Overview of Pulses Research at ICRISAT

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Abstract

This paper provides a brief overview of ICRISAT's interdisciplinary research on chickpea and pigeonpea. Global area under the two crops is mentioned, chief constraints in their production and priorities for research emerging therefrom are outlined, and ICRISAT's research progress in developing screening capabilities against biotic and abiotic stresses is summarized. Breeding efforts that follow the screening are outlined, and successes in release of improved materials to farmers mentioned.

The Pulses Improvement Program at ICRISAT is concerned with research on the two important pulse crops of the semi-arid tropics (SAT)—pigeonpea and chickpea. The research is interdisciplinary, with breeders, pathologists, entomologists, crop physiologists, and microbiologists working together on the common objective of improving stability and yield of the two crops.

The global area under chickpea cultivation at present is over 10 million ha, and chickpea is the third most important grain legume in the world, after beans and peas. Dr. Kanwar has already pointed out that presently chickpea yields are quite low—around 700 kg ha^{-1}. A little over 3 million ha are under pigeonpea cultivation, for which also present yield levels are quite low, around 600 kg ha^{-1}. Yield potential of both crops is high, however: around 4000 kg ha^{-1} have often been realized at experiment stations. The harvest index is markedly different in the two crops: in chickpea it may be as high as 60%, but in pigeonpea it ranges between 15 and 30%. Growth duration of the two crops depends upon location, season, and cultivar; crop duration is generally 4-6 months in chickpea and 4-10 months in pigeonpea.

Most of our research is carried out here at ICRISAT Center. In addition, we have facilities, made available through cooperative agreements, to work at other agricultural research centers and universities in India. At Hisar, we carry out experiments on short-duration pigeonpea and long-duration chickpea; the results of this work are relevant and applicable to northern Indian environments, as well as to Pakistan and Nepal. At Gwalior, our research is primarily on long-duration pigeonpea. We also have an off-season nursery at Tapperwaripora in Kashmir for multiplying chickpea seed, thus enabling us to rapidly advance generations. We have similar cooperative agreements to screen for tolerance to certain diseases, such as ascochyta blight and botrytis gray mold in chickpea. These diseases do not occur here at Patancheru, whereas they are endemic in those areas, thus making them excellent sites for our cooperative research.

If one analyzes the problems that confront increasing production of pulses, the following points emerge:

1. Chickpea and pigeonpea are considered low-priority crops by farmers because remunerative harvests are uncertain.
2. These crops are grown in subsistance rather than commercial farming systems.
3. Their response to fertilizers and irrigation is gen-

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erally not remunerative
4 These crops are relatively more susceptible to pests and diseases
5 Growth duration of 150 days in chickpea and more than 180 days in pigeonpea is excessively long
6 Traditional pigeonpea cultivars are too tall and thus difficult to manage Chickpea cultivars are short and bushy and lodge quite often their proximity to the ground encourages disease problems
7 Nodulation in farmers fields is generally poor for these two crops

I wish to point out that ICRISAT and the Indian national programs have directed efforts toward solving the above problems and that we have found satisfactory solutions in many cases

Chickpea

Chickpea is a self pollinated annual crop It is adapted to grow without rainfall during the growth period either on stored receding soil moisture or with irrigation Chickpeas are of two types—kabuli and desi The seeds of kabulis are light colored and have a smooth surface whereas seeds of desis are yellow to black with a rough surface Flower color also differs kabuli types produce white flowers and desi types produce colored flowers Chickpea is grown as a summer crop in the Middle East around the Mediterranean and in the Americas it is grown as a winter crop in more tropical climates The relative importance of chickpea in different geographical areas is shown in Figure 1 It is apparent that the Indian subcontinent and North Africa are areas with a large proportion of chickpea in relation to other cultivated crops However chickpea remains an important crop in many other countries

In chickpea research our objectives are to develop genotypes with characteristics that would contribute to higher and more stable yields of acceptable grain type under a range of cropping situations We are breeding short-duration desi types for southern India and short-duration kabuli types for Southeast Asia and North Africa Work on kabuli types in particular is being done in cooperation with the International Center for Agricultural Research in Dry Areas (ICARDA) based at Aleppo Syria Under a joint agreement ICRISAT has placed two scientists at ICARDA, from where they can properly serve regions of the world where kabuli chickpea is grown more widely We are also breeding long duration desi and kabuli types for northern India and Nepal and desi types for Pakistan Burma Iran and Ethiopia

Our achievement so far in terms of our capability to screen germplasm and breeding material for various stress factors—is shown in Table 1 While we are generally satisfied with our screening capability for tolerance to diseases and pests we still need to improve screening for tolerance to drought salinity and other abiotic factors The 0 5 on a 1 point scale means we have reached a level where we can start the screening process However we still need to improve the techniques until we reach a rating of 1 0 at which stage we can consider it an excellent technique A rating below 0 5 indicates we have not yet reached the screening stage

Disease resistance is a very important consideration in our plant improvement efforts Our breeders realize the imperative need to incorporate resistance to various diseases in all breeding material Whenever they feel they have materials ready for testing in multilocational trials we would already have gathered enough information on many of the factors mentioned in Table 1 Once the material is identified as elite we try to fill in the gaps in our knowledge and collect information on all the aspects mentioned in Table 1 as well as on certain aspects not listed there We collect information on about 22 different traits so that if a particular material is found useful in any national program we would have almost complete information related to that line By the time a genotype is ready for multiplication its strong and weak points are thus well documented Some of the information we already have follows

Heliothis is a very serious pest of chickpea as well as pigeonpea We have identified chickpea genotypes that are tolerant of this pest

Plant stands are often very poor in farmers fields

Table 1 Screening capabilities for biotic and abiotic stresses in chickpea

Trait	Score	Trait	Score
Wilt	1 0	Leaf miner	0 6
Ascochyta blight	0 9	Salinity	0 6
Dry root rot	0 9	Stunt	0 6
Heliothis	0 8	Drought	0 5
Black root rot	0 7	Grain quality	0 5
Botrytis gray mold	0 7		

1 1 0 excellent screening capability 0 5 screening may begin and 0 0 no capability for screening

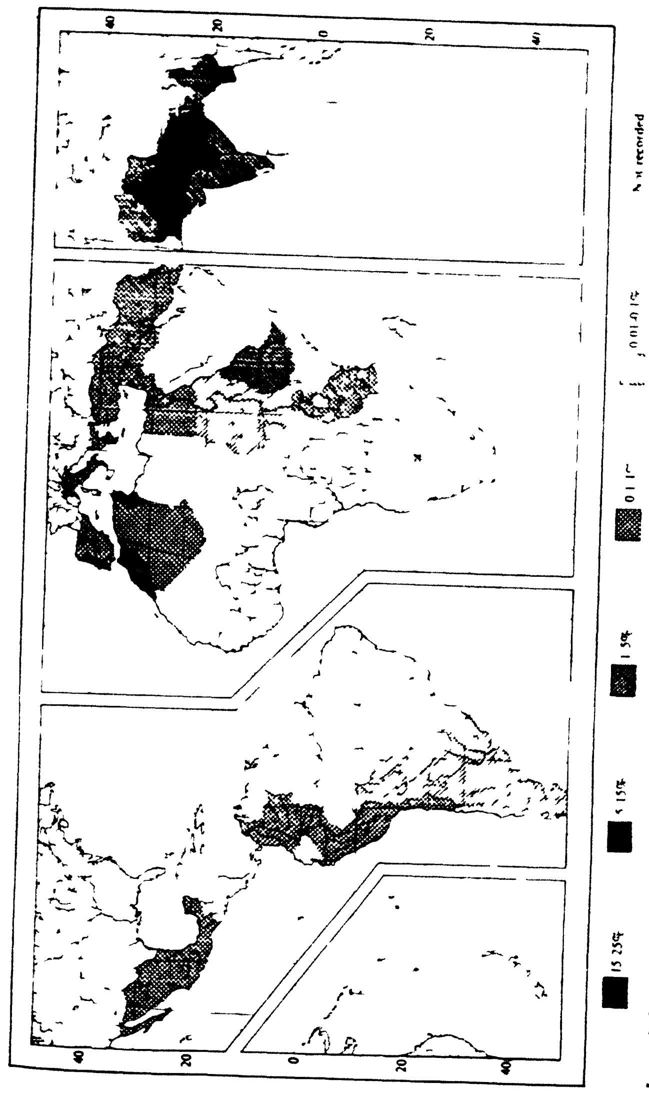

Figure 1 Chickpea producing regions in the world and their chickpea area as a percentage of total arable area

One major reason for this is low moisture in the seedbed at the time of sowing. Our physiologists have developed a field method and a laboratory technique that enable detection of genotypic differences in germination and emergence at suboptimal soil moisture levels. These results are promising and they should help ensure better plant stands.

Work has been done in nutrient stress as well. Genotypic differences in the efficiency of iron utilization have been identified. We have demonstrated that it is possible to ameliorate iron deficiency through sprays of iron sulfate. We also have attempted to understand the response to phosphorus in both crops.

Chickpea grows excessively vegetative either if there is excessive rainfall during the season or if, in irrigated areas, enthusiastic farmers overirrigate the crop. The excessive vegetative growth invites many problems, such as lodging and increased incidence of diseases caused by *Botrytis* and *Ascochyta*. Germplasm is being screened to identify genotypes that will not produce excessive vegetative growth even where moisture is above optimum. They will not then form a very thick canopy and will still allow the light to penetrate, thereby overcoming many of the problems mentioned earlier. Our research on responses to fertilizer and to irrigation will be covered in greater detail later in this workshop.

Our microbiologists have generated very useful information. They have found that chickpea rhizobia exist at soil depths greater than 1 m. Seasonal variations in rhizobial numbers, particularly in the top 5 cm, have been observed. Soil temperatures above 30°C have been found to adversely affect nitrogen fixation. It is interesting that chickpea rhizobia can survive in the soil for at least 5 years and can multiply in the rhizosphere of the other four mandate crops of ICRISAT. Between 87 and 90% of the plants' nitrogen seems to come from biological nitrogen fixation. So far, two strains of rhizobia have shown promise for efficient N_2 fixation. One of these, IC-76, has been recommended by the All India Coordinated Pulses Improvement Project (AICPIP) as a strain to be used for inoculating chickpea seeds. IC-26, the other strain isolated at ICRISAT from saline soil, has been found useful at ICARDA. Trials in Gujarat state of India indicated that good responses can be obtained to *Rhizobium* inoculation under field conditions.

One of the first breeding materials from ICRISAT was found to do well in Gujarat, and it is now released as a cultivar named ICCV 1 (ICCC 4). Some of the other lines are in the process of being approved for release. ICCC 37, which has done very well in peninsular India is one such line. ICCV 6 (ICCC 32), another cultivar identified for release by AICPIP, is of great interest because it is a kabuli type with wilt resistance, a combination that did not exist earlier in the chickpea germplasm collection at ICRISAT. In addition, there are several near releases or materials released in different countries, such as Australia, Ethiopia, Bangladesh, Nepal, and through our cooperative work with ICARDA in West Asia and the Mediterranean region. Some material is now being found promising in North Africa. One of the first lines released to farmers for winter planting in Syria is ILC 482, a product of our cooperative efforts with ICARDA.

In our germplasm collection we have several double-podded genotypes that bear two pods in the axil of a leaf instead of one as in conventional types. It has been found that the double-podded character confers a yield advantage of around 11% in peninsular Indian conditions. Unfortunately all the double-podded genotypes in our germplasm collection were extremely susceptible to wilt. Through breeders' efforts, double-podded genotypes were developed that are wilt resistant and such material has been found to be quite promising.

Chickpea genotypes differ in their growth habits. Breeders at ICRISAT have been concentrating more on the development of mid-tall types. We believe that mid-tall types hold a better promise for higher yields than the tall and dwarf types. In addition, we find lines that consistently show two, three, and even up to six seeds per pod. This has opened the possibility of breeding for multiseeded characters.

Pigeonpea

Pigeonpea is a partially cross-pollinated crop. It is perennial in habit but is cultivated as an annual. It is quite tall, except for dwarf genotypes that have been identified at ICRISAT. Pigeonpea grows well during the rainy season but yields are optimum if flowering and podding occur after rainfall ceases. It grows very slowly during the vegetative stage in the first 45 days after sowing. Maximum crop growth occurs between 45 days and the beginning of flowering.

There are some clear gaps in our screening capability in pigeonpea (Table 2). We are not yet ready to screen for tolerance against some diseases and pests. In the near future we hope to improve our capabilities to screen for yellow mosaic disease and tolerance to nematodes. At present we have no capability to screen for two diseases; witches' broom does not occur in India, and cercospora blight is a disease of minor importance to the crop in this country. Witches' broom is a very severe disease in Central America and cercospora blight is quite important in Kenya and other eastern African countries. It is necessary to screen for these diseases in the regions where they are prevalent. The Program Committee of our Governing Board has now recommended that we work on witches' broom.

Table 2. Screening capabilities for biotic and abiotic stresses in pigeonpea.

Trait	Score[1]	Trait	Score
Phytophthora blight	1.0	Grain quality	0.5
Sterility mosaic	1.0	Drought	0.5
Wilt	0.9	Bacterial blight	0.4
Alternaria blight	0.8	Yellow mosaic	0.3
Heliothis	0.7	Cyst nematode	0.3
Pod fly	0.7	Cercospora blight	0.0
Waterlogging	0.7	Witches' broom	0.0
Salinity	0.6		

1. 1.0 = excellent screening capability, 0.5 = screening may begin, and 0.0 = no capability for screening.

We conducted extensive surveys in India and eastern Africa on the occurrence and spread of wilt and sterility mosaic diseases of pigeonpea. We found that pigeonpea wilt is a problem in India as well as eastern Afica, but sterility mosaic is more or less restricted to the Indian subcontinent. These two diseases together cause losses of about US $113 million per year in India alone, and wilt causes losses of around US $5 million in eastern Africa. This amply demonstrates the attention and priority that these two diseases need. In India, very high incidence of wilt disease is reported in the states of Maharashtra, Bihar, and Uttar Pradesh. Sterility mosaic is important in several states, such as Tamil Nadu, Gujarat, Uttar Pradesh, and Bihar. Such surveys have helped us decide our research priorities for different regions in India in terms of resistance to diseases. In experiments on the effect of cultural practices on disease occurrence, pathologists and agronomists have found that intercropping pigeonpea with sorghum reduces wilt incidence in the first year of cultivation. The experiment was laid out in a wilt-sick plot. Factors that lead to reduction of wilt incidence in such an intercropping situation have not been isolated.

We have realized the increasing importance of nematodes. In one of the ICRISAT fields where sorghum and pigeonpea were intercropped for four consecutive years, we had the advantage of wilt reduction due to intercropping but a buildup in the population of lance nematodes. This nematode not only infests sorghum but also attacks pigeonpea. In an intercropping system where both the hosts are present together, this nematode finds a favorable environment in which to build its population.

Heliothis in pigeonpea is more regularly devastating than in chickpea and hence, we have devoted considerable attention to work on this pest. It causes an annual loss of US $200 million in India alone. To study the ecology of *Heliothis* in a region, we have established a network of pheromone traps. This work is being carried out in cooperation with the British Overseas Development Administration. Another serious pest of pigeonpea is the pod fly, which can devastate the crop, particularly in northern Indian environments.

We feel that ICRISAT can justifiably take credit for demonstrating the economic feasibility of cultivating postrainy-season pigeonpea. The idea was not new, but we did demonstrate its potential. Pigeonpea is grown in the postrainy season in parts of India such as Gujarat, but the system has great potential in many other areas. Subsequent to our work, the state of Bihar in northern India undertook this activity on a large scale. Postrainy-season pigeonpea has certain advantages. For example, the unmanageable height of the crop is considerably reduced, which permits easier plant protection. Also, yields very close to normal can be harvested in a shorter season.

Physiologists have been screening for tolerance of waterlogging problems, and some promising lines have been identified. ICP 1-6 is a line tolerant of waterlogging and of two major diseases, wilt and sterility mosaic.

Microbiologists have made important contributions to pigeonpea *Rhizobium* research. We now have a collection of 500 isolates. One of the strains has been recommended for use in India. In the case of pigeonpea, about 70 kg nitrogen ha^{-1} per season can be fixed by the symbiosis until the mid-pod-fill stage. This is around 88% of the total nitrogen content of the plant at that stage of growth. The residual effect on a following cereal crop can be as much as 40 kg nitrogen ha^{-1}. We have been promptly providing cultures to our cooperators on request.

The objectives in genetic improvement mentioned for chickpea apply also for pigeonpea. Some of the cultivars bred at ICRISAT have now been released[1]. Cultivar ICPL 92 was released for cultivation in Himachal Pradesh; ICPL 87, a short-duration type particularly suitable for multiple harvests, has also been released in peninsular India and in the state of Maharashtra in central India. One of our short-duration hybrids, ICPH 8, is also in a prerelease stage in minikit trials conducted in India. A cultivar, Hunt, has been released in Australia, and six more lines are in the prerelease seed increase stage there; this is a result of our cooperative work with the University of Queensland.

Vegetable pigeonpea types are important in Central America as well as in western and eastern Africa, where green peas are consumed as soups, etc. In Puerto Rico, vegetable types, generally large podded with large, sweet-tasting green seeds are preferred. Canned pigeonpeas are marketed in certain parts of the world. We have made considerable progress in developing vegetable types of pigeonpea and we do see a potential for them in some other parts of India.

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1 The status, as regards release, of cultivars mentioned here has been updated.