanpur.

Srivastava, B.K. 1964. Pests of pulse crops. Entomology in India. Entomol. Soc. India, 83-91.

Srivastava, A.S. and J.L. Srivastava. 1966. Insecticidal trials against Agromyza obtusa M (Dept. Agromyzidae). Lalidev J. Tech. Vol 4(2): 133-135.

Srivastava, A.S. and J.L. Srivastava. 1971. Incidence of Agromyza obtusa Mall in different varieties of arhar (Cajanus cajan) (Dept. Agromyzidae). Beitrage Zev Entomoligic 21, 192 (Secor RAE 61, 1193).

Thevasagayam, E.S. and I.S.C. Canagasingham. 1961. Some observations on the insect pests of dhal (Cajanus cajan) and their control. Trop. Agric. 116(4): 287-298.

The various Proceedings of the ICAR - All India Coordinated Research Project on Pulses published from 1966 to the present are a valuable source of information.

Appendix I. Pests of Pigeonpea

(Cajanus cajan Milsp) recorded in India

GROWING CROP

LEPIDOPTERA

Pod Borers	Adisura atkinsoni Moore
	*A marginalis Walk
	Etiella zinckenella (Tr.)
	*Euchrysops (Catachrysops) Cnejus F.
	*Eucosma critica M
	*Exelastis atomosa W.
	*HeHothis armigera Hub.
	*Lampides (Cosmo!yce) boeticus
	Marasmarcha liophanes (Meyrick)
	*Marica testulalis Geyr
	*Sphenarches anisodactylus W
	S. caffer Zell
Leaf-Eating Caterpillars	*Achertonia styr W
	*Amsacta albistriga W
	A. moorei B
	*Azazia tubricans B
	Cyphosticha coerulea Meyr.
	Estigmene lactinea C
	*Euproctis fraterna M
	*E. lunata (Wlk)
	E. Scintillans W
	*Gracillaria soyella D
	*Herse convolvuli L
	Olene mendosa Hub.
	Pingasa ruginaria C
	Plusia chalytes F

Leaf-Eating Caterpillars (Continued)	*P. orichalcia F
	*P. signata F
	Prodenia sp
	*Psalis securis Hub.
	Stauropus alternatus Wlk.
	*Stornopteoys nerteria M.
DIPTERA	
Pod Borer	*Melanagromyza obtusa (Mall.)
COLEOPTERA	
Flower and Leaf-Eating Beetles	Adoretus caliqinosusbicolor B
	*Alcides collaris P
	*Apion sp.
	Astyeus lateralis
	Cantharis setacea
	*Centhorrhynchus asperulus F.
	Demarchus pubipennis Jacoby
	Episomus lacerta F.
	*Gonocephalum depressum F.
	*G. elongatum
	Monolepta signata 01.
	*Mylabris pustulata Th.
	*Myllocerus spp.
	Sphenoptera perotetti Gl.
HEMIPTERA	
Plant-Sucking Bugs	Agonoscelis nubila Fb.
	*Anoplocnemis phasiana Fb.
	Ambrasca bariotata
	*A. fabae
	Aphis cardui
	*Aphis craccivora Koch
	*Calocoris angustatus Leth
	Ceroplastodes cajani Mas

Plant-Sucking Bugs (Continued)	*Cldvigrellahorrens Don
	*Clavigrella gibbosa Spin
	*Coptosoma cribraria Fb.
	C. nazirae
	Creontiades palidifer W
	Cyclopelta siccifolia W
	*Dolicoris indicus S
	Drosicha stebbingi G
	Graptostethus servus Fb.
	Lecanium longum D
	Lygaeus pandurus Scop.
	Margarodes niger G
	Menida histrio Fb.
	*Nezara viridula L
	Otinotus oneratus W
	*Oscycarenus laetus K
	*Oscyrhachis tarandus F
	Riptortus fuscus F
	*R. pedestris Fb.
	R. linearis F
	Tachardia lacca K
THYSANOPTERA	
Thrips	Dolichothrips varipes Bagn
	Frankliniella sulphurea (Schm)
	*Taeniothrips nigricornis Schm
HYMENOPTERA	
Bees	*Megachile anthracina S
	M. disjuncta F
	Solenopsis germinata Fb
ISOPTERA	
Termites	Odontoterures parvidens H

ORTHOPTERA

Grasshoppers	*_Catantops erubescens_ Wlk
	*_Chrotogonus spp_
	*_Coleroania spheneroides_ Bol
	*_Cyrtacanthacirs tatarica_ (L)
	*_Eyprepocnemis alacris alacris_ S
	*_Patanga succincta_ L
	*_Pyrgomorpha_ n. sp.

STORED CROP

COLEOPTERA

Bruchid Seed Beetles	_Bruchus theobromae_ L
	Callosobvuchus chinensis (L)
	C. maculatus F

OTHER PESTS

*Mites - Aceria cajani

*Millipedes

*Rodents

Appendix II. Pests ot Chickpea

(_Cicer arietinum L) recorded in India_

LEPIDOPTERA

Pod Borers	_Etiella Zinckenella_ (TR)
	*_Heliothis armigera_ Hub
	Lampides (Cosmolyce) _boeticus_ L
	Maruca testulalis B

Leaf-Eating Caterpillars	*Agrotis flamroatra* S
	A. segetum S
	A. *spinifera* H
	A. ypsilon R
	**Agrotis* sp
	**Azazia rubricans* B
	**Plusia orichalcia* F
	**P. signata* F
	Spodoptera (Laphygma) *exigua* H
DIPTERA	
Pod Borer	**Melanagromyza obtusa* Mall
HEMIPTERA	
Aphid	**Aphis craccivora* Koch
COLEOPTERA	
Beetles	*Tanymecus indicus* F
ORTHOPTERA	
Grasshoppers	**Acrotylus humbertiames* S
	**Aiolopus simulatrix simulatrix* Wlk
	**Atractamorpha crenulata* F
	**Catantops erubescens* Wlk
	**Chrotogonus trachypterus* K
	**Chrotogonus* sp.
	**C.yrtacanthacris tatarica* L
	**Eyprepocnemis aiacris alacris* S
	**Pyrgomorpha* sp
STORED CROP	
COLEOPTERA	
Bruchid Seed Beetles	**Callosobruchus chinensis* L
	*C. maculatus F
OTHER PESTS	
	*Rodents

PLENARY

SESSION

REPORT OF GERMPLASM DISCUSSION GROUP

D. W. Thorne - Convener

L.J.G. van der Maesen - Rapporteur

Collection Criteria

Rather than indiscriminate collection, the first aim should be the areas which have been least explored. Also unthought-of areas (China, Philippines, Java for pigeonpea) have to be looked into for small pockets of useful material. Collection for particular characteristics is difficult, since screening can only be done in areas of use.

Handling of Germplasm

(1) Different categories of germplasm material could be grouped together for easy reference: establishedcultivars,breeding stocks with particular singlegene resistance etc., promising lines, landraces. Consecutive chronological ordering has taken place, so a code added to the ICRISAT numbers might be the proper solution.

(2) To avoid calamities, a second collection should be maintained elsewhere (Fort Collins, Lebanon, Ethiopia or Turkey) in cold store. To avoid gene drift, multiplication should take place in place of origin or under similar environments.

(3) The idea of having a working collection of +1000 lines 1n other regions (e.g. the Americas) could be considered to overcome the worst quarantine barriers. Movement would be easier and cheaper within these regions.

(4) Collections growing elsewhere could be inspected by (e.g. Indian) quarantine officers to avoid delays because of inspection after despatch to ICRISAT.

(5) Gene pools should only be made in addition to normal separate accessions. Both unselected populations and those under low selection pressure (genetic park concept) could be practiced. Particular characteristics cannot be easily found back in a bulked gene pool.

(6) Accessions of the same origin through different sources can be bulked, provided no mixtures exist.

(7) The handling of plgeonpea germplasm is controversial. Mixed accessions should be kept mixed (House) but outcrossing left the material very heterogenous, so gene frequency is already changed. It is easier to procure one kg from the farmer and to store the seeds, rather than to increase a small sample. Presently the characteristics of the majority of the plants is considered as the original material. Selfing of each line yields about 5 pods per line and serves as a reference.

Collection Practice

(1) It is troublesome to collect at the right time at the right place. For this purpose cooperation of the local breeders, agronomists and their staff should be sought. Monthly training could be organized, and the people could collect in their areas for five consecutive years to cover area and time well enough.

(2) Harlan and de Wet's mimeographed travel diaries should be obtained for practical information and Harlan could be invited as a consultant.

(3) Nodules should be collected simultaneously, the material handed over to the microbiologist.

(4) Regional centers and authorities have to be visited first for guidance and information.

Documentation

(1) Computer techniques for storage and retrieval of data on germplasm are anticipated.

(2) The vigna catalog (IITA) by Dr. Rachie will be issued shortly and is useful as an example.

(3) Stressed is the need for universal code/accession numbering. Cooperation with Dr. House may be useful.

Immediate Program

Harvests and storage of pigeonpea (December-March) and chickpea (March), collection of pigeonpea in Madhya Pradesh (February, April) in collaboration with J.N.K.V.V. " Jabalpur and preparation of statement of objectives and further collections.

REPORT OF CHICKPEA BREEDING DISCUSSION GROUP

H. Doggett - Convener

A. K. Auckland - Rapporteur

Breeding Objectives

High yield of protein per unit area per unit of time and the retention of good amino acid profiles should be one of the most important objectives in chickpea breeding. Dr. Bythe's pattern analysis method as a possible measure of stability needs to be considered seriously.

Breeding Methodology

Need for an immediate short term as well as a long term approach for breeding methodology was stressed. In the immediate short term approach, pedigree breeding and the F2 modified progeny method was recommended.

, For the long term approach, the value of developing populations was emphasized and use of Jensen's method was recommended.

Cooperative International Breeding

(1) It was felt that the ICRISAT Cooperative Program should be careful to operate in a manner which strengthened rather than competed with the Indian national program. The first three objectives mentioned in the paper by A.K. Auckland and K.B. Singh were accepted.

(2) The distribution of chickpea varieties possessing specific characters of value such as resistance to pests and diseases was suggested as one of the responsibilities of ICRISAT.

It was stressed that material from the chickpea breeders all over the world should be included in the nurseries, trials and segregating populations distributed by ICRISAT.

(3) Certain basic studies such as improved plot techniques and the Identification of the primary gene pools could be included in the program at ICRISAT. Potential value cf having postgraduate students working on problems of this kind in a cooperative program with universities in various countries and at ICRISAT needs to be examined.

(4) A chickpea newsletter containing items of research news and a correspondence column, would be of great value to all chickpea workers and should be organized by ICRISAT.

(5) The potential value of non-nodulat1ng lines was emphasized.

(6) The potential value of mycorrhiza in the extraction of unavailable phosphate from the soil needs to be studied for this purpose. Chickpeas fertilized with rock phosphate should be grown in the greenhouse to Identify varieties with this capability.

REPORT OF PIGEONPEA BREEDING DISCUSSION GROUP

E. Aberg - Convener
J. M. Green - Rapporteur

Breeding Procedures

(1) Breeding lines should be tested both in a pure stand and with an appropriate companion crop.

(2) Pathologists and breeders should work together for maximum efficiency and progress in disease screening.

(3) Practical uniformity, not necessarily a pure line, should be the objective in variety development.

(4) Selection for seedling vigor should be for rapidly growing types for pure cultures and slowly growing types for mixed cropping.

(5) Breeders should be aware of host-cultivar-Rhizobium strain in nodulation and N fixation.

(6) Isolines are valuable for measurement of N fixation in the field and should be sought.

(7) Pigeonpea lines should be screened under low fertility conditions and for ability to utilize rock phosphate. Nitrogen fertilizer should not be added to plants used for breeding.

Quality Determinations

(1) Protein fractions should be studied and better nutritional fractions identified.

(2) Digestibility determinations need to be made, as well as other biological evaluations.

(3) Effect of storage on quality should be investigated.

(4) Guidelines should be developed for determining protein in pulses.

(5) All factors of consumer preference should be included in quality determinations: seed color, size, cooking time and volume.

Physiology

(1) Photosynthetic efficiency of leaves at various stages and of the pods should be determined.

(2) Investigation of different night temperatures on flowering should be arranged at an appropriate facility on a contract basis.

(3) Rhizobia

(a) Collections of Rhizobium should be made from various locations.

(b) Effect of organic matter on nitrogen fixation should be studied.

(c) Movement of carbohydrates and N within the plant in relation to pod fill should be studied.

(d) Search for associations with a longer period of nitrogen fixation should be made.

Suggestions Concerning International Cooperation

(1) A catalog of the germplasm should be made available as soon as possible.

(2) Breeding lines with special characters should be developed as genetically stable lines and made available.

(3) An international variety test which will include lines from national programs should be developed.

(4) Hybrid populations and breeding lines for cooperative testing and utilization should be provided.

(5) Contacts should be made by ICRISAT personnel visiting national programs.

REPORT OF PEST AND DISEASE RESISTANCE BREEDING DISCUSSION GROUP

W. J. Kaiser - Convener

Y. L. Nene - Rapporteur

1. There is an urgent need to give top priority to investigations on Chickpea wilt to determine the cause or causes responsible for the disease. If more than one pathogen is involved, it would be necessary to develop techniques for screening against each pathogen.

2. It would be necessary to carry out routine seed microflora studies and prepare lists of all microorganisms, pathogens, potential pathogens as well as nonpathogens associated with seed raised at ICRISAT in Hyderabad. This Information might assist scientists in cooperating countries to get the seed through their respective plant quarantines more easily. It would be desirable to request the Danish Institute of Seed Pathology, Copenhagen, to run parallel seed pathology studies on the same seed lots.

3. Investigations on pigeonpea wilt should be intensified. A wilt sick plot should be developed at the ICRISAT center for screening germplasm and breeding material.

4. Screening for resistance against pigeonpea sterility mosaic virus should be initiated immediately using known techniques.

5. Work on the bioecology of the eriophyid mite vector of pigeonpea sterility mosaic virus should be carried out jointly by the pathologist and entomologist.

6. Facilities for screening for resistance to chickpea _Ascochyta_ blight and _Botrytis_ grey mold should be developed at suitable locations 1n North India in cooperation with other institutions.

7. Research on developing more efficient screening techniques for resistance to various diseases should be intensified.

8. In the not too distant future, international disease nurseries should be operated from ICRISAT. Also, estimation of losses due to chickpea rust should be made for determining the priority in the breeding program.

9. There is a need to train young scientists in the Identification of diseases and pests and to acquaint them with research methodology. ICRISAT should arrange for training programs 1n these areas.

10. There 1s a need to collect detailed Information on the disease and pest incidence in the countries of the semi-arid tropics. ICRISAT should arrange to collect this Information through the participants of this workshop. Also, ICRISAT scientists should initiate chickpea and pigeonpea disease and pest surveys.

11. The committee felt that it was of great importance for ICRISAT to determine clearly the taxonomic status of the main pest species as soon as practicable—it was particularly important to the situation with regard to _Heliothis armigera_ and _Marasmarcha liophanes_ (_Exelastis atomosa_) particularly as it appeared that two species of Marasmarcha were present.

12. Detailed work on the biology of the pest species of economic importance and determination of specific areas where effort should be focused was necessary. Suggested areas were oviposition preference, antibiosis effects, seasonal incidence and carry over between seasons.

13. It is vital that further work on crop loss in the two legumes is done. The relative importance of the pests locally, nationally and Internationally must be clarified as quickly as possible in order to assist the plant breeders. Crop loss should be determined over the whole cycle, i.e., _throughout the whole of the crop's_

life, not just the podding phase.

14. It is hoped that advice on the range of types or classes of plants to be tested under pestiferous conditions can be determined in collaboration with the breeders so that preliminary guidelines can be obtained on pest preference as soon as possible. This topic involves development of suitable screening techniques for legume species.

15. Building on the biological Information and seasonal incidence data, techniques of minimal spray application should be worked out for control of pod borers. Pesticides inputs are likely to be of relevance in the instance of short term determinate pigeonpea in particular.

16. A study of the use of virus for control of Heliothis should be pursued with vigor in collaboration with outside, agencies.

17. It is important not to lose sight of the fact that the two crops are grown in peasant farmer conditions in intercrop situations and quite often at low plant populations. In these situations pest attack and damage can be very different from that which exists 1n single stand crop. It is important to survey the situation on farms within India and by cooperative effort in other areas of the semiarid tropics.

REPORT OF QUALITY OF GRAIN AND NUTRITION DISCUSSION GROUP

J. H. Hulse - Convener

R. Jambunathan - Rapporteur

Yield

The group supported the recommendation that yield be expressed in terms of protein per unit area of land per unit of time.

It is recognized that this may be achieved either by increasing the total yield at constant protein content or by the selection of genotypes of superior protein content with average yield capability.

Amino Acid Composition

The group agreed that breeding for modified amino acid composition should not be granted the highest priority rating. Nevertheless, the group considers that Information should be obtained on whatever variability exists among the chickpea and pigeonpea germplasm collection by systematic sampling and amino acid analysis. It would also be useful to discover if significant variation exists among varieties in the proportions of the main protein fractions present 1n the seed. The group is not prepared to recommend whether this work be undertaken at ICRISAT or under contract by some other competent institution.

Protein Digestibility

Some evidence suggests that there may be some variation in the digestibility of protein among different legume varieties. Further studies on this matter should be encouraged probably under contract to some competent research institution.

Carbohydrate Digestibility

Since the carbohydrate of the legumes makes a comparatively small contribution to the total diet, the group does not recommend a major study into legume carbohydrate digestibility even though some variability has been reported.

Polyphenol Content

Research should be encouraged to discover whether or not the dark seed coated varieties of chickpea and plgeonpea contain polyphenols and to what extent these polyphenols impair the nutritional quality of the legumes. If polyphenols exist only 1n the seed coats, the need to breed for low polyphenol content would be important where it is customary to eat the whole seed rather than the dehulled cotyledons.

Cooking Quality

It is important that the cooking quality of the superior breeder's lines be determined. The rate of water absorption and the time required for cooking will influence the acceptability in the eyes of consumers.

Methods for Breeders

It is important that the methods of analysis, biological evaluation and cooking quality be standardized between ICRISAT and all of its cooperative stations. It is suggested that a small working group be assembled to draw up a guideline for legume breeders to be adopted by all with which ICRISAT is cooperating and exchanging breeding materials.

HIGHLIGHTS OF THE WORKSHOP

L. ft. House[1]

INTRODUCTION

There has been a growing concern about the production of various legume crops, particularly following the availability of high yielding varieties of wheat and rice. This concern arises in part because legumes, which give effective nutritional balance to cereals in the diet, have declined in acreage in some locations as the area sown to wheat increases. Also, the fact that high yielding varieties of wheat and rice have been identified stimulates the thought that the same thing can be done for legumes if only the effort is made to do the necessary research. This meeting, as a function of ICRISAT, reflects this concern and the dedication to get on with the job.

Meetings such as this are organized for the purpose of bringing together scientists of common interest to meet each other and to exchange Information and ideas. This meeting has brought together scientists from all over the world and I am sure all agree that the opportunity to observe the developments at ICRISAT and to participate 1n the meeting has been most useful. Hopefully, this will only be the first meeting of scientists interested in the improvement of chickpeas and pigeonpeas and that more will follow-possibly on a periodic basis.

The conference has been organized so that various sessions have concentrated on the major disciplines involved in the improvement of these crops.

Reports were presented by individuals representing various areas of the world. It 1s apparent from these discussions that many research programs for the improvement of these crops are relatively new. This in itself reflects the increased concern for the improvement of legumes.

A number of interesting points were made. Mechanical harvesting is of importance in many growing regions, and modification of plants for mechanical harvesting becomes important. For example, the modification of chickpeas to larger, erect plants with pods of uniform maturity situated in the upper branches were considered important modifications. Plants of pigeonpea with pods of more uniform maturity clustered at the top of earlier maturing plants were characteristics considered desirable for mechanization. Row spacing and plant population were factors of interest; with pigeonpea, the use of smaller plants at higher populations was mentioned. Weed control is important and 1t 1s apparent that several herbicides have been used effectively; but it is also apparent that a herbicide used in one location may not be effective in another. Careful evaluation at each location is important. The need for training of research personnel was mentioned.

NUTRITIONAL PROBLEMS

Nutritional problems are important aspects of legume improvement as they are generally consumed with cereals and in this combination give better balance to human protein requirements. It was stressed that improvement in the quantity and quality of legume proteins should be important aspects of crop improvement programs.

Breeding for improved protein quality in cereals was stimulated with the Identification of single recessive factors resulting in a desirable shift in the concentration of fractions of storage proteins. This concentration change resulted in a higher lysine content. Interestingly, genes in several cereal crops resulting in increased lysine content have been obtained following treatment with mutagenic agents.

Simple selection for higher protein or higher concentration of sulfur amino acids or tryptophan, if undertaken in legumes, should be accompanied by other types of research. The sampling problem and environmental Interactions complicate protein analysis. Simple selection for high protein may result in a

---

[1] Arid Lands Agricultural Development Program, Ford Foundation, Beirut, Lebanon

poorer quality protein, and food preparation, taste characteristics and market value are all important aspects of quality considerations. Nitrogen fertilization and nitrogen fixation in relation to yield and composition are factors of interest. Protein availability is the most important nutritional trait. However, possible limitations in digestibility because of polyphenolic compounds, the presence of flatulants and Inhibitors which may or may not be destroyed by processing, and cooking quality were all mentioned indicating that quality considerations go beyond protein evaluation. The development of useful techniques for cooking quality and the accumulation of various food preparation procedures of these legumes around the world would be useful Information to have available in addition to the analytical techniques currently being published by the PAG. Cooperation of ICRISAT with nutritional laboratories in India and in other countries was emphasized.

GERMPLASM COLLECTION

Collection, maintenance and evaluation of germplasm is recognized as an important function. Stress was placed on the need to undertake collections in Turkey soon as older types are being replaced. Interest was expressed in the collecting of cultivated and wild species and, in the case of pigeonpea, related genera. Some reorganization of the taxonomy of the pigeonpeas and related genera may be useful.

It was reported that to date there has been no success with interspecific hybridization in the genus Cicer and it was emphasized that more attention should be given to this aspect.

Collecting is complicated by several factors; political considerations, difficulty in reaching inaccessible locations, and the difficulty of being on location at the right time to adequately collect an area. The importance of resident collectors and their training was mentioned. Interest centered on the collection of unimproved types, but the need to maintain a collection of improved varieties and of creating a gene bank was mentioned. The maintenance of the whole collection at more than one location was stressed for purpose of protection. In addition, pooling of germplasm into composites for germplasm maintenance was mentioned and, interestingly, the establishment of "gene parks'' to permit continued evolution of collections was suggested.

It is recognized that collections must be periodically increased and that this increase should be undertaken in an area with similar environment to that from which the collection came. The availability of working collections at a few locations in the world might be considered; this may have value in simplifying the problems of distribution. Possibly the functions of a gene park, maintenance of adapted collections, and the housing of working collections could be tied to the activities of major outreach locations of ICRISAT.

Description and evaluation of germplasm collections is valuable for their most effective use. The several techniques described by Dr. Murty are useful in identifying relationships. A system called TAXIR has been developed to standardize and computerize information accumulated by scientists anywhere working with a collection. Serious consideration should be given to using this system as it has received considerable attention and an effort is being made to develop a standard system for use on all crops. The collection of rhizobial bacteria by ICRISAT has been suggested.

BREEDING PROCEDURES

The discussions on plant breeding indicated that there 1s considerable searching for the best breeding procedures to use. It was pointed out that some fundamental studies on procedures would be valuable. Populations have been used extensively in the improvements of cereals. Their value as means of increasing the rate of recombination and the opportunity to select superior recombinates in cycles of selection was indicated. The rate of recombination is increased as outcrossing within the population increases and male sterility is usefully incorporated into composites. Interestingly, male sterility in pigeonpeas has been found. It was pointed out that repeated selection of male sterile types in a population of a primarily self-pollinated crop may result in some loss of fitness. Several population systems that are being evaluated at IITA, which may be useful in other legume breeding programs, were outlined.

It was recognized that variation can be increased by using accessions- from collections and by the use of mutagenic agent's. The use of wild types was mentioned as valuable as a possible method of increasing yield. The availability of gametocides would be very helpful 1n making crosses and a search for them may be rewarding.

Advances in crop production resulting from single gene changes was mentioned several times. Emphasis was placed on useful results that are forthcoming from the so-called "traditional breeding techniques". The breeding program described for soybeans is a beautiful example of the improvement possible by screening for disease and insect resistance coupled with pedigree selection. It was indicated that only a few chickpea varieties selected from F_2 populations have been released in India. The problem apparently related to "eyeball selection" of the parents and better results are being realized 1f the parents are selected based on their combining ability. A greater gain was realized from selections from double crosses than from single crosses. Selection from biparental crosses made in the F_2 was useful particularly 1f the crop was grown with good levels of fertility and irrigation. The importance of stabilizing yield by adding one by one such factors as drought tolerance, disease resistance, etc., was stressed.

It is recognized that traditional breeding techniques are useful per se and in conjunction with the use of populations. A balanced approach exploiting genetic variation by both the more traditional breeding procedures and population improvement appears to be relevant.

BREEDING OBJECTIVES

Numerous breeding objectives were mentioned: yield, disease, insect, and drought tolerance, quality, nitrogen fixation, and factors related to mechanical harvesting. Harvest Index was mentioned as a criterion for the selection of plants with higher efficiency. Evaluation of germplasm at selected locations in the world to keep breeding objectives focused on problems in various locations was mentioned as important for international institutes such as ICRISAT. The levels of management to be used while breeding was discussed. Generally, it was felt that the nursery should be grown under conditions of high fertility and adequate moisture. This is based on wide experience that varieties which perform well under good conditions will perform better under poorer conditions than lines which have been selected only under poor conditions. It is recognized that nurseries designed to select for particula traits, such as drought tolerance, would have to be grown under such conditions so that the trait is satisfactorily expressed. Limited Protection against insect pests and diseases should be used in the breeding nursery in order not to reduce the selection opportunity., Yield evaluation should be undertaken at several locations and under conditions of farmer cultivation.

ICRISAT, with Its worldwide contacts, might consider encouraging and assisting with the development of off-season breeding opportunities in various parts of the world where these would be useful.

It was pointed out that in many instances good yielding varieties are available and that increases in yield in the farming community are possible through the adoption of improved agronomic practices. The fact that legume crops are frequently intersown with other crops was mentioned; this practice has developed as a form of subsistence agriculture but it 1s a useful procedure in intensifying production. Legumes are also used 1n rotations and where moisture is available as part of intensive cropping systems. Nitrogen fixation was discussed and, interestingly, the ability of some plants to take up phosphorus from very poor soils was mentioned. A study of the relationship of legume plants to soil microorganisms was suggested.

The work on soybean improvement described an intensive, sustained and systematic effort at crop improvement. Diseases limiting yield were identified, individually solved and combined to produce higher yielding more stable varieties. It was pointed out that some 35 pathogenic organisms on chickpea and 47 on pigeonpea have been identified of which four on chickpea and two on pigeonpea have been found to be of major importance.

PEST CONTROL

Insect pests are important factors limiting production. It was pointed out that damage by insects to seeds in storage is important to consider along with damage to the crop in the field. Importance was placed on minimizing the use of insecticides as much as possible beginning with the research program itself. In this regard, agronomic practices including such factors as date of sowing were considered important. The possible use of viruses in insect control was mentioned. It was considered important to evaluate breeding stocks early in the improvement program rather than to simply see what the susceptibility pattern is in advanced breeding material.

A good team of scientists to focus on major problems of chickpea and pigeonpea production is now at ICRISAT. and we wish them well.

APPENDIX I

REMARKS ON BREEDING CHICKPEAS AND PIGEONPEAS FOR REGIONS WITH POOR GROWING CONDITIONS

S. Rehm[1]

ECOLOGICAL CONDITIONS

1. The ecological conditions in many semiarid regions of the tropics are extremely hazardous, mainly because of the uncertainty of rainfall which changes from year to year and shows an uneven distribution within each rainy season.

2. These climatic hazards prohibit high inputs into the production of crops, since it is uncertain if reasonable returns will be obtained.

3. Soil conditions in semiarid regions frequently are far from satisfactory. Deficiency of available P is the rule. Therefore, crops demanding a high input of fertilizer P are undesirable for these regions.

4. Breeders generally have to test the genetic potential of their material in favorable conditions of nutrient supply. Varieties developed in these conditions may be unsuited for the growing conditions in many developing countries, not only because the necessary resources are unavailable, but also because ecological conditions do not justify the inputs. Consequently, breeders should test their material for adaptability to low soil fertility and other agronomic shortcomings.

ABSORPTION OF P

Confining myself to the problem of P uptake from soils low in so-called available P, I should like to mention three examples: (a) at the Institute of Tropical and Subtropical Crops Husbandry in Goettingen, we are working on the exceptional feeding power of some tropical weeds (e.g.. Eupatorium odoratum). We found that they are able to take up P from various forms of water insoluble phosphates. This ability is due to mycorrhizal symbionts (Endogone spp.) and, probably, the association with other microorganisms in the rhizosphere. (b) In Thailand a rice variety was found which yielded 1 ton of paddy on a soil which was so poor in available P that other rice varieties yielded nothing, (c) Many years ago we found in South Africa that soil showing no available P with any of the methods used in soil analysis, still produced reasonable yields of several crop species.

RESEARCH SUGGESTIONS

1. These experiences may lead to methods of solving the problem of obtaining fair yields in low input agriculture, at least with some crops. To exploit this possibility is primarily the task of the agronomist, plant physiologist and soil microbiologist. But the plant breeder can contribute a great deal by selecting plants with a high feeding power, operating directly or via the association with microorganisms.

2. Consequently I should like to suggest that ICRISAT include in their program the breeding of varieties adapted to low fertility soils and to other ecological hazards. ICRISAT is the only one of the International agricultural research Institutes devoted to crop production in semiarid regions and might pay particular attention to ways of using the biological potential of the ecosystem of rainfed agriculture with the goal of minimizing the ecological hazards and economic limitations in dry areas.

---

[1] Institut fur Tropischen und Subtropischen Pflanzenbau der Universitat Goettingen, GrisebachstraBe, West Germany

"The International Crops Research Institute for the Semi-Arid Tropics receives support from a variety of donors, governments, foundations, etc. including IBRD, IDRC, UNDP, USAID, etc.

The responsibility for all aspects of this publication rests with the International Crops Research Institute for the Semi-Arid Tropics."

A- 0019