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International Workshop on Chickpea Improvement

International Crops Research Institute for the Semi-Arid Tropics

Proceedings of the

International Workshop on Chickpea Improvement

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Foreword

ICRISAT hosted a grain legume workshop in January 1975, very soon after the initiation of the Institute's chickpea breeding program. The object was to bring together food legume breeders of the world and to focus on the status of chickpea and pigeonpea improvement. Several aspects of production agronomy, ecological and physiological adaptation, and quality characteristics were considered. ICRISAT scientists presented a proposed program for improving genetic potential for yield.

In 1979, an international workshop with similar objectives was held exclusively for chickpea. In the intervening 4 years many contacts had been made with national programs, and multilocational testing of advanced genetic material was under way. Also during those 4 years, the programs of ICRISAT and ICARDA, both of which have a mandate for chickpea improvement, were integrated and plans were made for eliminating unnecessary duplication of work.

The aim of the 1979 workshop program committee was to provide a forum for summarizing development in all aspects of chickpea improvement research during the previous 4 years and to give special emphasis to breeding, because new approaches to quantitative breeding for yield require an increased level of cooperation between national breeding programs and the Centers. Basic data to be obtained are required to evaluate the procedures, to identify promising material, and to measure progress.

The International Workshop on Chickpea Improvement was held at Hyderabad from 28 February to 2 March 1979 to discuss these and other problems related to increasing production. The sessions were attended by 82 scientists from 14 countries. The consensus was that the ICRISAT/ICARDA proposal for quantitative breeding for yield was acceptable, and the participation necessary for its implementation was assured. Joint programs for germplasm collection and disease resistance ratings were also endorsed by the participants.

The proceedings of the Workshop are presented herewith. We believe the volume will be a valuable reference work for chickpea research scientists. If cooperation proves effective, we should be in a position to hold another very profitable international workshop approximately 4 years hence.

John M. Green
Workshop Coordinator

Inaugural Session

Chairman: J. M. Green

Objectives of the Workshop and of the ICRISAT/ICARDA Chickpea Improvement Project

J. S. Kanwar*

In his overview, Dr. Swindale has outlined the objectives of ICRISAT and described some highlights of its five crop improvement programs. The Pulse Improvement Program includes research on chickpea and pigeonpea.

The first international workshop on pulses sponsored by ICRISAT was held in January 1975. This week's workshop is the first international workshop devoted exclusively to chickpea improvement. The main objectives of the workshop are to:

1. Assemble chickpea breeders of the world for critical assessment of the status of chickpea improvement;
2. Discuss results and proposed future strategies of the ICRISAT/ICARDA international programs;
3. Encourage and promote cooperation in chickpea improvement;
4. Assess needs for training, improved communication, and technical assistance at the national level;
5. Provide breeders an opportunity to inspect and select germplasm and breeding material in ICRISAT fields.

You are no doubt aware that ICRISAT has chickpea research programs at Hyderabad, in Hissar, and at Tel Hadia, Syria in cooperation with the International Centre for Agricultural Research in Dry Areas (ICARDA). To achieve the objectives of this workshop and to discuss rationally the strategies and programs of research in chickpea at ICRISAT, it is important to give you the background of the ICRISAT/ICARDA joint project on chickpea improvement.

Chickpea is an important pulse crop in the Indian subcontinent and in western Asia, but research on chickpea began only recently. The first international effort to improve this crop was in 1962 when the Regional Pulse Improvement Project (RPIP) began in India and Iran. The project was funded jointly by the United States Department of Agriculture (USDA) and United States Agency for International Development (USAID), in collaboration with the Indian Pulse Research Program and the main emphasis was on collection and distribution of germplasm and research in breeding, agronomy, and related fields.

The chickpea improvement work at ICRISAT was initiated in 1973. The Arid Lands Agricultural Development Program (ALAD) in the Middle East and North Africa started a regional program on food legumes (broadbean, chickpea, and lentil) in 1972, and in 1977 this program was absorbed by ICARDA. Until last year, both ICRISAT and ICARDA had separate responsibilities for improvement of chickpea. In 1978 the boards of governors of the two institutes agreed to coordinate their efforts; ICRISAT has now appointed a chickpea breeder to work at ICARDA.

There are two main types of chickpea — kabuli and desi. The former has smooth, generally large, light colored seeds while the seeds of the latter are yellow to black, generally smaller, and with a rougher surface. The work at ICARDA is on kabuli-type chickpea since it is prevalent in the countries of that region while at ICRISAT the major emphasis is on desi types.

The objectives of the chickpea improvement work at the two institutes are to:

1. Strengthen national and regional programs;
2. Develop high-yielding disease and pest-resistant breeding material with good grain quality;
3. Furnish parental lines, segregating populations, and advanced breeding material to local programs;
4. Arrange exchange of information and germplasm;
5. Train personnel.

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* Director of Research, ICRISAT.

To achieve the above-mentioned objectives, studies are under way at ICRISAT on breeding, pathology, entomology, microbiology, physiology, quality and consumer acceptance and at ICARDA on breeding, pathology, agronomy, physiology, microbiology, and entomology. There is a genetic resources unit at ICRISAT that maintains, evaluates, and makes available germplasm to interested scientists and organizations There is close collaboration among the disciplines at each of the institutes, and there is frequent exchange of visits of scientists at the institutes.

Research Sites

At ICRISAT, the work on chickpea was started at Hyderabad (17°N). However, since ICRISAT Center is outside the main chickpea belt in India, it was proposed to take up chickpea work in northern India. After discussions with the Indian Council of Agricultural Research (ICAR), Haryana Agricultural University in Hissar (29°N) agreed to provide land and facilities to ICRISAT for chickpea research. The soil type at Hyderabad is a black Vertisol with good water-retention capacity. The crop is sown after the cessation of monsoon rains (total annual rainfall averages 760 mm) and usually does not require any irrigation. In some years, irrigation is required at sowing if the rains are scanty or if they stop early. The soil type at Hissar is an Entisol; total annual rainfall averages about 450 mm and presowing irrigation is generally necessary.

The work on short-duration desis is conducted at ICRISAT Center and on medium and long-duration desis and on kabulis at Hissar. Some testing and multiplication is done at Gwalior (26°N) in central India.

At ICARDA, the main program is based at Tel Hadia near Aleppo (36°N) in northern Syria which is at a 350 m elevation with relatively mild winters and low rainfall (350 mm). A second major site is planned at Tabriz (38°N), Iran, which represents the extreme high elevation of the Anatolian Plateau. In the meantime, testing sites have been established at Tekmadash near Tabriz (1800 m elevation), which generally has frost and a snow cover from October to April, and at Terbol (34°N), Lebanon, which receives 550 mm rainfall per year and being at 1000 m is somewhat less cold.

Cultural Management of Research Areas

Chickpea is generally grown on conserved moisture during the dry season of the year. Throughout most of the Indian subcontinent and eastern Asia, desi types are grown as an autumn-sown winter crop, while in western Asia the crop is mainly the spring-sown kabuli type. As a result of this reliance on conserved moisture, production is erratic. Low management inputs such as fertilization, pest control, and weed control, are the general rule.

Consequently, most breeding efforts have been directed toward development of genetic material suited to low input management and rainfed conditions. At ICRISAT, irrigation is rarely applied to general breeding plots except to ensure establishment, and all evaluation is done under relatively low nutrient status. Insect and pest management is directed to avoid excessive plant damage rather than to provide total protection. Except for those used in special studies of disease resistance, most breeding plots are sited on land known to be relatively free of the major soilborne pathogens. The objective is to allow expression of genotypic differences for production characteristics in the absence of excessive bias due to environmental modification.

The annual rainfall of approximately 350 mm at Tel Hadia is not considered adequate for a chickpea crop by farmers in the area; they consider 400 mm to be the minimum amount of rainfall required. Thus, it is necessary to irrigate early in the season (during the period of expectation of rain) to simulate the environment in which chickpea is normally grown. The winter-planted crop receives no irrigation, but (with the exception of the disease nurseries) a fungicide is applied against blight.

Because the site lies outside the normal chickpea area, the soils are deficient in natural *Rhizobium*, and it is necessary to inoculate to ensure adequate nodulation. As a precaution, until *Rhizobium* levels have been built up, a dressing of 30 kg N/ha is applied with 50 kg P_2O_5/ha. Both the winter and spring-planted crops are currently protected from pod borer and leaf miner.

Utilization of Germplasm

The collection, evaluation, and maintenance of the world chickpea germplasm, irrespective of type, are the responsibilities of ICRISAT, which has assembled over 11 000 accessions of desi and kabuli types. A collection of 3300 kabuli types has been established by ICARDA, and this will be integrated with the ICRISAT collection. It is planned that eventually the entire collection will also be maintained at ICARDA as an insurance. A detailed report on germplasm is to be presented separately by Dr. van der Maesen and colleagues.

The collection is being screened progressively for wilt resistance, heat tolerance, and protein content at ICRISAT Center. In addition, it is being checked for *Ascochyta* blight resistance and winter hardiness at ICARDA, as well as for production characteristics and adaptation. To date, a number of lines with superior yielding ability have been identified and distributed to national programs via the international and regional nurseries. Some of these lines have been found superior to the local check cultivar in those trials. These lines and others possessing particular characteristics, such as disease resistance, have been included in the crossing and general breeding programs of the centers. Further evaluation of the germplasm is planned in order to allow maximum explcitation of this resource.

Collections of several wild species have heen assembled and are being screened for various morphological and resistance characteristics. It is proposed to create a "gene park" to maintain these wild species in their "natural" habitat at Tel Hadia, after the farm has been fenced to prevent grazing.

Off-season Nurseries

The usefulness of an off-season nursery cannot be overemphasized in a breeding program. Since 1974, ICRISAT has grown off-season crops in Lebanon and in the Lahaul and Kashmir valleys in India. The operational quarantine and other difficulties for the summer crop in Lebanon and unfavorable weather conditions in the Lahaul valley led us to abandon our efforts there. Of the five locations tried in Kashmir we have identified one site — Tapperwaripora (1650 m) where a reasonably good summer crop can be raised. The best sowing time appears to be the first week of June. There is little rainfall in June, and the crop is planted with irrigation; it is ready by the end of September. We have now requested 2 ha of land at Tapperwaripora farm to advance F_1s and raise important multiplications. At present we do not plan any hybridization work there.

Some preliminary studies at ICRISAT Center indicate that a summer chickpea crop can be raised successfully if it is protected from direct rain. Therefore, if the crop can be covered during June and July, it may be possible to grow a successful summer nursery here and advance some of our breeding materials and expedite breeding work.

Several locations have been studied by ICARDA scientists for use as off-season sites. It appears that off-season advancement can be done at Terbol, Lebanon, for winter-planted materials at Tel Hadia, Syria. Spring-planted materials can be successfully advanced on a Government of Jordan experimental station at Shawbak; in fact, use has been made of this facility for the past 3 years.

Rapid Generation Turnover

Presently, we are conducting an experiment to explore the possibility of growing more than two generations of chickpea per year by modifying the environment in various ways, a system that has already been successful with soybeans (Byth, personal communication). If it is successful in chickpea, we may be able to advance generations rapidly using the single-seed descent method.

Regional Evaluation of Breeding Material

Breeding material is made available to chickpea scientists, on request, in both desi and kabuli types in a range of stages; for example, as F_2 or F_3 unselected bulk populations; as early generation segregating lines; as advanced breeding lines; and as elite lines and cultivars. The distribution of international and regional nurseries and trials is discussed in more detail in this workshop by Dr. K. B. Singh and colleagues.

The reason for furnishing near-homozygous advanced lines is to provide an opportunity for scientists to evaluate the material under local conditions for subsequent use directly in local experimentation, hybridization, release, and so on without the need for further reselection. As indicated above, multilocation testing over years is used by the centers to identify breeding material with promise in a number of environments; that is, with broad adaptation or with specific adaptation to particular locations.

With respect to wide adaptation and phenotypic stability over environments, the testing programs of the Centers are being expanded by the addition of further test sites that differ in agroecological conditions. Most desi breeding material is now evaluated at ICRISAT Center and Hissar, and kabuli material at Tel Hadia and Terbol. Testing will be extended to Gwalior and Tabriz. Some material will be evaluated over the years at ICRISAT Center, in Hissar and at Tel Hadia in an effort to identify differences in environmental adaptation.

Collaboration among Disciplines

The basic rationale of plant improvement is the development of high-yielding cultivars with stable performance across environments and acceptable quality characteristics. This is a multidisciplinary activity with the plant breeder as a member of a broad-based team of scientists in pathology, entomology, physiology, microbiology, and biochemistry. At ICRISAT we have a team of scientists working together to achieve the aforementioned objectives. Likewise, the Indian program has a good team of scientists working together at different centers. We collaborate with the Indian program and with national programs in other countries.

ICRISAT pathologists are interacting with breeders in India in the identification and development of lines resistant to *Fusarium* wilt disease and at ICARDA for *Ascochyta* blight resistance.

There is close collaboration with physiologists and agronomists for identification of factors limiting growth and development, and of genotypes that can tolerate stress conditions such as cold, heat, drought, and salinity. We hope, this will lead to definition of specific breeding objectives and development of appropriate breeding and selection strategies. Similarly, the development of optimal agronomic systems for new cultivars and for new plant habits is a critical part of any continuing breeding program. Crop adaptation studies are necessary to introduce chickpea into new areas or different cropping systems, such as winter planting in the Middle East, late planting under irrigation in northern India, and early planting under southern Indian conditions.

International Activities

Both ICRISAT and ICARDA have active programs of international cooperation in a number of different areas, the main objectives being to coordinate chickpea research and to facilitate development and interchange of superior genetic materials and improved technologies. Some of the more important activities are discussed briefly here.

International Trials and Nurseries

A number of international trials and nurseries are distributed annually for specific purposes. Until 1978, ICRISAT distributed both desi and kabuli trials. In future, ICARDA will coordinate all kabuli trials internationally and ICRISAT will handle the desi materials.

Training

Training of personnel in research methodology at various levels is an important activity, and courses of study are offered in five main categories: (1) group residential courses, (2) short-term training, (3) individual training, (4) graduate training in collaboration with a university, and (5) national level training. ICRISAT primarily participates but not exclusively in this activity with countries interested in desi types; similarly, ICARDA participate with countries interested in kabuli types.

A 6-month group-training course on food legumes research, attended by 18 participants, was conducted by ICARDA in 1978 and will be repeated in 1979. Three African research workers were trained at ICRISAT during the 1976–77 crop year and one postgraduate student is presently conducting research in this area. These research training programs will be strengthened and expanded to meet the requirements of specific countries. A training program in chickpea pathology was organized in January 1979 at ICRISAT; it had nine participatnts, including three from Mexico, the Sudan, and Iraq.

Workshops and Conferences

Periodic workshops and conferences are organized for exchange of ideas and experiences and to develop close contacts with the national programs and between ICRISAT and ICARDA.

A 4-day workshop was conducted by ICRISAT in 1975 to identify the more important problems in chickpea production in the world, and the proceedings were published.

The common problems of food legume production and improvement within the west Asian and Mediterranean regions were examined at a 6-day workshop organized by ICARDA in 1978, and the proceedings will be published soon by the International Development Research Centre (IDRC).

An annual breeders' meet has been regularly organized by ICRISAT, largely to promote personal contacts and exchange of ideas among breeders and to provide them with an opportunity to select material from the ICRISAT breeding plots. In addition to the Indian chickpea breeders, a number of breeders from other chickpea producing countries also participate.

Visits to National Programs

Frequent visits are made by ICRISAT and ICARDA scientists to the national programs, and limited funds are available to support visits by scientists of national programs to the ICRISAT and ICARDA centers.

Publications

Research developments are reported through annual technical reports, technical manuals, project reports, workshop proceedings, and other publications. Recently, a bulletin, *Diagnosis of some Wilt-like Disorders of Chickpea*, has been published. Training manuals have also been prepared by ICARDA. A bibliography on chickpea research has been published by ICRISAT scientists.

Session 1

Breeding Strategies

Chairman : E. Åberg
Co-Chairman: J. I. Cubero
Rapporteur: D. Sharma

ICRISAT/ICARDA Chickpea Breeding Strategies

D. E. Byth, J. M. Green, and G. C. Hawtin*

Appropriate breeding procedures for an international breeding program will vary with the crop, philosophy of the program, and stage of development of national programs, but in any case these procedures will be based on the same genetic principles as any national or local program. With 5 years' experience behind us, we have made an analysis of the efficacy of the work done and developed a proposal for the future program. We expect the collective judgment of the workshop to be brought to bear on the proposed program; we recognize that experience will also dictate modifications of the best thought-out plans, but we submit the following as a working basis for the chickpea breeding programs of ICRISAT and ICARDA and suggest that there are features of the program worthy of serious consideration by coordinated national and regional programs.

Singh and Auckland (1975) reviewed the status of chickpea production and improvement internationally and Hawtin (1975) described the status of chickpea research in the Middle East. These aspects and papers will not be discussed in detail here. However, Singh and Auckland (1975) concluded that initial breeding emphasis should be on yield and consumer acceptance, with stability of yield, resistance to pests and diseases, and seed protein quantity and quality at a lower level of priority. They advocated the use of a bulk pedigree method involving selection among F_2 derived families, with individual plant selection within the best families, and the bulk method for less promising crosses. The use of off-season nurseries for generation turnover and selection was envisaged, and recurrent selection following Jensen's (1970) diallel selective mating scheme was suggested.

Singh and Auckland recognized that ICRISAT Center near Hyderabad is geographically outside the main area of chickpea culture in India and internationally, and they recommended acquisition of a selection and testing site in northern India. Subsequently, close collaboration in chickpea improvement developed with ICARDA, and the two programs were integrated in 1978. This statement of breeding strategies applies to the improvement program of both institutes.

Experience to Date in Chickpea Improvement

Breeding Objectives

The overall objectives of the programs are as follows:

1. To develop high-yielding disease and pest-resistant cultivars with good grain quality;
2. To furnish advanced breeding lines and segregating populations to national and local breeding programs;
3. To support regional and national programs through exchange of information, germplasm, and training of personnel.

Specific aims exist within these general objectives and are already the basis of particular projects. Some of these will be discussed in this paper. ICARDA has been concerned primarily with kabuli chickpea, while ICRISAT has developed programs on both desi and kabuli types.

Testing and Selection Strategies

Despite the projected use of bulk pedigree and bulk-breeding methods at ICRISAT (Singh and Auckland 1975), almost all breeding material to date has been handled using the classical

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pedigree method. At ICARDA, most of the breeding has involved advancing bulks to the F_3 generation and using conventional pedigree breeding thereafter. In both cases, elite material is made available to international cooperators as early-generation or selected, advanced-generation bulk lines through screening nurseries or yield trials.

Selection Procedures

Hybridization and Choice of Parents

A large number of crosses involving many parents have been made and evaluated within the ICRISAT/ICARDA programs (Table 1). In the absence of adequate information on their breeding value and regional performance, parents have been chosen on the basis of ecogeographical diversity or complementary characteristics or of specific characteristics, such as disease resistance, high yield, seed characters, double-pod development, maturity class and so on. Single and multiple crosses are made largely within the desi or kabuli types; however, considerable hybridization of the two types has also occurred.

Selection among Crosses

In view of the large number of crosses and diverse parentage used, there is considerable interest in discarding crosses in order to allow concentration on those crosses most likely to be productive. Selection has been practiced among crosses on F_1 performance based on a visual estimation of merit, both agronomically and in terms of disease resistance. A formal study of a restricted set of crosses that were relatively high, medium, and low yielding in the F_1 generation has indicated that rejection of crosses on the basis of low F_1 yield would eliminate few crosses with relatively high mean performance in later generations (Table 2). However, the correlations of rank mean performance of the crosses over generations were not particularly high, and this may reflect cross × environment interaction. Some crosses with low mean performance and/or with restricted variation for yield in the F_3 generation were retained. This suggests that while grossly inferior crosses may be discarded on F_1 performance with minimal risk, all crosses retained should be subjected to bulk F_2 or F_3 tests or evaluated using random F_2 or F_3 derived lines in order to determine their real potential in breeding.

Table 1. Chickpea crosses completed at ICRISAT and ICARDA, 1973–78.

	Main season		Off season			
Year	ICRISAT Center	Hissar	Lahaul	Lebanon	Total	No. of parents
ICRISAT						
1973–74	424	0	247	86	757	130
1974–75	1337	0	598	23	1958	248
1975–76	1586	693	148	0	2427	337
1976–77	1232	597	0	0	1829	150 D; 16 K
1977–78	884	298	0	0	1182	89 D; 49 K
Total	5463	1588	393	109	8153	
ICARDA	Lebanon	Egypt		Syria	Total	No. of parents
1974–75	224	0		0	224	85
1976–77	0	202		0	202	69
1977–78	31	0		48	79	0
Total	255	202		48	505	

D = Desi, K = Kabuli

Table 2. Mean yields and ranks of crosses placed in high, medium, and low groups and F_1 yield in F_1, F_2 and F_3 generations, 1976–78.

	F_1		F_2		F_3 bulk		F_3 progeny mean	
Cross	Yield (g/plant)	Rank	Yield (kg/ha)	Rank	Yield (kg/ha)	Rank	Yield (kg/ha)	Rank
High								
JG-39 x P-436	50.0	1	2367	3	1034	1	1100	2
P-502 x BG-1	44.5	2	1981	5	902	3	970	5
T-3 x L-532	43.9	3	1647	10	435	13	473	15
T-3 x P-4375	43.3	4	1853	8	631	11	1003	3
T-3 x NEC-721	42.7	5	1960	6	625	12	510	13
Mean	44.9	3.0	1963	6.4	726	8.0	811	7.6
Medium								
P-861 x T-103	34.7	6	2400	2	938	2	477	14
P-502 x P-514	34.7	7	2427	1	805	6	1217	1
P-861 x Pant-104	34.7	8	1927	7	878	5	873	7
T-3 x T-103	34.5	9	2260	4	895	4	567	11
P-648 x P-1243	34.5	10	1093	9	649	10	977	4
Mean	34.6	8.0	2141	4.6	833	5.4	823	7.4
Low								
Ceylon-2 x P-662	21.3	11	1567	13	411	14	733	9
P-648 x G-543	20.7	12	1620	11	702	8	700	10
JG-39 x Pant-102	20.3	13	1527	14	753	7	903	6
Ceylon-2 x NEC-835	19.5	14	1320	15	325	15	510	12
JG-39 x P-3172	19.0	15	1613	12	681	9	837	8
Mean	20.2	13.0	1529	13.0	574	10.6	737	9.0

Selection within Crosses

As indicated above, most of the breeding programs at both institutions have involved conventional pedigree methodology. At ICRISAT, a general strategy has been adopted that involves growing F_2 populations at both Hissar and ICRISAT Center with visual selection of desirable phenotypes, followed by evaluation of all plant progenies at both sites in the F_3. In subsequent generations, visual ranking of plant rows and selection of plants within the best progenies is followed by testing at both of these sites. The selection intensity has been high (Table 3); thus, the breeding strategy has been based heavily on visual phenotypic ranking of plants and progenies for selection and on testing at two main locations — one in southern India and the other in northern India. More recently facilities for yield testing of progenies have been developed.

At ICARDA, the breeding strategy in the past has been based mainly on advancing crosses as bulks to the F_3 generation and using a conventional pedigree selection system thereafter. In F_2 bulk populations following kabuli x desi crosses, mass selection of kabuli and near kabuli types is practiced. In the F_3 generation, selection of individual plants is based on a visual phenotypic rating for which plant growth characters, seed characters, maturity, and pods per plant are all considered. In winter-planted chickpea, special emphasis is placed on selection for cold tolerance and *Ascochyta* blight resistance.

Because of the shifting program base in the past (1973–75 in Lebanon, 1975–77 in Egypt, and 1977–79 in Syria) it has not been possible to develop a definite strategy on multilocation testing and selection. Now, however, with the program firmly established in Aleppo and with a substation located at Terbol in Lebanon, it is intended that populations and selections be evaluated in both environments. When a high elevation site is developed, it will also be in-

Table 3. Populations and lines grown and selections evaluated at ICRISAT, 1977–78.

Generation	No. of lines and Populations grown		No. of plants selected		No. of lines bulked	
	ICRISAT Center	Hissar	ICRISAT Center	Hissar	ICRISAT Center	Hissar
Desi type						
F_2 populations	154	234	1118	1338	0	0
F_3 progenies	4649	4733	1337	1374	0	0
F_4 progenies	2074	2204	662	551	0	0
F_5 progenies	794	859	635	267	33	30
F_6 progenies	1008	1190	102	462	36	48
F_7 progenies	315	315	0	0	18	18
Kabuli type						
F_2 populations	0	0	746	709	0	0
F_3 progenies	862	862	952	119	0	0
F_4 progenies	468	489	238	200	0	0
F_5 progenies	43	45	15	7	0	0
F_6 progenies	150	148	109	62	12	4
F_7 progenies	45	45	0	0	6	0
New plant type						
F_2 populations	58	33	376	203	0	0
F_3 progenies	517	517	233	251	0	0
F_4 progenies	312	312	199	95	0	0

cluded in the testing/selection scheme. Depending on the availability of seed, progenies are being evaluated in winter and spring plantings at Tel Hadia.

Methods of Evaluation

As indicated previously, visual appraisal of plant and line performance and multilocation testing have been adopted at ICRISAT within a pedigree system framework. The effectiveness of these methods requires evaluation.

EFFECTIVENESS OF VISUAL APPRAISAL. In an effort to determine the effectiveness of visual appraisal of phenotypic merit in a range of genetic backgrounds and habits, 150 F_4 lines were sampled at random from a large number of crosses involving three common parents of differing crop duration (H-208, 850-3/27, and JG-62). Phenotypic rank score (1–5, with 1 most favorable and check cultivars usually scoring 3) and seed yield of each line were compared for both ICRISAT Center and Hissar (Table 4). For each of these populations in each location, there was a close association of rank score and mean yield of lines within a rank, indicating that, on the average, visual ranking distinguished differences in seed yield.

The correlation between rank score and seed yield over all lines was low to moderate (r = −0.38 to −0.64), and the distribution of seed yields of the rank groups overlapped substantially (Table 4). Apart from the highest ranked group in each case, most classes included virtually the entire range of yield distribution.

A similar situation existed where the three populations of lines were pooled and separated into early, medium, and late maturing groups of lines (Table 5). Furthermore, within those F_6 lines yielding at least 50% more than the moving average of the best check cultivar at ICRISAT Center or Hissar in 1977–78, there was a wide range of rank score and low association of seed yield as a percentage of the nearest check row and visual ranking (Table 6).

These data indicate that while visual scoring of phenotypic merit does reflect average differences in seed yield, the ranking has only limited

Table 4. Mean and range of seed yield (kg/ha) within five visual rank scores for 150 random F₄ lines from each of three common parents (H-208, 850-3/27, JG-62) evaluated at ICRISAT Center and Hissar, 1975–76

	ICRISAT Center			Hissar		
Rank	Number of lines	Mean	Range	Number of lines	Mean	Range
H-208 parentage						
1	1	3122	3122	0	NA	NA
2	5	2600	2250–3028	9	3173	2292–4167
3	16	2199	1242–2488	35	2525	1292–3417
4	44	2123	747–2977	45	2390	646–3917
5	94	1655	670–2827	61	1690	250–3389
Mean		2340			2445	
r			−0.38			−0.61
850-3/27 parentage						
1	2	3021	2917–3125	0	NA	NA
2	6	2466	2110–2847	3	3333	2833–3833
3	48	2123	805–2958	22	2606	1208–3694
4	57	1022	708–2932	58	2453	722–4104
5	37	1794	887–2377	67	1745	271–3354
Mean		2265			2543	
r			−0.43			−0.48
JG-62 parentage						
1	1	2383	2383	1	4083	4083
2	5	2122	1795–2533	5	3042	2354–3917
3	35	2054	1283–2643	32	2422	979–3944
4	66	1862	975–3333	39	1935	354–2875
5	43	1509	753–2180	73	1367	146–3854
Mean		1986			2870	
r			−0.39			−0.64

r = Correlation coefficient between rank scores and seed yields.
NA = Not applicable

association with seed yield for individual lines. Thus, truncation of rank may be expected to result in only limited selection differential for seed yield. This may be due to the fact that a number of traits were considered in allocating rank; for example, while pod number was the primary consideration, lower rankings were given because of unsuitable maturity, possession of undesirable seed characteristics (color, size), and other reasons. Further, the correlations between rank score and actual yield were substantially greater than those between rank score and yield as a percentage of the nearest check cultivar plot (Table 6). This indicates that little consideration was given to the check plots of the augmented designs in allocating rank score, and this is disturbing.

The heritability of rank score is of concern. To examine this question, large populations of F₃ lines derived from F₂ plants selected visually at ICRISAT Center and Hissar, and evaluated in those locations in 1976–77 and 1977–78, were ranked visually (Table 7). These locations provide distinctly contrasting environments for chickpea, and any effective selection for performance at either site should have been reflected in an expression of differential adaptation between the sites in the F₃ generation. Despite the large populations and extremely high selection pressures used in the F₂, there was never greater than 2% of the F₃ progenies in ranks 1 and 2, and there was no apparent influence of location of F₂ selection on F₃ line performance. Similarly, populations of F₄ lines

Table 5. Mean and range of seed yield (kg/ha) within five visual rank scores for early, medium, and late maturing F_4 lines, ICRISAT Center, 1975–76.

Rank	No. of lines	Mean	Range
Early lines			
1	1	3122	
2	3	2471	2250–2597
3	10	2056	805–2675
4	15	2222	1395–3267
5	8	1637	1108–2100
Mean		2302	
r			−0.44
Medium lines			
1	1	2917	
2	11	2367	1795–3028
3	59	2139	1283–2958
4	118	1974	708–3333
5	83	1808	753–2827
Mean		2241	
r			−0.32
Late lines			
1	2	2754	2383–3125
2	2	2478	2377–2578
3	28	2103	1115–2615
4	33	1768	747–2775
5	76	1673	670–2595
Mean		2155	
r			−0.42

derived as single plant progenies from F_3 lines selected on visual rank at ICRISAT Center and Hissar, and evaluated at these sites in 1976–77 and 1977–78, revealed a very low frequency of lines with high rank (Table 8). There was a trend for the selected group to have a greater frequency of lines with higher rank in the environment of selection of the F_3 than in the alternate test environment, but the effect was small.

The conclusion is unavoidable that visual rank score has little relationship with seed yield, and that visual discrimination among F_2 or F_3 rows was relatively ineffective in influencing rank score in the subsequent generation. Since there is no evidence of differential adaptation of the selections from contrasting sites in the F_2, and only very limited evidence of it in the F_3–F_4, the limitation in visual ranking appears to be in the reproducibility of the scoring, rather than in genotype × environment interaction. Clearly, effective use of visual discrimination in selection of chickpea requires the development of a scoring system that is more reproducible and more closely related to seed yield.

USAGE OF MULTIPLE LOCATIONS. Both ICARDA and ICRISAT have investigated the use of particular locations as off-season nurseries to attain rapid turnover of generations of breeding populations. At ICARDA, it may be possible to advance winter-planted material from Tel Hadia during the off-season at Terbol and a Government of Jordan experiment station at Shawbak has been used successfully for summer advancement of spring-planted material. Off-season advancement has been attempted by ICRISAT at several sites in northern India and can be accomplished reliably with spring planting at Tapperwaripora, Kashmir.

The major breeding activities of ICRISAT are conducted at two sites in India: ICRISAT Center near Hyderabad and Haryana Agricultural University, Hissar. These locations represent contrasting environments for chickpea, the former

Table 6. **Distribution of rank scores for F_6 lines yielding at least 50% more than the moving average of the best check cultivar at ICRISAT Center and Hissar, 1977–78.**

Site and population	Rank score 1	2	3	4	5	No. of lines	Correlation of rank score with: Seed yield as percentage of check yield	Actual seed yield
ICRISAT Center								
All lines	0	5	16	45	31	97	0.33	0.71
Early crosses	0	3	5	10	0	18	0.03	0.79
Medium late crosses	0	2	8	6	1	17	0.09	0.43
Late crosses	0	0	3	29	30	62	0.59	0.59
JG-62 parentage	0	2	5	9	4	20	0.01	0.62
H-208 parentage	0	2	4	12	6	24	0.28	0.66
850-3/27 parentage	0	1	5	8	2	16	0.28	0.60
Hissar								
All lines	2	5	12	5	0	24	0.05	0.14
Early crosses	0	2	3	1	0	6	0.05	0.53
Medium-late crosses	0	2	4	3	0	9	0.07	0.37
Late crosses	2	1	5	1	0	9	0.09	0.04

Table 7. **Frequencies of F_3 lines in particular visual rank classes for populations selected on rank at ICRISAT Center or Hissar in the F_2 and evaluated at both sites in the F_3, 1976–77 and 1977–78.**

Selection location		RANK SCORES 1	2	3	4	5	Total
F_3 progenies grown at ICRISAT Center, 1976–77							
ICRISAT Center	No.	7	8	228	1162	1328	2733
	%	0.26	0.29	8.34	42.52	48.59	
Hissar	No.	7	9	194	1222	1735	3166
	%	0.22	0.25	6.13	38.60	54.80	
F_3 progenies grown at Hissar, 1976–77							
ICRISAT Center	No.	1	28	631	1712	361	2733
	%	0.03	1.02	23.09	62.64	13.21	
Hissar	No.	4	46	919	1877	305	3171
	%	0.13	1.45	29.61	50.19	9.62	
F_3 progenies grown at ICRISAT Center 1977–78							
ICRISAT Center	No.	1	13	380	942	561	1897
	%	0.05	0.68	20.03	49.66	29.57	
Hissar	No.	3	19	185	1098	1223	2728
	%	0.11	0.70	14.11	40.25	44.83	
F_3 progenies grown at Hissar, 1977–78							
ICRISAT Center	No.	5	31	315	616	922	1889
	%	0.26	1.64	16.68	32.61	48.81	
Hissar	No.	7	47	803	1350	637	2844
	%	0.25	1.65	28.23	47.47	22.40	

Table 8. Frequencies of F_4 lines in particular visual rank classes for populations selected on rank at ICRISAT Center or Hissar in the F_3 and evaluated at both sites in the F_4, 1976–77 and 1977–78.

Selection location		RANK SCORES					
		1	2	3	4	5	Total
F_4 progenies grown at ICRISAT Center, 1976–77							
ICRISAT Center	No.	0	0	72	563	211	846
	%	0	0	8.51	66.55	24.94	
Hissar	No.	3	3	51	421	393	871
	%	0.34	0.34	5.86	48.34	45.12	
F_4 progenies grown at Hissar, 1976–77							
ICRISAT Center	No.	0	10	132	551	146	839
	%	0	1.19	15.73	65.67	17.40	
Hissar	No.	1	16	158	652	45	872
	%	0.11	1.83	18.12	74.77	5.16	
F_4 progenies grown at ICRISAT Center, 1977–78							
ICRISAT Center	No.	1	15	239	479	180	914
	%	0.11	1.64	26.15	52.40	19.70	
Hissar	No.	0	5	252	580	329	1166
	%	0	0.43	21.61	49.74	28.22	
F_4 progenies grown at Hissar, 1977–78							
ICRISAT Center	No.	1	12	135	372	310	830
	%	0.12	1.45	16.26	44.82	37.35	
Hissar	No.	3	32	282	572	485	1374
	%	0.22	2.33	20.52	41.63	15.30	

being considered suitable for short duration desi types and the latter for mid and long duration desi and kabuli types. To date, all segregating material has been tested initially at both sites, and selection is practiced for adaptation to each environment. Marked differences exist in the relative performance of lines and populations between these sites. F_4 lines of 85 crosses were evaluated at both sites in 1975–76, each cross being represented by at least 5 lines and some up to 57 lines. The relative cross mean performance varied substantially between sites. Of the top 21 crosses at each site, only one (7399, 850-3/27 x JG-221) was common to both sites; it was ranked 7th at Hissar and 21st at ICRISAT Center. Within the top 33 crosses at each site, only seven crosses were common, and those ranked high at one site were inevitably ranked low at the second site (Table 9). The top ten crosses at each site are listed in Table 10. Despite the lack of correspondence of crosses within the superior group at each of the two sites, some parents occurred more commonly than others in the best crosses; e.g., H-208 occurred five and four times, 850-3/27 occurred twice and five times, and Annigeri occurred twice and zero times at ICRISAT Center and Hissar, respectively. Similarly, all crosses common to the top 33 crosses at these sites included H-208 or 850-3/27 parentage (Table 9).

In the absence of more specific information on the breeding value of particular parents at these locations, these results provide some guidelines as to the potential value of parents. The most common parents involved in the crosses evaluated in 1975–76 were H-208, 850-3/27, JG-62, and G-130, and a crude estimate of their breeding value may be obtained as the mean of all crosses involving each of these parents at ICRISAT Center and Hissar (Table 11). These data suggest that H-208 and 850-3/27 were, on the average, superior in hybrid combination and that JG-62 and G-130 were relatively inferior as parents at Hissar and ICRISAT Center, respectively.

Table 9. Crosses common to the superior 33 crosses for mean yield (kg/ha) over F$_4$ lines at ICRISAT Center and at Hissar, 1975–76.

		ICRISAT Center		Hissar	
Cross	Parentage	Rank	Mean yield	Rank	Mean yield
739	H-208 × Pant-110	19	2082	23	2409
7310	H-208 × T-3	3	2506	25	2396
7341	H-208 × No. 59	23	2052	29	2315
7388	850-3/27 × F-61	29	1990	4	2945
7398	850-3/27 × Pant-110	31	1985	17	2502
7399	850-3/27 × JG-221	21	2074	7	2870
73114	850-3/27 × GW-5/7	22	2063	32	2270

Table 10. Ten crosses with the greatest mean yields over F$_4$ lines at ICRISAT Center and at Hissar, 1975–76.

ICRISAT Center			Hissar		
Rank	Cross	Parentage	Rank	Cross	Parentage
1	73129	JG-62 × Radhey	1	73119	850-3/27 × H-223
2	738	H-208 × BEG-482	2	7392	850-3/27 × C-235
3	7310	H-208 × T-3	3	73111	850-3/27 × H-208
4	7314	H-208 × Annigeri	4	7388	850-3/27 × F-61
5	73217	F-404 × Ceylon-2	5	7333	H-208 × F-496
6	73143	JG-62 × Annigeri	6	73167	JG-62 × F-496
7	7394	850-3/27 × N-59	7	7399	850-3/27 × JG-221
8	7330	H-208 × EC-12409	8	73185	G-130 × Chafa
9	7389	850-3/27 × F-378	9	7332	H-208 × F-370
10	7315	H-208 × B-108	10	7328	H-208 × CP-66

Table 11. Mean yield over F$_4$ lines within all crosses involving four different common parents, ICRISAT Center and Hissar, 1975–76.

			Location mean yield (kg/ha)		
Common parent	No. of crosses	No. of lines	Hissar	ICRISAT Center	Average
H-208	29	478	2329 (1)[a]	1906 (2)	2118 (2)
850-3/27	27	302	2260 (2)	1984 (1)	2122 (1)
JG-62	35	524	1836 (4)	1809 (3)	1823 (4)
G-130	10	114	2148 (3)	1520 (4)	1834 (3)
Mean			2143	1805	1974

[a] Numbers in parentheses indicate rankings in the trial.

Adaptation of Chickpea Genotypes

As indicated in the paper by Singh et al. (this workshop) on the international trials and nurseries, substantial entry × location interaction has existed in each of the international trials grown to date. This has been so for most plant characters examined, as well as for seed yield. For yield, relatively few entries occurred commonly in the superior group at many of the test locations.

The importance of such interactions has implications on the strategy of research into chickpea improvement, and three main aspects will be considered here. First, since few lines have shown wide adaptation over locations, there is a clear need to select for local adaptation as well as for broad adaptation, using multilocation evaluation across regions. This has been discussed in other sections of this paper.

Second, it is necessary to understand the similarities and differences among the cultural environments internationally in order to identify the major factors that differentially influence or limit plant development of the test lines. This has basic importance in defining new methods and objectives in selection and clearly requires detailed consideration of plant characters in addition to seed yield and close collaboration with physiologists. The importance of obtaining data on the characteristics of the test environments is emphasized.

Third, subdivision of the cultural environments internationally into groups that elicit generally similar responses from chickpea genotypes would allow rationalization of testing, rapid adoption of superior genetic material, and more objective definition of relevant breeding objectives. As discussed in the companion paper on the international trials and nurseries (Singh et al. this workshop), there is a disturbing lack of evidence of reproducibility of line performance throughout the non-Indian international test environments examined. While this implies the need to select simultaneously for local and broad adaptation, it is important also to consider the relevance of selection at particular locations within the main ICRISAT/ICARDA breeding programs. The correlations of line performance at the main ICRISAT testing sites at Hissar and Hyderabad in 1975–1978 with that at the various non-Indian international test locations in the International Chickpea Cooperative Trial, Desi-Late (ICCT-DL) trial are presented in Table 12. Twelve entries were common to these trials.

With few exceptions, line performance at Hissar and ICRISAT Center was poorly associated with that at all other locations considered here. Many negative coefficients existed, some being reasonably strong (ICRISAT Center 1975–76 with Faisalabad), suggesting that selection at a central site prior to distribution of lines for local evaluation could actually be counterproductive. However, the magnitude and direction of the coefficients were relatively consistent across years of test at the central sites, and some evidence of specific association of performance existed, e.g., for Hissar and Faisalabad. Furthermore, as discussed in the companion paper on international trials and nurseries (Singh et al. this workshop), reasonable degrees of association of line performance have occurred in some cases between ICRISAT Center and certain southern Indian locations, and between Hissar and certain northern Indian locations.

These results are limited in scope, and further investigation of the implications of selection at particular sites on adaptation elsewhere is required as a matter of priority. However, three aspects appear reasonably clear. First, ICRISAT and ICARDA need to examine the use of additional central testing sites to strengthen their main breeding programs and the international implications of their use in selection. Second, the importance of dissemination of relatively unselected but reasonably homozygous breeding lines for regional and local evaluation and selection is self-evident. Third, national and local programs should exploit to the fullest the facilities available through ICRISAT and ICARDA for requesting hybridization and advancement of specified crosses for selection by the local cooperator. Each of these aspects is being developed within the institutes and has been discussed in other sections of this paper.

Progress Made to Date

While the assessment of the effectiveness of selection in the program to date is not encouraging, nonetheless advanced lines have been developed that have given high yields in the Indian coordinated trials. Of five lines sub-

Table 12. Correlations of line performances for seed yield at ICRISAT's Hissar and Hyderabad testing sites in 1975–1978 with that at various international test sites for 12 common entries.

	ICRISAT – Hissar			ICRISAT – Hyderabad	
Entry	1975–76	1976–77	1977–78	1975–76	1976–77
1975–76					
Colchagua, Chile	0.16	0.14	0.29	−0.25	−0.29
La Platna, Chile	0.44	−0.28	0.24	−0.36	−0.15
Ibb, Y.A.R.	0.01	−0.03	0.08	−0.44	−0.11
Debre-Zeit, Ethiopia	0.18	0.18	0.06	−0.15	−0.05
Ed-Damer, Sudan	−0.20	−0.13	0.08	0.49	0.38
D.I. Khan, Pakistan	0.37	0.11	0.43	0.05	−0.17
Faisalabad, Pakistan	0.79	0.20	0.48	−0.59	−0.48
1976–77					
Parwanipur, Nepal	−0.21	0.21	−0.19	0.18	−0.12
1977–78					
Feni, Bangladesh	−0.12	0.00	0.04	0.08	0.00
Yezin, Burma	0.09	−0.19	−0.20	−0.12	0.00
Dokri, Pakistan	−0.23	0.12	−0.21	−0.19	0.07
Faisalabad, Pakistan	−0.15	−0.26	0.23	0.02	−0.03
Tarnab, Pakistan	−0.03	0.21	0.11	−0.24	−0.31

mitted for testing in 1977, two were advanced from the initial evaluation trial to the Gram Coordinated Varietal Trial (GCVT) in 1978. Eight new lines were included in the initial evaluation trial in 1978 on the basis of their performance in observation nurseries at 13 locations.

Additional evidence of yield gains was seen (Table 6); 97 F_6 lines at ICRISAT Center and 24 at Hissar yielded at least 50% more than the moving average of the check. It is fair to conclude that high yielding material has been developed; nonetheless we will address the question of increasing the effectiveness of breeding for yield in a later section.

Future Breeding Strategies

Organization of Programs

With the integration of the chickpea programs of two Centers, there is an opportunity to optimize utilization of resources for maximum efficiency. With the availability of skilled workers in India, we intend to make most of the crosses at ICRISAT Center. Limitations of this approach will exist in adaptive requirements of some parents and the nonavailability of most of the kabuli germplasm lines at ICARDA. However, we will expedite the transfer of germplasm between Centers, with the objective of ultimately maintaining complete collections at both. Crosses will necessarily continue at all sites in order to utilize newly identified parent material and to meet other needs of the program at each site.

Breeding for High Yield

We consider the improvement of genetic yield potential to be our primary objective. Yield, however, is the least heritable of the traits under selection, and ample evidence exists not only for specificity of adaptation to location, but to years within a location. We consider the pedigree method utilizing visual selection to be well adapted for highly heritable characters, such as disease resistance and specific plant characters, but poorly adapted for yield.

Selection of individual plants in F_2 for yield in chickpea has not been effective for us. Similar results have been reported with other crops; in wheat by Knott (1972), McGinnis and Shebeski (1968), DePauw and Shebeski (1973); in barley by Fiuzat and Atkins (1953); and in oats by Frey (1962).

Additional disadvantages of the pedigree method are: (1) selection within a single environment for local adaptation, when our mandate is to provide superior material for many locations, (2) the uniqueness of each year's climate, which results in changing selection pressure each year, and (3) the limitation on the amount of material and particularly genetic diversity that can be advanced.

We propose to be continually more selective in choice of parents for the yield program and to restrict the number of crosses. Bulk F_2 testing is proposed at a number of sites to identify not only crosses with high yield over locations but also those with specific adaptation. Yield testing of F_2 (or F_3) bulks has been suggested for dry beans by Hambling and Evans (1976), and for wheat by Knott and Kumar (1975), Cregan and Busch (1977), and Bhullar et al. (1977).

In 1978, ICRISAT planted tests of 172 F_2 bulks at three locations, and of 46 of those bulks at an additional four locations in cooperation with the All India Coordinated Program. Cooperators can choose the best crosses for use in their programs. ICARDA is testing F_3 bulks at ten locations.

Single seed descent (Goulden 1939; Brim 1966) is a logical means of advancing populations without selection while preserving genetic variance for later selection. However, single pods will be harvested instead of single seeds to permit overseeding and thinning as a means of maintaining population size. The objections to use of bulk advance on the basis of its being slower than pedigree breeding have been answered recently by Jensen (1978). However, if the contention of Harrington (1937) that homozygosity is reached more rapidly in pedigreed lines than in the bulk populations should be true, we would consider this an additional advantage in avoiding rapid fixation of genotypes. We do agree with Jensen's arguments, however, and expect to find practical homozygosity in the progeny of many F_5 plants. Our choice of single pod descent over bulk hybrid advance is based on the avoidance of the effects of selection, competition among seed sizes, and other factors as discussed by Hamblin (1977).

Crosses not tested as F_2 or F_3 bulks will be evaluated on the basis of performance of F_3 or F_4 derived lines in perhaps five environments internationally. The best crosses will be regrown subsequently in larger populations of F_3 or F_4 derived lines for rigorous selection.

We plan to restrict our selection for yield to progeny tests of derived lines. Those crosses tested in early generation bulks will ordinarily be advanced to F_4 or F_5, when plants will be taken for growing lines for evaluation in the next generation. It will be desirable to do only mild selection in the first year at a given location, to allow for maintenance of selections that would be extremely well adapted to the next year's climatic conditions, or at other locations.

All breeding material will be tested and advanced as far as possible under reasonably favorable, but not idealized, agronomic management; that is, with plantings made on a full profile of moisture, good stands ensured, irrigation applied to avoid unnecessary stress, and avoidance of excessive insect or disease pressure. The objective is to encourage expression of genetic differences for production characters in order to facilitate truncation in selection, and to avoid excessive bias in selection due to entry × year interaction by using a more reproducible selection environment. Advanced lines will be evaluated in insecticide-free conditions and in disease nurseries prior to distribution in cooperative trials.

Breeding material will continue to be supplied to cooperators internationally as elite lines through the International Chickpea Cooperative Trials, as advanced lines through the International Chickpea Screening Nurseries, and as bulk F_2 and F_3 populations of specific crosses on request. Further, cooperators will be encouraged to select among the random F_3 or F_4 derived lines of most crosses, which will be grown annually at four or five sites internationally.

Rapid Generation Turnover

The yield-breeding program visualized can be effectively speeded up by rapid generation turnover.

Conceptually, it should be possible to attain turnover of three generations annually, at least in winter-grown chickpea, using an autumn crop planted in August or September, a spring crop planted in late December, and a summer crop planted in May or June. Research is under way to determine the environmental modifications necessary to attain this objective and the availability of suitable locations. It is emphasized that the objective is generation advancement only, and that selection would normally be practiced only in the normal cropping season. Assuming that three generations could be grown per year, this system would allow field testing of F_3 derived lines in the F_5 generation only 2 years after making the initial cross. We hope modifications of photoperiod and temperature will permit even more rapid advance of some material.

Breeding for Resistance to Diseases and Insects

Pedigree selection is expected to be the most effective method for developing resistance to diseases and pests, and this method is currently being used in the development of lines in disease-sick plots and laboratory screening. Bulk advance of resistant plants in early generations will be used in some crosses to increase the amount of material handled, and single pod descent will be used to maintain variation in advanced populations.

The race situation is not clear as yet for most chickpea diseases, and if their existence is proved, other methods will be employed. In the case of multiple races, it may be possible to identify or develop sources resistant to all races, perhaps through gene pyramiding. However, if the race situation is complex, horizontal resistance may be sought through the development of composite crosses, as proposed by van der Plank (1968). This involves biparental intercrossing of lines with moderate levels of resistance and wide adaptation, and bulking the F_2s equally to form a composite population. This would be grown in multilocation tests annually, with bulk harvest followed by mixing seed from all locations in equal proportions to reconstitute the population. If this method is effective, such a population could be distributed to national programs for release, reselection, or breeding purposes.

The status of research on disease and insects will be reported in other workshop papers. Considering the distribution of disease problems, it is not realistic for an international center to undertake to combine local adaptation for yield and disease resistance for all locations. For this reason, we are advocating the quantitative approach for breeding for yield as a separate objective, and we recommend resistance-breeding procedures appropriate for the specific disease situation. All advanced lines developed in the yield program will be screened to classify them for disease reaction. Local breeding programs with a severe disease problem will find it necessary to use disease resistance as a first culling objective, but they will then be able to profitably use quantitative methods to select for yield within the resistant population. The ineffectiveness of single-plant selection for yield is as real in local programs as in regional, national, or international programs.

Preliminary evidence exists regarding differences among chickpea lines for resistance to, and tolerance of, *Heliothis armigera*. Exploratory studies of inheritance will be initiated shortly in this area. In the general breeding program, resistant or tolerant lines will be used as parents and all advanced breeding lines will be evaluated under insecticide-free conditions to determine their reaction.

Breeding for Quality and Consumer Acceptability

Chickpea is recognized as one of the most digestible of the pulses. Considering the relative importance of increasing yield and incrementally improving a highly acceptable food product, we have put little effort on quality to date. The need for monitoring cooking time and chemical composition of advanced lines has been emphasized (Hawtin et al. 1976).

Currently, routine screening for protein content is done on material from both the desi and kabuli programs, and a special project of breeding for a higher level of protein in desi has been initiated. If and when protein percentage is increased substantially, the quality of protein in the high lines will be compared with that of normal cultivars so we can determine if higher protein percentage per se is a worthwhile objective.

Visible characters influencing consumer acceptability are more complex in desi than in kabuli cultivars; we hope information brought to this conference will help to catalog local preferences for seed size and color.

Breeding for Modified Plant Habit

In general, chickpea is characterized by a semi-prostrate bushy plant habit and by single flowers per peduncle and low numbers (1–2) of seed per pod. Genotypes producing two flowers per peduncle exist and have been studied genetically and used in breeding at ICRISAT. Lines with up to five ovules per pod have been identified elsewhere. Tall, erect kabuli types have been obtained from the USSR. These characters open exciting prospects in chickpea breeding since they offer an opportunity to redesign the canopy structure and to develop prolificacy of reproductive sinks per plant and per node. Considerable research is planned in both desi and kabuli types using these traits.

The use of tall erect types would facilitate harvesting, both by hand and by mechanical methods. In one trial at Tel Hadia, a tall type (NEC-138) produced 60% more yield at 500 000 plants/ha than at 167 000 plants/ha, while a local bushy cultivar showed little response. The possibility exists that redesigning the canopy type and the agronomic system may result in substantial yield increases.

Currently there are 22 tall germplasm accessions available. ICARDA scientists are investigating populations of tall × bushy kabuli types, and ICRISAT is working mainly with crosses between tall kabuli and bushy desi parents. Segregating material involving these parents will be selected using the pedigree system and/or bulk populations with mass selection for plant habit. Studies are being made of the inheritance of plant habit and of the interrelationships of plant habit with other plant characters at different densities.

Breeding for New Applications of Chickpea

Increasing emphasis will be put on the development of chickpea breeding material adapted to new or relatively unexploited cultural regimes. The objective is to provide further options for chickpea cultivation in new or existing areas of culture of the crop. The potential benefits to be realized through advances in new applications can hardly be overemphasized.

Winter Cropping of Kabuli Chickpea in Western Asia

In the Mediterranean region, chickpea is grown almost exclusively as a spring crop. Although farmers have argued that this is related to inability of the crop to withstand severe winters, winter plantings at Kfardan, Lebanon, in 1974–75 resulted in survival of all lines and in higher yields than for the spring crop. Subsequently, other studies have suggested that the main danger involved with autumn plantings is the higher risk of occurrence of *Ascochyta* blight. Significant yield increases have been obtained from winter cropping as compared with spring cropping, where this disease did not occur or where it was controlled by use of fungicides (Table 13).

There is a strong possibility of introducing chickpea as a winter crop in the region. Cost-benefit ratio studies on fungicidal use are planned for 1978–79 in large scale trials, and new cultural practices are being developed and some promising cultivars are being multiplied. In some years, early commencement of the rains may prevent planting before spring so that cultivars which perform well over a wide range of planting dates would be desirable. This appears to be a feasible objective; e.g., ILC-263, which ranked sixth in the winter planted yield trial, ranked third in the same trial planted in spring.

The entire kabuli germplasm has been sown at Tel Hadia and Tekmadash to screen for winter hardiness, and it is envisaged that *Ascochyta* blight resistance will be incorporated into high yielding cultivars adapted to winter planting.

Depending on the results of the 1978–79 studies, an international nursery may be distributed to national programs interested in developing winter planting.

Late Sowing in Northern India

For various reasons (largely involving rotation with rainy-season crops), considerable interest exists in adaptation of chickpea to late winter (November) sowings in northern Indian conditions. Commonly, lines exhibit substantial flower drop, pod curling, and restricted pod set under these conditions, but differences in adaptation have been identified. The cause of these symptoms is not known but probably involves differential sensitivity and reaction to low

Table 13. Yield increase of winter over spring planting in the advanced trial, 1977–78, Aleppo.

Entry	Yield (kg/ha) Winter	Yield (kg/ha) Spring	Increase over spring (%)
Highest yielding			
ILC-262	1852 (1)[a]	1073 (23)	73
ILC-51	1807 (2)	1098 (22)	64
ILC-237	1737 (4)	1005 (30)	73
ILC-23	1725 (6)	988 (35)	75
ILC-493	1719 (8)	1146 (13)	50
Syrian local	1677 (11)	1027 (27)	63
Lowest yielding			
ILC-52	1532 (24)	1201 (5)	28
ILC-205	1086 (36)	860 (47)	26
ILC-673	1457 (32)	1108 (20)	31
ILC-812	1548 (22)	1163 (10)	33
ILC-1028	1473 (31)	1142 (16)	29

[a] Numbers in parentheses indicate the rankings in the trial.

minimum temperature. Breeding studies have been initiated at Hissar to improve adaptation to late sowings, including mass selection for pod and seed production under these conditions and screening of germplasm.

Early Sowing in Southern India

Crop growth in southern Indian environments commonly is terminated by a combination of high temperature and low available soil water. Early sowing in these environments may extend the duration of the crop and possibly result in improved utilization of available moisture. This may incur problems associated with seedling response and root and other diseases, particularly where late rains are received. Screening of germplasm and of populations of breeding lines has been initiated to determine the genetic variability available for ability to tolerate and respond to early (September) sowing. Apart from its potential for dry seed production, this system may also offer potential for early production of green pods for vegetable use.

Development of Chickpeas for High-Input Culture

As indicated previously, chickpea is generally grown as a rainfed crop on conserved moisture with low inputs, and most breeding effort is directed to improve production under these regimes. However, the development of irrigation has resulted in a challenge by cereals for acreage in traditional chickpea areas. This has had an unfavorable influence on the availability and price of chickpea and can only be met by the development of chickpea cultivars more responsive to high-input culture.

ICRISAT and ICARDA have conducted only limited investigations in this area to date, but screening of germplasm and breeding populations for response to high-input culture has been initiated.

Study of Environmental Interactions

Very little detailed study of the response of chickpea cultivars and lines to different production environments has been made. The evidence available suggests that substantial line × environment interaction exists and that there is considerable specificity of adaptation of lines for particular locations. It is apparent that the attainment of broad adaptation to a range of production environments presents a significant breeding challenge in chickpea. Three main lines of attack on this problem will be involved.

Analysis of Multilocation International Trials

The international trials and nurseries are the major points of contact between the centers and chickpea workers and production environments internationally. Detailed analysis of the results of such trials will provide hard evidence on differences in adaptation of lines, and this information can be used to guide the selection of parents and the definition of specific directions of selection for adaptation. The importance of collecting all possible plant and environmental data from each site is emphasized so that an adequate data base can be provided for interpretation of differences among lines in response.

Use of Multilocations within the Breeding Program

The use of multiple environments for testing within the breeding programs of the centers will allow opportunity to identify and select material with specific forms of response to environment, including wide adaptability. This occurs in all segregating generations, ranging from the multilocation bulk F_2 or F_3 tests to final selection among elite advanced generation lines. It is emphasized that because of the apparent magnitude of genotype × environment interaction in this crop, rigorous selection of early generation material should be avoided, particularly on a single plant basis. Local cooperators can contribute substantially to the development of wide adaptation by instituting multi-environment trials over years within their areas as part of their testing program.

Response to Selection for Photoperiod- and Thermo-insensitivity

Special exploratory studies are possible. For example, it appears that photoperiod and temperature have important influences on chickpea adaptation, so that genotypes with lower photo- and thermo-sensitivity may be more widely adapted. At ICARDA, crosses will be made between parents of different origin and between relatively widely adapted parents, and a composite population will be formed by mixing equal proportions of F_2 seed of each cross. Selection will be practiced in alternate generations for earliness under very short day conditions in Egypt or Sudan for maximum seed production and under long day conditions in Syria, Lebanon, and Iran, and a new composite will be formed for further cycles of selection. The impact of such selection on environmental response will be determined subsequently. This is a form of phenotypic recurrent selection, with selection practiced in tandem for different forms of adaptation. We are considering methods of incorporating regular cycles of recombination into this breeding scheme.

Summary and Conclusions

We have reviewed the first 5 years of the chickpea breeding program at ICRISAT. Evidence on the relative ineffectiveness of visual scoring and the lack of availability of the ratings suggests that more efficient breeding methods might be employed; however, progress was made in yield potential, as evidenced by the performance of advanced lines.

We are suggesting modifications that we now think would be appropriate for a breeding program at an international center. We will rely largely on quantitative evaluation in selection for yield and will devote a substantial portion of our resources to that part of the program with high yield as a sole objective.

Conventional pedigree selection will be the main method of breeding for highly heritable characters; pest and disease resistance will be the primary objective of other phases of the breeding program. All new lines will be tested for disease and pest reaction, and the incorporation of disease resistance into high yielding cultivars will be part of the program at each of the Centers' breeding locations.

Emphasis on breeding for new applications of chickpea — including winter sowing in western Asia, late planting in northern India, and early planting in southern India — will increase. Attention to high input production will begin.

Breeding for modified plant types and plant characters is an open ended program in which various plant types and combinations of plant characters will be developed. Present emphasis is on tall, erect plant types for high population and for mechanical harvest.

Implicit in our suggested program for quantitative breeding for yield — including multilocation testing at early as well as advanced stages of breeding — is a high level of cooperation among chickpea breeders. Problems of disease and pest resistance or tolerance also require cooperation at several locations. Cooperation of national programs and individuals to date is greatly appreciated; we have made a good beginning. Closer cooperation, more effective communication (including better follow-through), and more joint planning will help us accomplish what must be our overriding objective: to get to the farmers' fields, in the shortest possible time, with chickpea cultivars that will produce more calories and protein in a form desired by the consumer.

Acknowledgments

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References

Bhullar, G. S., Gill, K. S., and Khera, A. S. 1977. Performance of bulk populations and effectiveness of early generation testing in wheat. Indian Journal of Agricultural Science 47: 300–332.

Brim, C. A. 1966. A modified pedigree method of selection in soybeans. Crop Science 6: 220.

Cregan, P. B., and Busch, R. H. 1977. Early generation bulk hybrid yield testing of adapted hard red spring wheat crosses. Cro Science 17: 887–891.

Depauw, R. M., and Shebeski, L. H. 1973. An evaluation of an early generation yield testing procedure in *Triticum aestivum*. Canadian Journal of Plant Science 53: 465–470.

Fiuzat, Y., and Atkins, R. E. 1953. Genetic and environmental variability in segregating barley populations. Agronomy Journal 45: 414–420.

Frey, K. J. 1962. Effectiveness of visual selection upon yield in oat crosses. Crop Science 2: 102–105.

Goulden, C. H. 1939. Problems in plant selection. Pages 132–33 *in* R. C. Burnett (ed.), Proceedings of the 7th International Genetics Congress. Cambridge University Press, England.

Hamblin, J. 1977. Plant breeding interpretations of the effects of bulk breeding on four populations of beans (*Phaseolus vulgaris* L.) Euphytica 26: 157–168.

Hamblin, J. and Evans, A. M. 1976. The estimation of cross yield using early generations and parental yields in dry beans (*Phaseolus vulgaris* L.). Euphytica 25: 515–520.

Harrington, J. B. 1937. The mass-pedigree method in the hybridization improvement of cereals. Journal of the American Agronomy Society 29: 379–384.

Hawtin, G. C. 1975. The status of chickpea research in the Middle East. Pages 109–116 *in* Proceedings of the International Workshop on Grain Legumes, ICRISAT, Hyderabad, India.

Hawtin, G. C., Rachie, K. O., and Green, J. M. 1976. Breeding strategy for the nutritional improvement of plants. International Development Research Center, TS 7e: 43–51.

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

Jensen, N. F. 1978. Composite breeding methods and the DSM system in cereals. Crop Science 18: 622–626.

Knott, D. R. 1972. Effects of selection for F_2 plant yield on subsequent generations in wheat. Canadian Journal of Plant Science 52: 721–726.

Knott, D. R., and Kumar, J. 1975. Comparison of early generation yield testing and a single seed descent procedure in wheat breeding. Crop Science 15: 295–299.

McGinnis, R. C., and Shebeski, L. H. 1968. The reliability of single plant selection for yield in F_2. Pages 109–114 *in* Proceedings of the Third International Wheat Genetics Symposium, Canberra, Australia.

Singh, K. B., and Auckland, A. K. 1975. Chickpea breeding at ICRISAT. Pages 13–17 *in* Proceedings of the International Workshop on Grain Legumes, ICRISAT, Hyderabad, India.

van der Plank, J. E. 1968. Disease resistance in plants. Academic Press, New York. 206 pp.

The Current Status of Chickpea Germplasm Work at ICRISAT

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ICRISAT's Genetic Resources Unit is serving as a world center for the assembly, evaluation, preservation, and supply of germplasm of five crops, one of which is chickpea (*Cicer arietinum* L.) and its wild relatives. An introduction to the work was prepared earlier (van der Maesen 1976).

Collection

At present the collection contains 11 225 accessions of chickpea. Of wild *Cicer* spp, we have 33 accessions of 8 annuals and 14 accessions of 6 perennials (see Introgression, this paper). The largest numbers of chickpea accessions are from India (4863) and Iran (3868). From 33 other countries, we have 2207 accessions (287 unknown). The major part of the collection has been received from various agricultural universities and research institutes in India and abroad. Our own collection expeditions to various states in India, Turkey, Pakistan, and Afghanistan have so far yielded 787 entries. In 1978 we collected 13 samples in Pakistan, of which 8 were cleared for postentry quarantine isolation. Mimeographed travel reports are available. For future explorations, our own analyses and priorities declared by the International Board for Plant Genetic Resources will be followed. Apart from Ethiopia, where only limited roadside collection is done, the existing geographical coverage is very reasonable.

Seed Storage

Seeds are stored in plastic bottles arranged on metal trays in humidity-controlled, air-conditioned rooms (60–65% relative humidity [RH], 14–18°C). Soon we will shift to medium-term storage rooms at 4°C and 30% RH; long-term storage (IBPGR 1976) is in the planning stage. A naphthalene ball per bottle keeps out insects. At 4°C this precaution will no longer be necessary; however, a pot test revealed no harmful effects of naphthalene on germination and growth when seeds were stored for 3 years with a naphthalene ball (see Seed Viability, this paper).

Evaluation and Rejuvenation

Routine Evaluation and Rejuvenation

Evaluation and seed multiplication are carried out at ICRISAT Center and Hissar to obtain data on the performance of cultivars under peninsular and north Indian conditions. Each entry is sown in two rows, 4 m long. Ridge-to-ridge spacing is 75 cm; each ridge accommodates two rows, and plant-to-plant spacing in the row is 10 cm. At Hissar, however, single rows of 6 m and a row spacing of 60 cm are used. One of three standard check cultivars — JG-62, G-130, and L-550 — is sown every 21st row, the checks being repeated in sequence.

This year we planted 2691 accessions at ICRISAT Center on 17 and 18 October for evaluation and rejuvenation. The material includes 2137 exotic lines and 554 lines from different parts of India. At Hissar, 2263 accessions were sown on 21 and 22 October.

For chickpea, data on 22 morphological and agronomic traits are recorded. We have 40 descriptors, including the passport data, flowering data, flower and seed colors, maturity, yield, seed weight, resistance to pests and diseases, and protein content.

Rejuvenation of chickpea is no problem as the crop is self-pollinated. Rejuvenation is carried out simultaneously with evaluation. However, we have some problems in keeping pace with the ever-increasing demand for seeds of wild

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Cicer. Perennial species do not flower under natural conditions at ICRISAT Center. Temperature-, humidity-, and light-controlled rooms are required for maintenance and seed production of the perennials. Among the annuals, *C. yamashitae* and *C. echinospermum* are difficult to maintain. Their emergence is poor and seed set is not satisfactory.

A pedicel mutant was detected in cv L-550 (Pundir and van der Maesen 1977).

In addition to the standard evaluation the following special tests were conducted:

Yield Test and Harvest Indices

Replicated trials were conducted for 84 early and 100 late cultivars during the 1976–77 and 1977–78 postrainy seasons; results of the ten best cultivars are presented in Table 1. The yield test, repeated in 1977–78 for the 100 late cultivars, did not yield data because of poor emergence and bad field conditions. Harvest index was measured on 100 cultivars (germplasm selections) during 1977–78, and the results of the best 12 with high harvest index at late-maturity stage are listed in Table 2. This year we are repeating these tests.

For yield testing, 100 early cultivars and 100 late cultivars were sown with three replications on 17 October 1978. To measure harvest index, 100 germplasm selections were also sown on 17 October 1978, with two replications. There was an initial incidence of root rot by *Sclerotium* and a heavy attack by *Heliothis* during the middle of November; however, the crop growth has improved after spraying with insecticide (Endosulfan).

Seed Viability

Seed viability tests are carried out four times a year to monitor germination percentage under normal room and cool-room conditions with various seed containers. Every 3 months the germination is tested following the first test after 6 months' storage.

Germination tests (nonreplicated) on seeds of five cultivars stored for 18 months after harvest revealed the following: At cool temperatures, the cultivars BEG-482, P-3090, and Hima did not reveal any difference in germination percentage when seeds were stored in fairly airtight plastic bottles or paper packets. However, for

Table 1. Average yields (kg/ha) of ten best chickpea cultivars, 1976–78.

Early cultivars, trial 1976–77			Early cultivars, trial 1977–78			Late cultivars, trial 1976–77		
ICC No.	Pedigree	Yield	ICC No.	Pedigree	Yield	ICC No.	Pedigree	Yield
4918	Annigeri	2060	10 301	PRR-1	2163	2461	P-2249	2503
7695	2-57-61	2050	7 698	20-1	2120	1503	P-1294	2317
551	P-434	2007	7 694	2-28-23	2107	6482	NEC-500	2173
7698	2-1	1917	4 918	Annigeri	2093	9107	NEC-818	2130
7693	2-26-13	1853	7 755	NEC-760	2057	9100	NEC-795	2087
7753	NEC-754	1836	8 316	Chafa 8-16	2053	3392	P-4079	2047
1003	P-819	1757	5 004	10-2-3	2048	465	P-349-1	2027
5716	Brown leaf	1730	8 381	Parner 4-14-1 × 31-2	2033	353	P-264	1977
4934	Chafa	1663	7 708	147-3	2030	6926	NEC-1166	1957
5742	Chrysanthifolia	1620	7 706	72-5	2000	1030	P-861	1955
CV (%)		10.22	CV (%)		9.75	CV (%)		11.33

Table 2. Harvest index (%) and seed yield (kg/ha) for the 12 cultivars with the highest harvest index at maturity, 1977–78.

ICC No.	Pedigree	Harvest index	Yield	ICC No.	Pedigree	Harvest index	Yield
1341	P-1209	63.08	2159	867	P-690	58.75	2455
5594	WFWG × 810-140-15T	61.94	2100	4951	JG-62	58.63	2178
5794	Gram pink Ujjain	61.83	2300	1859	P-1499	58.54	2337
5823	K-4-2	60.71	2363	3505	P-4206	57.64	1907
920	P-732-1	60.22	2466	7708	147-3	57.63	2263
5810	Harigantas	59.08	1474	5434	Ponaflar-2	57.58	1633

L-550 (kabuli) and kaka (black-seeded desi) germination dropped considerably in paper packets (50% and 20%, respectively).

No appreciable difference in germination was noted between the two temperatures when seeds were stored in plastic bottles. On the other hand, when stored in paper packets at room temperature, seeds of all five cultivars lost most of their viability.

Seed coat structure appears to be an important factor in controlling moisture uptake, which in turn affects viability. For example, L-550 (kabuli) seeds increased from 7 to 12% moisture after one rainy season storage in cloth bags, whereas desi cultivars BEG-482, P-3090, and Hima hardly took up any moisture (1% increase).

Collaborative Work within ICRISAT

Pathology

A total of 6913 samples were sent to the Pulse Pathology section between June 1977 and November 1978 for various secreenings and collaborative works. This total includes a number of wild species and introgression materials.

From about 2000 germplasm accessions screened against wilt, 30 were found without infection. Of the nine wild annual species screened, only *Cicer judaicum* was found to be resistant to wilt. Of 1334 entries screened against stunt, 67 were found disease free and are under further testing. Against *Ascochyta* blight, 2159 entries were screened and a few lines were found tolerant. Within the 12 wild species screened against this disease, some entries of *C. bijugum* and *C. judaicum* showed tolerance. *C. reticulatum* showed resistance, but not in all entries. The resistance in some accessions of *C. reticulatum* has been successfully transferred to some of the popular cultivars by our own introgression efforts (see Introgression, this paper). Further attempts to cross *C. bijugum* with chickpea are being made, with the same objective.

Entomology

A total of 2270 entries were supplied to the Entomology section in 1977–78. Of 1596 new accessions screened in nonreplicated plots, 67 had no borer damage. From 8629 accessions screened previously, 955 lines were selected and were again tested this year. Several lines with markedly less pod damage were selected for further testing.

Microbiology

We sent 561 entries to the Microbiology section and the data on the nodulation of 500 lines are under analysis. Lines were compared with cultivar 850-3/27.

Biochemistry

For protein estimation, we sent 2034 samples including ten wild materials to the Biochemistry section. During 1970, 3440 cultivars were analyzed, and the data are available. Protein percentage varied from 17.3 (cv ICC-10962) to 27.7 (cv ICC-9913).

Breeding and Physiology

We supplied 294 samples to the Pulse Breeding section and 28 to the Physiology section for

Table 3. Chickpea germplasm lines supplied to research agencies in India and other nations during 1977–78.

Institution	Location	Entries
India		
Regional Station, Indian Agricultural Research Institute	Kanpur, Uttar Pradesh	109
Agricultural Experimental Institute	Vayalogum, Tamil Nadu	100
Department of Plant Breeding, Punjab Agricultural University	Ludhiana, Punjab	71
Department of Plant Breeding, Banaras Hindu University	Varanasi, Uttar Pradesh	64
Department of Genetics and Plant Breeding, Haryana Agricultural University	Hissar, Haryana	50
Department of Genetics & Botany, Osmania University	Hyderabad, Andhra Pradesh	40
Department of Plant Breeding, G. B. Pant University of Agriculture and Technology	Pantnagar, Uttar Pradesh	23
Department of Plant Breeding, Andhra Pradesh Agricultural University	Rajendranagar, Andhra Pradesh	23
Indian Agricultural Research Institute	New Delhi	20
Department of Genetics, Chandrasekhar Azad University of Agriculture & Technology	Kanpur, Uttar Pradesh	9
Pulse Improvement Project	Bhubaneswar, Orissa	6
Department of Botany, Punjabrao Krishi Vidyapeeth	Akola, Maharashtra	5
Department of Agriculture & Plant Breeding, Jawaharlal Nehru Krishi Vishwa Vidyalaya	Jabalpur, Madhya Pradesh	5
Other Nations		
ICARDA	Aleppo, Syria	1514
Division of Genetics, National Institute of Agricultural Sciences	Hiratsuka, Kanagawa-254, Japan	500
Crop Development Centre, University of Saskatchewan	Saskatchewan, Canada	300
Estacion Experimental Sociedad Nacional de Agricultura	Fundo la Vega, Huelguen, Paina, Chile	100
Department of Agronomy, University of Florida	Florida, U.S.A.	33
Kenya Agricultural & Forestry Organization	Nairobi, Kenya	20
Rangpur Dinajpur Rehabilitation Service	Lalmanirhat, Rangpur, Bangladesh	11
M/s Macondray & Co., Inc.	Manila, Philippines	10
Project Tapis Vert	Niamey, Niger	3
Agriculture Research Institute, Wagga Wagga	Wagga Wagga, Australia	2

various tests, e.g., development of drought-screening methods.

Introgression

Wild *Cicer* spp at ICRISAT are as follows:

Annuals	Perennials
*C. bijugum**	*C. anatolicum*
*C. chorassanicum**	*C. floribundum*
*C. cuneatum**	*C. graecum*
C. echinospermum	*C. isauricum*
*C. judaicum**	*C. microphyllum*
*C. pinnatifidum**	*C. montbretii*
*C. reticulatum**	*C. pungens*
C. yamashitae	*C. rechingeri*

(* Seeds available for supply)

Only *C. reticulatum* hybridizes readily with cultivated species. To transfer *Ascochyta* blight resistance, *C. reticulatum* was crossed with cultivars G-130, JG-62, and P-5462; F_2 and BC_1 were produced. The seeds were harvested from individual plants and handed over to the Pathology and Breeding sections for screening against *Ascochyta* blight. Pulse Pathology has raised the F_3 and BC_1 F_2 generations, and from their screening several tolerant lines (3-5 on a scale of 1–9) were selected. These will be tested further, and the more tolerant lines will be used in breeding programs. Attempts to cross chickpea with *C. bijugum* will be intensified to transfer resistance against blight.

Other crosses are being attempted. *Cicer judaicum* was found to be wilt resistant and only moderately susceptible to blight. *Cicer pinnatifidum* and *C. bijugum* were crossed with *C. judaicum* with limited success; the F_1s produced a few seeds. With *C. judaicum* × *C. bijugum*, only one F_2 seed developed into a plant.

Inheritance Studies

Inheritance of three morphological characters — prostrate growth habit, doublepodded peduncle, and green seed-coat color — were studied in the F_2 and BC_1. These characters were found to be recessive and monogenically inherited.

To determine the genetic behavior of bipinnate leaf, simple leaf, narrow leaf, purple foliage, light-green foliage, fasciated stem, and white and black seed coat colors, the F_2 and BC_1 populations are now being studied.

Documentation

Full morphological and agronomic data were obtained for 3085 accessions (excluding checks), and prepared for computerization. For 10 842 entries evaluated one to three times during previous years, the computer storage and retrieval system was further developed. The catalog will not be published as such. Instead, specialized catalogs matching the requirement of the user will be supplied on request. A publication to this effect is under preparation.

Seed Supply outside ICRISAT

In total, 525 samples of cultivated and wild *Cicer* were supplied to 13 institutions in India and 2493 samples to 10 institutions abroad (Table 3).

References

IBPGR. 1976. Report of IBPGR (International Board for Plant Genetic Resources) working group of engineering, design and cost aspects of long-term seed storage facilities. Rome, 19 pp.

van der Maesen, L. J. G. 1975. *Cicer* germplasm collection trip to Trukey June–July 1975. ICRISAT Mimeograph, 15 pp.

van der Maesen, L. J. G. 1976. Germplasm collection and evaluation in *Cicer* and *Cajanus*. Pages 229–237 *in* Workshop on Grain Legumes, 1975. ICRISAT, Hyderabad, India.

van der Maesen, L. J. G. 1977. Food legume collection trips in Afghanistan. ICRISAT Mimeograph, 21 pp.

van der Maesen, L. J. G. 1978. Genetic Resources at ICRISAT. Position paper, IBPGR/Government of India Workshop on the Genetic Resources of South Asia, New Delhi, 9–12 May 1978. ICRISAT Mimeograph, 16 pp.

Pundir, R. P. S., and van der Maesen, L. J. G. 1977. A pedicel mutant in chickpea (*Cicer arietinum* L.). Tropical Grain Legumes Bulletin IITA, Ibadan, (in press).

International Chickpea Trials and Nurseries

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Chickpea is grown in many countries of the world. The major producing areas for the desi type are in and around the Indian subcontinent and for the kabuli type, in western Asia and North Africa. There are strong local preferences for the different types, and different production systems are used for desi and kabuli types, which are grown mainly as winter and spring crops, respectively. Furthermore, chickpea exhibits substantial specificity of adaptation. Because of these factors, evaluation and breeding work must be carried on in the different regions of culture.

Until 1977–78, ICRISAT and ICARDA had separate, but largely complementary, responsibilities for chickpea improvement. The programs were integrated in 1978 so that in the future, ICRISAT will organize and coordinate the international testing trials and nurseries of the desi type and ICARDA will do the same for the kabuli type.

In 1977–78, ICRISAT dispatched international trials and nurseries (desi and kabuli) to 63 locations in 28 countries and ICARDA (kabuli only) to 23 locations in 14 countries. Desi trials were sent to Afghanistan, Australia, Bangladesh, Burma, Ethiopia, India, Iran, Iraq, Mexico, Nepal, Pakistan, Philippines, Tanzania, Thailand, Venezuela, and Yeman Arab Republic. The kabuli trials were distributed to Afghanistan, Algeria, Argentina, Australia, Bangladesh, Burma, Chile, Cyprus, Egypt, Ethiopia, India, Iran, Iraq, Jordan, Lebanon, Libya, Mexico, Morocco, Nepal, Pakistan, Peru, Spain, Sudan, Syria, Tanzania, Tunisia, Turkey, and Yemen Arab Republic.

Table 1 lists the trials and nurseries at ICARDA and ICRISAT; these acronyms are used in Tables 2 to 4 and throughout the text.

The Trials and Their Objectives

The international chickpea trials and nurseries were established in 1975 with the following objectives:

1. To strengthen national and regional programs;
2. To supply cultivars, segregating populations, and advanced breeding lines having specific characteristics (disease resistance, high yield, high protein, etc.) to cooperators for evaluation, use in breeding, and (if promising) finishing for release;
3. To identify among line differences in adaptation regionally and internationally through multilocation testing, and to characterize environments in which chickpea is grown;
4. To promote international cooperation through personal visits and information exchange.

To achieve the above mentioned objectives, a wide range of types of breeding material is offered to any individual or organization engaged in chickpea improvement work. Types of chickpea materials distributed are described below; particular trials distributed through 1978 are listed in Table 2.

Parent Lines

These are genetic stocks and advanced breeding lines with specific traits which include high yield, high pod number, tall plant habit, large seed size, double pods, disease and insect resistance, and high protein content. This material is distributed on request (mainly to stations where hybridization work is undertaken) for

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* Chickpea Breeder, ICARDA, Aleppo, Syria; Chickpea Breeders, ICRISAT, Patancheru, Andhra Pradesh, India; and Program Leader, Food Legumes Improvement Program, ICARDA, respectively.

Table 1. Chickpea trials and nurseries, ICRISAT and ICARDA.

Abbreviation	Title	Year begun	Superseded by
ICARDA			
CRN	Chickpea Regional Nursery	1974	CISN
CISN	Chickpea International Screening Nursery (kabuli)	1978	
CRPYT	Chickpea Regional Preliminary Yield Trial	1975	CIYT
CIYT	Chickpea International Yield Trial (kabuli)	1978	
CAT	Chickpea Adaptation Trial (kabuli)	1978	
ICRISAT			
ICSN-A	International Chickpea Screening Nursery (short duration desi)	1976	
-B	(long duration desi)	1976	
-C	(kabuli)	1976	
ICRISAT			
ICCT-D	International Chickpea Cooperative Trial (desi)	1975	
-DE	(desi early, short duration)	1977	
-DL	(desi late, long duration)	1977	
-K	(kabuli)	1975	
ICMT	International Chickpea Microplot Test	1977	
ECGN	Elite Chickpea Germplasm Nursery	1975	ICON
ICON	International Chickpea Observational Nursery	1976	

Table 2. Total number of ICRISAT/ICARDA chickpea trials and nurseries distributed, 1975–78.

	Name of trial or nursery[a]						
	ICCT-D	ICCT-K/ CRPYT	ICSN-A, B	ICSN-C/ CRN	ICMT	F_2/F_3 Bulks	ECGN/ ICON
1975–76 (Winter) 1976 (Summer)	31	29 (13)	0	13 (13)	0	18 (0)	28
No. of countries	17	13	0	8	0	12	20
1976–77 (winter) 1977 (summer)	34	49 (13)	35	25 (20)	0	43 (11)	35
No. of countries	16	28	7	17	0	20	20
1977–78 (winter) 1978 (summer)	35	42 (9)	40	41 (23)	5	47 (13)	0
No. of countries	12	26	8	20	4	19	0

[a] Figures in parentheses are numbers of trials sent from ICARDA. See Table 1 for abbreviations: CRPYT, CRN, and F_3 from ICARDA, rest from ICRISAT.

local evaluation and use in breeding. This nursery was originally distributed as the Elite Chickpea Germplasm Nursery (ECGN) but was renamed as the International Chickpea Observational Nursery (ICON) in 1976. Cooperators were requested to forward information on the usefulness of the lines in their area.

Early Generation Segregating Bulks

Breeders can request and obtain F_2 and F_3 generation unselected bulks of crosses which have shown promise at ICRISAT sites. These populations are intended particularly for those breeders with only limited resources for systematic hybridization. It is anticipated that cooperators will evaluate these bulk populations for local adaptation and select within the superior populations. Three types of early generation bulks (desi × desi, desi × kabuli, and kabuli × kabuli crosses) have been supplied, according to the requirement of particular regions. Cooperators are requested to forward information on the usefulness of specific bulks in their area.

Advanced Breeding Lines

A number of uniform superior lines are bulked individually in advanced generations every year at our research centers and are distributed on request, for local evaluation. These populations of lines are particularly useful to breeders whose facilities for sustained reselection are limited. Cooperators test and characterize the performance of these breeding lines, and can evaluate promising material in larger scale multi-environment trials in subsequent years.

The International Chickpea Screening Nursery-A (ICSN-A), which includes short-duration desi lines; the International Chickpea Screening Nursery-B (ICSN-B), comprising long-duration desi lines; and the International Chickpea Screening Nursery-C (ICSN-C), which includes kabuli lines, have been offered since 1976–77 by ICRISAT. Beginning in 1974, ICARDA distributed the Chickpea Regional Nursery (CRN) substituting it in 1978 with the Chickpea International Screening Nursery (CISN), which includes only kabuli lines. In each case, cooperators are requested to record and forward specific information on plant performance as well as information on the test environments used.

Elite Lines and Cultivars

These trials are intended to make available to cooperators those lines and cultivars that have shown greatest promise regionally or internationally. This material is particularly relevant to those cooperators with very limited facilities for breeding, but who wish to evaluate in their area improved genetic material, with a view to its subsequent release.

Beginning in 1975–76, ICRISAT distributed the International Chickpea Cooperative Trial (ICCT), which included desi and kabuli lines with varying maturity periods. In 1976–77, the trial was split as ICCT-D for desi and ICCT-K for kabuli types. In 1977–78, ICCT-D was further subdivided into the ICCT-DE (desi early) and ICCT-DL (desi late) in order to service the specific demands in areas with short and long growing seasons. Beginning in 1975–76, ICARDA distributed the Chickpea Regional Preliminary Yield Trial (CRPYT) and in 1978–79 renamed it the Chickpea International Yield Trial (CIYT) which includes only kabuli types. The trials distributed in 1978–79 are listed in Table 3.

Allocation of Trials

Care is used in allocating the trials to national programs. Some important considerations are: (1) requests for material by national cooperators; (2) flexibility of consumer demand — desi or kabuli, or both; (3) crop duration of the trial; (4) facilities and expertise available; (5) specific problems of the area; and (6) season of growth.

We now follow the All India Coordinated Pulse Improvement Project (AICPIP) in allocating long-duration desi-type trials to northern India and short-duration desi chickpea to southern India. We are using the results of trials to characterize the environments of other countries and regions regarding the relevance of long and short-duration desi chickpea. ICARDA has initiated a chickpea adaptation trial comprising material from the national programs of the region. This trial is being conducted at 25

Table 3. Number of International chickpea trials distributed by ICRISAT/ICARDA, 1978–79.

ICCT-DE	ICCT-DL	CIYT	ICSN-A	ICSN-B	CISN	CAT	F_2/F_3 bulks
11	14	23	13	18	22	26	26

locations in 18 countries and will continue for 3 years. Thereafter efforts will be made to characterize the whole region.

Seed color of the desi type (yellow, brown, black, green) and seed size in kabuli types are other important criteria in furnishing material.

Conduct of the Trials

Guidelines for Experimentation

ICRISAT and ICARDA prepare and distribute broad guidelines to cooperators for the conduct of nurseries and trials. These include general information on the material, design of the experiment, guidelines for character observation, and field books for recording data. The cooperator is invited to make any alterations in cultural management necessary to suit local conditions and to add either a local check cultivar or substitute it for a nominated entry. They are requested to forward data for subsequent analysis and publication, using a duplicate field book supplied. Data are requested on several specific plant characters, such as days to first flowering, plant stand, plant height, days to maturity, 100 seed weight, plot yield, and insect and disease damage, as well as information on the location, cultural management, and environmental conditions of the test site. Cooperators are encouraged to provide their own assessment of the material and to nominate lines found useful in that area.

Entry Recommendations by Cooperators

Any individual or organization may nominate specific entries for inclusion in the international trials and nurseries, and all entries proposed to date have been included. If excessive numbers of entries are nominated in the future, it will become necessary to establish criteria for choosing among the nominated lines. Any person nominating a particular entry is informed that any other breeder or region may adopt that entry as a cultivar for local use, after duly acknowledging its source of origin. The entries nominated — including germplasm lines, nominations from cooperators, and ICRISAT/ICARDA breeding lines — are allocated to the various international trials according to the criteria described earlier. In view of the importance of the source of seed used and the need to correctly classify the material into various trials, all lines proposed for entry will be grown at the ICRISAT or ICARDA center for seed increase and will be included in the trials in the following year. It is hoped that this will ensure uniform and high seed quality for all trials.

Visits by ICRISAT/ICARDA Staff to Trial Sites

ICRISAT/ICARDA scientists visit as many trial sites as possible in order to develop a better understanding of local and regional problems and to interact with local cooperators. Obviously it is not possible to visit all test locations each year. In 1977–78, we visited 21 of the 63 locations to which ICRISAT trials were sent. During the same period 6 of 23 locations were visited where ICARDA nurseries were sent.

Data Collection, Analysis, and Publication

Cooperators are requested to forward the data books to ICRISAT or ICARDA for all trials received, including those not planted or which were partial or complete failures. Unfortunately, data have not been received from all locations in the past (Table 4). The importance of reporting data, even if the results are incomplete, cannot be overemphasized. The value of the trials to all cooperators will be increased greatly if all results are available for analysis.

The results received from all locations are combined for analysis to determine differences in adaptation of the entries over the test environments. Various analyses are conducted. The primary objective is to identify any entries with superior performance over all environments or in particular regions and locations. However, we also investigate the interrelationships among plant characters within each location, the phenotypic stability of entries over locations, and the degree of similarity of relative performance of the entries in the different locations. The last aspect is important in characterizing differences and similarities of locations for chickpea production, and this has impor-

Table 4. Numbers and percentages (in parentheses) of trials for which cooperators supplied data, 1975–78.

Year	ICCT-D	ICCT-K	ICSN-A, B	ICSN-C	ICMT
		ICRISAT			
1975–76 (winter)	13 (50)	0	0	0	0
1976 (summer)	3 (19)	4 (80)	0	0	0
1976–77 (winter)	11 (39)	9 (38)	26 (58)	4 (40)	0
1977 (summer)	1 (20)	5 (42)	0	0	0
1977–78 (winter)	24 (77)	13 (62)	29 (73)	6 (60)	2 (40)
1978 (summer)	0	3 (25)	0	2 (25)	0
		ICARDA			
	CRPYT	CRN	F_3		
1975	2 (67)	4 (40)			
1976	3 (38)	6 (40)			
1977	6 (67)	8 (40)	5 (50)		
1978	6 (50)	12 (85)	7 (70)		

See Table 1 for abbreviations.

tance in breeding and recommendation of cultivars. In this context, the full reporting of background information on the environmental and cultural conditions of each trial can assist greatly in establishing the causes of differences in line performance between locations.

A detailed report on the results of each international trial and nursery is compiled and published annually. These reports are distributed to all scientists interested in chickpea improvement. Results of the first and second ICRISAT international trials and nurseries have been published, and the third report is now available. Similarly, ICARDA is publishing reports of its international trials.

Results of the Trials

No attempt will be made here to summarize results of the international trials and nurseries, since these have been presented and discussed in detail in the various published reports. Rather, we will consider only the following two important aspects which arise from the results of these trials.

Identification of Superior Lines

Entries with superior performance at individual locations or over locations are identified and comparison is made over years for those entries common to more than one year of testing. Local and common check cultivars are used for comparison.

At most locations, substantial differences among the entries for seed yield have been identified, and this indicates that considerable opportunity exists for selection for local adaptation in most cases. However, entry × location interaction has been of major importance in trials grown to date, and relatively few entries have shown wide adaptation; that is, few have occurred commonly in the superior group of entries at several test locations. This infers that selection for high yield and broad adaptation will be difficult in chickpea.

In 1977–78, Annigeri, 73129-16-2-B-BP, 7384-18-5-B-BP, and P-127 in ICCT-DE; 7332-7-2-B-BH, BG-203, B-108, Pant G-113, and P-324 in ICCT-DL; and L-550, 7385-17-2-B-BH, 7347-6-4-B-BH, and 7358-8-2-B-BH in ICCT-K were the highest yielding lines when averaged over all locations. Of the lines common to 3 years of testing, P-436 and JG-62 in ICCT-DE and P-324, K-468, C-214, B-108, and P-436 in ICCT-DL had the greatest seed yields. P-436 has shown superior performance over years, both in ICCT-DE and ICCT-DL, indicating that it has some breadth of adaptation for both short- and long-duration environments. Based on the 2-year average for ICCT-K, L-550, GL-629, K-4, and P-2221 were the highest yielding entries.

In general, the ranking of entries common to 2 years of testing in ICSN-A, B, and C was similar, although specific exceptions existed. This suggests that 1 year of multilocation testing in the ICSNs should be sufficient for rejection of those lines with poor performance.

A number of lines exceeded the best check in each of the ICSN nurseries. The best checks were ranked 7th (JG-62 in ICSN-A), 18th (G-130 in ICSN-B), and 2nd (L-550 in ICSN-C) for mean seed yield over all test locations. The ranges of number of lines exceeding the best check by more than one or two standard deviations at the individual locations are listed in Table 5. Clearly, lines performing substantially better than the best check cultivar existed at each location. Entries 7310-26-2-B-BP, 7343-14-3-B-BP, and 7394-14-2-B-BP in ICSN-A; and 73111-7-2-B-BH, 7380-1-1-B-BH, 73126-6-2-B-BH, 737-18-B-BH, 7310-26-2-B-BH, and 7343-14-3-B-BH in ICSN-B had the greatest average yields across locations of all lines common to the 1976–77 and 1977–78 trials. In ICSN-C, although one line in 1976–77 and two in 1977–78 were marginally superior to L-550, none of these yielded higher than it in each of the years or on the 2-year average.

For the 1977–78 season, the CRPYT comprising 36 entries including checks was furnished to 12 locations representing six countries, five of which supplied complete data. While a detailed report will be prepared separately, a brief mention is made here. The yields of the best cultivars, the yields of the check, the number of cultivars exceeding the check, and the percentage of increase of the best cultivars over the check for each location are given in Table 6. The best yielding cultivars exceeded the local checks by a margin of 21 to 215%. The number of cultivars outyielding the local checks varied from 2 in Jordan to 33 in Algeria.

The results indicate the usefulness of the nursery in different countries of the region. In a few of the countries, the top yielding cultivars have been included in multilocation trials in national programs. For example, Syria has included a few entries in a Chickpea Regional Trial being conducted at five locations in the country. We have had a large number of requests (over 40) during 1978–79 for this nursery. Unfortunately, we could not meet all the demand, and some of our cooperators were disappointed.

Table 5. Ranges of number of lines exceeding the best check cultivar by one or two standard deviations (SD) at individual locations, ICSN trials 1977–78.

Margin of superiority	Ranges of number of lines for the test locations		
	ICSN-A	ICSN-B	ICSN-C
1 SD	2–10	1–13	2–11
2 SD	0– 5	0– 5	0– 7

Table 6. Performance of cultivars in CRPYT at different locations during 1977–78.

Country	Yield (kg/ha)		Cultivars exceeding check	Increase of best cultivar over check %
	Best cultivar	Check		
Algeria	1524	484	33	215
Jordan	1302	1073	2	21
Cyprus	1795	867	18	107
Tunisia	1786	1272	12	40
Syria	481	364	13	32
ICARDA (winter planting)	1607	1235	15	30
ICARDA (spring planting)	1837	932	29	97

Differences among Locations in Line Response

As indicated above, substantial entry × location interaction has existed in each of the international trials to date. This complicates discrimination among entries, because comparisons of performance become confounded with the environment of testing.

The interactions are complex and cannot be interpreted simply. One approach to interpretation is to search for similarities of relative performance of the entries in the different locations; that is, to characterize the environments of the locations in terms of the degree of similarity of the responses they elicited from the entries. In this way, it may be possible to identify groups of locations that are generally similar in their characteristics as far as chickpea performance is concerned. This could lead to rationalization of testing sites, since relative line performance could be extrapolated across those locations with some confidence, and this would allow more efficient experimentation and rapid capitalization on superior genetic material. Equally, the characterization of locations into subsets that elicit different responses of the entries must lead to definition of specific breeding objectives for particular target environments.

We have used the correlation coefficients of line performance for seed yield in the different locations to quantify the relative similarity of the locations in the ICCT-DE, ICCT-DL, and ICCT-K for 3 years. The results for the different trials were generally similar, and we will only consider the ICCT-DL results here. For this case, 13 test locations outside India and 5 within India were used over the 3 years, and 12 entries were common to all trials.

Correlation coefficients of line performance among the Indian locations are presented in Table 7. In most cases, there was little similarity of relative line performance for different years at the same location, and in some cases there were negative coefficients. There was no correlation of line performance between locations in the same year exceeding 0.70, and there was

Table 7. Correlation coefficients between locations of seed yields of 12 entries at five major Indian locations, ICCT[a] 1975–78.

	ICRISAT Center	Jabalpur	New Delhi	Pantnagar	Hissar
ICRISAT Center	0.70	0.36	−0.54	−0.06	−0.37
	ND	0.30	−0.32	0.18	0.14
	ND	ND	ND	ND	ND
Jabalpur	−0.13	−0.40	0.21	0.21	0.02
	to	−0.12	0.22	0.10	−0.24
	0.25	0.29	−0.05	ND	0.29
	−0.08	−0.45	0.33	0.21	0.64
New Delhi	to	to	0.05	−0.18	−0.02
	−0.43	0.82	0.02	ND	−0.12
	0.25	−0.24	−0.27	−0.21	0.16
Pantnagar	to	to	to	ND	0.49
	0.37	0.27	0.16	ND	ND
	−0.40	−0.37	0.05	−0.14	0.42
Hissar	to	to	to	to	0.05
	0.27	0.38	0.42	0.20	0.37

a. ICCT (1975–76), ICCT-D (1976–77), and ICCT-DL (1977–78).

ND = No data.

Note: The three sections of the table are as follows:

Diagonal:	top, 1975–76 vs 1976–77; middle, 1976–77 vs 1977–78; bottom, 1975–76 vs 1977–78.
Upper triangle:	top, 1975–76; middle, 1976–77; bottom, 1977–78.
Lower triangle:	range over different combinations of years 1975-76, 1976–77, and 1977–78.

marked inconsistency of association within different years. This was also true of line performance at different locations in different years

For the non-Indian locations, correlations of line performance in the different sites were generally very low, commonly negative, and the closest positive association (0.52) occurred between Colchagua, Chile and Tarnab, Pakistan Table 8.

The consistently low magnitude of association emphasizes the importance of entry x location interaction in these trials. The generality of this result for the three ICCT trials suggests that chickpeas exhibit marked and highly specific adaptation responses to environments. As indicated above, some lines have revealed some breadth of adaptation, but these clearly are exceptions.

For some data sets, closer degrees of association of line performance at different locations have been identified within regions of India. Within the south Indian area, generally similar relative performance of entries over locations within years has occurred in the ICCT-D 1976–77 and ICCT-DE 1977–78, particularly for ICRISAT Center, Gulbarga, Rahuri, and Junagadh (Table 9). Similarly, for northern Indian conditions, line performance at Hissar, New Delhi, and Ludhiana has been closely associated in some years. These similarities within regions need to be confirmed, but in general they support the decision by India to separate the advanced All India Gram (chickpea) Coordinated Varietal Trial into subzones for testing purposes.

These results indicate that, with the possible exception of India, we are presently unable to characterize groups of locations with respect to adaptation of chickpea. This is disturbing and requires further study. It implies that selection for local adaptation should be emphasized within the national programs in the short term, and that breeding activities by ICRISAT/ICARDA should emphasize improvement in local adaptation as well as multilocation testing and selection for broad adaptation. Aspects of this are discussed in the companion paper on breeding strategies (Byth et al., this workshop).

Adoption of Lines by Cooperators

Cooperators are encouraged to utilize superior test entries in local breeding work and to con-

Table 8. Correlation coefficients between locations of seed yields of 12 entries at 13 non-Indian locations[a], ICCT[b], 1975–78.

Location	1	2	3	4	5	6	7	8	9	10	11	12	13
1 Colchagua, Chile		0.02	0.45	0.12	−0.13	0.29	0.31	−0.20	−0.18	−0.48	0.40	0.23	0.52
2 La Platina, Chile			−0.17	0.06	0.06	0.05	0.32	−0.64	−0.03	0.11	−0.25	−0.01	−0.06
3 Ibb, U.A.R.				0.19	−0.35	0.13	0.20	0.08	−0.15	0.04	0.34	0.11	0.44
4 Debre-Zeit, Ethiopia					−0.36	0.03	0.29	−0.15	0.25	0.17	0.06	−0.16	0.16
5 Ed-Damer, Sudan						−0.02	−0.17	0.18	−0.07	−0.17	0.15	0.21	−0.24
6 D. I. Khan, Pakistan							0.40	0.02	0.08	0.02	0.03	0.24	−0.01
7 Faisalabad, Pakistan								−0.14	0.22	0.07	0.06	−0.09	−0.04
8 Parwanipur, Nepal									−0.16	0.16	0.06	0.18	−0.03
9 Feni, Bangladesh										0.00	−0.01	0.05	−0.08
10 Yezin, Burma											−0.25	−0.17	−0.03
11 Dokri, Pakistan												−0.16	0.06
12 Faisalabad, Pakistan													0.22
13 Tarnab, Pakistan													

a. Locations 1 to 7 in 1975–76, 8 in 1976–77, and 9 to 13 in 1977–78. b. ICCT (1975–76), ICCT-D (1976–77), and ICCT-DL (1977–78).

Table 9. Correlation coefficients between locations of seed yields of common entries[a] at four south Indian locations, ICCT[b], 1976–78.

	Gulbarga	Hyderabad	Junagadh
Rahuri			
1976–77	0.40	0.64	ND
1977–78	0.66	0.66	0.65
Gulbarga			
1976–77		0.44	ND
1977–78		0.70	0.49
Hyderabad			
1976–77			ND
1977–78			0.59
Junagadh			
1976–77			
1977–78			

a. 49 and 16 entries common to 1976–77 and 1977–78, respectively.
b. ICCT-D (1976–77) and ICCT-DE (1977–78).
ND = No data.

duct more extensive evaluation of selected individual lines locally. ICRISAT and ICARDA do not release cultivars in any country; however, any cultivar or line from these trials can be released by the national or regional program, the only stipulation being that the origin of the line should be acknowledged.

Most cooperators have reported the outstanding entries in the various international trials and nurseries. For example in 1977–78, the cooperator from Berhampore (West Bengal, India) reported that a desi line P-326(ICCT-DL) was well adapted for his area. The breeder from Ankara (Turkey) has included a kabuli line from ICSN-C, 7358-8-2-B-BH (L-550 × K-4), in advanced trials. Similarly, the cooperator at Akola (Maharashtra, India) has selected entries 73241-3-1-1P-LB-BP (Chafa × JG-61) and 73111-8-2-B-BP(850-3/27 × H-208) from ICSN-A for multiplication and inclusion in his advanced trials. Particular F_3 bulks have been found to be useful by cooperators in Syria, Pakistan, India, Burma, and Nepal.

Trial results from locations in India are summarized separately, and those breeding lines which perform best in the ICCTs and ICSNs are offered to the AICPIP for multilocation testing. In 1977–78, we proposed five entries ICCC-1 to ICCC-5, for the Gram Initial Evaluation Trial (GIET). Two of these, ICCC-4 and ICCC-2, have now been promoted to the GCVT. Eight new entries, ICCC-6 to ICCC-13, were offered for testing in GIET in 1978–79.

Although several lines furnished by ICARDA through regional nurseries have performed exceedingly well in a number of countries, adoption of those lines has generally been disappointing. The main reason for this is the lack of manpower and support for research on food legumes. Therefore, one of the major efforts has been to build up technical competence in the region through training programs. In several countries research on food legumes has been strengthened by ALAD/ICARDA trainees. ICARDA has been assisting countries in obtaining support from donors. IDRC is now supporting projects on food legumes in Turkey, Algeria, Egypt, and the Sudan.

Exchange of Visits

Cooperators are invited to annual meetings and occasional workshops that are held at each institute. This allows exchange of material, information, and ideas among cooperators and ICRISAT/ICARDA staff. Cooperators are encouraged to visit ICRISAT/ICARDA Centers to exchange ideas and to select material for evaluation and use in their specific environments. The selected material is sent to the cooperators soon after harvest. To date, we have held four

Breeders' Meets at ICRISAT, and similar meetings of food legumes breeders are planned at ICARDA. An international chickpea workshop was organized by ICRISAT in 1975 to identify priorities in chickpea research, the proceedings of which were published and distributed to chickpea workers internationally. A 6-day workshop to discuss common problems of food legume production was organized by ICARDA in May 1978. Proceedings of this will be published soon.

Future Development of Trials

Since an important purpose of distribution of the international trials and nurseries is to meet the needs of local programs, the types of trials made available must be adjusted to fit changing needs. In this context, one significant change has occurred in the past year. A decision was jointly taken by ICRISAT and the AICPIP to terminate the conduct of the ICCT trials in India and instead to channel elite lines through the All India Coordinated Trials.

Recent experimentation in the Mediterranean region has shown that considerable potential exists for winter planted chickpea, provided *Ascochyta* blight can be controlled or avoided. Further research is in progress, and if the current indications are confirmed, it is proposed to initiate a winter planted trial next season.

Multilocation replicated F_2 or F_3 bulk trials have been initiated for both desi and kabuli chickpea, the main objective being to determine the potential value of particular crosses and parents locally and regionally.

As indicated previously, any person or national program may nominate lines for entry into the various international trials and nurseries. This offers the opportunity for international multilocation evaluation and for wide dissemination of superior genetic material. To date, relatively few chickpea breeders have submitted lines for entry, and this is regrettable. We urge the fullest possible exploitation of the facilities now available for international evaluation.

An International Grain Legume Workshop held at ICARDA in 1978 identified a lack of information on appropriate agronomic practices as one of the major constraints in increasing the productivity of food legumes including chickpeas, in several parts of the ICARDA region. It was recommended that national programs in the region be encouraged and supported in generating the needed information. Therefore, ICARDA initiated in 1978–79 an international fertility plant population trial on kabuli type chickpea in the region with the aim of quantifying responses to application of starter nitrogen dressing, phosphate fertilization, and inoculation, and to determine optimum levels of plant population for different fertility levels. The cooperators have been provided with complete details of treatments and layout and the necessary supply of *Rhizobia* inoculant for the purpose. It is envisaged that studies of other agronomic aspects would be initiated in future.

Acknowledgments

We very much appreciate and acknowledge the contribution of chickpea breeders internationally for conducting these trials and nurseries over the years and sending the results for analysis and compilation. The substantial contribution of J. M. Green, Program Leader, Pulse Improvement, ICRISAT, and D. Byth, Consultant, University of Queensland, Australia in the preparation of this paper is acknowledged.

International Disease Nurseries

Y. L. Nene, M. P. Haware, and M. V. Reddy*

One of the major objectives of ICRISAT's Chickpea Improvement Program is to breed for disease resistance. It is important, therefore, to identify stable sources of resistance to serious diseases, and to do so, testing of promising material in widely different agroclimatic regions is essential. The first International Chickpea Cooperative Disease Nursery, 1976–77 was operated mainly to get feedback on the types of diseases prevailing in various chickpea growing countries. The nursery consisted of 31 entries that had been claimed resistant or tolerant to one or more diseases in some part or other of the world. Also included were some entries claimed to be superior, presumably because of tolerance to various stresses, including diseases. This multilocation testing was considered a logical step to initiate the cooperative effort so that all cooperators and ICRISAT pathologists could have an opportunity to critically look at some of the lines and cultivars that had been considered resistant or tolerant.

The nursery was sent to 16 locations in 6 countries, and data were received from 12 locations in 4 countries. The report is available separately. Of the 31 entries, three that merit special consideration are listed in Table 1.

After operating the "trial" nursery, we realized that *Ascochyta* blight is the major disease and that root rots and wilt are minor in some countries. The reverse is true in others. In a few countries, all three diseases are serious. Therefore, from 1977–78 we initiated two disease nurseries, i.e., the International Chickpea Root Rots/Wilt Nursery (ICRRWN) and the International Chickpea *Ascochyta* Blight Nursery (ICABN). These nurseries were initiated with three clear objectives:

1. To identify stable genetic sources with tolerance or resistance to various root rots, wilt, and *Ascochyta* blight;
2. To develop improved varieties that incorporate disease resistance;
3. To provide a convenient medium for the exchange of genetic material and information among cooperators.

International Chickpea Root Rots and Wilt Nursery

For 1977–78, the ICRRWN which contained 60 entries originating in 6 countries and from ICRISAT was sent to 27 locations in 12 countries. Although data books were received from 16 locations in 6 countries, results of only 10 locations in 4 countries could be considered. A report on this nursery is available separately (ICRISAT Pulse Pathology Progress Report 4). Entries that merit consideration are listed in Table 2.

Nine entries were found promising at 5 locations and 16 entries at 4 locations.

For 1978–79, the ICRRWN with 63 entries has been sent to 37 locations in 19 countries. The first results are expected in March 1979.

International Chickpea *Ascochyta* Blight Nursery

For 1977–78, the ICABN consisting of 24 entries originating in four countries and from ICRISAT was sent to ten locations in eight countries. Data books were received from six locations in four countries. At one location, disease did not develop and hence results from five locations were analyzed. A report on this nursery is also available separately (ICRISAT Pulse Pathology Progress Report 4). Entries that merit consideration are listed in Table 3.

In the ICABN for 1978–79, 46 entries have been sent to 13 locations in 9 countries. Now that an ICRISAT sponsored chickpea breeder has been positioned at ICARDA, we propose to operate ICABN through ICARDA from 1979–80.

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* Principal Pulse Pathologist, and Pulse Pathologists, ICRISAT.

Table 1. Promising entries in the first International Chickpea Cooperative Disease Nursery, 1976–77.

ICC No.	Pedigree	Remarks
4935	C-235	Tolerant to *Ascochyta* blight (AB) at Ankara (Turkey) and to root-knot nematodes at Ludhiana (India).
7519	12-071-10050	Tolerant to AB at Ankara and Eskisehir (Turkey).
8933	WR-315	Resistant to wilt at Kanpur, Jabalpur, and ICRISAT (India). Susceptible to other soil pathogens at most locations. Susceptible to powdery mildew at Karaj (Iran), to rust at Debre-Zeit (Ethiopia), and to stunt at Hissar (India). Susceptible to AB at all locations.

Table 2. Promising entries in ICRRWN, 1977–78.

ICC No.	Pedigree	Locations where found promising against root rots and wilt
788	P-623	Berhampore, Hissar, Ludhiana, Gurdaspur, and Varanasi (India); Ethiopia; U.S.A. (7 locations out of 10)
858	P-678	Berhampore, Hissar, ICRISAT, Ludhiana, Gurdaspur, and Varanasi (India); Ethiopia; U.S.A. (8 locations out of 10)
1443	P-1265	Hissar, Hyderabad, Ludhiana, and Varanasi (India); Ethiopia; U.S.A. (6 locations out of 10)
1450	P-1270	Berhampore, Hissar, Ludhiana, Gurdaspur, and Varanasi (India); Ethiopia (6 locations out of 10)
1967	P-1590	Berhampore, Hissar, Ludhiana, and Gurdaspur (India); Ethiopia; U.S.A. (6 locations out of 10)
6671	NEC-790	Hissar, Ludhiana, Gurdaspur, and Varanasi (India); Ethiopia; U.S.A.; Yemen Arab Republic (7 locations out of 10)
6761	NEC-920	Hissar, Ludhiana, Varanasi, and Kanpur (India); Ethiopia; U.S.A. (6 locations out of 10)
7777	NEC-1639	Hissar, ICRISAT, Ludhiana, and Varanasi (India); Ethiopia; U.S.A. (6 locations out of 10)
8250	NEC-2413	Hissar, Ludhiana, Varanasi, and Kanpur (India); Ethiopia; U.S.A. (6 locations out of 10)

Table 3. Entries resistant to *Ascochyta* blight in three or more locations in 1977–78.

ICC No.	Pedigree	Locations where found promising against *Ascochyta* blight
1903	P-1528-1-1-1	Ethiopia; Latakia and Tel Hadia (Syria); Tunisia; Eskisehir (Turkey) (all 5 locations)
4935	C-235	As above
5127	F-8	Ethiopia; Latakia and Tel Hadia (Syria); Eskisehir (Turkey) (4 locations out of 5)
7520	12-071-10054	As above
4939	F-61	Ethiopia; Latakia (Syria); Tunisia (3 locations out of 5)
7513	12-071-05132	Ethiopia; Latakia and Tel Hadia (Syria) (3 locations out of 5)
7514	12-071-05093	Latakia and Tel Hadia (Syria); Eskisehir (Turkey) (3 locations out of 5)

Problems Encountered

For ICRRWN, uniform "sick plots" are not available. Enough facilities to produce *Ascochyta* blight artificially, if necessary, are not available at all locations because of local difficulties; cooperators are unable to follow the design suggested; sometimes seed does not reach the destination or arrives very late; and reports are received late and this results in the omission of some promising entries in the next season's nursery. Reports from some locations are not received.

Session 1 – Breeding Strategies

Discussion

Byth et al. Paper

R. M. Shah

What is more rewarding — attempting a greater number of crosses and rejecting on the basis of F_1 performance, or making fewer crosses and carrying all of them in F_2 and then making selections? Give reasons to support your opinion.

J. M. Green

Where resources are limited, I prefer carrying all crosses made to F_2 and then selecting among crosses, preferably on the basis of replicated F_2 tests, for crosses to advance. Where resources permit a large number of crosses to be made, very poor F_1s can be discarded on a visual basis and F_2 populations can be compared for mean yield. Probability of successful selection for yield will be increased if (1) critical comparison of a large number of crosses is made in early generations and (2) the number of crosses advanced is reduced so the number of derived lines per cross can be increased.

M. C. Kharkwal

This is with reference to future breeding strategies. I would like to comment that in pulse crops in general, and chickpeas in particular, mutation breeding offers a large scope for improvement of various characteristics, such as yield, plant type, and disease resistance. I wonder if ICRISAT/ICARDA can afford to ignore this potential tool altogether in their future strategies of chickpea breeding.

J. M. Green

We recognize the potential value of mutation breeding but think that our priorities should be on utilizing existing variability, which is considerable. We are following with interest a study of mutation breeding currently in progress at Haryana Agricultural University, and will continue to consider mutation breeding as an option as our program progresses.

T. S. Sandhu

The lines in F_4 or F_5 giving yields 150% of the moving average of the check generally come down to about 15% higher yield or even less in regular large scale yield trials. Probably wider spacing used as a matter of necessity during the selection process may be the underlying factor. What can we do in this respect?

J. M. Green

Certainly we have observed more realistic differences when lines are evaluated in replicated tests. We consider the large yield advantages observed in single unreplicated plots compared with a nearby check result from random effects. In the ICRISAT program, F_2 and F_3 generations were space planted, while F_4 and more advanced generations were grown at crop density.

R. B. Singh

1. In your Table 9 and other tables, the female parents are usually H-208 or 850-3/27. If so, it would be better to make use of these elite parents randomly as male or female parents (considering no maternal effect) to avoid the problem of narrow cytoplasmic base.
2. Keeping in view low heritability of yield and high instability, the bulk method or the single-seed descent (provided adequate F_2 plants are sampled) method coupled with multilocation testing should be preferred over routine pedigree method.

J. M. Green

1. Your point is well taken. However, H-208, for example is listed first only because it was the common parent. Crosses are made reciprocally, and reciprocals are often bulked in F_2.
2. Thank you for your support.

S. Chandra

In keeping with the ICRISAT policy of not releasing a named line and in consonance with its ability to provide genetic materials to breeders for local selection, would it not be worthwhile to pile up genetic diversity in different types of crosses and pass on early generation materials to respective breeders? This might avoid problems with supply of homogeneous lines that have failed to perform well at such stations.

J. M. Green

Our proposed program is intended to provide a broad spectrum of genetic diversity to local programs. However, we will necessarily be providing F_6 generation by the time we have an adequate increase of seed for distribution. These lines will be bulks of F_4 derived lines, which will permit profitable reselction within and among lines. Since this material will have been subject to mild selection at one location, we will not expect a high percentage of superior lines at any given location. The real advantage to the local program is in having near homozygous material in which to select. We do, however, fill requests for material in any generation desired.

M. C. Kharkwal

Isn't mutation breeding overlooked at ICRISAT?

J. M. Green

No blight resistance was found after considerable mutation breeding efforts by Dr. Abdullah Khan, Lyallpur.

S. Chandra

Is it some sort of coincidence that "despite the projected use of bulk pedigree and bulk method at ICRISAT, almost all breeding was handled using the pedigree method" or were there some reasons that necessitated this change?

J. M. Green

This question should be referred to K. B. Singh, who was in the program at that time.

K. B. Singh

The bulk pedigree method was proposed in 1975 with a view to handle long-duration material, and the pedigree method was to be used for short-duration material. After the site at Hissar was available, the entire material was handled by the pedigree method. We believe the pedigree method is more effective and can produce results more quickly than the bulk method.

van der Maesen et al. Paper

R. C. Misra

Temperature and moisture are important with regard to earliness and lateness.

L. J. G. van der Maesen

These are mentioned in the document that introduces evaluation of chickpea germplasm at ICRISAT. The document is issued as a prepublication.

Singh et al. Paper

D. C. Erwin

I wonder if the lack of correlation between performance of varieties at different locations could be due to the variation in inoculum levels of different pathogens? If so, root pathogens could be limiting factors that confound yield results.

J. Kumar

We do get data on plant stand and disease ratings from various locations. In earlier years, not many locations reported damage by root diseases. Although minor variation in plant stand of chickpeas may not make much difference, we agree that this cannot be ignored as a factor in line performance.

P. N. Bahl

In order to quantify the relative similarity of the location, we may choose those cultivars showing maximum entry × location interaction and then run rank correlations (based on relative yield ranking of cultivars at different locations).

J. Kumar

The 12 entries that were common to 3 years of testing showed considerable entry × location interactions. We ran rank correlations in addition to those on actual yield. There was general similarity of values.

L. Singh

Lack of correlation for performance, between and within locations, is caused by two factors compounded together:

1. Management of conduct of trials under rainfed conditions.
2. Location effect.

There is need for a standardization of test practices under rainfed conditions.

J. Kumar

The Indian locations for which correlations were reported have fairly well managed trials, and in northern India pre-sowing irrigation is generally given to ensure good stands. If we standardize cultural practices for these trials, I wonder how will the results of these be relevant to particular areas.

Nene et al. Paper

J. S. Grewal

ICC 5127 was infected by *Ascochyta rabiei* in India as early as the 1950s, but it has been found to be free from blight at Eskisehir in Turkey in 1977–78. Blight-resistant ICC-1903, however, has shown disease reaction 2 or 3 in Turkey. Should I presume that physiologic races of *A. rabiei* in Turkey are different from those in India. Or are there any other reasons?

Y. L. Nene

We know nothing about the existence of physiologic races of *Ascochyta rabiei* in Turkey. The possibility of the existence of races very definitely exists. As we go along, I am sure we will gain more knowledge on this aspect.

J. S. Kanwar (*to all breeders*)

Do breeders agree on F_3 testing?

L. Singh

Breeders would like to get an indication of superior crosses as early as possible. Since multilocation testing in F_1 is not feasible, and even in several cases in F_2, perhaps F_3 multilocation testing is the best bet.

J. Kumar

We have a trial of 50 F_2 bulks grown at seven locations, and I have visited four. There are considerable differences among entries at two of the four sites. As an international institute, we wish to test a number of such bulks at many different sites and supply the best ones to local breeders on the basis of multilocation performance.

J. S. Sindhu

Chickpea line 850-3/27 evolved at Kanpur has been released and named as K-850. It is a happy note that this line is being used quite extensively as a parent in most of the hybridization programs at ICRISAT, and for convenience only, henceforth this line may be referred to as K-850.

M. V. Reddy

Differential reaction of the parents involved in the progenies to diseases tested at Hyderabad and Hissar appears to be the major factor for lack of correlation. Parents with good levels of resistance have given progenies with stable yields.

Session 2

Yield Improvement through Kabuli-Desi Introgression

Chairman : Laxman Singh
Co-Chairman: I. H. Najjar

Rapporteur: S. C. Gupta

Kabuli-Desi Introgression: Problems and Prospects

G. C. Hawtin and K. B. Singh*

The value of crossing between divergent subgroups within a species has been recognized by plant breeders for some time. Much of the success of the Corn Belt dent maizes, which were so widely grown before the introduction of hybrid varieties, has been attributed to the natural introgression of genes from the white southern dents, thought to have originated in Mexico, and the American Indian northern flints. The heterosis that frequently results from crossing between inbred lines from different geographic origins has been made use of repeatedly by breeders in the production of hybrid and synthetic varieties. In Kenya, for example, a significant breakthrough in yield was achieved in the mid 1960s following the development of hybrid varieties based on crosses between local synthetic varieties and lines introduced from Ecuador in Latin America (Harrison 1970).

A similar story has been reported in the case of sorghum (Doggett 1970). The cultivar Martin, the most widely grown grain sorghum in the United States up to the release of hybrids in 1956, was selected from the variety Wheatland, which in turn originated for a Kafir × Milo cross made in 1919. Studies on hybrid vigor in sorghum have indicated that, in general, heterosis for yield is greatest following crosses between different types, e.g., Milo's with grain sorghums such as Kafirs from southern Africa, Feteritas from East and West Africa and Sudan, and Kaoliangs from China, and with broom corn. Most modern grain sorghum hybrids in the United States are based on Kafir × Milo crosses.

In addition to crossing between genetically divergent groups for increased heterosis, which in turn may or may not become fixed through selection, it has frequently been the case that one group may contain genes for particular characters that might usefully be transferred to another group within the same species. It is this possibility, rather than increased vigor alone, that has stimulated much of the recent interest in hybridization between two-row and six-row barleys. Attempts are being made by breeders to transfer the tillering capacity of two-row barleys into the six-row type and to transfer earliness in the opposite direction. In crosses between winter and spring wheats, considerable success has been achieved in transferring the drought resistance of the winter into the spring types. Two features of drought resistance in the winter wheats that are not present in the spring wheats are a deepset crown (leading to stronger secondary root development), and the ability to withstand atmospheric drought without reaching the wilting point.

In the reverse direction, spring wheats may act as a source of genes for disease resistance that is lacking in the winter wheats.

In both the ICARDA (previously ALAD) and ICRISAT breeding programs, the first wide crosses within chickpea were made both to transfer specific characters between groups and in the hope that the introgression of "yield" genes from substantially different genetic backgrounds might produce transgressive segregants for high yield. While the usefulness of the scheme for yield improvement per se in chickpea is still open to question, there is no doubt that the subgroups within *Cicer arietinum* have many characters that can usefully be transferred to each other.

Intraspecific Classification in Chickpea

Many attempts have been made to describe subgroups within the species *Cicer arietinum*. A historical review of these systematics has

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* Leader and Plant Breeder (Chickpea), respectively, Food Legume Program, ICARDA.

been given by van der Maesen (1972) starting with the classifications of Jaubert and Spach who recognized three varieties: *vulgare, rytidospermum*, and *macrocarpum*. He, van der Maesen, based his own classification on the work of Popova who recognized four subspecies (*orientale, asiaticum, mediterraneum*, and *eurasiaticum*), which were further subdivided into 13 proles (subraces) and 64 varieties.

Systems of intraspecific classification based on geographic systems are complicated by ancient and recent exchanges of materials and hybridization. Recognizing this problem, van der Maesen proposed a system for general use based entirely on seed characters. In this classification he recognized ten types.

Recently, intraspecific classification has been the subject of attention by Moreno and Cubero (1978) who presented data taken on a collection of 150 lines from major chickpea growing regions throughout the world. They undertook a series of analyses, on 23 characters, and reported the existence of two complexes within the cultivated chickpea, which they designated *macrosperma* and *microsperma*. Of the metrical characters studied, pod length, pod width, and seed size all showed a clear bimodal distribution, while other characters (e.g., leaflets per leaf, leaflet size, and number of primary branches) showed a tendency toward bimodality or a clear unimodal distribution (e.g., rachis length, pods and seeds per plant, and seeds per pod). They described the two groups as follows:

> *Microsperma* groups, populations, and cultivars with small pods (less than 23 mm long), small seeds (weight less than 0.35 g), small leaves (rachis length less than 4 cm), and small leaflets (length less than 12 mm). The seeds show a great diversity of colors, forms, and reliefs with 1–3 seeds per pod. A high frequency of colored flowers and vegetative organs characterizes this race.
>
> *Macrosperma* groups, populations, and cultivars with big pods, seeds, leaves and leaflets. Seeds are mainly white, pinkish, reddish or black, but other colors exist at low frequencies. Seeds are strongly sheepheaded, in most of the cases with a rough coat and low in number of seeds per pod. High frequency of white flowers and colorless vegetative organs occur.

They indicated that the *microsperma* group can be found throughout the range of geographic distribution of the species but is very scarce in western Mediterranean countries where *macrosperma* types predominate.

The system proposed by Moreno and Cubero (1978) has a certain taxonomic merit and goes some way toward putting the intraspecific classification of chickpea on a sound scientific basis. Certain problems still exist, however, especially in relation to the types common throughout much of North Africa, Egypt, Sudan, western Asia, and Afghanistan and to the types commonly referred to as kabuli in India. These types were poorly represented in the 150 entries of Moreno and Cubero (only 17 originated in eastern Mediterranean countries), and their relative absence may have biased the results. Table 1 shows mean seed sizes for certain entries in the ICARDA germplasm collection, originating in this region. Almost all the entries are light beige in color, some with a pinkish or slightly darker tinge, a characteristic "sheephead" or "brain" shape, white flowers, and no anthocyanin pigmentation in the vegetative parts.

In many respects, therefore, these types have much in common with the *macrosperma* group. As can be seen from Table 1, however, samples from many countries have a mean seed weight of less than 35 grams per 100 seeds, with individual samples being less than 10 grams per 100 seeds. Clearly, many of these types are intermediate between *macrosperma* and *microsperma*, as defined by Moreno and Cubero.

Until these types have been examined further in genetic and biosystematic studies, the system commonly used by many breeders of dividing chickpea into kabuli and desi types is probably still the most useful. There is a fairly clear distinction between the two types, which is generally agreed upon by breeders but is difficult to define systematically. This distinction is based almost entirely on seed shape and color but also takes account of geographical origin and uses. A third group having round pea-like seeds with the characteristic *Cicer* beak, is also to be found in world collections. These are comparatively rare in local markets, but are frequent in breeding programs following kabuli × desi crosses. Such round-seeded types (which may be any color from light beige to black, including green) are generally desig-

Table 1. Seed size of entries, selected at random from the ICARDA kabuli collection and originating from various countries of West and Central Asia and North Africa.

Country	No. of samples	Mean 100-seed weight (g)	Range in 100-seed weight (g)
Afghanistan	6	19.9	14.5–28.3
Algeria	10	36.1	23.2–43.9
Egypt	10	13.7	9.7–27.7
Iran	10	23.1	14.2–34.8
Iraq	10	32.6	25.3–37.3
Jordan	10	29.1	16.0–35.0
Lebanon	10	29.9	18.6–41.6
Morocco	8	33.6	28.0–39.9
Sudan	3	10.4	9.6–11.0
Syria	10	37.6	27.1–41.2
Tunisia	10	37.2	27.2–42.3
Turkey	10	32.3	23.7–40.3

nated "intermediate" or "pea" types by breeders.

Since it is not proposed to discuss intraspecific classification in detail in this paper, but rather to consider the breeding implications of crossing between divergent subgroups, the terms kabuli, desi, and intermediate will generally be used.

Kabuli and Desi Gene Pools

Within *C. arietinum*, it is generally considered that the kabuli group originated by selection from the more primitive desi. The divergence probably occurred in comparatively recent times and almost certainly in the Near East or Mediterranean region. Moreno and Cubero (1978) hypothesized that the basis of the selection was white flowered plants (and its correlated colorless seed), which appeared as a mutant in the local *microsperma* populations. In view of this, they suggested that the *macrosperma* group has very few starting points, which may account for its relatively narrow gene pool compared to the *microsperma* group. The study of Moreno and Cubero certainly indicated that genetic variation within *macrosperma* was less than in *microsperma* in the samples analyzed. In view of the arguments outlined in the section on classification, however, it is highly questionable whether this is also necessarily true if one considers the full range of kabuli versus desi types. This commonly held view may reflect to a large extent the greater amount of work that has been done on collecting and describing the variation in desis, especially in the Indian subcontinent. Now, with greater emphasis being put on the genetic improvement of kabulis in the Mediterranean region and elsewhere, it is probable that this view will change. As an example of this, the ICABN nursery of ICRISAT contains only desi types, reflecting the preponderance of desis in the collection. When 1200 kabuli accessions were screened in the field at Aleppo in 1978, 40 kabuli entries from diverse geographical origins were identified as having *Ascochyta* blight resistance, of which 37 were reconfirmed as resistant this year.

Whatever the extent of the respective gene pools, it is certainly true that each group has certain characteristics that might usefully be transferred to the other. The kabuli group, for example, in addition to having a greater range in seed size, tends to have more primary branches, greater cold tolerance, a more upright and in some cases taller growth habit, and greater resistance to chlorosis caused by a shortage of available iron in the soil. Desis, on the other hand, tend to have a bushier growth habit, more seeds per pod, more pods per plant, and greater tolerance to drought and heat. A number of specific characters have also been identified in the desi background, such as double-podding and resistance to wilt and salinity. However, the presence of the latter characters in the desi background, may again merely reflect the greater research input on this group.

Genetics of Kabuli and Desi Types

Several attempts have been made to look for cytogenetic differences between kabuli and desi types. Ladizinski and Adler (1976) reported that when red flowered cultivars of *C. arietinum* were crossed with *C. reticulatum*, meiosis was normal and the hybrids fertile. However, in a cross between a white flowered cultivar and *C. reticulatum*, a quadrivalent, anaphase I bridge and fragment were found at meiosis, resulting in low pollen fertility and no seed set in the F_1. This has been taken to indicate chromosome repatterning within *C. arietinum*; however, Ladizinski and Adler did not indicate whether or not the white flowered cultivar was a true kabuli.

In a study of crossability between groups, Martinez et al. concluded that cytogenetic differences are of little importance in preventing crossing. They reported average success rates of 14.9, 15.8, and 13.6% for *macrosperma* × *macrosperma*, *microsperma* × *microsperma*, and *macrosperma* × *microsperma* crosses, respectively. They concluded that the variances were large enough to cover the differences between these figures. Large differences in success were reported, however, between individual crosses, but this depended on the specific genotypes involved and was not related to either the botanical group or geographic origin of the parents. Experience at ICRISAT, at both Hissar and Hyderabad, has led to the somewhat different conclusion that, at least in those environments, crossing is more successful when the desi parent is used as the female. Kabuli × kabuli and kabuli × desi crosses are generally less successful. Clearly, further studies are required on this.

Little work has been done on the genetics of kabuli vs desi chickpeas. Martinez et al. (1979) reported the results of three sets of diallel crosses (one within *macrosperma*, one within *microsperma*, and one involving lines from both groups) and concluded that, in general, characters that can be considered primitive, such as small leaflets, leaves, pods, grains and high seeds per pod, tended to be dominant.

Table 2 summarizes some data on the segregation into kabuli vs desi and intermediate types in F_2 populations following crosses between kabuli and desi parents. The F_2 plants were classified into the two types based on the visual appearance of the F_2–F_3 seed. As can be seen in the table, the average of recovery of true kabuli seeded types in the F_2 was 16%. Considerable variation between different populations was recorded, however, ranging from less than 6% to over 22%.

In order to study the recovery of kabuli types in the F_3 generation, F_2 and F_3 bulked seed from seven of the populations was divided into kabuli, intermediate, and desi types and was planted out. Table 3 shows the recovery of

Table 2. Numbers and percentage of plants classified as kabuli and intermediate/desi types in F_2 populations of kabuli × desi origin.

Cross	No. of F_2 plants tested	Kabuli		Intermediate and desi	
		No.	%	No.	%
X74IC 1	112	14	12.5	98	87.5
X74IC 5	112	25	22.3	87	77.6
X74IC 10	86	16	18.6	70	81.4
X74IC 21	86	15	17.4	71	82.6
X74IC 22	52	3	5.8	49	94.2
X74IC 32	69	13	18.8	56	81.2
X74IC 33	74	7	9.5	67	90.5
X74IC 43	33	7	21.2	26	78.8
Total	624	100	16.0	524	84.0

kabuli types from each of the three groups. Over 80% of the types classified as kabuli in F_2 gave rise to kabuli progenies in the next generation. Neither of the types classified as intermediate or desi in F_2, however, produced many kabuli segregates in the F_3 and tended, as the kabulis, to breed true.

While the figures in Tables 2 and 3 may be biased due to the somewhat arbitrary nature of the classification method, the trend is very clear and indicates both the low recovery of kabuli types in the segregating generation following a kabuli × desi cross and the speed at which the seed characters are to a large extent "fixed."

The study was taken a stage further in three populations in which F_2 and F_3 seeds classified as intermediate were further subdivided into those closest to the kabuli end of the spectrum (near-kabuli) and the remaining intermediate types. The recovery of kabuli types in the F_3 following this separation is shown in Table 4. As can be seen, 41.9% of the group classified as near-kabuli in F_2 were classified as kabuli in the F_3. Although this figure may be inflated due to classification problems, recovery of kabuli types in the other two F_2 classes was clearly very small. It can thus be concluded that in a program aimed at the improvement of kabulis, there is little point in retaining intermediate and desi types beyond F_2, with the possible exception of those intermediate types having characteristics very close to true kabulis.

The recovery of true desi types in segregating populations is also comparatively low, the major portion of the segregates falling into the intermediate category. Data are not available on this at present, but it is expected that a picture similar to that which has been found in the kabulis would emerge.

Unfortunately, data are also not yet available on the effects of backcrossing or three-way crossing on seed characters. It is to be expected, however, that backcrossing or three-way crossing to kabulis would greatly enhance the recovery of kabuli types, and vice versa for the desis. Backcrossing also has other important implications in relation to kabuli × desi introgression, and these are discussed in the next section.

In the absence of a backcross or three-way cross, F_2 populations should be sufficiently large to allow adequate gene recombination for

Table 3. **Numbers and percentages of plants classified as kabuli and intermediate/desi types in F_3 bulks of kabuli, intermediate, and desi types in F_2. (Means of 7 crosses).**

		F_3 plants			
		Kabuli		Intermediate/desi	
F_2 class	Total no. tested	No.	%	No.	%
Kabuli	281	228	81.7	51	18.3
Intermediate	344	44	12.8	300	87.2
Desi	370	33	8.9	337	91.1

Table 4. **Numbers and percentages of plants classified as kabuli and intermediate/desi types in F_3 bulks of kabuli, intermediate, and desi types in F_2. (Means of 3 populations).**

		F_3 plants			
		Kabuli		Intermediate/desi	
F_2 class	Total no. tested	No.	%	No.	%
Near-kabuli	43	18	41.9	25	58.1
Intermediate	165	14	8.5	151	91.5

characters other than seed quality to occur within the small proportion of the total population having the desired quality. Kabuli and near-kabuli types, or desi and near-desi types, can be mass selected in the F_2 for subsequent evaluation and selection in the F_3 and later generations.

Kabuli × Desi Introgression for Increased Yield

Although cultivars commonly grown throughout the Mediterranean and West Asia region are kabuli, several desi types (originating mainly in Iran) have been found to perform very well in the region, especially under spring planting conditions. Table 5 shows the yield and other attributes of the top entries in advanced yield trials grown at Aleppo in the 1977–78 season. In the winter planted trial the top two entries were kabuli, whereas in the spring (the normal planting time in the region), the top two were desi. This may be attributed, at least in part, to a greater heat tolerance in the desis, although a desi entry was also ranked third in the winter trial.

In the Chickpea Regional Preliminary Yield Trial (CRPYT) conducted in the 1977–78 season, 8 out of the 35 entries supplied were desi; the rest were all kabuli. Data received from eight locations in six countries showed that four of the top five entries with the highest mean yield over all locations were desi types.

The transfer of kabuli seed characteristics into the genetic background of these desis, or conversely, the introgression of "yield" genes into the kabuli background, might reasonably be expected to result in the development of superior kabuli cultivars for West Asia.

Apart from the hope of raising kabuli yields through hybridization with already superior yielding desis, the original intergroup crosses were made in the hope of obtaining transgressive segregates, based on the theory that such segregants are most likely when crossing between diverse gene pools.

Auckland and Singh (1977) reported that transgressive segregation with respect to growth habit, seed size, pod number, and yield was greater in populations involving both kabuli and desi parentage than in populations involving only desis. Apart from this report, however, there is little evidence for widespread transgressive segregation following kabuli × desi crossing.

Studies conducted by ICRISAT at both Hyderabad and Hissar in the 1975–76 and 1976–77 crop seasons have indicated, in general, that F_2 populations involving 100% desi in their parentage were evaluated as promising more frequently and discarded less frequently than populations containing a portion of kabuli genes. This is shown in Table 6 (adapted from 1976–77 ICRISAT Chickpea Breeding Annual Report) which summarizes the data for three-way crosses having 100%, 75%, 50%, and 25% of desi genes in their parentage.

Progenies of single plants selected in the promising F_2 populations were rated in the F_3, and in general, little overall difference was found with respect to the percentages rated promising or discarded between those with and without kabuli genes in their background (Table

Table 5. Origin, yield, and seed type of the three highest yielding entries in the advanced yield trials planted in winter and spring, Aleppo, 1978.

Pedigree	Country of origin	Yield kg/ha	Rank	Seed type	100-seed weight (g)
Winter planted					
74TA 528	Turkey	1852	1	Kabuli	33
74TA 60	Iraq	1806	2	Kabuli	28
75TA 16947	Iran	1769	3	Desi	27
Spring planted					
74TA 1619	Iran	1442	1	Desi	21
74TA 1629	Iran	1252	2	Desi	24
NEC 293	Turkey	1233	3	Kabuli	33

7). The general conclusion to this study was that there was little to be gained from the introgression of kabuli genes into the desi background for the improvement of desis in the Indian subcontinent.

Both in India and West Asia, however, the current indications are that kabuli × desi introgression might prove of great value in the improvement of kabuli types rather than desis. At ICRISAT in 1976–77, F_4 progenies were evaluated for yield at both Hissar and Hyderabad, and the best 29 kabuli entries were entered in the international testing program for the 1977–78 season. Of these top 29 progenies, 20 originated from kabuli × desi crosses.

The Indian cultivar L-550 was originally released in Punjab in 1973 and subsequently released by the All India Variety Release Committee in 1975. This cultivar, renowned for its wide adaptation, originated from a desi × kabuli cross made at Ludhiana.

In 1977 in Aleppo, 190 F_2 populations were rated on a 1–5 scale for overall growth and yield characteristics, where 1 indicated the most promising and populations rated 5 were discarded. The results are shown in Table 8. Based on the information in this table, it would appear at first glance that kabuli × desi crosses were considered less promising than kabuli × kabuli crosses. When the figures were considered on the basis of the origin of the parents, however, a somewhat different picture emerged, as shown in Table 9. When both parents originated in West Asia, the F_2 populations were very promising; in fact, it appeared that overall, the origin of the desi parent had a greater influence on the performance of the F_2 than did the origin of the kabuli. While this last point certainly requires

Table 6. Number of F_2 populations involving various proportions of desi (D) and kabuli (K) genes evaluated as promising (PR) and those discarded (DIS). The data are totals for the 1975–76 and 1976–77 seasons.

Percentage of genes		No. of F_2 populations					
		Hyderabad		Hissar		Total	
D	K	PR	DIS	PR	DIS	PR	DIS
100	0	33	89	64	58	97 (40)[a]	147 (60)
75	25	13	44	15	26	28 (29)	70 (71)
50	50	13	42	26	42	39 (32)	84 (68)
25	75	4	33	9	14	13 (22)	47 (78)

[a] Figures in parentheses are percentages. Adapted from ICRISAT Chickpea Breeding Annual Report, 1976–77.

Table 7. Number of F_3 progenies involving various proportions of desi (D) and kabuli (K) genes evaluated as promising (PR) and those discarded (DIS). The data are totals for the 1975–76 and 1976–77 seasons.

Percentage of genes		No. of F_3 progenies					
		Hyderabad		Hissar		Total	
D	K	PR	DIS	PR	DIS	PR	DIS
100	0	78	946	67	259	145 (11)[a]	1205 (89)
75	25	15	129	11	54	26 (12)	183 (88)
50	50	5	28	6	27	11 (17)	55 (83)
25	75	22	282	23	151	45 (10)	441 (90)

[a] Figures in parentheses are percentages. Adapted from ICRISAT Chickpea Breeding Annual Report, 1976–77.

further study, the question of adaptation of the parents seems to be of far greater significance in the cross performance than merely whether they were of kabuli or desi origin. A similar picture emerges if we look at the origin of the kabuli parents in kabuli × kabuli crosses, as shown in Table 10.

The question of adaptation in chickpea and its implications in chickpea breeding was discussed briefly by Auckland and Singh (1977). They reported that, when F_2 populations of crosses involving Indian desi × Indian desi parentage were grown in Lebanon in 1975, there was little phenotypic variability and the plants were all of short stature and gave low yields. It was not possible to select individual plants from these populations. Within F_2 populations of kabuli × desi crosses, however, and to a lesser extent within Indian desi × Iranian desi crosses, they reported that large phenotypic differences were observed and "single plant selection could be carried out with impunity." They hypothesized that if adaptability is important in chickpea, a superior cultivar for East Asia would be produced by a (kabuli × desi) × desi backcross and for West Asia by a (kabuli × desi) × kabuli backcross. Some evidence for this was provided by two reciprocal backcrosses involving the cultivars F-378 (an Indian desi) and Rabat (a Moroccan kabuli). The two populations were grown contiguously. All the plants within these two backcrosses were harvested, and individual plant seed yield was recorded. The results are given in Table 11 and show clearly the advantage of the backcross to the kabuli in the West Asian environment. From each F_2 backcross population, the 15 highest yielding, 15 lowest yielding, and 15 random plants were selected. The results of this are given in Table 12. As expected, the backcross to the desi

Table 8. Performance of F_2 crosses, grown in Aleppo, 1977.

Type of cross	No. of crosses	Mean rating[a]	Mean no. of plants selected
Kabuli × Kabuli	23	2.2	5.6
Kabuli × Desi	146	3.2	2.5
Desi × Desi	21	3.4	0.5

a. 1 = Most promising, 5 = Least promising.

Table 9. Rating of F_2 populations of kabuli × desi crosses from West Asian and exotic parents, grown in Aleppo, 1977.

Origin of kabuli parent	Origin of desi parent	No. of crosses	Mean rating[a]	Mean no. of plants selected
West Asia	Iran	6	1.7	5.7
West Asia	India	61	3.2	2.3
North and North East Africa	Iran	5	1.6	6.0
North and North East Africa	India	61	3.4	2.0

a. 1 = Most promising, 5 = Least promising.

Table 10. Rating of F_2 populations of kabuli × kabuli crosses from parents of different origins, grown in Aleppo, 1977.

Origin of parents	No. of crosses	Mean rating[a]	Mean no. of plants selected
West Asia × West Asia	4	1.5	6.25
West Asia × Exotic[b]	11	2.0	6.6
Exotic × Exotic[b]	8	2.9	3.9

a. 1 = Most promising, 5 = Least promising.

b. Exotic includes India, Sudan, Egypt, Ethiopia, and Afghanistan.

Table 11. Production of divergent segregants by backcrosses of F-378 and Rabat strains of chickpea (F_2 generation, Lebanon, 1975).

Cross/parent	% frequency: seed weight (g) classes 0–40	40–80	80–120	120–140	Mean seed weight (g/plant)
(F378 × Rabat) × Rabat	43.4	46.6	9.7	0.3	46.3
(F378 × Rabat) × F378	79.7	19.7	0.6		32.8
F378	90.0	10.0			22.4
Lebanese local[a]	85.0	15.0			25.5

[a] Rabat was not grown. Lebanese local, a large-seeded kabuli, has similar characteristics. From Auckland and Singh (1977).

Table 12. Mean seed weights (g/plant) of selected segregants from backcrosses of F-378 and Rabat strains of chickpea (mean of 5 plant samples for each progeny row).

Cross	Mean seed weight (g/plant) Lebanon (F_2), 1975	India (F_3), 1975–76	Correlation of F_2/F_3
(F378 × Rabat) × Rabat			
High-yielding segregants	90.7	21.7	0.25
Random segregants	46.4	22.2	0.18
Low-yielding segregants	10.4	23.4	– 0.47*
Cross mean	49.8	22.4	– 0.10
(F378 × Rabat) × F378			
High-yielding segregants	73.3	30.6	0.37
Random segregants	33.0	32.9	0.00
Low-yielding segregants	3.4	31.6	– 0.52*
Cross mean	36.5	31.7	– 0.31

* Denotes significance at P<0.05. From Auckland and Singh (1977).

parent, F-378, performed comparatively better in India. It is interesting that there was little difference in mean F_3 performance between the progenies of the three classes of F_2 segregants within each cross; however, on average, the F_3s of the backcross to F-378 were nearly 50% higher yielding than the backcross to the kabuli parent.

Although the evidence is meager, and further studies are certainly needed, all the data point in the same direction indicating the importance of backcrossing to the adapted parent. Some further studies on this have been initiated at ICARDA, including a look at the value of a second backcross to the adapted (kabuli) parent in crosses with both adapted and highly unadapted desi parents.

Conclusion

The importance of crossing between the two major subgroups of chickpea has been clearly established. Each type can benefit from the transfer of certain specific genes from the other. The kabulis for example, might be improved by the transfer of greater secondary branching or heat tolerance from the desis, which in turn, might benefit from the addition of genes for a taller, more erect growth habit or cold tolerance from the kabulis.

Since it is probable that the respective gene pools have been separated for many years, it is likely that genes for certain characters, e.g., disease resistance, might differ between the two groups. It is thus possible that crossing, say *Ascochyta* blight resistant kabulis with resistant desis, may result in an increased chance of raising overall resistance levels or improving resistance to a greater number of strains of the pathogen. This aspect of kabuli × desi introgression is currently receiving attention at ICARDA.

The introgression of a few specific genes from one group into the other can best be achieved by a conventional backcrossing program, and it may be desirable to make several backcrosses to the recurrent parent in the process. The transfer is likely to be simplest when the donor parent is well adapted to the local environment. The original hopes of making significant yield advances following crossing between high yielding West Asian kabulis with high yielding (in India) Indian desis have not so far been achieved. The implications are that adaptation is very important in chickpea and that yield genes cannot be considered independently of this. Part of the problem can be overcome by backcrossing to the adapted parent, though in the first instance a greater emphasis should be placed on kabuli × desi crossing when both parents are well adapted. In either case, the backcross will significantly increase the percentage of recovery of the desired seed type.

Following the backcross, the F_1 plants can be selected on the basis of seed characters. In view of the close association between kabuli seed characters and white flowers, pink-flowered plants can be removed from the F_2 bulks when breeding for improved kabulis. This, in turn, will help to increase the proportion of F_2/F_3 kabuli seed. From the F_3 generations the populations can be handled exactly as in any other conventional breeding system.

If we are going to achieve significant yield advances in chickpea, a bold approach must be taken toward the breeding of the crop. With more time and study, kabuli × desi introgression in the future might provide an important contribution toward achieving such advances.

References

AUCKLAND, A. K., and SINGH, K. B. 1977. The exploitation of natural genetic variability for the chickpea (*Cicer arietinum*). Pages 83–95 *in* Genetic Diversity in Plants. Eds. A. Muhammed, R. Aksel, and R. C. von Borstel. Plenum Publishing Corporation.

DOGGETT, H. 1970. Sorghum improvement in East Africa. Crop improvement in East Africa, ed. C. L. A. Leakie. Commonwealth Agricultural Bureaux, London.

HARRISON, M. N. 1970. Maize improvement in East Africa. Crop improvement in East Africa, ed. C. L. A. Leakie. Commonwealth Agricultural Bureaux, London.

LADIZINSKI, G., and ADLER, A. 1976. The origin of chickpea *Cicer arietinum* L. Euphytica 25: 211–217.

MARTINEZ, A., COIDURAS, A., MORENO, M. T., and CUBERO, J. I. 1979. Quantitative inheritance and barriers to crossability in *Cicer arietinum* L. Theoretical and Applied Genetics 54. (in press).

MORENO, M. T., and CUBERO, J. I. 1978. Variation in *Cicer arietinum* L. Euphytica 27: 465–485.

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, The Netherlands. 342 pp.

Studies on Desi and Kabuli Chickpea (*Cicer arietinum* L.) Cultivars
I. Chemical Composition

R. Jambunathan and U. Singh*

Although the existence of desi and kabuli chickpea cultivars has been known for a long time, little information on chemical composition of the two types is available. Therefore, it is desirable to obtain more information on the chemical composition of desi- and kabuli-type cultivars so that the relative importance of various constituents may be identified. Such information might be useful in a selection program involving desi × kabuli crosses.

Preliminary analysis carried out in our laboratory on five desi- and five kabuli-type chickpea samples revealed striking differences in fat and fiber contents of these two types (ICRISAT 1977). We are reporting herein the chemical composition of a rather limited number of cultivars of desi and kabuli types grown in two locations.

Materials and Methods

Seeds of eight desi and seven kabuli cultivars grown at ICRISAT Center (17°N) and at Hissar (29°N) during the rabi (postrainy) season of 1977–78 were obtained by pooling seeds from single plots and were received from our chickpea breeding section.

Whole-seed samples for analysis were ground dry. Dhal (decorticated split seeds) samples were prepared by soaking whole seeds in an excess of distilled water and storing them at 5°C overnight. After decanting the excess water, seed coats were removed by forceps and samples were air dried. Air-dried samples of whole seed, dhal, and seed coat were ground in a Udy cyclone mill to pass through a 60-mesh sieve, and the ground materials were stored in aluminium containers with tight-fitting caps. Portions of the material were oven dried to determine moisture content, and appropriate corrections were made to express results on a moisture-free basis.

Crude protein was estimated by multiplying the nitrogen content, determined by the standard micro-Kjeldahl procedure, by a factor of 6.25; fat, ash, and crude fiber were estimated following the standard AOAC procedures (Association of Analytical Chemists 1975).

Soluble sugars were extracted from the defatted materials with hot ethanol (80%) and were estimated by the phenol-sulphuric acid method (Dubois et al. 1956).

Starch was determined using the enzyme glucoamylase (Sigma Chemical Co., USA); the procedure (Thivend et al. 1972) was slightly modified as follows. The sample (75 mg) was placed in a conical flask, and a few drops of ethanol and 10 ml of distilled water were added. After heating the suspension on a water bath for 10 minutes, the suspension was autoclaved at 19 lb pressure (125°C) for 90 minutes. The suspension was cooled; 1 ml of acetate buffer (2 M, pH 4.8) was added, followed by 25 mg glucoamylase enzyme (3460 units/g); and the final volume was made up to 25 ml. Then the flask was incubated in a water bath at 55°C with continuous mild shaking for 2 hours. The glucose thus liberated was estimated as described by Dubois et al. (1956). Starch content was calculated by multiplying the glucose content by a factor of 0.9.

Results and Discussion

Mean values of all constituents are presented in Table 1. To make the data available to interested scientists, results of proximate analysis of samples of each of the eight desi and seven kabuli cultivars that were grown at ICRISAT Center and Hissar are presented in Tables 2–5.

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Table 1. Mean values of constituents of desi and kabuli chickpea cultivars, 1977–78.

	Whole seed		Dhal	
	ICRISAT Center	Hissar	ICRISAT Center	Hissar
Protein (%)				
Kabuli	22.4	24.0	24.0	25.0
Desi	22.0	22.4	25.9	26.8
Starch (%)				
Kabuli	49.2	48.6	56.0	55.6
Desi	45.6	43.7	56.3	54.4
Sugars (%)				
Kabuli	6.1	6.1	5.2	5.4
Desi	5.3	5.4	4.6	5.2
Fiber (%)				
Kabuli	2.7	3.2	1.0	1.2
Desi	8.4	9.2	1.1	1.1
Fat (%)				
Kabuli	5.4	4.7	6.0	5.3
Desi	4.6	4.1	5.8	4.8
Ash (%)				
Kabuli	3.1	3.2	3.1	3.1
Desi	3.4	3.3	2.7	2.9
100-seed weight (g)				
Kabuli	23.4	22.7	ND	ND
Desi	18.1	17.6	ND	ND
Seed coat (%)				
Kabuli	6.4	7.1	ND	ND
Desi	16.2	16.0	ND	ND
Seed coat N (%)				
Kabuli	0.86	0.95	ND	ND
Desi	0.46	0.59	ND	ND

ND = No data.

Protein Content

The mean protein content of whole-seed samples of desi and kabuli cultivars from both locations did not differ much, while dhal samples of desi cultivars had a slightly higher protein content than did the kabuli dhal samples. Mean protein values of desi dhal samples were about 4.2 units higher in comparison to whole-seed mean protein values, while the mean protein difference between kabuli whole seed and dhal samples was less than 2 units (Table 1).

Starch Content and Soluble Sugars

Usually, starch values of grain samples are reported by subtracting all values, except that of starch, from a total of 100 and then assuming that the difference in values represents the total starch content in the sample. Earlier workers have used either the difference method to calculate the starch content (Verma et al. 1964; Meiners et al. 1976) or have determined the starch content alone without analyzing for other constituents (Srinivasa 1976). To our knowledge, this is the first time that the starch values have been chemically determined in addition to other constituents on desi and kabuli chickpea samples grown in two locations.

When the mean starch values of samples from the same location were compared, the desi whole-seed sample values were 4 to 5 percentage units lower than the kabuli whole-seed samples, while no such difference seemed

Table 2. Proximate analysis of chickpea (desi) whole-seed samples grown in two locations[a], 1977–78.

Cultivar (desi)	Location[b]	Protein[c] (%)[d]	Starch (%)[d]	Sugars (%)	Fiber (%)[d]	Fat (%)[d]	Ash (%)	Total	100-seed weight (g)	Seed coat (%)	Seed coat N (%)[d]
USA-613	HY	24.0	44.6	5.3	7.9	4.0	3.6	89.4	16.8	15.6	0.44
	HI	22.8	43.1	5.2	9.6	3.9	3.3	87.9	16.9	17.6	0.55
850-3/27	HY	20.4	49.3	5.4	4.9	5.0	3.7	88.7	25.3	13.7	0.50
	HI	22.8	44.9	5.6	7.1	4.4	3.7	88.5	28.4	12.8	0.58
Pant G-114	HY	23.1	41.0	4.9	10.7	3.8	3.8	87.3	14.1	17.9	0.43
	HI	24.0	42.0	5.3	9.6	3.1	4.2	88.2	11.5	17.3	0.51
CPS-1	HY	25.9	43.7	5.3	8.8	4.7	2.9	91.3	18.5	15.4	0.43
	HI	23.8	40.8	5.4	9.7	5.0	2.9	87.6	17.2	16.9	0.64
T-3	HY	23.3	46.8	5.5	7.4	5.1	3.3	91.4	21.7	13.1	0.48
	HI	21.5	46.2	5.5	8.2	4.6	3.1	89.1	20.6	13.9	0.64
Annigeri	HY	17.7	50.8	5.8	8.0	5.8	3.3	91.4	19.4	16.3	0.52
	HI	22.1	44.0	5.5	9.6	4.4	3.0	88.6	18.5	16.2	0.78
BG-203	HY	20.6	42.6	5.3	10.2	3.9	3.7	86.3	10.6	19.4	0.48
	HI	21.9	44.4	5.1	8.9	3.6	2.9	86.8	12.6	16.8	0.45
P-5462	HY	20.7	45.9	4.8	9.3	4.3	2.9	87.9	18.7	17.9	0.46
	HI	20.2	44.4	5.2	10.8	3.8	3.2	87.6	15.2	16.7	0.59
Mean	HY	22.0	45.6	5.3	8.4	4.6	3.4	89.2	18.1	16.2	0.46
	HI	22.4	43.7	5.4	9.2	4.1	3.3	88.0	17.6	16.0	0.59

a. Moisture-free basis.
b. HY = ICRISAT Center, Hyderabad; HI = Hissar.
c. N × 6.25.
d. Average of two determinations.

Table 3. Proximate analysis of chickpea (kabuli) whole-seed samples grown in two locations[a], 1977–78.

Cultivar (kabuli)	Location[b]	Protein[c] (%)[d]	Starch (%)[d]	Sugars (%)	Fiber (%)[d]	Fat (%)[d]	Ash (%)	Total	100-seed weight (g)	Seed coat (%)	Seed coat N (%)[d]
K-4	HY	20.7	50.8	6.3	3.5	4.5	2.7	88.5	21.7	6.7	0.80
	HI	22.9	48.7	5.9	3.8	4.1	3.1	88.5	20.0	8.3	1.04
C-104	HY	21.5	48.6	6.2	2.3	6.4	2.8	87.8	24.5	6.2	0.89
	HI	24.8	47.3	5.8	2.6	5.3	2.9	88.7	25.8	6.0	0.52
Rabat	HY	21.6	49.4	6.3	2.5	5.6	2.5	87.9	27.8	5.9	0.86
	HI	24.0	49.9	6.1	2.8	4.5	3.2	90.5	23.4	6.7	1.26
L-550	HY	22.1	49.8	6.4	2.4	4.6	4.3	89.6	19.0	7.1	1.05
	HI	21.7	51.1	6.2	2.9	4.8	3.1	89.8	22.3	5.7	0.98
GL-629	HY	24.1	48.8	5.9	2.3	5.8	3.1	90.0	20.7	5.8	0.89
	HI	23.8	49.2	6.1	2.9	4.8	3.1	89.9	20.1	6.1	1.01
Giza	HY	24.3	47.6	5.9	3.8	5.2	3.1	89.9	16.2	7.8	0.70
	HI	25.6	45.7	6.4	4.7	4.3	3.6	90.3	15.8	8.2	0.82
No. 501	HY	22.8	49.6	5.8	2.2	5.4	3.3	89.1	33.6	5.2	0.85
	HI	25.0	48.2	6.0	2.7	4.8	3.5	90.2	31.7	8.8	0.99
Mean	HY	22.4	49.2	6.1	2.7	5.4	3.1	89.0	23.4	6.4	0.86
	HI	24.0	48.6	6.1	3.2	4.7	3.2	89.7	22.7	7.1	0.95

a. Moisture-free basis.
b. HY = ICRISAT Center, Hyderabad; HI = Hissar.
c. N × 6.25.
d. Average of two determinations.

Table 4. Proximate analysis of chickpea (desi) dhal samples grown in two locations,[a] 1977–78.

Cultivar (desi)	Location[b]	Protein[c] (%)[d]	Starch (%)	Sugars (%)	Fiber (%)	Fat (%)	Ash (%)	Total
USA-613	HY	28.3	54.9	4.8	1.0	5.0	2.7	96.7
	HI	27.7	54.6	5.0	1.2	4.2	2.5	95.2
850-3/27	HY	24.0	56.3	4.4	1.2	6.1	2.9	94.9
	HI	28.0	52.7	5.6	1.1	4.8	2.9	95.1
Pant G-114	HY	29.6	56.0	4.3	1.1	5.3	2.6	98.9
	HI	30.5	51.1	5.4	1.1	3.5	3.1	94.7
CPS-1	HY	27.4	55.8	4.3	1.0	6.7	2.1	97.3
	HI	26.9	54.6	4.7	1.1	5.5	2.8	95.6
T-3	HY	25.3	55.9	4.6	1.1	5.8	2.6	95.3
	HI	23.8	55.1	5.0	1.2	6.2	2.8	94.1
Annigeri	HY	20.6	58.1	5.4	1.1	7.5	2.5	95.2
	HI	24.7	54.9	6.0	1.3	5.4	2.8	95.1
BG-203	HY	25.2	55.7	4.9	1.0	4.8	3.3	94.9
	HI	27.1	56.2	4.9	1.1	4.5	3.3	97.1
P-5462	HY	26.8	57.8	4.1	0.9	5.5	3.0	98.1
	HI	25.3	56.2	5.3	0.7	4.3	3.1	94.9
Mean	HY	25.9	56.3	4.6	1.1	5.8	2.7	96.4
	HI	26.8	54.4	5.2	1.1	4.8	2.9	95.2

a. Moisture-free basis.
b. HY = ICRISAT Center, Hyderabad; HI = Hissar.
c. N × 6.25.
d. Average of two determinations.

Table 5. Proximate analysis of chickpea (kabuli) dhal samples grown in two locations,[a] 1977–78.

Cultivar (kabuli)	Location[b]	Protein[c] (%)[d]	Starch (%)	Sugars (%)	Fiber (%)	Fat (%)	Ash (%)	Total
K-4	HY	23.1	56.8	5.3	1.0	5.8	2.7	94.7
	HI	24.4	55.7	5.4	1.2	5.2	2.8	94.7
C-104	HY	24.4	55.2	5.5	1.1	6.8	3.2	96.2
	HI	27.8	55.7	5.0	1.2	5.8	2.9	98.4
Rabat	HY	22.3	57.4	5.3	1.0	5.8	3.2	95.0
	HI	24.7	56.0	5.6	1.2	4.9	3.4	95.8
L-550	HY	22.6	58.1	5.2	1.1	4.8	3.3	95.1
	HI	22.1	57.0	6.0	1.2	5.8	3.2	95.3
GL-629	HY	25.1	55.2	4.8	1.0	6.2	3.7	96.0
	HI	23.8	54.1	5.5	1.2	5.8	3.1	93.5
Giza	HY	26.7	54.3	4.8	1.0	6.1	2.7	95.6
	HI	26.6	53.5	5.5	1.2	4.6	3.1	94.5
No. 501	HY	24.5	54.9	5.2	1.0	6.1	3.0	94.7
	HI	26.7	57.5	5.0	1.1	5.4	3.0	98.7
Mean	HY	24.0	56.0	5.2	1.0	6.0	3.1	95.3
	HI	25.0	55.6	5.4	1.2	5.3	3.1	95.8

a. Moisture-free basis.
b. HY = ICRISAT Center, Hyderabad; HI = Hissar.
c. N × 6.25.
d. Average of two determinations.

to exist between mean starch values of the desi and kabuli dhal samples (Table 1).

Pure starch was used as a check in the starch-estimation method. Recovery studies were carried out by adding starch to the cultivar 859-3/27 and a mean recovery value of 99.2% was obtained.

Mean soluble sugar values were slightly higher in the whole-seed kabuli types when compared with desi types from either location (Table 1).

Fat, Fiber, and Ash Contents

Although we observed marked differences in the fat content of desi and kabuli cultivars earlier (ICRISAT 1977), in the present study there was an overlap in the fat contents of these different types (Tables 2–5).

A clear distinction between desi and kabuli types was observed in fiber contents of whole seeds (Table 1). The mean value of fiber content of whole-seed samples of desi from both locations was 8.8% (range 4.9–10.8%) while that of kabuli was 3.0% (range 2.2–4.7%). Mean values of ash content of kabuli whole seed and dhal did not differ in desi types; ash content was slightly lower in dhal samples.

Seed Weight and Seed Coat Content

The 100-seed weight of desi whole-seed samples from both locations varied from 10.6 to 28.4 g (mean 17.9 g), while for kabuli it varied from 15.8 to 33.6 g (mean 23.1 g). Although kabuli chickpea cultivars are often described as generally having larger seeds than desi cultivars, there was considerable overlap in the cultivars studied (Tables 2, 3).

A striking difference between the desi and kabuli cultivars was the percentage of seed coat. Desi types ranged from 12.8 to 19.4 with a mean of 16.1%, while kabuli types ranged from 5.2 to 8.8% with a mean of 6.8% seed coat.

Although the 100-seed weights of some of the desi and kabuli cultivars were similar, the seed coat percentage of these cultivars show remarkable differences (Tables 2, 3).

For example, the 100-seed weights of cv Giza from the two locations were 16.2 and 15.8 g and their seed coat percentages 7.8 and 8.2, respectively. When these values were compared with the desi chickpea cv USA-613, it was observed that although the 100-seed weights from both locations were 16.8 and 16.9 g, the seed coat percentages were 15.6 and 17.6%, respectively — almost twice the amount present in kabuli cultivars of similar weight. Thus, the quantitative difference in seed coat appeared to be consistent and real.

The nitrogen content of seed coat of kabuli cultivars ranged from 0.70 to 1.26% (mean of 0.90%); that of desi cultivars ranged from 0.43 to 0.78% (mean of 0.53%).

Total of all the Constituents

In desi whole-seed samples, the range of the total constituents varied from 86.3 to 91.4, with a mean of 88.6%. For kabuli whole-seed samples, the range was from 87.8 to 90.5, and the mean was 89.4%. Total constituents when added up in the case of desi dhal samples varied from 94.1 to 98.9, with a mean of 95.8% and for kabuli samples, the range was from 93.5 to 98.7, with a mean of 95.5%.

We believe that one reason for the lower recovery of whole-seed samples might be due to the dilution effect of seed coat in the estimation of starch and other constituents. Another reason could be the method employed for the estimation of crude fiber. Acid detergent fiber and neutral detergent fiber methods would give us a better idea of the amount of hemicellulose, cellulose, and lignin content of chickpea, and perhaps could provide an explanation for the lower recovery reported in this paper.

Starch values of desi and kabuli dhal samples did not show any appreciable difference, while the starch content of desi and kabuli whole-seed samples exhibited greater differences (Table 1). Differences in other constituents tend to disappear as well in dhal samples of desi and kabuli types. This is another indication of possible seed-coat influence in the chemical estimation of constituents.

Preliminary analysis carried out on two samples revealed that the seed coat of desi and kabuli contained 11 and 15% of carbohydrate material, respectively, as determined by the glucoamylase method. Further work is in progress.

Influence of Seed Coat on Dhal Recovery

It is estimated that only about 10–15% of the total world production is of the kabuli types. Most of the desi chickpea is processed into dhal for human consumption. Therefore, our findings are relevant because seed coats are lost during processing and a higher percentage of seed-coat reduces the yield of dhal. This can be overcome by breeding for desi-type varieties that have higher seed weight or lower seed coat percentage, as we observed a negative and significant correlation between seed weight and seed coat percentage. Not only does this strategy increase the effective yield of dhal, but also it increases the fat and starch contents, which provide the bulk of the energy in the diet.

The objective of this study was to find out the chemical composition of desi and kabuli cultivars. Although samples were obtained from two locations, the experiment was not designed to provide information on genotype and environment interaction. Samples are from single plots at the two locations, so statistical analysis for relative effects of genotypes and environment is not possible. A simple way to evaluate these effects is to use the data presented in Table 1. Differences between locations can be obtained by subtracting the results obtained from each location shown in the columns, while the differences between kabuli and desi types can be obtained by subtracting the values across the table. In whole seed, genetic differences appeared to be more important than environmental effects for starch, sugars, fiber, 100-seed weight, seed coat percentage, and seed coat nitrogen contents. In dhal, genetic differences with the possible exception of protein were not important.

Conclusion

Of the constituents analyzed, percentage of seed-coat and fiber can be considered as the only two constituents that could be used to distinguish the desi and kabuli types of chickpea cultivars. It would be desirable to monitor the seed-coat content of desi types and breed for varieties having lower seed-coat percentage.

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References

AOAC (Association of Analytical Chemists). 1975. Official methods of Analysis (12th ed). The Association, Washington, D.C.

Dubois, M., Giles, K. A., Hamilton, J. K., Rebers, P. A., and Smith, F. 1956. Colorimetric method for determination of sugars and related substances. Analytical Chemistry 28: 350.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 1977. Page 111 *in* ICRISAT Annual Report, 1976–77, Hyderabad, India.

Meiners, C. R., Derise, N. L., Lau, H. C., and Murphy, E. W. 1976. Proximate composition and yield of raw and cooked mature dry legumes. Journal of Agricultural and Food Chemistry 24: 1122.

Srinivasa Rao, P. 1976. Nature of carbohydrates in pulses. Journal of Agricultural and Food Chemistry 24: 958.

Thivend, P., Christiane, M., and Guilod, A. 1972. Determination of starch with glucoamylase. Page 105 *in* R. L. Whistler and J. N. BeMiller (Eds.), Methods in Carbohydrate Chemistry, Vol. VI. Academic Press, N.Y.

Verma, S. C., Lal, B. M., and Ved Prakash. 1964. Changes in the chemical composition of the seed parts during ripening of Bengal gram (*Cicer arietinum* L.) seed. Journal of the Science of Food and Agriculture 15: 25.

Disease Resistance in Kabuli-Desi Chickpea Introgression

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Experience in transferring disease resistance from desi to kabuli chickpeas and vice versa has been very limited to date. Another paper (Nene) in this workshop covers the general situation on chickpea diseases, so in discussing our work on resistance to wilt (*Fusarium oxysporum* f sp *ciceri*) and other diseases, we will give particular reference to kabuli-desi introgression.

The major problems in chickpea are wilt (*F. oxysporum* f sp *ciceri*), dry root rot (*Rhizoctonia bataticola*), stunt (virus), *Ascochyta* blight, and root/collar rots. While wilt and root rots are reported from most chickpea-growing countries, *Ascochyta* blight is mostly confined to areas with low temperatures and high humidity during the growing season.

In Ethiopia, where chickpea is sown in July and August, it is caught by *Ascochyta* blight. Desi and kabuli types alike are attacked. September sowings escape the blight. The situation is different for wilt and root rots, which may take their toll throughout the season. In India, blight is only occasionally a problem; wilt is most serious and appears in most areas throughout the growing season.

We are screening for disease resistance in the desi and kabuli types of chickpea. Most of the kabuli chickpeas are highly susceptible to major chickpea diseases. Most of our resistant sources are desi types.

Wilt

Sources of Resistance

So far, more than 6000 germplasm accessions have been screened in the wilt-sick plot at ICRISAT Center and 118 appear to be promising for wilt resistance. Many of these lines have been included in the second International Chickpea Root Rots/Wilt Nursery.

Breeding Material Screened

The wilt-sick plot first became available in the 1977 planting season, and we planted F_2 to F_4 breeding material, which involved one or more wilt-resistant parents and all F_5 to F_7 generation progenies (Table 1). JG-62, the susceptible check, was planted on every third ridge and showed almost complete and uniform mortality because of wilt. Inoculum obviously was present throughout the plot. Initial stand was taken, and wilted plant counts were taken at 20-day intervals. Desi and kabuli selections are listed in Table 1; recovery of kabuli segregants was very low.

Evidence on Inheritance of Wilt Resistance

Not much work has been done on the inheritance of *Fusarium* wilt resistance in chickpea. We could find only four reports, all of which indicate simple inheritance for resistance to this disease. Ayyar and Iyer (1936) reported one gene pair with incomplete dominance responsible for resistance. Lopez (1974) presented data to show that resistance was governed by one or two pairs of genes and susceptibility was dominant. Pathak et al. (1975) and Tiwari et al. (1978) showed that resistance was governed by one single recessive gene. These studies were done under field conditions. We also have similar results from the wilt-sick plot in several single crosses, and results for those involving desi × kabuli parents are listed in Table 2. Since these studies were conducted in the field, where other pathogens cause mortality, the results are to be considered with caution.

In wilt-sick pots we grew F_1s and parents of

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crosses of highly susceptible cv JG-62 with putative resistant lines. The F_1s and JG-62 died within 21 days after sowing. The resistant parents CPS-1 and WR-315 were free from disease. In wilt-sick pots we grew F_3 progeny of resistant segregants (selected in the wilt-sick plot) from a few crosses. All progenies of kabuli types and some from the desi types wilted completely. The remaining desi type progenies showed segregation. Even if we consider those that wilted completely as escapes in the wilt-sick plot, segregation for wilt in the progeny of resistant F_2 plants cannot be explained on the basis of a single recessive gene for resistance. One problem in such studies is that plants from a resistant parent can also get wilted as was shown in flax wilt (Kommedahl et al. 1970), and drawing conclusions becomes difficult. The reasons for such wilting are not apparent.

We are presently growing parents, F_1s, F_2s, and F_3 single-plant progenies of a few crosses to study the inheritance in detail.

Stunt

Screening for stunt resistance is done at Hissar under natural conditions. To date, no resistant kabuli has been found. A number of promising lines have been identified among desis. Since the resistance of ICC-3735 is almost confirmed, it will be included in desi-kabuli introgression for stunt resistance.

Ascochyta Blight

Sources of Resistance

More than 3500 germplasm accessions have been screened in isolation plant propagators at ICRISAT. The disease reaction was rated 1–9, with 9 most susceptible. Only 18 lines rated as low as 3. Some of these are included in the International Chickpea Ascochyta Blight Nursery. Five desi types included in ICABN, i.e., ICC-4935 (C-235), -5127 (F-8), -7513 (12-071-05132), -7514 (12-071-05093), and -7520 (12-071-10054) were

Table 2. Percentage of plants wilted in desi × kabuli F_2 populations involving one resistant parent, ICRISAT Center, 1977.

Pedigree		Total plants (no.)	Plants wilted (%)
P-36	× Lebanese local	470	70
	× NEC-141	473	72
	× Ofra	466	72
	× NEC-139	462	70
	× NEC-108	472	76
	× L-534	421	78
	× Giza	469	82
	× P-9623	491	85
WR-315	× GL-651	441	83
	× Bet Degan-302	489	77

Table 1. F_2-F_7 breeding material grown and tentatively selected in the wilt-sick plot, ICRISAT Center, 1977.

Generation	Total	Desi × Kabuli	No. of plants selected	
			Desi	Kabuli
F_2 populations				
Single Cross	62	11	2694	83
Multiple Cross	47	23		
F_3 progenies	371	190	317	30
F_4 progenies	417	209	548	50
F_5 progenies[a]	750	148	687	26
F_6 progenies	1173	221	620	59
F_7 progenies	280	40		5

[a] In F_5, F_6, and F_7 generations, three, nine, and one progenies, respectively, were from kabuli × kabuli-type crosses.

found resistant to blight, both at Tel Hadia and Latakia, (K. B. Singh, ICARDA, personal communication). We have three F_1 crosses and ten F_2 populations involving these and kabuli parents available, and they will be screened for *Ascochyta* blight resistance at ICARDA next year.

Inheritance of Resistance

Three studies (Hafiz and Ashraf 1953; Vir et al. 1975; Eser 1976) on the inheritance of *Ascochyta* blight resistance all report that one dominant gene was responsible for resistance in the materials studied. We are currently attempting crosses between *Ascochyta* blight-resistant and susceptible parents of both desi and kabuli types. These studies will be undertaken at ICARDA.

References

AYYAR, V. R., and IYER, R. B. 1936. A preliminary note on the mode of inheritance of reaction to wilt in *Cicer arietinum*. Proceedings of Indian Academy of Sciences 3: 438–443.

ESER, D. 1976. Heritability of some important plant characters, their relationship with plant yield and inheritance of *Ascochyta* blight resistance in chickpea (*Cicer arietinum* L.). Ankara Univ. Agricultural Faculty, Turkey 620: 40 pp.

HAFIZ, A., and ASHRAF, M. 1953. Studies on the inheritance of resistance to *Mycosphaerella* (*Ascochyta*) blight in gram. Phytopathology 43: 580–581.

KOMMEDAHL, T., CHRISTENSEN, J. J., and FREDERIKSEN, R. S. 1970. A half century of research in Minnesota on flax wilt caused by *Fusarium oxysporum*. Tech. Bull. 273. Agri. Expt. Sta., Univ. Minnesota, 36 pp.

LOPEZ GARCIA, H. 1974. Inheritance of the character resistance to wilt (*Fusarium* sp) in chickpea (*Cicer arietinum*) under field conditions (in Spanish). Agricultura Tecnica Mex. 3: 286–289.

PATHAK, M. M., SINGH, K. P., and LAL, S. B. 1975. Inheritance of resistance to wilt (*Fusarium oxysporum* f *ciceri*) in gram. Indian Journal of Farm Science 3: 10–11.

TIWARI, A. S., PANDEY, R. L., MISHRA, P. K., and KOTASTHANE, S. R. 1978. Studies on wilt inheritance in gram (*Cicer arietinum* L.). Paper *in* All India Rabi Pulse Workshop, 3–6 Oct 1978, Bhubaneshwar, India.

VIR, S., GREWAL, J. S., and GUPTA, V. P. 1975. Inheritance of resistance to *Ascochyta* blight in chickpea. Euphytica 24: 209–211.

Kabuli-Desi Introgression: The Experience in Australia

E. J. Knights*

Production of winter crops in Australia occurs mostly in the temperate zones between latitudes 27° and 37°S. In this region, where climate varies from true Mediterranean to humid mesothermal with more or less evenly distributed rainfall, wheat and other winter cereals have traditionally been the mainstays of agriculture. However, the temporary imposition of wheat production controls in 1969 has led to a gradual diversification in cropping enterprises.

Grain legumes are one group of crops gaining acceptance as a useful part of farm rotations. In these rotations a leguminous pasture ley of 3–5 years is followed by an exploitative phase of cereal cropping. The length of the cropping phase is partly determined by the rate of depletion of soil nitrogen. Recently, alkaloid-free varieties of narrow-leafed lupins (*Lupinus angustifolius*) have been used to extend this phase.

Lupins are well adapted to the higher rainfall parts of the Australian wheatbelt. However, no grain legume is currently available for the drier areas where severe moisture and temperature stress normally occurs for at least part of the reproductive phase. It was recognized that chickpea was theoretically suited to this environment, and work on the development of the crop commenced in 1972.

The future availability of adapted chickpea varieties will offer farmers in the drier wheatbelt areas a source of nitrogen for subsequent cereal crops. The grain could be used on the farm as a feed reserve in times of drought. Alternatively, it could be sold as a cash crop for use in stockfeed formulations, either locally or on export markets.

Chickpea Breeding in Australia

Although many centers throughout Australia are currently undertaking research into chickpea (Corbin 1975), the only breeding program is being conducted by the New South Wales Department of Agriculture at Wagga Wagga. Initially, the pedigree method of breeding was used, and this program has now been advanced to the F_3 stage. Recently, some emphasis has shifted to the use of a modified form of single-seed descent with field evaluation of random homozygous lines.

The aims of the breeding program are twofold. Highest priority is given to the development of small-seeded, high-yielding "stockfeed" varieties tall enough to permit mechanical harvesting. The preferred seed type is kabuli.

Culinary types are presently imported into Australia to service a small but increasing market. The second objective of the Wagga program is to breed high-yielding, lodging-resistant culinary varieties. In this case, the seed type must be kabuli.

Seed Type

Classification

From observation of germplasm collections and segregation studies, three general seed types are proposed — pea, desi, and kabuli.

Description and Characteristics

Pea

This type is nearly spherical except for the characteristic chickpea beak. A very loose

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adherence of the seed coat to cotyledons predisposes it to severe seed damage. Presumably this type has consistently been rejected during domestication and improvement.

Desi

A wrinkled surface and irregular shape differentiate this type. The seed coat is thick with a generally tight adherence to the cotyledons.

Kabuli

This is a more rounded type than desi, with a less wrinkled surface. In many ways it appears to be intermediate between the pea and desi types. The seed coat is very thin, yet it adheres well to the cotyledons, and seed damage during harvest is generally slight. The reduced seed coat component is reflected by a considerably lower fiber content than that of desi seeds. A compensatory increase in the level of carbohydrate and possibly protein is expected. Seed weights and percentage seed coat, fiber (acid determined) and crude protein values for desi and kabuli types are presented in Tables 1 and 2.

Desi × Kabuli Crosses

The breeding program at Wagga has made use of single, three-way, and double crosses both within and between desi and kabuli groups. Mean success rates for the three cross types—desi × desi, desi × kabuli (and reciprocal), and kabuli × kabuli—are presented in Table 3.

Table 1. Seed weights and percentages of seed coat and fiber of desi and kabuli cultivars at Wagga Wagga, 1977.

Line/Variety	Seed type	100-seed weight (g)	Seed Coat (%)	Fiber (%)
CPI 56296-b	Kabuli	14.1	7.4	5.6
K1184	Kabuli	20.2	5.8	5.3
C235	Desi	10.4	19.7	17.4
NP53	Desi	11.6	19.9	17.4

Table 2. Crude protein percentages (%N × 6.25) of desi and kabuli cultivars.

	Location and year			
Seed type	Condobolin (1974)	Condobolin (1976)	Temora (1976)	Wagga (1976)
Desi	25.87	20.81	24.45	21.83
Kabuli	26.40	21.60	25.08	22.53

Table 3. Cross-success rates.

Cross type	% Success rate (without) emasculation	
	1977	1978
Desi × desi	48.1	82.0
Desi × kabuli (and reciprocal)	34.2	75.0
Kabuli × kabuli	23.1	insufficient crosses for reliable figure.

It can be seen from the data that no apparent barriers to hybridization existed between the desi and kabuli genotypes used; however, in order to maximize the recovery to F_1 seeds from desi × kabuli crosses, desi types should be used as the female parent.

Inheritance of Seed Type

The dominance relationships are: pea dominant to both desi and kabuli; and desi dominant to kabuli.

The F_2 segregations from desi × kabuli crosses generally produce up to five classes—pea, desi, kabuli, and the two intermediate forms, pea-desi and pea-kabuli. Frequencies of these classes are variable and dependent on the parental lines used. In the F_2 generation, recovery of desi types has ranged from 2.3 to 53.3% and that of kabuli types from 0 to 9.8%.

With continued inbreeding, there is further segregation of desi and kabuli from pea and intermediate types. Conversely, a lower frequency of desi and kabuli lines revert to pea or intermediate types. Generally, there is a net increase of desi and kabuli segregants with inbreeding, with desi being numerically superior.

The small number of segregation classes suggests that seed type is under the control of only a few major genes; however, the variable frequencies of segregation classes, together with the instability of desi and kabuli types in early generations, indicate epistasis.

Breeding Strategies

Stockfeed Varieties

The aim of incorporating a kabuli-type seed into "stockfeed" chickpea varieties has already been stated. Kabuli seeds have a fiber content of approximately 5–6% compared to 17–18% for desi seeds. For monogastric animals at least, a higher energy value of kabuli seeds is implied. This, together with the possibility of a small increase in protein content, is the reason for inclusion of kabuli types in selected progeny.

Nearly all kabuli lines have white seeds. These lines are generally susceptible to preemergence damping off, and surviving plants are not as vigorous as those of colored desi lines. A relationship between seed color and establishment has been recorded in *Phaseolus vulgaris* (Deakin 1974; Ma and Bliss 1978), *P. lunatus* (Kannenberg and Allard 1964), and *Pisum sativum* (Muehlbauer and Kraft 1978). A similar relationship in chickpea is evident from Table 4.

It is interesting to note that CPI 56296-b, a kabuli line with light brown seed, had an establishment similar to that of the colored desi lines. While seed color (or the chemical factors responsible for or linked to it) is clearly related to establishment, sufficient data are not available to associate reduced establishment with kabuli seed type.

Accordingly, some kabuli lines have been used in single, three-way, and double crosses

Table 4. Establishment and seed color in chickpea.

			Plant establishment (%)[a]		
Line/variety	Seed type	Seed color	Without seed dressing	With seed dressing	Difference
CPI 56329	Kabuli	White	54.0	77.0	23.0
K 1190	Kabuli	White	47.3	88.0	40.7
CPI 56296-b	Kabuli	Light brown	85.7	91.6	5.9
CPI 71173	Desi	Brown	89.7	91.3	1.6
NP 53	Desi	Brown	87.7	89.0	1.3
CPI 56564	Desi	Dark brown	82.3	94.0	11.7
CPI 56315	Desi	Black	88.0	87.7	−0.3

a. Seed dressing = 1:1 thiram/captan 0.6% w/w.

with tall desi lines. The aim has been to combine in the one variety acceptable yield, protein, height, and earliness with a colored kabuli seed. Of 139 F_2 plants selected from such crosses, only 12 (8.6%) were found to have kabuli seed type at maturity. The remainder were composed of desi (32.4%) and pea or intermediate types (59.0%). When a single seed from each of the 12 kabuli plants was selfed, only 8 retained the kabuli form.

Clearly, much selection pressure can be wasted through the inability to determine F_2 and F_3 seed type until plant maturity. This problem can be partly overcome by increasing the proportion of kabuli and/or desi segregates. Three ways are suggested:

1. Particular combinations of parent lines can be chosen that segregate a high proportion of kabuli and/or desi types. This information can be obtained either through single-seed descent with rapid generation turnover or by recording class frequencies during the course of breeding.
2. The type of cross used will largely determine the frequency of types segretated. For example, a high proportion of kabuli types can be recovered by making the three-way cross (desi × kabuli-1) × kabuli-2 and selecting only those hybrids having kabuli seed. One cross of this type made at Wagga yielded 77.0% kabuli plants in the first segregating generation. This method would be useful where only a small number of characters need to be introgressed from the desi line.
3. Uncertainty of seed genotype may be avoided by permitting segregating generations to self until near homozygosity — say F_5. At Wagga, under controlled glasshouse conditions, one generation can be obtained every 110 days, with only 19 months being required from the sowing of parent material to the harvesting of F_5 plants. The derived F_6 lines, which are effectively homozygous, can then be sown in the field in single rows for preliminary yield evaluation.

A modified form of single-seed descent, where mild selection can be practiced, is now being used at Wagga. In the glasshouse at a spacing of 50 plants per m², it is possible to discard plants on the basis of height, earliness, seed size, and pod set. The advantages of this method are a progressive reduction in the workload and considerable saving in time. The major disadvantage is the likely loss of superior segregates through random selection of single seeds.

Culinary Varieties

Over a long period of time, intense selection for large-seededness has probably been at the expense of yield. An objective of the Wagga program is to improve the yield of presently available culinary varieties through the introgression of desi germplasm.

Culinary chickpea production in Australia will most likely be confined to irrigation districts. The greater vegetative production under irrigation will make the incorporation of lodging resistance essential. This resistance is available in the subrace *bohemicum* (van der Maesen 1972); many representatives of which have thick, strong stems and an erect growth habit.

One line in particular, K-368, has shown excellent lodging resistance but has the disadvantages of pea-type seed and very late maturity. It has been crossed with the high-yielding early maturity variety JG-62 to derive a tall, lodging-resistant line with medium maturity and desi seed (WWC1). This has subsequently been crossed with culinary lines in the following ways, namely, (WWC1 × culinary-1) × culinary-2; and (WWC1 × desi) × culinary-1.

The first cross, as previously discussed, can provide a high frequency of kabuli segregates, but it has the disadvantage of introgressing only 25% of desi genes. The second cross introgresses 50% of desi genes, but it has the disadvantage of reducing the proportion of segregates having kabuli and/or acceptably large seed.

References

CORBIN, E. J. 1975. Present status of chickpea research in Australia. Pages 87–94 *in* Proceedings, International Workshop on Grain Legumes, ICRISAT, 13 Mar 1975, Hyderabad, India.

DEAKIN, J. R. 1974. Association of seed color with emergence and seed yield of snap beans. Journal of the American Society for Horticultural Science 99(2): 110–114.

KANNENBERG, L. W., and ALLARD, R. W. 1964. An association between pigment and lignin formation in the seed coat of the lima bean. Crop Science 4(6): 621–622.

MA, Y., and BLISS, F. A. 1978. Tannin content and inheritance in common bean. Crop Science 18(2): 201–204.

MUEHLBAUER, F. J., and KRAFT, J. M. 1978. Effect of pea seed genotype on pre-emergence damping off and resistance to *Fusarium* and *Pythium* root rot. Crop Science 18(2): 321–323.

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 Landbouwhogeschool Wageningen, Nederland.

Kabuli-Desi Introgression and Genesis of New Plant Type in Chickpea

P. N. Bahl*

Improved plant type has played a very important role in recent years in raising the yield plateau in cereals and in certain legumes. In the case of cereals, particularly wheat and rice, this has been achieved by breeding dwarf varieties capable of favorably responding to such inputs as irrigation and fertilization. In contrast to this, mid-tall genotypes have given higher yields in some of the legumes, like broadbeans and soybeans. However, chickpea cultivars continue to be notoriously low in yield in the Indian subcontinent. Chickpea has been traditionally grown in this part of the world under marginal conditions of moisture stress and low soil fertility. These stress environments, where land races of chickpea are even now being grown, are not very much different from those of their wild habitats (Swaminathan and Jain 1973). Natural selection under these conditions has played a more important role than human selection in determining morphological and physiological structure.

The chickpea genotypes have adapted themselves to these conditions by developing such characteristics as bushy, spreading, and indeterminate growth habit, nonsynchronous development, and photo- and thermo-insensitive habit (Bahl et al. 1978). Under these conditions, adaptive response must have resulted in the evolution of ecctypes possessing coadaptive gene complexes that are now conserved by genetic linkages. Therefore, the foremost requirement of a plant breeder is to change the physiological makeup by restructuring the plant type so as to identify early maturing photo- and thermo-insensitive determinates and widely adapted genotypes that can be grown under different cropping patterns and farming systems.

Correlations and Path Analysis

Table 1 (Bahl and Jain 1977) shows simple phenotypic correlations between different characters, including grain yield and harvest index recorded on 16 chickpea cultivars. Grain yield showed a highly significant positive correlation with branches per plant, pods per plant, biological yield, and harvest index. The biological yield, pods per plant, and harvest index are practically contributed by the number of branches per plant, with which they all show positive association. As the grain yield is the product of biological yield and harvest index, it is interesting to find that both yield components are positively correlated. An important finding is that these yield parameters can be increased simultaneously, in contrast to maize and some other cereals where dry matter is negatively correlated with harvest index (Jain et al. 1976).

Path-analysis studies on 21 cultivars of chickpea revealed that branches per plant contributed substantially and directly toward pods per plant, which is always strongly correlatea with grain yield in most legumes, including chickpea (Bahl et al. 1976). It was concluded from these observations that plant breeders should look for genotypes that bear more pods per branch, so that vegetative yield is reduced and harvest index is increased. This will permit partitioning the total dry matter in a favorable direction so that higher grain yields are obtained.

From these studies, it was theorized that an improved plant type in chickpea should be characterized by a large number of branches and an erect growth habit, with many primary and secondary branches. This would help intercept more sunlight, permit larger plant populations to be raised per unit area, and help avoid a wastage of energy in the production of tertiary and late-order branches; such branches do not appear to contribute much to grain formation.

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Table 1. Correlation coefficients between various characters in chickpea, 1977.

Character	Branches/ plant	Pods/ plant	Seeds/ pod	100-seed weight	Biological yield/ plant	Economic yield/ plant	Harvest index
Plant height	0.095	0.124	0.199	0.137	0.303*	0.200	0.076
Branches/plant		0.891**	0.180	−0.095	0.740**	0.701**	0.470**
Pods/plant			0.280*	−0.237	0.694**	0.726**	0.540**
Seeds/pod				−0.309*	0.263*	0.306*	0.283*
100-seed weight					0.167	0.179	0.258*
Biological yield/plant						0.819**	0.528**
Economic yield/plant							0.870**
Harvest index							

* Significant at $p = 0.05$. ** Significant at $p = 0.01$. Bahl and Jain (1977).

In this conceptual plant ideotype of chickpea, some of the vertical growth in tall, erect, and compact types will replace the horizontal spread of traditional types to some extent without losing on the number of pod-forming loci. This will amount to looking for a plant type that is architecturally adapted to high plant density and narrow row-spacing, which we think will be conducive to optimum yield environment, as visualized in maize by Mock and Pearce (1975).

Genetic Diversity among Kabuli and Desi Cultivars

Within cultivated species of chickpea, kabuli and desi types are two distinct groups of practical importance (van der Maesen 1973). Desi types, with yellow to brown testa and a 10–15 g 100-seed weight, are mostly planted as a winter crop in the tropics; kabuli types, with salmon white testa and weighing more than 26 g per 100-seeds, are generally planted as a summer crop in temperate climates. However, in terms of seasons and space, there is some amount of overlap in the distribution of desi and kabuli types. Nevertheless, the inferential criterion of ecogeographical diversity is often used to discriminate between desi and kabuli types as separate groups within the cultivated species.

However, information on the extent of genetic divergence and factors contributing to intraspecific differentiation in chickpea is very meager. Figure 1 (Salimath 1979) shows genetic divergence in a set of 80 genotypes consisting of 39 indigenous desi, 15 exotic desi, 11 indigenous kabuli, and 15 exotic kabuli types. Of the 80 genotypes, 50 came from India, 14 from Iran, 6 from USSR, 2 each from Afghanistan, Egypt, and Morocco, and 1 each from Lebanon, Algeria, Turkey, and the USA (Table 2).

In this study a set of nine quantitative characters — plant height, total number of branches, primary branches, secondary branches, days to 50% flowering, days to maturity, number of pods per plant, seeds per pod, and 100-seed weight — related to fitness or yield were used for estimating genetic divergence, using the D^2 statistic of Mahalanobis (1936) and canonical analysis. On the primary axis of differentiation, the potent factors causing divergence were seeds per pod, number of pods per plant, and primary branches. On the secondary axis of differentiation the potent factors were pods per plant, total branches, and primary branches per plant. On the tertiary axis, the single most potent factor was days to 50% flowering. Another important aspect emerging from this study is that kabuli and desi types form two distinct constellations, with the exception of one genotype from each group having fallen in the other cluster.

The study has brought out some interesting features of subspecific differentiation in the cultivated species of chickpea. The unique divergence of kabuli from desi may indicate that these two types represent different germplasm pools (intergroup $D^2 = 143.30$). Second, within-group divergence was greater in kabulis (intragroup $D^2 = 103.48$) than in desi types (intragroup $D^2 = 90.31$). Third, kabuli as a group had high mean values for primary branches, 100-seed weight, and plant height, whereas the desi

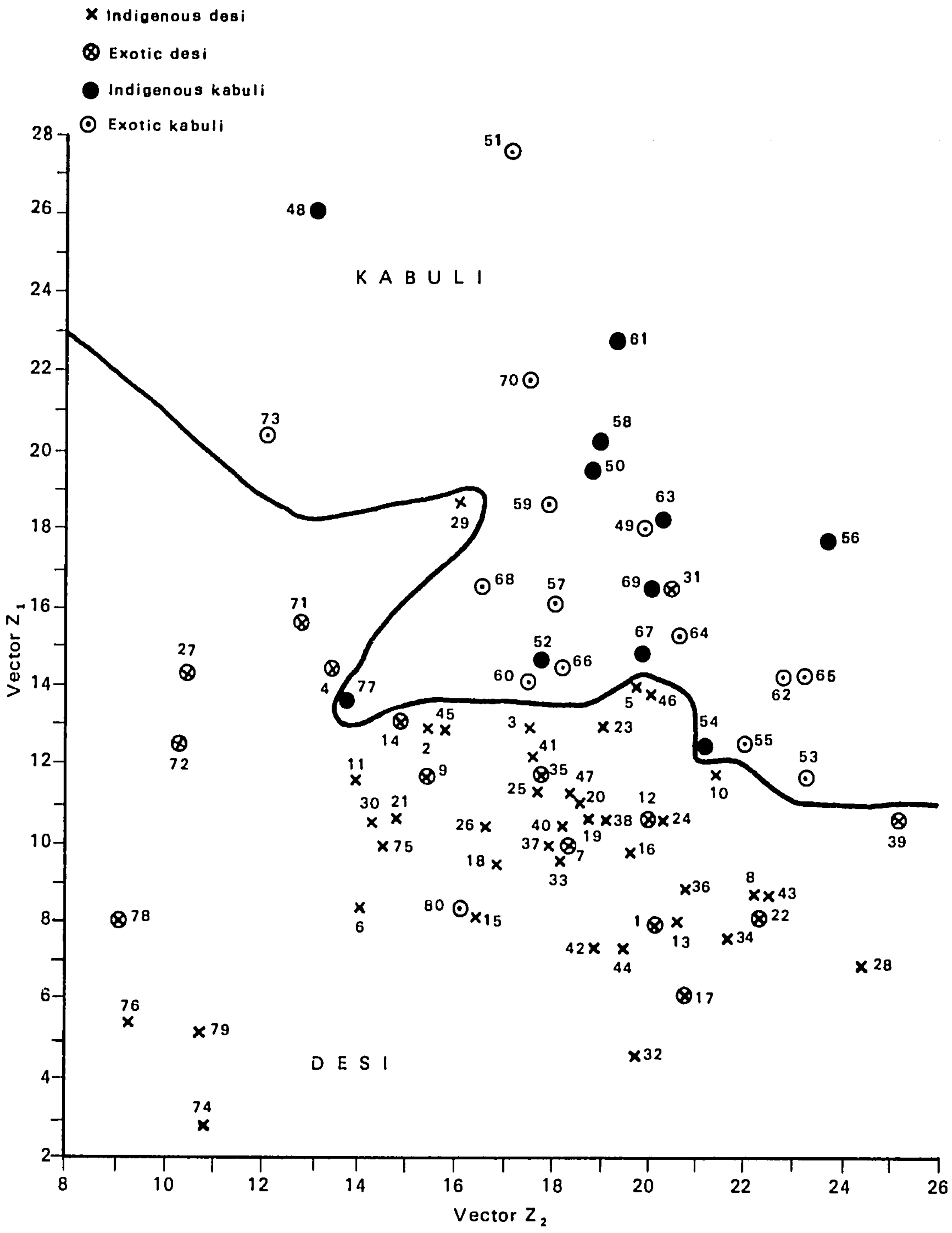

Figure 1. Two-dimensional representation of divergence of 80 genotypes of chickpea using the first two canonical vectors (Z_1 and Z_2). Source: Salimath (1979).

Table 2. Particulars of 80 genotypes of chickpeas used in Figure 1.

Number, and entry name[a]	Country of origin
Desi	
2 (B. gram), 3 (Radhey), 5 (T3), 6 (P436), 8 (P324), 10 (NEC249), 11 (B110), 13 (P514), 15 (P127), 16 (Annigeri), 18 (P182), 19 (P1243), 20 (P1137), 21 (JG62), 23 (P1132), 24 (B108), 25 (C214), 26 (P47), 28 (P325), 29 (850-3/27), 30 (F378), 32 (P517), 33 (NP50), 34 (P481), 36 (K468), 37 (G130), 38 (H 208), 40 (C235), 41 (BG1), 42 (P326), 43 (Pant. G113), 44 (P70), 45 (P1208), 46 (P1209), 47 (BG206), 74 (BG 203), 75 (F370), 76 (P10), 79 (P1387)	India
1 (P3552), 4 (P2559), 7 (P496), 14 (P2974), 22 (Kaka), 27 (Pyrouz), 31 (NEC1196)	Iran
9 (NEC 240), 71 (P9656), 72 (NEC 136), 78 (P852)	USSR
12 (P4235), 39 (P896)	Afghanistan
17 (P840)	Morocco
35 (USA 613)	USA
Kabuli	
48 (L534), 50 (L532), 52 (L550), 54 (K 1071), 56 (K4), 58 (C104), 61 (No. 501), 63 (Hy. 16-3), 67 (GL629), 69 (JG20), 77 (P179)	India
57 (P3896), 59 (P2264), 62 (P2663), 64 (P2245), 65 (P2221), 66 (P2566), 80 (P3090)	Iran
70 (P9847), 73 (K1480)	USSR
53 (Giza), 55 (NEC 1572)	Egypt
49 (Rabat)	Morocco
51 (P 9800)	Turkey
60 (Lebanese local)	Lebanon
68 (NEC 1646)	Algeria

a. Name or accession number of the cultivar is given in parentheses.

group had high mean values for seeds per pod, pods per plant, and secondary branches (Table 3). Therefore, genes from kabuli can be transferred to desi and vice versa by hybridization and selection for several combinations of characters already present in the two groups.

It will be reasonable to assume that — like spring and winter wheats — kabuli- and desi-type chickpeas represent two different germplasm pools. Kabuli types possess genetic qualities that the breeder wants for desi types, such as primary branches, 100-seed weight, and upright compact habit. By contrast, desi types can contribute qualities needed in kabuli types, such as seeds per pod, pods per plant, and drought resistance. In short, kabuli and desi germplasm pools — which have been sparingly crossed in the past — offer new sources of variability for many characters.

Kabuli-Desi Introgression

Reviewing the improvement in yield capabilities of different crop species, Frey (1971) ob-

Table 3. Group means for six characters in chickpea.

Group	Primary branches (no.)	100-seed weight (g)	Plant height (cm)	Seed/pod (no.)	Pods/plant (no.)	Secondary branches (no.)
Kabuli	5.46	20.46	67.27	1.23	53.89	16.94
Desi	4.49	14.01	60.65	1.30	88.77	20.42

served that "the primary dilemma facing the plant breeder who wishes to introduce new germplasm into his breeding populations to improve yields per se is where to find such genes." He gives examples from different crops to show that valuable genes do exist in rather remote and unexpected material.

One of the major problems of chickpea is that traditional cultivars of the Indian subcontinent show a bushy habit with dense vegetative growth. Major gains in yield can be achieved if selection is done for an improved plant type in terms of high harvest index, response to increased plant population per unit area, and early maturity. The improvement in plant type with high harvest index is likely to be associated with determinate and compact growth habit (Jain 1975).

We reviewed our present problems and possible experimental approaches in 1973 and planned an aggressive and diversified breeding program with the clear objective of evolving a plant type as theorized on the basis of correlation and path-analysis studies. As a first step in this direction, we augmented our existing germplasm collection by obtaining germplasm lines through communication and through FAO. In order to lay our hands on valuable genes, we stressed geographical diversity in choosing parents for hybridization. Also, in the majority of our planned cross combinations, we used kabuli as one of the parents. In general, kabuli types tend to be semi-erect but give lower yields under Indian conditions than desi types. However, when we compared desi × desi with desi × kabuli types of crosses, we had the unique experience of recovering a higher percentage of transgressive segregates in terms of various yield components in the later type of cross combination. Also, crosses of desi × kabuli parentage showed more phenotypic variability in segregating generations.

Introduction in 1974 of semi-tall ($\simeq$90 cm) kabuli cultivars from USSR marked the beginning of a new approach in our breeding program. Some of the Russian cultivars show an erect growth habit, as they have probably been selected for mechanical harvesting. A distinct weakness of the Russian kabuli talls has been shy podding restricted to about the top one-fourth of the plant. Another difficulty in kabuli × desi type of crosses is the recovery of recombinants with intermediate types of grain, which are neither kabuli nor desi and, therefore, will not attain consumer preference.

We have found by experience that two-way and three-way crosses where we topcross desi × kabuli with another desi type gives us better results. We lay more emphasis on transgressive genes from kabuli to desi types as this is a more pressing problem at the moment. Experience in handling cross combinations involving kabuli germplasm — particularly semi-talls and compact types from USSR — and desi types has been rewarding in many ways. First, we got transgressive segregates in terms of earliness in flowering time, and some of the F_4 lines are 35–45 days earlier than the parents. We hope to select genotypes in this material that will fit into certain nonconventional seasons. These varieties may be specifically relevant to those areas where rabi sowings are delayed due to late harvest of paddy. Also, early maturing types are likely to escape physiological wilt, which comes late in the growing season. Second, we recovered combinants that show almost determinate growth habits. Moving from an indeterminate, which is a wild character, to a determinate type of growth habit involves an expected type of change in chickpea, as ancestral forms of most of the pulses have been found to be indeterminate (Smart 1976). Third, remarkably, we could get individual plants in which the harvest index was better by 10% than the check varieties. Fourth, some of the recombinants from these crosses have relatively erect branches with pod formation starting near the base of the plant.

Thus recombination breeding involving Indian desi types, Mediterranean kabulis, and tall Russian cultivars has helped us to reconstruct new plant types that correspond with the ideotype considered ideal on the basis of our studies earlier referred to in this paper. In such recombinants, part of the increased yield is inherent, and part will be due to performance under high plant populations.

In a few planned crosses in the kabuli-desi introgression program, a proportion of the desi and kabuli germplasm has been so manipulated that it varies from 12.5 to 87.5% in various cross combinations. Plant populations from these crosses with different percentages of kabuli and desi germplasm in F_2 are being studied for individual as well as combinations of characters. On this basis, prediction of the percentage of kabuli germplasm in hybrid combinations giving good scope for selection will be attempted.

Acknowledgments

The author wishes to thank Dr. H. K. Jain, Director, Indian Agricultural Research Institute, New Delhi, under whose direction and guidance this work was done. Thanks are also due to my friend and colleague Mr. R. B. Mehra, who went through the manuscript to offer some very useful suggestions.

References

Bahl, P. N., and Jain, H. K. 1977. Association among agronomic characters and plant ideotype in chickpea (*Cicer arietinum* L.). Zeitschrift fuer Pflanzenzuechtung 79: 154–159.

Bahl, P. N., Mehra, R. B., and Raju, D. B. 1976. Path analysis and its implications for chickpea breeding. Zeitschrift fuer Pflanzenzuechtung 77: 67–71.

Bahl, P. N., Singh, S. P., Hayat Ram, Raju, D. B., and Jain, H. K. 1978. Breeding for improved plant architecture and high protein yields. *In* FAO/IAEA International Symposium on Seed Improvement in Cereals and Grain Legumes. 4–8 Sep 1978.

Frey, K. J. 1971. Improving crop yields through plant breeding. Pages 15–58 *in* Moving off the yield plateau. ASA special publication No. 20.

Jain, H. K. 1975. Breeding for yield and other attributes in grain legumes. Indian Journal of Genetics 35: 169–187.

Jain, H. K., Mukherjee, B. K., Singh, R. D., and Agarwal, K. N. 1976. The present basis and future possibilities of breeding for yield in maize. Zeitschrift fuer Pflanzenzuechtung 76: 90–101.

Mahalanobis, P. C. 1936. On the generalized distance in statistics. Proceedings of National Academy of Science (India) 2: 49–55.

Mock, J. J., and Pearce, R. B. 1975. An ideotype in maize. Euphytica 24: 613–623.

Salimath, P. M. 1979. Unpublished Ph. D. thesis, IARI, New Delhi.

Swaminathan, M. S., and Jain, H. K. 1973. Food legumes in Indian Agriculture. Pages 69–82 *in* Nutritional improvement of food legumes by breeding, (ed. M. M. Milnes).

van der Maesen, L. J. G. 1973. Chickpea: distribution of variability. Pages 30–34 *in* Survey of crop genetic resources in their centres of diversity, (ed. O. H. Frankel), FAO report.

Session 2 – Yield Improvement through Kabuli-Desi Introgression

Discussion

Hawtin and Singh Paper

S. Chandra

There has been considerable interest in desi × kabuli crosses in the late 1950s and 1960s in Punjab (including Haryana). There were three kabuli types (C-104, L-144, L-550) and one desi type (S-33) that were developed and released for cultivation in that region and resulted from desi × kabuli crosses. Other important conclusions drawn in this line of work are:

1. The early generation advantage exhibited by these crosses was due to unusually high heterosis that characterized them in contrast to desi × desi crosses or kabuli × kabuli crosses.
2. The population sizes required in segregating populations for recovery of transgressive segregants were nearly three to four times the sizes required for desi × desi crosses.
3. The intermediates were highly unstable and took many more generations for fixation than the desi or the kabuli-like types.
4. There is an unmanageably large number of intermediate seed types emerging from these crosses. They had the disadvantage of poor seed coat adherance and poor consumer acceptability.
5. Genetic studies showed a conspicuous presence of epistatic and interallelic interactions.

These experiences might well be kept in view while pursuing the work on this aspect.

M. V. R. Reddy

At ICRISAT while screening for *Ascochyta* blight, we have seen that kabuli types produce more vigorous and stronger seedlings than the desis. Because of stronger and vigorous stems they do not die so quickly as the desis do, and whenever there is the chance they do recover better.

G. C. Hawtin

Under field conditions in Syria and Lebanon, kabuli types adapted to West Asian conditions certainly exhibit a greater degree of seedling vigor than nonadapted desis. I agree that this may be important in recovery following pest and insect attack.

C. L. L. Gowda

I feel that kabulis definitely evolved later, probably by mutation. Hence they have less variability and are more susceptible to disease, pests, and vagaries of nature. The fact that they are more exacting in their needs shows that they underwent a shorter evolution than the hardy desi types.

G. C. Hawtin

I agree that kabulis probably evolved later than desis. The evidence suggests they have arisen within the past 2000 years. This does not automatically lead to less variation; however, the range of environments in which kabulis are well adapted is huge. I am not sure we can necessarily assume that kabulis arose at one place from a single mutation.

C. L. L. Gowda

The *macrosperma* do not contain anthocyanin and are white flowered but do not have colorless vegetative organs.

G.C. Hawtin

The term colorless was quoted from the paper of Morcano and Cubero. Obviously, the plants have chlorophyll. The absence of anthocyanin throughout the plant seems to be characteristic of kabulis. I have yet to see a pink-flowered kabuli. This can be made use of in breeding to increase the proportion of kabuli seeds in segregating populations through the roguing of pink-flowered plants.

M. V. Reddy

What could be the reason for cold tolerance in kabulis and heat tolerance in desi types? Kabulis when compared to desis, have more unwanted characters, such as more disease and insect susceptibility. What are the probabilities of linkage between good and bad characters?

G. C. Hawtin

We certainly do not yet know enough about the differences between kabulis and desis, either genetically or physiologically, to give an adequate answer to your question. Until the last few years, very little work has been done on kabuli types, compared to the work on desis in the Indian subcontinent. It is possible that we will find resistance to many insects and pathogens within the kabuli group if we look harder for it. This was certainly the case with *Ascochyta* blight resistance. The absence of anthocyanin pigmentation throughout the plant in the kabulis may ultimately be shown to be responsible, at least in part, for poor disease and insect characteristics. This, however, has certainly not been adequately proven yet, and even if it is, can we not envisage the existence of other resistance mechanisms that might be used in improving kabuli types.

A. Q. Samet

I would like to draw your kind attention to the fact that the origin of kabuli chickpeas is Kabul, capital of the Democratic Republic of Afghanistan. Fifty years ago, when the great Russian botanist Vavilov was collecting the plants from West Asia, his report clearly mentioned that the place of origin of chickpea is Kabul, so kabuli belongs to Kabul.

L. J. G. van der Maesen

The designation "kabuli" was given in India when the large-seeded white chickpeas first came to that country through Kabul. This happened about 3 centuries ago.

R. B. Singh

1. Low recovery of kabuli types in the kabuli × desi crosses may not be generalized. Certain genotype combinations may give the expected proportion of kabuli and desi types in the F_2 populations. In case you visualize a genetic drift as a cause for the abnormal proportions, what is your basis of thinking so?
2. I feel crosses among "near-kabuli" segregants of the kabuli × desi crosses coupled with directional selection should yield the desired results.

G. C. Hawtin

I do not consider genetic drift to be an important factor determining the low recovery of kabulis in West Asia. If it is a factor at all, one would expect the reverse, i.e., a greater recovery of seed characters associated with the more adapted parent. Obviously, a large number of genes are involved in the determination of kabuli and desi characteristics, and it would appear that the recovery of kabulis may depend to a considerable extent on the interactions between the two parental genotypes. We at present know nothing about modifying genes, epistatic effects, and so on in regard to the determination of seed characteristics. As shown in my paper, of seven F_2 populations studied, recovery of kabulis ranged from less than 6% to over 22%. Other people have also found such wide variation.

D. Sharma

While studying transgressive segregation for yield in kabuli × kabuli, desi × desi, and desi × kabuli crosses, have you compared crosses involving parents with comparable seed size in the two groups? Generally, a kabuli parent used in the crosses is the one with a large seed size. Recovered kabuli with higher yield than the kabuli parent is smaller in seed size than the kabuli parent.

G. C. Hawtin

We have not made any detailed studies on seed size. I do not believe, however, that there is a strong negative correlation between yield and seed size within the seed size range of, say 20–35 grams per 100 seeds. Most of the parents used have fallen within this range.

J. S. Sindhu

Which component of yield is likely to be improved in the desi × kabuli crosses, and why is it that the advantage of that character component goes to the improvement of kabuli and not desi chickpea?

G. C. Hawtin

I don't think the advantage of kabuli-desi introgression is merely the combining of complementary yield components. Different responses to stress conditions, different growth characters, and possibly different yield-efficiency genes may have developed in the separate gene pools. The introgression of these factors is likely to reflect itself in increased yield per plant, which presumably will reflect most in seeds per plant or pods per plant, although of course, other components may be affected.

Jambunathan and Singh Paper

M. V. Reddy

Is there any information on the chemical composition of kabuli and desi plants themselves? Some of the chemical differences in the plants could be affecting physiological efficacy of these two subgroups.

R. Jambunathan

We have not analyzed any kabuli- or desi-type plants for proximate composition.

Umaid Singh

A considerable amount of chickpea, particularly in India, is consumed as parched or puffed chickpea. Large variations in the percentage of seed coat exist between kabuli and desi types. There is a point in measuring the thickness of seed coats where this factor plays a greater role in determining the extent of parching or puffing that remain consumer preferences.

R. Jambunathan

As mostly desi types are used for parching and puffing, I am not sure whether information on the thickness of seed coat of both desi and kabuli types would be of much help.

Umaid Singh

This is a suggestion regarding the chemical analysis of kabuli and desi types. As we have seen, there are some differences in the chemical constituents of kabuli and desi types. From a nutritive point of view, it would be worthwhile to study the levels of antinutritional factors in kabuli and desi types. Further, the biological value and digestibility of kabuli and desi chickpeas should be studied.

R. Jambunathan

I agree that it will be worthwhile to have this information.

V. P. Gupta

It would be advisable to study the amino acids of kabuli and desi because we are interested in both the consumer quality and the protein quality in kabuli specifically. Our studies have indicated that kabuli (L-144) type has a better essential amino acid index (92%) than does desi (H-208, 80%). This was mainly due to the high amount of lysine (more than 20%) and methionine in kabuli as compared to desi.

R. Jambunathan

We have analyzed a few desi and kabuli cultivars for their amino acid composition and there appear to be no significant differences between these two types.

Haware et al. Paper

J. S. Sindhu

At Kanpur we have worked out the genetics of wilt resistance in chickpeas. Segregation patterns in F_2 and BC_1 populations in the wilt-sick plot have proved that resistance to this disease is governed by a single recessive gene.

M. P. Haware

We know about your studies at Kanpur. I feel that to study inheritance of resistance in soilborne pathogens, studies should be conducted under controlled conditions. Under field conditions, due to presence of other root rot pathogens, results are sometimes misleading.

R. B. Singh

In view of the possible occurrence of biotypes or physiological races of *Aschochyta* blight, the oligogenic inheritance (monogenic) of resistance as suggested by you and others needs to be searched more critically. A detailed study involving diverse genotypes on genetics of resistance to *Aschochyta* blight is warranted.

M. P. Haware

I agree with you, as we are getting more evidence about the presence of races in *Ascochyta rabiei*. International nurseries may provide us with more information on races, and if so, study involving diverse genotypes on genetic resistance will be undertaken at ICARDA.

Knights Paper

M. C. Saxena

Your presentation highlights the need for chemical weed control in Australia. Would you please specify the chemicals and rates recommended for use.

E. J. Knights

Simazine has been found to be the most effective herbicide for broad-spectrum weed control, although the level of control is dependent on soil moisture at and immediately after application. A rate of 1.5 kg active ingredient/ha usually gives excellent control, although toxicity systems show up in some cultivars.

Jagdish Kumar

In seven desi × kabuli F_2 populations we recovered less than 5% kabulis. The kabuli-type parents used were P-9623, L-550, and Giza. I wonder what were the parents you used?

E. J. Knights

The kabuli parents were: K-1480 (USSR), K-583 (USSR), CPI-56565 (USSR), CPI-56329 (Iran), and CPI-56296-6 (Afghanistan).

A. S. Gill

Why was germination reduced in the case of desi types when they were treated with Thiram/Captan?

E. J. Knights

Generally, there was a slight, but nonsignificant increase. The one exception, CPI-56315, could be explained by experimental error.

Y. S. Tomer

Why was the germination of the black-seeded types reduced when treated with Thiram/Captan?

E. J. Knights

First, the reduction was minimal and can most reasonably be explained by experimental error. Alternatively, there may be a correlation between concentration of phenol and intensity of color.

C. L. L. Gowda

The black-seeded cultivar CPI-56315 gave a higher percentage of germination in the untreated check. At ICRISAT, the black-seeded cultivars lose most of their viability after 18 months of storage at ambient temperature. How long was the seed in your study stored, and how do you relate your results with our experience?

E. J. Knights

Storage was for 18 months. Temperature and humidity are lower at Wagga Wagga than in India. The −0.3% difference is probably due to natural variation.

J. Kannaiyan

Do you encounter any serious disease problems in chickpea in Australia?

E. J. Knights

There is a root rot/aerial blight complex that can reduce yields under low temperatures. The major fungal genera are *Botrytis, Sclerotinia, Rhizoctonia*, and *Fusarium*. Appropriate seed dressing can substantially reduce disease incidence.

Bahl Paper

A. S. Tiwari

1. Experiences of desi-kabuli introgression at Jabalpur reveal that wide variations occur not only for seed color but also for seed shape and size.
2. Selection for complementary characters is difficult because of tight linkages resulting in little yield increases.
3. Therefore, a word of caution that in such introgression either a very large F_2 should be raised or crossing among F_2s may be attempted in order to break tight linkages.
4. Besides the desirable characters of kabuli mentioned, two such types, JG-18 and JG-20, were found to have a very high positive response to *Rhizobium* inoculation compared to desi types, such as JG-74.

R. B. Singh

Higher genetic diversity revealed by D^2 analysis among the kabuli types as compared to desi types may not be real. The number of strains sampled, background selection history, and edaphic geoecological parameters would affect the estimates, and thus before any generalization is made regarding variability as revealed by D^2 analysis, information on the parameters mentioned above should be considered.

P. N. Bahl

Our data does show greater genetic heterogeneity among kabuli cultivars. I agree, however, that additional data and other studies in this direction may help to elucidate further some points raised by Prof. Singh.

T. S. Sandhu

I wonder whether we should search for a determinate plant type, keeping in view the growth habit of the chickpea plant, or should we search for genotypes with desirable growth habit less influenced by environmental conditions? The chickpea plant is very sensitive to environmental conditions. Its growth habit is highly influenced by spacing, sowing time, rainfall, and other related factors.

P. N. Bahl

Search for both desirable plant type as well as determinate type.

J. M. Green

After much discussion, which if taken seriously, would discourage you, I trust you will persevere in the development of your target ideotype. You (P. N. Bahl) have made excellent progress to date.

J. P. Yadavendra

Path coefficient analysis may be more precise if computed through genotypic correlations and not through simple correlation.

P. N. Bahl

Path coefficient analysis was done on genotypic values. Data given in the paper on simple correlations and path analysis came from different studies.

R. B. Deshmukh

What is your experience of crosses between genetically diverse parents among the desi types in respect to heterosis, combining ability, and segregation in early generations? How do they compare with crosses between desi × kubuli types? Don't you think that kabuli may transfer some undesirable characters, such as susceptibility to heat and poor plant stand?

P. N. Bahl

Magnitude and direction of heterosis will differ according to the parents involved in each of the two types of crosses. But we have had good success in kabuli × desi crosses. There are good combining parents in both the types. You can get rid of undesirable characters by applying the right type of selection pressure.

A. R. Sheldrake

1. Branching varies greatly according to spacing. How would you select for this?
2. We have tested upright types at high population density and find they have no advantage over normal types.
3. What does Dr. Bahl mean by determinate type?

P. N. Bahl

1. Selection is done on the pattern of branching. Also branching is compared with check varieties repeated at regular intervals under identical conditions.
2. Your data on upright types relate to unadapted cultivars. I am talking of tall upright recombinants that will be adapted to our conditions. We hope these will respond to high population density.
3. Determinate types here refer to those plants with a shorter span of flowering duration and which put up a restricted number of branches.

S. Lal

What is the flowering duration in determinate segregants in kabuli × desi crosses? If it is shorter than in an indeterminate type, it serves the meaning of determinate type. At the same time, what is the sequence of flowering in the determinate types — acropetal or basipetal?

P. N. Bahl

Flowering duration was reduced in a proportion of the segregants in the kabuli × desi crosses. The sequence of flowering is still acropetal, but these determinate types quit flowering early.

Session 3

Chickpea Agronomy and Physiology

Chairman : E. H. Roberts
Co-Chairman: M. Abdullah Khan
Rapporteur: S. C. Sethi

Recent Advances in Chickpea Agronomy

M. C. Saxena*

Because of the growing awareness of the importance of chickpea as a food legume crop in the semi-arid tropics and the Mediterranean areas of the developing world, increasing attention is being paid to chickpea improvement through national and international efforts. For the full exploitation of the yield potential, chickpea cultivars must be grown with adequate agronomic management. Thus, research on production agronomy is of great significance.

The agronomic requirements of chickpea and past research on its production agronomy have been reviewed elsewhere (van der Maesen 1972; Saxena and Yadav 1975). This paper covers some of the more recent work and is heavily dependent upon local reports, since much of the information on agronomic research is location specific and does not find its way into research journals.

Planting Date

Several studies in the various chickpea-growing areas have established the significance of date of planting in influencing crop growth and yield. As in the past, most of the recent studies on response of newly developed genotypes of chickpea to dates of planting in different parts of India, under the All India Coordinated Project, have indicated that mid-October to mid-November is the ideal period of planting and any deviation from this causes conspicuous reduction in yield (Kaul and Sekhon 1976; Saxena and Singh 1977; Panwar 1978; Sharma 1978). In areas where the winter period is rather short, e.g. in the eastern and southern parts of India, the optimum range for planting becomes still narrower. For example, Sen (1978) reported that the first week of November was the best planting time for chickpea in Berhampur, West Bengal. Studies on date of planting, with six promising genotypes of chickpea at Debre-Zeit in Ethiopia, revealed that 1 September was the best and delaying the planting any further caused drastic yield reductions (Bezuneh 1975).

How date of planting could affect the crop performance through interaction between the altered aerial and edaphic crop environment has been well illustrated by studies of Ageel and Ayoub (1977) at Hudeiba Research Station in Ed-Damer, Sudan. In their study, which was carried out with irrigated chickpea on alkaline soils of three different textural classes, sowing date affected the yield by influencing not only the growth and major yield components per plant but also plant stand (Table 1). The best sowing date was found to be between the end of October and the end of November, which resulted in maximum survival of the plants. Seedlings from the plantings made earlier or later than this period showed symptoms of toxicity associated with excessive sodium accumulation. High mean maximum temperature and low relative humidity to which the seedlings were exposed when planted outside the optimum time range led to excessive sodium accumulation in the shoots and resulted in seedling mortality. Surviving plants showed poor vegetative and reproductive growth and thus gave low seed yield primarily through reduced pod formation per plant (Table 1).

A significant advancement in the agronomy of chickpea in West Asia is the possibility of a complete change of the traditional sowing season from spring to early winter (Kostrinski 1974). Throughout most of the Mediterranean and the Near East where major rainfall occurs in winter, chickpea is grown on conserved soil moisture in the early spring. A rapid rise in temperature and the desiccative power of the atmosphere cuts short the vegetative and reproductive growth period of the crop, thus resulting in low yield. Studies initiated in the Arid Land Agricultural Development (ALAD) Program in Lebanon, in 1974–75, revealed that

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Table 1. Effect of sowing date on plant survival, crop growth rate (CGR), total plant dry weight at maturity, and pods per plant in local chickpea at the Hudeiba Research Station, Sudan.

Date of planting	No. of plants/m²[a]	CGR[b] (g/m²/week)	Dry weight (g/plant)	No. of pods/plant
Oct 1	0	NA	NA	NA
Oct 15	4	0.7	3.1	10
Oct 29	9	12.1	10.8	39
Nov 12	11	34.7	24.5	77
Nov 26	13	32.1	23.8	72
Dec 10	11	26.1	11.9	31
Dec 24	10	18.4	9.5	25
Jan 7	8	11.4	6.9	24
Jan 21	6	12.1	10.6	34
S.E. ±	0.3	4.9	1.02	4.6

a. Original population established 16.7 plants/m².
b. Between the period from 4 weeks after planting to onset of flowering.
NA = Not available.
Source: Ageeb and Ayoug (1977).

the existing chickpea lines have enough cold tolerance to survive the winter in the low- and medium-elevation areas of the region. But there is greatly increased risk of severe crop losses from *Ascochyta* blight. This was well demonstrated in a yield trial during the 1976–77 winter season in northern Syria, where all entries except one were destroyed by the disease (Hawtin et al. 1978). That planting in winter could give a considerable yield advantage was also established by this study as the single surviving entry (NEC-2305) in the trial with moderate resistance to *Ascochyta* blight yielded more than 3 tonnes/ha, compared with 950 kg/ha in spring planting. The best variety in the same trial in spring produced only 1621 kg/ha.

With the establishment of the ICARDA research station at Tel Hadia, Syria (36°N, 37°E, 392 m above sea level) in 1977, systematic dates of planting studies were initiated using local cultivars and some promising genetic stocks under fungicidal protection from *Ascochyta* blight. In one such study, eight genotypes were planted on six different dates covering the range from early winter to spring. Seedling establishment in the last date of planting (March 26) was extremely poor, and the crop failed. The yield performance of the crop from the first four dates is shown in Table 2. Averaged over all genotypes, the yield from spring planting (March 6) was about 38% of that obtained from the December 4 planting. Genotypes differed in the magnitude of their response; NEC-1656 showed much more reduction in the yield with delay in planting than the Syrian local. The reduction in the yield was mainly because of reduction in pod number per plant (Table 3).

Similar response to date of planting was observed in another trial where the effect of row spacings and plant population levels on the performance of Syrian local and NEC-2300 cultivars planted on different dates was studied (Table 4). Thus, substantial increases in yield are possible by winter planting if the crop is protected from *Ascochyta* blight either by increasing crop tolerance or by chemical control.

At higher elevations, e.g. on the Anatolian plateau, where winter temperatures can become extremely low, sometimes reaching −30°C without a protective snow cover, the planting has to be done in spring, and tolerance to these extreme conditions will have to be introduced in the varieties before they can be grown successfully there in winter. Studies on irrigated and rainfed kabuli and desi chickpea in Tabriz, Iran, have shown that the end of April to the beginning of May is the best period for planting ([illegible] 1976).

Table 2. Effect of date of planting on the grain yield (kg/ha) of eight genotypes of chickpea at Tel Hadia, Syria, 1977–78.

Genotype	Date of planting				Mean
	Dec 4	Dec 29	Feb 2	Mar 6	
NEC-30	1820	1662	1639	787	1477
NEC-144	1409	1576	1031	572	1147
NEC-266	1468	1576	1294	954	1323
NEC-239	1954	1900	1531	809	1548
NEC-1540	1907	1868	1618	768	1541
NEC-1656	2142	1918	1542	741	1586
NEC-2305	1744	1487	1241	698	1292
Syrian local	1689	1804	1422	955	1467
LSD (0.05)			438.8		215.6
Mean	1767	1724	1415	666	
LSD (0.05)			211.7		
CV%			18.5		

Table 3. Effect of date of planting on mean height, number of branches, and number of pods per plant of eight genotypes of chickpea at Tel Hadia, Syria, 1977–78.

Attribute	Date of planting			
	Dec 4	Dec 29	Feb 2	Mar 6
Plant height (cm)	34.0	32.3	26.7	22.3
Number of branches/plant	6.5	6.5	5.6	5.0
Number of pods/plant	22.0	19.4	13.9	10.9

Table 4. The effect of date of planting and plant population on the grain yield (kg/ha) of Syrian local and NEC-2300 cultivars of chickpea at Tel Hadia, Syria, 1977–78.

Cultivar/population level	Date of planting			Mean
	Dec 4	Feb 2	Mar 6	
Cultivar				
Syrian local	1732	1004	661	1132
NEC-2300	1412	928	652	997
LSD (0.05)		239.6		138.4
Population per ha				
185 000	1487	947	632	1022
278 000	1657	984	681	1107
LSD (0.05)		85.6		49.4
Mean	1572	966	657	
LSD (0.05)		169.5		
CV%		14.3		

Plant Population and Planting Geometry

The optimum level of plant population seems to differ depending upon the environmental conditions and the plant type. In a congenial environment that permits an adequate period for vegetative and reproductive growth, most of the genotypes show little change in yield with large variations in population, as has become evident from studies carried out in north India (Panwar 1978; Saxena and Sheldrake 1977; Saxena and Singh 1977). Most of these and earlier studies suggest that a population level of about 33 plants/m^2 is adequate.

If plant growth is restricted by an unfavorable aerial environment, the response to plant population varies with the availability of soil moisture. Studies at Tabriz showed that yield increased with increasing plant population up to 50 plants/m^2 for irrigated chickpea, whereas for unirrigated chickpea the optimum level was 24.8 plants/m^2 (Anon. 1976). Kostrinski (1974) observed a 52% increase in yield when the population level of winter chickpea in Israel was doubled by reducing the row spacing to 30 cm from the usual 60 cm spacing. Significant increase in yield of rainfed chickpea at Tel Hadia, Syria, during 1977–78 was obtained as the population was raised from 18.5–27.8 plants/m^2 only in the winter planted crop (4 Dec 1977) and not in the March planting (Table 4).

The response of winter and spring planted chickpea, raised with supplemental irrigation, was studied to increasing plant density in a fan-type design at Tel Hadia in 1977–78 using genotypes of differing growth habit. The yield generally increased as the population level was raised from 4.4 to 71.7 plants/m^2 (Table 5).

Genotypic differences in response to plant population have been frequently observed (Panwar 1978; Saxena and Sheldrake 1977; Saxena and Singh 1977). Studies at the ICARDA site in Tel Hadia (Table 5) indicated that an increase in yield due to increased plant population was of greater magnitude in NEC-141, a relatively compact and upright-growing genotype, than in the Syrian local cultivar, which had a spreading growth habit. In a separate study at the same site with spring planted chickpea raised with supplemental irrigation, the yield increased by 28 and 62% in NEC-249 and NEC-138 chickpea respectively, as the population was raised from 16.6 to 50 plants/m^2. Both these genotypes had a somewhat compact and upright growth habit. In contrast to this, NEC-1540 and Syrian local, the two spreading types, showed relatively less increase in yield with the increase in population.

Planting geometry does not seem to have a conspicuous effect on crop performance at an adequate level of plant population. Studies at ICRISAT (Saxena and Sheldrake 1976) compared rectangularity ranging from 1 to 12 during

Table 5. Yield of Syrian local and NEC-141 chickpea, grown at Tel Hadia, 1977–78, supplemental irrigation[a], as affected by plant population varied in a fan-type design.

Plant population (plants/m^2)	Grain yield (kg/ha)			
	Winter		Spring	
	Syrian local	NEC-141	Syrian local	NEC-141
4.4	784	495	629	292
6.3	1051	729	764	311
9.2	1294	840	673	617
13.4	1023	1076	772	758
23.6	1357	1133	991	637
28.4	1721	1616	1295	778
41.3	2535	2143	1158	1020
48.9	2811	2773	1707	1471
71.7	3041	2868	2223	2008

a. Crop was irrigated two times in the spring.

the 1975–76 crop season. Based on this and previous studies, it was concluded that there was no need for square planting of chickpea in Hyderabad. Studies at ICARDA during 1977–78 with rectangularity ranging from 1.6 to 6.66 at 18.5 plants/m^2 and 2.5 to 6.0 at 27.8 plants/m^2 plant population level revealed that there was no significant effect of this on the yield of Syrian local and NEC-2300 chickpea.

Effect of variations in the seed size within a cultivar and the row direction was studied at Hyderabad and Hissar by Saxena and Sheldrake (1976). The yield was not affected by these variables in all the genotypes studied.

Fertilizer Use

Total uptake of nitrogen by a chickpea crop has been estimated to vary from 60–143 kg/ha, depending upon the growing conditions of the crop (Saxena and Sheldrake 1977). These estimates are very near to the ones made earlier (Saxena and Yadav 1975). Positive response to starter nitrogen dressing of about 15–25 kg N/ha has been reported by several workers on the sandy and sandy loam soils poor in organic matter (Tripathi et al. 1975; Sharma et al. 1975; Chundawat et al. 1976; Rathi and Singh 1976). No such response, however, has been obtained on soils of relatively better fertility status (Chowdhury et al. 1975; Raikhelkar et al. 1977; Saxena and Singh 1977; Dhingra et al. 1978). Symbiotic N fixation apparently seems to be effective enough in most of these areas to meet the major nitrogen need of the crop. Studies by Saxena and Sheldrake (1976) on the effect of starter N dressing (20 kg N/ha) on nodulation and crop growth revealed that there was no adverse effect on the former and the early crop growth was slightly improved. The positive effects, however, became less and less conspicuous with the advancement in age and, therefore, no yield advantage was obtained. In areas where nodulation has been either very poor or has completely failed, significant response to increasing rates of N application have been obtained. Experiments at Hudeiba Research Station in Sudan, from 1973–1976, with irrigated chickpea have shown such positive responses up to 120 kg N/ha. Split application (1/2 at seeding and 1/2 at flowering) was found to be better than a complete, single application, particularly when an intermediate amount of N (80 kg N/ha) was used. During the 1977–78 crop season, chickpea nurseries at ICARDA in Tel Hadia had to be topdressed with nitrogen as they had poor nodulation and showed nitrogen deficiency symptoms. No chickpea had been grown on that site in the recent past, and the nursery seeds were not inoculated with *Rhizobium* culture.

Phosphorus uptake has been reported to range from 5 to 10 kg/ha, depending upon the crop growth conditions (Saxena and Sheldrake 1977). The latter also affected the course of P accumulation. Considerable attention has been paid to the response of chickpea to phosphate fertilization. Positive response to phosphate application (up to 50–75 kg P_2O_5/ha) has been obtained at Delhi (Chowdhury et al. 1975), at Kanpur (Rathi and Singh 1976; Panwar et al. 1977), in Rajasthan (Chundawat et al. 1976), and at Jabalpur (Sharma et al. 1975) in India. The soils used were reported to be low in available phosphorus content. Panwar et al. (1977) analyzed the phosphate response for 2 years at Kanpur and 1 year at Bareilly and found that the response was quadratic. The mean yield equation was given as

$$Y = 2090.7 + 17.182X - 0.1488X^2$$

where Y is yield (kg/ha) and X is kg of P_2O_5/ha.

In contrast to these observations, several other investigators have found no positive response to phosphorus application even in soils testing medium to low in available phosphorus (Srivastava and Singh 1975; Anon. 1976; Saxena and Sheldrake 1976, 1977; Raikhelkar et al. 1977; Saxena and Singh 1977; Dhingra et al. 1978). Lack of response to phosphate application could not be attributed to reduced soil moisture availability, as even under irrigated conditions no response was obtained (Saxena and Sheldrake, 1976, 1977; Raikhelkar et al. 1977; Saxena and Singh 1977). Even different methods of application, including soil incorporation of phosphate in a preceding rainy season or just before planting, or deep placement, had no effect on chickpea grown on soil testing low in available phosphate (2–5 ppm) during 1975–76 at Hyderabad in the studies carried out by Saxena and Sheldrake (1976). Analysis of the soil at the end of the crop season in their 1975–76 and 1976–77 studies revealed that the phosphate fertilization did not increase the available phosphate status of the soil.

Therefore, it was concluded that the high phosphate-fixing capacity of the soil was responsible for lack of crop response to applied phosphate. It may be mentioned, however, that dusting the crop with finely ground rock phosphate and single superphosphate also had no stimulatory effect under similar soil conditions (Saxena and Sheldrake 1977). At the same time, in none of these studies were any apparent symptoms of phosphate deficiency noted on the crop. Studies at ICARDA have revealed that chickpea failed to respond to phosphate fertilization on the same soil on which lentil and broadbean showed phosphate deficiency symptoms without P and growth promotion with P fertilization. All this points to the possibility that chickpea might be more efficient in uptake and utilization of soil phosphorus.

Lately, considerable interest has been shown in the use of foliar spray of N, P, K, and S solution at the time of pod filling in food legumes following the observations of Hanway (1976) that such spray could increase the yields of a well-managed crop of soybean. Studies carried out at Pantnagar (India) during 1976–77, as a part of the Coordinated Research Program of the International Atomic Energy Agency and FAO Joint Division, revealed that there was no improvement in the yield of chickpeas from foliar spraying of Hanway solution (Table 6). Labelling of fertilizer nitrogen with N^{15} and using a nonnodulating crop of linseed, we estimated the symbiotic N fixation of the chickpea crop receiving 20 kg N/ha as starter dressing to be 63 kg N/ha, which was 92% of total N yield in the crop. Soil and foliar application of more N reduced the symbiotic N fixation.

A number of cultivars of chickpea, when grown on high pH soils rich in calcium carbonate, show typical symptoms of iron deficiency. The deficiency has been observed at Hyderabad (Saxena and Sheldrake 1977) and at various ICARDA sites in Syria and Lebanon. Local kabuli cultivars from Syria and Lebanon do not show any such deficiency, whereas some of the desi cultivars, particularly NEC-2300, NEC-2304, and NEC-2305, show very conspicuous symptoms early in the season. Saxena and Sheldrake (1977) obtained a 42% increase in the yield of susceptible cultivars (ICC-1685 and ICC-10157) from spraying a 0.5% w/v ferrous sulfate solution near the beginning of reproductive growth and a fortnight later. No further advantage was obtained with repeated spraying.

On soils testing low in available zinc, symptoms of zinc deficiency have been observed early in the crop season. Conspicuous varietal differences have been observed in the

Table 6. Chickpea response to soil-applied N and foliar spray of Hanway solution[a] (80N + 8P + 24K + 4S) at Pantnagar, 1976–77.

Treatment				
	At pod filling		Yield (kg/ha)	
At seeding	Top dress	Foliar spray	Grain	Total dry matter
0	0	0	1725	2815
0	0	+ (N)[b]	1581	2594
20 kg N[b]	0	0	1865	2989
20 kg N	0	+ (N)[b]	1514	2466
20 kg N	20 kg N[b]	0	1610	2780
20 kg N	20 kg N[b]	+	1520	2504
20 kg N	20 kg N[b]	0	1490	2466
20 kg N	80 kg N[b]	+	1347	2249
F test			NS	NS
S.E.M. ±			150	265
C.V. (%)			24	21

a. Foliar spray of Hanway solution was applied four times to provide a total of 80 kg N, 8 kg P, 24 kg K, and 4 kg S/ha.
b. N labelled with N^{15}.

susceptibility to zinc deficiency. The deficiency can be corrected by a foliar spray of 0.5% w/v zinc sulfate solution (Saxena and Singh 1977). Positive yield response to soil application of 25 kg zinc sulfate/ha has been observed at Ludhiana, India (Dhingra et al. 1978). Recent studies at Kanpur, India (Panwar 1978), have shown that soil application of 1 kg sodium molybdate/ha increased the seed yield of T-3 chickpea by 19% over the diammonium phosphate-applied check and by 38% over the absolute control.

Water Requirement and Irrigation

The potential evapotranspiration of a chickpea crop, as computed by the Thornthwaite formula, under the conditions of Hissar (India), ranged from 204 to 280 mm, depending on the crop season (Sharma et al. 1974). Studies made by Gupta and Agrawal (1976) at Jabalpur (India) indicated that consumptive use of water based on water balance in the root zone was 247, 257, and 290 mm for the JG-62 variety of chickpea under 0, 1, and 2 irrigations, respectively.

Although most of the chickpea crop in the world is grown on moisture conserved in the soil from the rain received prior to planting, the crop responds favorably to supplemental irrigation (Sharma et al. 1974; Kaul 1976; Koinov and Vitkov 1976; Raikhelkar et al. 1977; Panwar 1978; Sharma 1978). Irrigation during the preflowering period (at the early stage of vegetative growth on soils having low water-holding capacity and at the late vegetative phase on heavier and deeper soils) and at early pod filling stage has consistently resulted in increased yields at several locations in India (Kaul 1976; Raikhelkar et al. 1977; Saxena and Singh 1977; Panwar 1978; Sharma 1978). Irrigation improved the nodulation and increased the per plant yield by increasing the pod number (Kaul 1976).

Weed Control

Crop yield losses due to weeds have been estimated to range from 30 to 50% (Panwar and Pandey 1977; Sandhu et al. 1978; Singh et al. 1978). Whereas hand weeding at 30 and 60 days after planting has been very effective in controlling weeds, several herbicides have also given promising results. Laptiev (1976) reported that the application of 1 – 3 kg Gesagard 50 (prometryne) or A 3623 (terbuthylazine + terbutryne) per ha decreased the population of annual weeds by 70–80% and increased seed yield. Preemergence application of 1.5 kg a.i./ha of nitrofen or 0.5 kg a.i./ha of prometryne were found to be very effective at Kanpur (Panwar and Pandey 1977). Pre-plant incorporation of 1 kg a.i./ha of Basalin gave good weed control on silty-clay loam soils of Pantnagar (Singh et al. 1978). Pre-plant application of Basalin (48 EC) at the rate of 1 kg product/per ha was found effective on the sandy loam soils of Ludhiana (Sandhu et al. 1978). Preemergence application of 1 kg product of either terbutryne (80% WP) or Lorox (50% WP) also proved highly promising. It is apparent from the foregoing that no single herbicide is effective for all conditions and the choice of herbicide as well as its rate of application will vary depending upon the nature of weed infestation and the soil type.

References

AGEEB, O. A. A., and AYOUB, A. T. 1977. Effect of sowing date and soil type on plant survival and grain yield of chickpea (*Cicer arietinum* L.). Journal of Agricultural Science U.K. 88(3): 521–527.

ANONYMOUS. 1976. Annual Report of 1975 on grain legumes, Tehran University School of Agriculture, Karaj, Iran.

BEZUNEH, T. 1975. Status of chickpea production and research in Ethiopia. Pages 95–101 *in* International Workshop on Grain Legumes, ICRISAT, Hyderabad, India.

CHOWDHURY, S. L., RAM, S., and GIRI, G. 1975. Effect of P, N and inoculum on root, nodulation and yield of gram. Indian Journal of Agronomy 20(3): 290–291.

CHUNDAWAT, G. S., SHARMA, R. G., SHEKHAWAT, G. S. 1976. Effect of N, P and bacterial fertilization of growth and yield of gram in Rajasthan. Indian Journal of Agronomy 21(2): 127–130.

DHINGRA, K. K., SEKHON, H. S., and TRIPATHI, H. P. 1978. Pages 29–31 *in* Pulses agronomy progress report 1977–78, Department of Plant Breeding, PAU, Ludhiana: 29–31.

Gupta, R. K., and Agrawal, G. G. 1976. Consumptive use of water by gram and linseed. Indian Journal of Agricultural Science 47(1): 22–26.

Hawtin, G. C., Singh, K. B., and Saxena, M. C. 1978. Some recent developments in the understanding and improvement of chickpea and lentil. International Legume Conference, Royal Botanical Gardens, Kew, England, 31 July–5 Aug 1978.

Kaul, J. N. 1976. Pulses agronomy report of 1975–76, Plant Breeding Department, PAU, Ludhiana.

Kaul, J. N., and Sekhon, H. S. 1976. Performance of three chickpea (gram) genotypes, as affected by the dates of sowing and row spacing. Crop Improvement 3(1/2): 22–26.

Koinov, G., and Vitkov, M. 1976. Investigation of irrigation regime for chickpea on podzolized chernozem soils in northeastern Bulgaria. Rastenievʺdni Nauki 13(8): 59–62.

Kostrinski, J. 1974. Problems in chickpea cultivation and grain crop rotation in Israel. Special Publn., Agric. Res. Org., Volcani Centre, No. 34, 51 pp.

Laptiev, A. 1976. Chemical control of weeds in chickpea. Turdy, Nauchno-issledovatel'skit. Institut Zashchity Rastenii No. 12: 150–158.

Panwar, K. S. 1978. Latest technology for cultivation of gram. All-India Subject Matter Seminar on Pulse Production Technology (Rabi Pulses) held at C.S.A. Univ. of Agric. Tech., Kanpur, 28–30 August 1978.

Panwar, K. S., and Pandey, K. 1977. Weed control studies in Bengal gram. Indian Journal of Agronomy 22(4): 257–259.

Panwar, K. S., Singh, Y. P., Singh, U. V., and Misra, A. S. 1977. Response of gram, lentil, and field peas to inoculation and levels of nitrogen and phosphorus. Indian Journal of Agronomy 22(3): 145–148.

Raikhelkar, S. V., Quadri, S. J., and Bagade, D. N. 1977. Irrigation and fertilizer requirement of gram. Journal of Maharashtra Agricultural Universities 2(2): 144–147.

Rathi, S. S., and Singh, D. 1976. Effect of nitrogen and phosphate fertilization on the growth and yield of gram. Indian Journal of Agronomy 21(3): 305–306.

Sandhu, K. S., Kolar, J. S., Kalsi, N. [illegible], and Singh, S. 1978. Chemical weed control in irrigated gram. Journal of Research, PAU 15.

Saxena, N. P., and Sheldrake, A. R. 1976. Pulses physiology annual report 1975–76, Part II: Chickpea physiology, ICRISAT, Hyderabad, 176 pp.

Saxena, N. P., and Sheldrake, A. R. 1977. Pulses physiology annual report 1976–77, Part II: Chickpea physiology, ICRISAT, Hyderabad, 179 pp.

Saxena, M. C., and Singh, H. P. 1977. Studies on agronomic requirements of winter pulses. Pages 23–42 *in* Research on Winter Pulses, G.B.P. Univ. of Agric. and Tech., Exp. Sta. Bull. 101. 23–42.

Saxena, M. C., and Yadav, D. S. 1975. Some agronomic considerations of pigeonpea and chickpeas. Pages 31–61 *in* International Workshop on Grain Legume, ICRISAT, Hyderabad, India.

Sen, S. N. 1978. Studies on suitability of the different improved types of gram under early and late sowing conditions. 1977–78 Agronomy report of pulses and oil seeds research station, Berhampur, W. Bengal.

Sharma, J. 1978. Report of the agronomy section of the pulses improvement project at University of Agric., Udaipur Research Station, Durgapura, 1977–78.

Sharma, H. C., Tejsingh, and Mohan, D. S. R. 1974. Response of gram varieties to irrigation.Haryana Agricultural University Journal of Research 4(4): 255–260.

Sharma, P. P., Singh, P., and Singh, P. P. 1975. Response of N and P in relation to method of application on the yield of gram (*Cicer arietinum*). JNKVV Research Journal 9(1/2): 21–23.

Singh, N. P., Singh, H. P., Sahu, J. P., and Sharma, B. B. 1978. 1977–78 Report on the agronomy of rabi pulses, G. B. Pant University of Agric. and Tech., Pantnagar.

Srivastava, S. P., and Singh, A. P. 1975. Phosphorus fertilization in gram under dryland conditions. Science and Culture 41(11): 527–528.

Tripathi, R. S., Dubey, C. S., Khan, A. W., and Agrawal, K. B. 1975. Effect of application of *Rhizobium* inoculum on the yield of gram varieties in Chambal Command area of Rajasthan. Science and Culture 46(6): 266–269.

van der Maesen, L. J. G. 1972. *Cicer* L. A monograph of the genus with special reference to chickpea (*Cicer arietinum*), Wageningen, The Netherlands.

Effect of Edaphic Factors on Chickpea

S. Chandra*

In nature's agricultural environment, soils play the vital role of a medium for plant nutrition and productivity. Productivity can be tremendously enhanced by addition of inputs such as fertilizers, water, and soil amendments. Alternatively, and preferable to such inputs is the development, utilization, and perpetuation of improved plant types.

Unfortunately, such a simple and straightforward application of technology is often not possible. This is the case with salt-affected soils or where only saline water is available for irrigation to crops. Soil salinity occurs when the soil solution contains salts in such proportions or quantities that plant growth is adversely affected. The lower limit for a saline soil is conventionally set at an electrical conductivity of 4 mmhos/cm in the saturated soil extract (USDA Handbook 60, 1954). Alkali soils, the other type of salt-affected soils, are those characterized by high pH, and exchangeable sodium that occupies more than 15% of the cation-exchange sites. In the so-called saline-sodic soils, where a high salt content in soil solution is associated with a high sodium-absorption ratio, the effects of salinity predominate over those of sodicity. Thus, soils may be described as saline or sodic, depending on the type of problem created.

In brief, salinity causes nutritional imbalances and specific ion deficiencies, especially with regard to Ca, Mg, and K, while excessive uptake of Na causes toxic effects on plants. Sodicity, on the other hand, is associated with poor physical soil conditions that cause problems of root aeration, hydraulic permeability, high bulk density, and physical impediment to root growth and its activity. Both salinity and sodicity cause problems with water availability and water transport in plants, a condition that is sometimes referred to as physiological drought.

In India and Pakistan, where the bulk of the World's chickpea (*Cicer arietinum* L.) is cultivated, there is a history of domestication of this crop under adverse edaphic environments. Indeed, the crop has earned such titles as "risk insurance crop," "farmers' friend in adversity," and so forth. More recently in this subcontinent, it has been pushed further into cultivation under increasingly adverse conditions whereby its productivity has been adversely affected. In the present discussion, an effort has been made to present some effects of soil salinity, sodicity, and soil-water deficit on the chickpea plant.

In my treatment of the edaphic factors of chickpea, I might be expected to deal with the situation as a soil scientist or a physiologist. Since I am a plant breeder, however, my treatment will be characterized by the limitations inherent in such an approach.

Methods of Determining Response to Salinity

Field conditions representing typically adverse environments might be ideal to study plant response, but field experimentation is not always the best way because of the inherent heterogeneity in the field. Moreover, control over some of the contributing side factors may not be possible in the field. Thus, there is a vast variety of techniques used by different workers to evaluate plant response to salinity and water deficit, using nutrient media, culture, lysimeters, pots, even blotting papers and petri dishes, and they also look at different growth stages which are apparently differentially sensitive to stress. Efforts are therefore required to standardize the techniques employed so that data obtained from different sources may be intercorrelated and compared. Our Institute has been emphasizing this aspect of work related to studying plant responses; however, much of the work done in this direction pertains to cereals. We feel there may be a useful application of this work to legumes.

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Plant yield is recognized as the most worthwhile attribute for deducing relative tolerances of crop species and cultivars within a crop. Using this approach, chickpea (gram) has been classified as one of the most sensitive crops to both alkali (Table 1) and saline soils (Table 2). In this context, it may be desirable to describe briefly the standard measures of tolerance based on yield which are being used by us to ascribe a relative level of salt tolerance to a test material. It is interesting that, if necessary, besides yield, other test criteria could be utilized in a similar approach to compare test materials.

For instance, the relative level of salt-affectedness which causes 50% reduction in yield as compared to normal soil in the yield test may be determined using graded levels of salt-affectedness in the soil. Thus, in Figure 1, the genotype A, which reaches 50% of its yield in a normal soil, at a lower level of salt-affectedness than either B or C, is less tolerant than the latter, the order of descending tolerance being C, B, A.

Table 1. Relative tolerance of crops to exchangeable sodium (alkali soils).

Tolerant	Semi-tolerant	Sensitive
Rice	Barley	Cotton (at germination)
Dhaincha	Wheat	Maize
Sugar beet	Sugarcane	Groundnut
Spinach	Raya	Peas
Turnip	Cotton	Cowpeas
Paragrass	Berseem	Mung
	Senji	Mash
	Bajra	Lentils
	Sorghum	Sunflower
	Potato	Guar
	Watermelon	Gram

Source: Abrol et al. (1973).

Table 2. Relative tolerance of crops to salinity (saline soils).

Tolerant	Semi-tolerant	Sensitive
Date palm	Pomegranate	Citrus
Barley	Wheat	Cowpeas
Sugar beet	Oats	Gram
Spinach	Rice	Peas
Rape	Sorghum	Groundnut
Cotton	Maize	Guar
	Sunflower	Lentils
	Potato	Mung

Source: Abrol et al. (1977).

Another method is to determine the slope of the response curve in the additive response range. Thus in Figure 2, genotype B is much less tolerant than A or C. However, A is more tolerant than B at low salt levels by virtue of a peak showing favorable response to low or moderate salt-affectedness. Maas and Hoffman (quoted by Framji 1976) used these slopes to quantify relative crop tolerances to salinity (Table 3) and even worked out an equation that can be called the Maas and Hoffman equation to obtain yield for a given soil salinity exceeding the threshold level. Thus,

$$Y = 100 - B\,(ECe - A)$$

where Y is the predicted yield at threshold level A, measured as ECe (mmhos/cm), and B represents the percentage of decrease in yield per unit of salinity increase.

In certain cases where economic yield levels

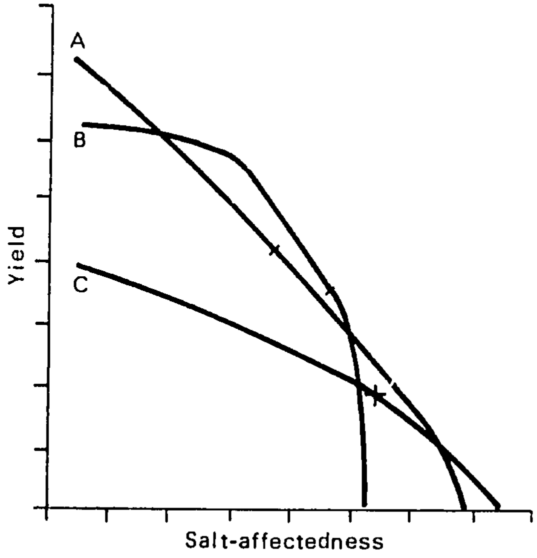

Figure 1. The extent of salt affectedness bringing about a 50% reduction in yield as a means of relative salt tolerance among genotypes.

under graded soil conditions drop off rather sharply beyond a threshold value, it may be advisable to test yield performance at the salt-affect threshold value. The lines representing above-average performance would be relatively more tolerant than the average ones, and likewise, the below-average lines would be intolerant ones.

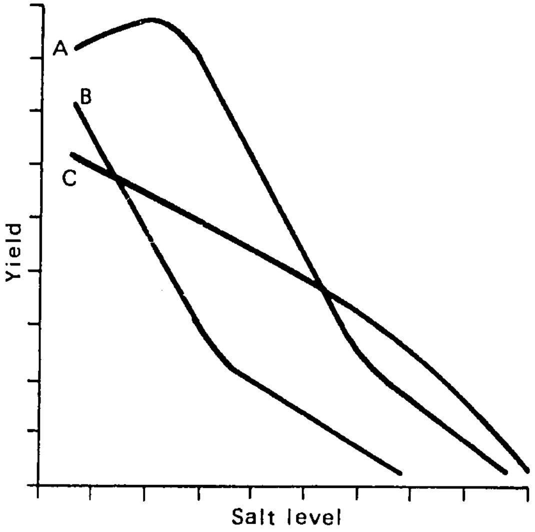

Figure 2. Slope of response curve as a measure of relative salt tolerance of different genotypes.

A character such as germination percentage could be used in the above measures to classify test cultivars. It has been found that the above three parameters are rather independent and do not necessarily give the same picture of relative tolerances. They would perhaps represent different categories of tolerance and thus help to attribute diversity of tolerance.

Determining Biochemical Parameters

We have shown interest in identifying some biochemical parameters which quantify relative tolerance to salinity. It was indicated that the following would constitute relative tolerance in cereals: (1) high accumulation of free proline, an amino acid, in the seedling leaves; (2) high K/Na uptake ratio in leaves at the tillering stage; and (3) high inorganic P status in leaves at the rank growth stage.

Although evidence in favor of the above conclusions has been recorded on previously classified representative tolerant, semi-tolerant, and intolerant genotypes, their use in defining variability for tolerance has been rather limited, especially as regards items (1) and (3) above.

Table 3. Crop yield responses to soil salinity.

Crop	Salinity level at initial yield decline (mmhos/cm)	% Yield decrease per unit increase in salinity beyond threshold level (mmhos/cm)	Salinity tolerance rating[a]
Barley (*Hordeum vulgare*)	8.0	5.0	T
Wheat (*Triticum aestivum*)	6.0	7.1	MT
Rice (*Oryza sativa*)	3.0	12.0	MS
Maize (*Zea mays*)	1.7	12.0	MS
Bean (*Phaseolus vulgaris*)	1.0	19.0	S
Cotton (*Gossypium hirsutum*)	7.7	5.2	T
Sugarcane (*Saccharum officinarum*)	1.7	5.9	MS
Sugar beet (*Beta vulgaris*)	7.0	5.9	T
Alfalfa (*Medicago sativa*)	2.0	7.3	MS
Berseem (*Trifolium alexandrinum*)	1.5	5.7	MS
Bermuda grass (*Cynodon dactylon*)	6.9	6.4	T

Source: Mass and Hoffman as quoted by Framji (1976).
[a] T = Tolerant; MT = Medium tolerant; MS = Medium sensitive; S = Sensitive.

Pot Studies of Genotypes

Since chickpea is one of the most sensitive of the crops, even among legumes (Fig. 3), it does not offer itself as a suitable material to study variability based on yield-based criteria. Thus, a more preliminary level of evaluation has had to be employed in looking at its response pattern.

Field conditions are not the best way to examine these responses because of heterogeneity. Thus porcelain pots have been used, where the soil was brought up to a desired level of salinity and seeding was done in the pots. Irrigation was not applied as usual (from the top) because of its adverse effects on soil condition. Rather, the pots were allowed to stand in water made up to a calculated salinity value that would not substantially alter the salt-affectedness of the soil.

Different genotypes had a differential response to a soil salinity of 5.8 ± 0.2 ECe (mmhos/cm). In the case of G-24, the germination was normal but the growth was arrested almost soon after. In the variety E-100Y (ICRISAT source), stem elongation was not very much affected though germination was comparatively less. In the case of C-235, there was succulence and greening coupled with a reduction in growth under saline conditions. The genotype H 75-36 appeared to be relatively less affected.

More frequent irrigation had to be given to saline pots where the general wilting appeared rather soon compared to normal pots. Also, the bottom portion of the stem in saline soil appeared to show a degree of decomposition, which was generally related to sensitivity of genotype.

During the progress of growth, different genotypes became progressively affected and mortality began to rise with advancement of age. Even in lines that registered good germination and good survival, many failed to flower or set seed (Table 4). Only seven varieties set any seed at all, of which H 75-36, L-550, and RG-2 may be considered worth mentioning because others put up only one or two seeds.

Singh et al. (1974) and Singh (1975) tried to establish that in cereals the ability to accumulate free proline in leaves was correlated with

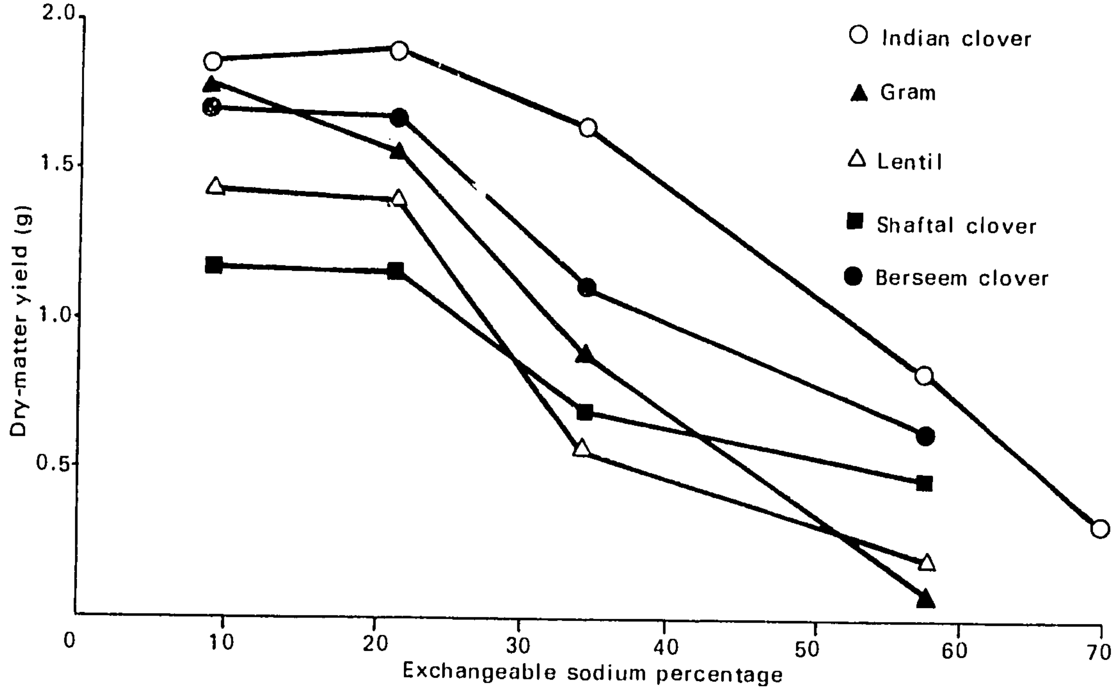

Figure 3. Dry-matter yield of some winter legumes as affected by soil exchangeable sodium percentage.

Table 4. Nature of response of certain chickpea varieties to soil salinity (ECe $\simeq$ 5.8 ± 0.2 mmhos/cm).

Response	Genotype (s)
I. Germination: delayed, poor Survival : very poor	BG-211, BEG-482, Bengal gram, F-378, GG-550, GL-629, JG-1254, KE-30, L-345, Pant G-121, WF-WG
II. Germination: not much delayed, extent good Survival : low	850-3/27, P-1353, P 1358-3, P-9800
III. Germination: good Survival : good	NEC-240, NEC-50, P-416, P-257, P-662, P 1305-1, USA-613 (+ genotypes in IV, V)
IV. Reproductive ability not attained	C-235*, JG-35, P-6625 (+ genotypes in III)
V. Reproductive ability attained	C-214, E-100, H-208, H 75-35, H 75-36, L-550. RG-2

* Classification doubtful.

salt tolerance. In trying to obtain similar data on chickpea (Table 5), we found variable trends in the genotypic behavior of certain genotypes. Among the genotypes which could be carefully evaluated, H 75-36 and L-550, the most tolerant ones (Table 4), showed this ability. However, with regard to other genotypes, the situation was reverse, i.e., the proline content was lower under salt stress than in unstressed. Other genotypes which indicated a tendency to accumulate proline did not belong to the more tolerant category. However, under the drought stress, increase in proline was very common and only three varieties, i.e., Annigeri, P-1148, and BEG-482 failed to record a rise in free proline content under drought stress. Apparently the level of salinity at which these genotypes were tested did not cause a problem of water potential in the plant and the expression of most genotypes was in response to ion imbalance or toxicity. However, detailed observations in this direction are necessary.

Table 5. Accumulation of free proline in certain chickpea varieties under drought and salinity stress.

	Leaf proline (μg/g dry weight)		
Variety	Without stress	Salinity stress (ECe 5.5–6.2)	Drought stress (> 15 bars)
C-235	7680	9308	9 876
C-214	2315	2458	3 759
G-24	2775	4630	9 657
G-130	6357	2402	4 462
H-208	4985	2400	4 973
E-100Y	6905	1850	1 680
JG-221	2535	727	4 422
BG-203	3567	3323	6 817
BG-109	2763	4568	5 913
L-550	2340	5091	11 370
P-6625	900	9262	11 867
P-4356	6910	1855	7 861
H 75-35	2647	2600	3 778
H 75-36	2558	4203	11 471
Annigeri	7868	3656	4 568
Jyoti	2674	2315	3 559
P-1148	3725	7365	3 547
P-1231	4832	5211	12 133
P-692	5016	4775	10 357
BEG-408	7055	2773	3 105

Chickpea in Sodic Soils

Sodic soils are widespread in the area where chickpea enjoys large acreages in India. Because of the problems of root aeration and physical soil properties, these soils are very inhospitable to chickpea. During the early years of work at CSSRI, attempts were made to raise a number of crops on such soils by first trying to improve their physical and chemical properties in the top 15 cm through the application of gypsum. Results of the experiment (Table 6) to study the behavior of this crop after continuous and discontinuous use of gypsum coupled with a rice crop during kharif and a wheat crop during rabi revealed that only in the third year of reclamation is it possible to obtain any economic yield of chickpea, when the pH of the surface soil is well below 9.0. The yield differences among different treatments were not significant because of a high coefficient of variation, resulting from field variation, large enough to cause damage to chickpeas.

The type of sensitive reaction shown by chickpea under these conditions was a shallow root system, poor branching, browning and dropping of leaflets, and poor nodulation. It may be seen from Table 7 that the chickpea rhizobia isolated from normal soil for attempts at multiplication in saline-sodic soil failed to reproduce at all. Nodulation of chickpea under sodic soil was either too poor to allow isolation of bacteria or the bacterial strain was too inefficient to be cultured under a high level of saline-sodic soils. By comparison, certain other legumes developed rhizobia which could be subjected to studies in alkali soils. However, the most interesting feature of the data in Table 7 is that bacterial growth patterns are quantitatively associated with relative tolerances of these crops under sodic soil conditions, as the data in Table 8 also indicate. It is therefore very desirable that work on rhizobial studies be associated as a component of the tolerance studies.

Rooting Patterns of Chickpea in Salt-Affected Soils

Shallow rooting or perhaps poor rooting has been thought to be associated with the poor performance of chickpea under salt-affected soil conditions. Studies on rooting pattern under these situations are therefore of significance. However, of necessity, such studies must be conducted with great caution. Under field conditions, there are a very large number of uncontrollable factors. As an initial step, therefore, we made efforts in porcelain pots to identify the effect of salt-affected soils on root growth. In spite of the problems inherent in a direct comparison between affected and normal soil, we were encouraged by our data.

Using a steel plate, we divided porcelain pots into two halves and filled the pots with normal soil in one half and sodic or saline soil in the

Table 6. Effect of gypsum doses applied over years on the soil pH and yield of gram in 1974–75 (variety C-235).

Gypsum (t/ha)			pH before gram		Grain yield of gram (g/ha)	pH after gram	
1st year	2nd year	3rd year	0–15 cm	15–30 cm		0–15 cm	15–30 cm
6.5	0	0	8.7	9.0	11.4	8.6	8.8
6.5	6.5	0	8.5	8.9	9.6	8.6	9.0
6.5	6.5	6.5	8.4	9.3	11.2	8.5	9.3
13.0	0	0	9.1	9.4	11.0	8.6	9.0
13.0	6.5	0	8.5	9.2	9.6	8.6	9.1
13.0	6.5	6.5	8.4	9.0	12.6	8.7	9.1
19.5	0	0	9.0	9.5	11.5	8.5	8.9
19.5	6.5	0	8.5	9.5	12.6	8.6	9.4
19.5	6.5	6.5	8.6	9.0	11.4	8.5	8.9
26.0	0	0	8.5	9.2	11.6	8.5	9.6
26.0	6.5	0	8.5	9.2	12.2	8.6	9.1
26.0	6.5	6.5	8.5	8.9	13.7	8.8	8.9
C.D. at 5%					N.S.		

Table 7. Growth and survival of various *Rhizobium* species in saline-sodic and normal soil.

Rhizobium sp of	Nature of soil	No. of bacteria × 10^4/g soil
Pea (*Pisum sativum*)	Normal	0
Soybean (*Glycine max*)	Normal	0
Gram (*Cicer arietinum*)	Normal	0
Indian clover (*Melilotus parviflora*)	Normal	80
Indian clover (*Melilotus parviflora*)	Saline-sodic	0
Berseem (*Trifolium alexandrinum*)	Normal	12
Berseem (*Trifolium alexandrinum*)	Saline-sodic	35
Guar (*Cyamopsis tetragonoloba*)	Normal	0
Guar (*Cyamopsis tetragonoloba*)	Saline-sodic	21
Urd (*Vigna mungo*)	Normal	0
Daincha (*Sesbania aculeata*)	Normal	45
Daincha (*Sesbania aculeata*)	Saline-sodic	116
Cowpea (*Vigna sinensis*)	Normal	30
Cowpea (*Vigna sinensis*)	Saline-sodic	38

Source: Adapted from Annual Report of CSSRI 1971.

Table 8. Occurrence and effectiveness of the rhizobia in saline-sodic soil.

Host	No. of nodules per plant	Dry weight (g) per 4 plants	% increase over uninoculated control (%)
Glycine max		1.00	
Vigna mungo		0.45	
Pisum sativum		0.90	
Cicer arietinum		0.56	
Vigna sinensis		0.85	
Trifolium alexandrinum	6	0.42	23.0
Cyamopsis tetragonoloba	4	0.38	21.0
Medicago sativa	19	0.50	36.0
Melilotus parviflora	29	0.50	43.0
Sesbania aculeata	31	1.40	46.0

Source: Adapted from Annual Report of CSSRI 1973.

other half. In a way, this represented the horizontal variation that may be encountered in nature under field conditions. Likewise, vertical variation was created by filling the bottom half and the top half of a pot with different kinds of soil. Even conditions representing a point surrounded by different kinds of soil were created, but it did not yield information of the kind shown in Table 9. The conclusions that can be drawn from this table are that the roots are shallower in a sodic soil than in a saline soil, but both soils affect rooting to a great degree. However, the sodic-normal borders of patches are not likely to be as detrimental to root growth as saline-normal patches.

Monitoring Water Status

The physiological drought that may sometimes be associated with salt stress makes it important to monitor internal plant water status

Table 9. Effect of saline and sodic soils on root growth and dry matter yield in chickpea[a]

Soil type	Root Length (cm)	Vol. (ml)	Wt. (g)	Dry plant weight (g)	Root color
Normal	55.3	38.2	5.8	25.3	Normal
Saline	35.1	18.6	3.3	10.8	Brownish
Sodic	30.4	16.4	3.0	8.7	Whitish
Horizontal variation					
Nor/Sal	35.9	16.0	5.2	20.1	Normal[b]
Nor/Sod	42.6	18.9	5.5	18.5	Normal
Sal/Sod	27.5	12.3	3.0	9.2	Whitish[b]
Vertical variation					
Nor/Sal	33.8	16.5	3.1	18.6	Upper normal, lower brownish
Nor/Sod	40.4	19.9	3.7	19.4	Upper normal, lower whitish

[a] Three varieties were tested, but their genotypic differences were small.

[b] Some brownish discoloration occurred.

in different varieties to understand the mechanism of tolerance. This line of work is going to be handled by us in future studies.

Conclusions

Salinity as well as sodicity can adversely affect germination, growth, and yield of chickpea. Chickpea has a very low level of tolerance against salinity and, indeed, we cannot yet make any recommendations for cultivation even in soils marginally affected by salts. Under saline conditions, toxicity of ions and/or ion imbalance appears to be associated with chickpea's susceptibility. In sodic soils, nodulation and root growth and also poor soil aggregation seem to be the major reasons for chickpea's subeconomic production potential. Genotypic differences can be identified for salt tolerance, but the extent to which salts can be tolerated does not seem to be high enough.

Future approaches to screening chickpea for tolerance to salinity are as follows:

1. Rapid rejection of susceptible world collections on the basis of germination and survival tests in microplots or pots during the first 3 weeks at ECe $\simeq$ 5.5.
2. Carry forward only promising lines for more critical testing based on dry-matter production at ECe $\simeq$ 5.5.
3. Identification of lines possessing satisfactory reproductive ability under saline conditions as sources of relative tolerance.
4. Intensification of gene frequencies for salt tolerance by developing a random mating population among salinity-tolerant lines and selection for progressively greater tolerance.
5. Supplementing tolerance studies by nodulation and rooting pattern studies of genotypes.
6. If feasible, tapping the unselected indigenous bulk mixtures in India and other parts of the world for latent genetic diversity for salinity tolerance, which may be still existing in them in view of a lack of conscious or unconscious selection for this attribute in the untouched native land races.

References

Abrol, I. P., and Fireman, M. 1977. Alkali and saline soils. CSSRI Bull. No. 4, Central Soils Salinity Research Inst., ICAR, Karnal, India. 32 pp.

ABROL, I. P., DARGAN, K. S., and BHUMBLA, D. R. 1973. Reclaiming alkali soils. CSSRI Bull. No. 2, Central Soils Salinity Research Institute, ICAR, Karnal, India. 58 pp.

FRAMJI, K. K. (ed.) 1976. Irrigation and salinity: a world-wide survey. Internat. Comm. Irrgn. Drng., New Delhi. 671 pp.

SINGH, T. N. 1973. Page 61 in Annual Report CSSRI.

SINGH, T. N., ASPINALL, D., and PALEG, L. G. 1974. Proline accumulating ability as a criterion of drought resistance, *in* Breeding researches in Asia and Oceania. Indian Journal of Genetics 34 A: 1074–1083.

USDA. 1954. United States Salinity Laboratory Staff: Diagnosis and improvement of saline and alkali soils. USDA Handbook 60, 1954, 185 pp.

Physiology of Growth, Development, and Yield of Chickpeas in India

N. P. Saxena and A. R. Sheldrake*

Crop physiology research on chickpea started only recently in India, and the information available on this pulse is therefore rather limited than on other crops, such as cereals and cotton. However, a number of papers have been published on some physiological aspects, including the effect of certain treatments on enzyme activities and the effect of growth regulators; in addition, a few papers have appeared on photosynthesis and translocation of assimilates. Saxena and Yadav (1975) reviewed previous work on the agronomy and physiology of chickpea; some growth and developmental aspects have also been discussed by Argikar (1970).

The purpose of this paper is to report ICRISAT research on crop growth processes, the physiology of yield, and the influence of environmental and cultural practices. Information is being sought for a better understanding of the complex phenomenon of yield determination.

In India, chickpea is grown as a winter crop from as far south as Karnataka (14°N) to as far north as Palampur (32°N). However, 53% of the chickpea production area is in the Indo-Gangetic plains of northern India, and 30% is in central India between latitudes 23° and 26°N; the rest of the chickpea-producing area is in peninsular India. Average yields in North India are around 800 kg/ha as compared to only 400 kg/ha in peninsular India. The crop is usually sown with the onset of cooler temperatures in October and November, utilizing moisture from the preceding monsoon rains in fields that were fallowed during the rainy season. When a rainy-season crop has been taken (in northern India), chickpea is planted after a presowing irrigation. Soil moisture is gradually depleted downward in the profile as crop growth proceeds. Toward the end of the growing season, the evaporative demand of the atmosphere is on the increase (Sheldrake and Saxena 1979a). Limited moisture availability finally terminates growth and forces the plants to mature. Thus, the period in which chickpea can be grown is limited, and is determined at a given location by climatic conditions. Climate is an important determinant of yield.

Data are collected on crop growth, development, and yield aspects at ICRISAT Center near Hyderabad (a short-growth duration location, representative of peninsular India) and at Hissar (a longer growth duration location, representative of northern parts of India).

Climatic Conditions at the Two Locations

Climatic conditions during the chickpea-growing period at Hissar and at ICRISAT Center are summarized in Figure 1. Minimum temperatures at Hissar decline from late October onward and remain low during December and January; the temperature starts rising again in late March. On the other hand, at ICRISAT Center, temperatures decline around the end of November or early December and start to increase again in mid-February. Open-pan evaporation during the growing period follows the same pattern. Thus, the fall of temperature with the onset of winter and the rise at the beginning of summer determines the duration of crop growth. This period is shorter in peninsular India than in the northern parts of India, and so are the growth durations.

Early-duration cultivars perform better than late-duration cultivars at ICRISAT Center, as they are better adapted to the short-growth duration conditions. The amount of rain received in the preceding rainy season as well as that received during the crop-growing period at ICRISAT Center is a little less than

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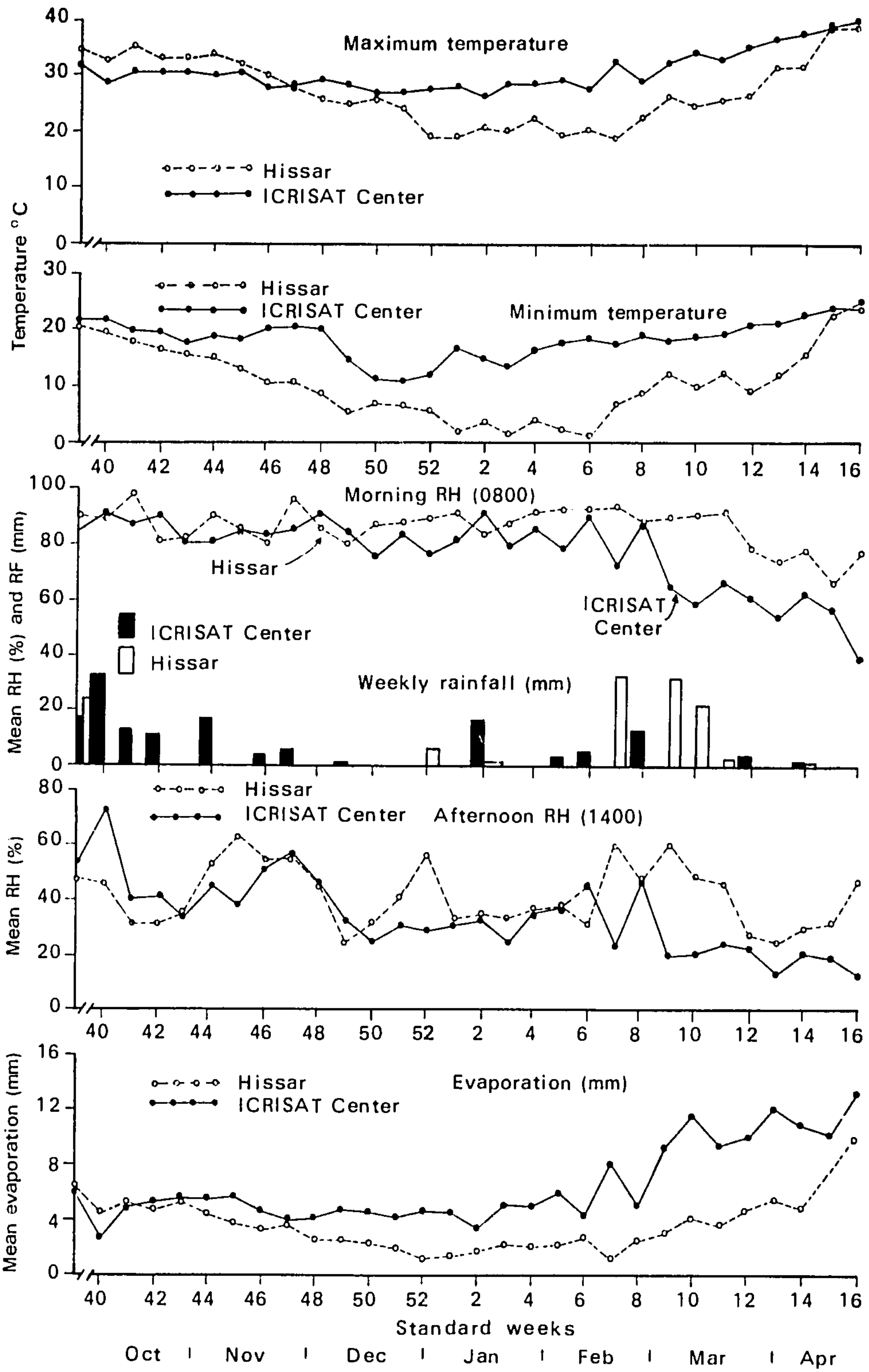

Figure 1. Weekly mean maximum and minimum temperature, rainfall, relative humidity in mornings and afternoons, and open pan evaporation throughout the monsoon season 1977–78 at Hissar and ICRISAT Center.

twice that received at Hissar (Table 1). The soils from both locations are low in available P and high in pH (Table 2). The soils at ICRISAT Center are Vertisols (fine, clayey, deep black cotton soils, typic chromustert); Entisols (sandy, typic cambarthids, alluvial) are found at Hissar. The cation-exchange capacity of the former is higher than that of the latter. The soils, fairly representative of the chickpea-growing areas of central and peninsular India, are rich in potash.

Table 1. Average monthly rainfall (mm) at Hissar and Hyderabad (average of 30 years, 1931–1960)[a].

Period	Hyderabad	Hissar
May–Sep	612.6	368.6
Oct	70.8	14.6
Nov	24.9	7.5
Dec	5.5	4.5
Jan	1.7	19.1
Feb	11.4	14.7
Mar	13.4	17.0
Apr	24.1	6.2
Oct–Apr	151.8	83.6

a. Climatological tables of observatories in India. India Meteorological Department.

Root Growth, Development of Leaf-Area Index, and Dry-Matter Accumulation

Sheldrake and Saxena (1979a) studied the root system of chickpea at ICRISAT Center by taking soil cores with a mechanical auger two times before and two times after flowering. They found that as the soil in the surface zone dried, there was little or no development of roots in this zone, but the roots continued to develop in deeper soil layers down to 120 cm; where there was enough water, development continued until harvest. Most of the nodules were found to be confined to the 0–15 cm depth. Nodule mass increased during the vegetative period and declined in the later part of the reproductive period. Toward the end of the reproductive phase, more than half of the roots lay in the region below 45–60 cm.

Subramania Iyer and Saxena (1975) also described the rooting pattern in nine varieties of gram during pod development using p^{32}. The soils are rich in organic matter and have a relatively high water table. They reported that 50–65% of the root spread occurred in a radius of 7.5 cm around the plant. Root penetration was studied only up to a depth of 30 cm, which revealed that 40–50% of the extractable roots were found in the top 10 cm of the soil. Perhaps this is the case when moisture is not limiting in the surface layers.

Table 2. Soil characteristics at ICRISAT Center and at Hissar.

Location	Depth (cm)	pH	EC (mmhos/ cm)	Available nutrients (ppm) N	P	K	CEC (me/100 g)
ICRISAT Center	0–15	8.0	0.45	52.0	2.0	163	40.9
	15–30	8.0	0.30	57.0	1.0	144	40.8
	30–45	8.1	0.30	49.0	Traces	128	40.8
	45–60	8.1	0.35	49.0	"	119	40.2
	60–75	8.0	0.40	48.0	1.0	169	NA
	75–90	8.2	0.35	41.0	Traces	145	NA
Hissar	0–15	8.1	0.23	87.1	7	203	8.1
	15–30	8.3	0.15	63.0	2.7	176	9.5
	30–60	8.3	0.13	63.0	2.7	149	10.6
	60–90	8.3	0.17	54.6	3.2	95	10.7

NA = Not available.

The dry-matter accumulation pattern in a short- (adapted to peninsular Indian conditions) and a long-duration cultivar grown at ICRISAT Center has been described by Sheldrake and Saxena (1979a). The pattern of dry-matter accumulation at Hissar is described here. Development of leaf area and addition of dry matter continued even after flowering in both cultivars (Fig. 2). Since chickpea is indeterminate, addition of dry matter in the vegetative structures continues even after the onset of reproductive growth. Pod number increased as dry matter and leaf area increased, but once the leaf area started to decline, there was no further increase in pod number.

There were big differences in flowering dates of the cultivars, both at ICRISAT Center and at Hissar. Pod set commenced with the onset of flowering at ICRISAT Center, but at Hissar the flowers on early cultivars and some on late cultivars did not bear fruit while temperatures were low. At Hissar, in both cultivars, pod set commenced at the same time (when temperatures were high enough), irrespective of the time of flower initiation.

At ICRISAT Center, senescence of the lower leaves generally begins before flowering in late cultivars and much after flowering in early cultivars. Data for 1974–75 are shown in Figure 3. At the time when senescence commenced, maximum and minimum temperatures had remained unchanged, but moisture was being progressively depleted from the upper soil profile. This suggests that soil moisture is an important factor in triggering senescence. Senescence occurred later in the border rows of plots, which had access to a better moisture supply; senescence is also delayed by irrigation.

At Hissar, both in early and late cultivars, considerable addition in leaf area occurred after 50% flowering, and the maximum leaf-area index was generally more than twice that at ICRISAT Center. Barring this exception, the

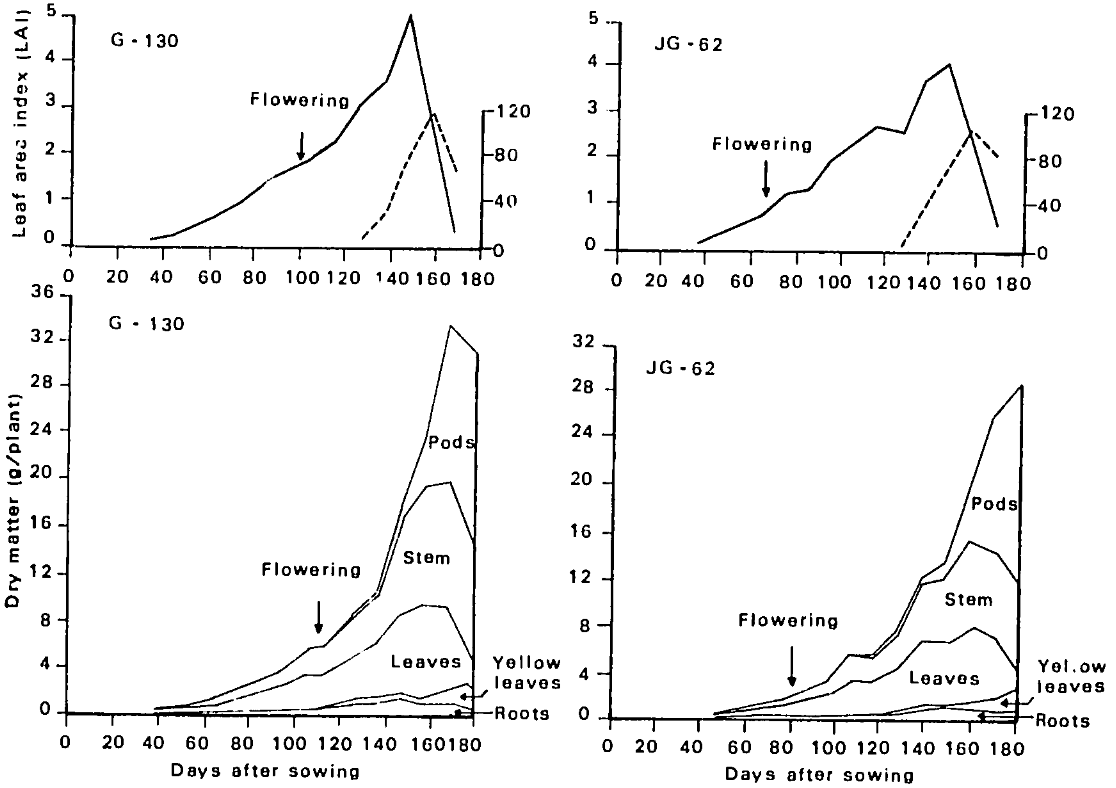

Figure 2. Development of leaf area, increase in pod number, and dry-matter partitioning over time in two chickpea cultivars at Hissar (1977–78).

pattern of development of leaf area and its relation to pod development was similar at both locations.

The accumulation of dry matter at Hissar continued for a protracted period, owing to longer growth duration. In the early cultivar, JG-62, flowering commenced early in the season when temperatures were low and flowers produced during this period did not set pods. Even though the plant was physiologically in the reproductive growth stage, growth in the vegetative structures continued vigorously, and the node number at harvest was not much different from that of late cultivars.

The senescing pinnae drop off the plant, and at harvest only the rachis remains attached to the plant. A considerable part of total biological yield is sloughed off in the dropped pinnae, resulting in underestimates of total biological yield. The effect of this on harvest index (HI) is discussed later.

Pod Development

Pod development was studied in flowers tagged soon after they opened. Sampling of pods was done periodically until they matured at harvest. The pod wall was the first to develop, and more dry weight accumulated here than in the seeds during the first 15–17 days after anthesis. There was a rapid addition of dry matter in the seeds starting about the time growth of the pod wall ceased (Fig. 4). In the

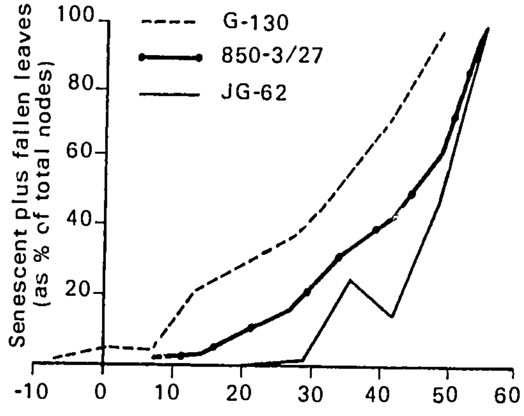

Figure 3. Time course of leaf senescence (1974–75).

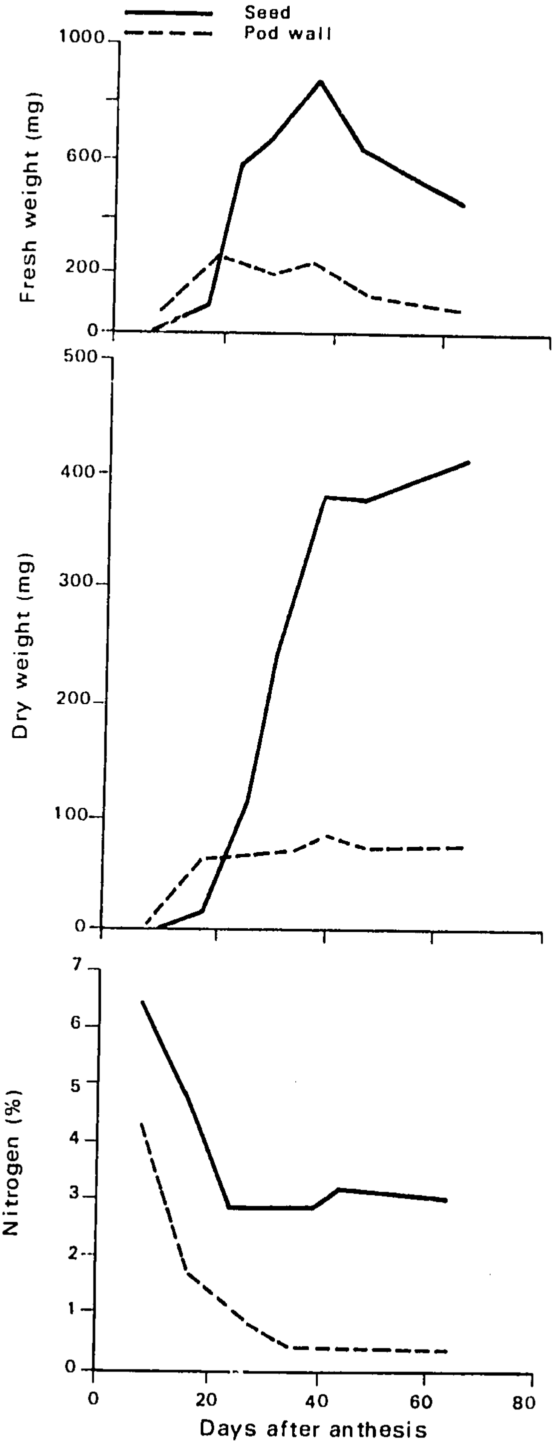

Figure 4. Fresh and dry weight and percent nitrogen of seed and pod wall of a developing pod in CV 850-3/27 (1974–75).

early cultivars, which were suited to peninsular India, the addition of dry matter in the seed continued up to 35 to 40 days, whereas in cultivars of longer duration, which were subject to forced maturity, dry matter addition ceased after 25 to 30 days. This period may be considered as the time required for the individual pods to reach physiological maturity. Cultivars differed in rate of pod development and the time of maximum dry-matter accumulation. Pods of smaller-seeded cultivars tended to reach physiological maturity earlier.

In both the seed and pod wall, the percentage N was highest at first and declined with the growth of the pod. It remained unchanged after 24 days in the seed and after 31 days in the pod wall. Thus, during the period of most rapid growth of seeds, accumulations of dry matter and nitrogen take place in parallel.

Pods in chickpea are capable of photosynthesis. Kumari and Sinha (1972) reported variation in fruit-wall photosynthesis in Bengal gram; however, they made no assessment of the contribution to seed yield of fruit-wall photosynthesis.

Sinha (1974) suggested that selection of genotypes in which fruits come out of the plant canopy might be more useful in legumes because of greater photosynthetic activity in the pod walls. Such cultivars are known to occur in cowpea and mung bean. At ICRISAT Center, such cultivars have also been identified in chickpea.

Chickpea pods normally hang below the leaves and are consequently shaded. In a field experiment, pods were exposed to sunlight by hooking them onto the upper surface of the leaves to eliminate any possible limitation by light on their photosynthesis (Saxena and Sheldrake 1980a). No significant effect of pod exposure on yield was observed.

Sheldrake and Saxena (1979b) reported that at ICRISAT Center and at Hissar there was a decline in pod number per node, weight per pod, seed number per pod, and/or weight per seed in later-formed pods. The percentage of nitrogen in the seeds was the same in earlier- and later-formed pods at ICRISAT Center; at Hissar, the later-formed seeds contained a higher percentage of N. The decline in yield components suggests that pod filling was limited by the supply of assimilates or of nutrients. In one small-seeded cultivar, there was no decline in the number or weight of seeds in later-formed pods, indicating that yield was limited by sink size.

Analysis of Yield at Hissar and at Hyderabad

The growth duration at Hissar, as discussed earlier, is almost twice that at ICRISAT Center. Yield at Hissar is also about twice that at Hyderabad (Table 3). Differences in yield between early and late cultivars are quite evident at ICRISAT Center but are less pronounced at Hissar (Saxena and Sheldrake, unpublished data). The reason seems to be the less marked differences in growth duration of early and late cultivars at Hissar. Productivity per day, in total dry matter and to some extent in yield, was higher at Hissar than at Hyderabad. The response to longer growth duration was relatively more in total dry-matter production than in yield, and resulted in a lower harvest index at Hissar than at Hyderabad. The fall of pinnae, as mentioned earlier, results in underestimation of total biological yield and overestimation of harvest index. The fallen pinnae were collected in the field to correct the total biological yield at harvest. Harvest indices were calculated sepa-

Table 3. Differences in growth duration, growth, yield, and yield components of chickpea (average of two cultivars, 850-3/27 and JG-62) at ICRISAT Center and at Hissar (1977–78).

Character	ICRISAT Center (Hyderabad)	Hissar
Vegetative period (days)	49	76
Period of ineffective flowering (days)	0	48
Reproductive period (days)	41	48
Total growth duration (days)	90	172
Total nodes/plant (number)	167	346
Total dry matter (kg/ha)	2072	6176
Yield (kg/ha)	1166	2495
Harvest index (%)	50	40
Total dry matter (kg/day)	22	36
Yield (kg/day)	12	14

rately, using biological yield corrected and not corrected for pinnae fall (Table 4). On an average, the harvest index was overestimated by 10%, both in the desi and kabuli cultivars. The ranking of cultivars for harvest index changed only slightly, which suggests that the uncorrected harvest indices give a reasonably reliable indication of varietal differences.

High harvest index and high yield are two different things. The efficiency of partitioning of total dry matter into seeds was higher at ICRISAT Center; even then, the yield was about half that harvested at Hissar.

The harvest index (HI) thus seems to be greatly influenced by climatic conditions. At a given location, the high-yielding cultivars generally have higher harvest indices. Dahiya et al. (1976) suggested selection of early maturing, high-HI cultivars for North Indian locations. How these cultivars compare in yield with cultivars of later duration was not discussed in their paper. The harvest indices of around 50 for chickpea in peninsular India (Tables 3 and 4) are comparable with those reported for wheat and rice.

Uptake of Nitrogen and Phosphorus

The content of nitrogen is very high (about 5% of total dry matter) in the green leaves of chickpea; when the leaves senesce, the content drops to around 1%. Stems in early stages of growth contain about 1.5–1.8% nitrogen which drops to about 0.6–0.8% at harvest. The corresponding values for P in leaves in early stages and at harvest are 0.7 and 0.2%, whereas in stems they were around 0.5 and 0.3%, respectively. A considerable amount of nitrogen and phosphorus seems to be remobilized from older plant parts to seed and other younger tissues.

The amount of nitrogen and phosphorus in the above-ground parts and in the roots and nodules that could be recovered at ICRISAT Center and at Hissar are presented in Table 5.

Table 5. Seed yield, total dry matter, N, and P content at ICRISAT Center and at Hissar (kg/ha) of attached plant parts of chickpea. In neither location was N fertilizer supplied to the crop (1976–77).

Character	Hyderabad	Hissar
Seed yield	1500	3400
Total dry matter	2600	7000
N removed	58	143
P removed	5	10

Table 4. Effect of leaf fall on harvest index (HI) and its ranking in chickpea cultivars (1975–76)[a].

Type	Cultivar	Harvest index (HI) Corrected	Uncorrected	Mean	Increase (uncorrected/corrected)	Ranking Corrected	Uncorrected
		%	%	%	%		
Kabuli	Leb. local	34	44	39	29	6	5.5
	L-550	38	50	44	31	4	4
	K-16-3	34	42	38	23	6	7
	Rabat	29	41	35	41	8	8
	Mean	34	44	38	31		
Desi	BEG-482	34	44	39	29	6	5.5
	Chafa	53	61	57	15	1	1
	JG-62	46	54	50	17	2	3
	850-3/27	43	55	49	28	3	2
	Mean	44	53	48	22		

[a] LSD (0.05); cultivar means, 3.7; treatment means, 1.2; treatments within a cultivar, 3.5; cultivar within a treatment, 4.4.

The total N removed at ICRISAT Center is less than half, and P removed is half that at Hissar, a relationship similar to dry-matter production and yield. Since nitrogen fertilizer was not supplied to the crops and the soils were low in available N, most of the nitrogen was presumably fixed by the nodules.

Source-Sink Relationships

The two important factors that determine yield are the photo-assimilate supply (source size and activity) and the storage capacity — i.e., number and size of pods (sink size). To evaluate which is a greater limitation to yield in chickpeas, shading, defoliation, and flower removal experiments were conducted.

Effect of Shading

Sheldrake and Saxena (1979a) reported the effects of shading with horizontal shades over the crop canopies during the reproductive period of growth at ICRISAT Center. When photosynthetically active radiation (PAR) was reduced by 50%, senescence was delayed and yield significantly increased up to 15%. This was ascribed to the fact that shading reduced the stresses that were accelerating the senescence process. It was assumed that, in spite of 50% PAR reduction, light intensity might still be near saturation. Further reduction in light intensity delayed senescence even more, but also reduced yield.

The studies on shading were extended to Hissar in the 1976 postrainy season using horizontal shades of cloth, which transmitted the following percentage of light through to the canopy:

Control (no shade) = 100%
Mosquito net cloth = 77% transmission
Thin cloth = 45% transmission
Thick cloth = 16% transmission

The shades were placed on the canopy when pod set commenced, rather that at flowering, because the crop virtually continues growing vegetatively until temperatures rise. Pod set, as it is determined by temperature, began in all cultivars at about the same time. Yield progressively declined with the increase in thickness of the shade (Table 6). There was a significant reduction in yield in all the cultivars, even with shades intercepting only 25% of the sunlight. Drastic reduction in total dry matter, harvest index, pods/m², and seeds per pod occurred at 84% light interception, i.e., 16% transmission (Tables 7, 8).

At Hissar, temperatures were not really very high at the time of pod set, when shading was started. Therefore, in the winter of 1977, shading at Hissar was delayed until the temperature began to rise. Even then, shading did not produce increases in yield and dry matter (Table 9), as was reported for ICRISAT Center, where reduction in yield occurred only under the thickest shade that transmitted only 16% sunlight. Senescence was delayed in all the shade treatments at Hissar, as was observed at ICRISAT Center.

Light becomes a limiting factor to dry-matter production and yield at Hissar, even at levels only 15% below full sunlight. This does not seem surprising in view of the high leaf area

Table 6. Effect of shading treatments on grain yield (kg/ha) of four chickpea cultivars at Hissar, postrainy season 1976–77.

Cultivar	Control	Mosquito net	Thin cloth	Thick cloth	Mean
P-173	3422	2479	2344	679	2231
850-3/27	3539	2848	2579	1229	2547
L-550	3879	3190	2701	1237	2752
G-130	3353	2356	1992	705	2102
LSD (0.05)			315.5		170.1
Mean	3548	2718	2404	960	2408
LSD (0.05)			126.1		
CV%			6.5		9.8

Table 7. Effect of shading treatments on total dry weight, harvest index and yield components of chickpea (means for 4 cultivars), postrainy season, Hissar, 1976–77.

Shading treatment	Total dry weight (kg/ha)	Harvest index (%)	Pod number/m²	100-seed weight (g)
Control	7980	45	2547	19.2
Mosquito net	6590	42	2331	18.9
Thin cloth	6494	38	1789	17.9
Thick cloth	4067	24	984	19.6
LSD	754.1	5.2	749.0	1.39

Table 8. Effect of shading treatments on seed number per pod of 4 chickpea cultivars at Hissar, postrainy season, 1976–77.

	Seed number per pod				
Cultivar	Control	Mosquito net	Thin cloth	Thick cloth	Mean
P-173	1.19	0.98	0.99	0.82	0.99
850-3/27	0.79	0.87	0.89	0.84	0.85
L-550	1.07	0.87	1.24	0.94	1.03
G-130	1.25	1.21	1.02	0.95	1.11
LSD		0.229			1.107
Mean	1.07	0.98	1.03	0.88	0.99
LSD		0.150			
CV%		18.9			15.0

Table 9. Effect of shading treatments on total dry weight, yield, harvest index and yield components, postrainy season, Hissar, 1977–78.

Shading treatment	Total dry weight (kg/ha)	Yield (kg/ha)	Harvest index (%)	Seeds/ pod	100-seed weight (g)
Control	5550	1990	37.2	0.97	19.7
Mosquito net	5161	1956	38.8	1.00	19.0
Thin cloth	5393	1933	36.8	0.95	19.7
Thick cloth	4636	1112	24.7	0.86	14.7
LSD	444.5	238.2	0.06	0.15	1.59

index (LAI) values (around 5.0, Fig. 2) reached in this crop at Hissar, where mutual shading and light penetration in the canopy could be an important factor. On the other hand, at ICRISAT Center with a LAI of around 2.0 (35 days after flowering), the light transmission ratio was 40–50%.

Effect of Leaf Removal

Different degrees of partial defoliation were carried out at ICRISAT Center and at Hissar, starting at the time of flowering and continuing until harvest. There was practically no effect of 25, 33, or 50% defoliation, on total dry-matter production, but these treatments had a small effect on yield, although not in proportion to degree of defoliation. A 50% reduction in leaf area reduced yield only 20%, whereas 100% defoliation reduced yield by 70–80%. This suggests either that leaf area is not a primary factor in limiting yield or that the remaining leaves are able to compensate for the removal of leaves by an increased photosynthetic rate.

There is a possibility that such treatments modify the water balance of plants. To investigate this, the defoliation treatments were repeated with and without irrigation. Treatment effects were not modified by irrigation. Changes in plant water potential in response to defoliation were also monitored soon after defoliation and continued throughout the day. The water potential of defoliated and nondefoliated plants did not differ. These experiments suggest that the compensation was not because of changes in water status of plants after defoliation, but because of other factors.

The effects of defoliation were more severe at ICRISAT Center. Comparison of results at the two locations suggest that leaf area is not a serious constraint to total dry-matter production, but yield was relatively more sensitive than was total dry-matter production to defoliation.

Effect of Flower Removal

Flower removal experiments were conducted at ICRISAT Center and at Hissar to study the effect of altered sink size on dry matter production and its partitioning. Two kinds of experiments were conducted at the time of 50% flowering: (1) removal of all flowers for different periods of time; and (2) flower removal to different degrees (partial flower removal) until harvest.

Both flower removal treatments extended the growing period. The prevention of pod set by different flower removal treatments resulted in more growth of roots and nodules (tenfold increase in nodule weight) and delayed senescence of the plant.

Removal of flowers on some branches and not on others of the same plant resulted in delayed senescence of the branches on which pod set was prevented. This suggests that the stimulus or signal that initiates senescence is related to pod set and is localized within the plant. Such an observation is also reported in soybean (Lindoo and Nooden 1977).

There was no significant decline in yield when one-third of the flowers were removed throughout the growing period. Similarly, removal of all flowers for 14–28 days resulted in no significant reduction in total dry matter and yield. Both experiments on partial flower removal and flower removal for a specified period of time suggest that chickpea plants have some ability to compensate for the loss of potential sinks.

Extension of the growing period in response to flower removal provided one opportunity for yield compensation. Continued growth causes addition of flowering nodes, and more pods can be formed. Indeed, this activity was observed. The second means of compensation was the increase in the number of seeds per pod. The increase in seeds per pod was in a range of 24–26% of the plants in which flowers were removed, when compared to the controls. The third and final type of compensation involved increase in seed weight. The compensation in seed weight generally occurred in small-seeded cultivars, and was relatively small — ranging from 8–20%. In bold-seeded cultivars, the 100-seed weight declined in response to flower removal.

Response of Chickpea to Cultural Practices

Saxena and Yadav (1975) reviewed the work on agronomy in the International Workshop on Grain Legumes. Additional aspects are included in this paper.

Response to Irrigation

Saxena and Yadav (1975) summarized work on response to irrigation, suggesting a positive response to irrigation in areas where winter rainfall is negligible. We obtained positive responses to irrigation ranging between 3 and 94% on Vertisols and a threefold increase on an Alfisol at ICRISAT Center.

Response to Nitrogenous Fertilizer

Nitrogen is not generally applied to legumes, as it is symbiotically fixed by the plants. In the deep black soils at ICRISAT Center (Table 2), chickpea cv JG-62 (a high-yielding cultivar of that region) did not respond to nitrogenous fertilizer applications up to 100 kg N/ha nor to manuring with farmyard manure. Combined nitrogen at the rate of 100 kg N/ha reduced the nodule mass. Response to applied nitrogen was observed in greater vegetative growth and LAI development. This advantage was not reflected in total dry-matter production or yield at harvest. Sinha (1977) reported an increase in yield in some cultivars and a decrease in others when nitrogen was applied at the rate of 75 kg N/ha. Singh (1971) and Singh and Yadav (1971) reported an increase in yield of cickpea with nitrogen application at the rate of 22.5 kg N/ha on soils low in total nitrogen (0.042%). Singh et al. (1972) and Rathi and Singh (1976) also reported positive response to soil applied N at the rate of 30.2 and 20.0 kg N/ha, respectively.

No significant increase in yield in response to nitrogen application was reported by Manjhi and Chowdhury (1971) and Rao et al. (1973). The latter authors attributed it to low or total absence of rainfall during the crop season.

Response to Phosphatic Fertilizer

Saxena and Yadav (1975) summarized well the responses to phosphatic fertilizers reporting conspicuous responses to soil-applied P. At ICRISAT Center on deep black soil low in available P and high in pH (Table 1), no positive response to soil-applied P was obtained in broadcast application with and without irrigation or with placement. Though placement increased the yield, the increase was not statistically significant.

It was felt that interference in the uptake of soil-applied nutrients, especially under dryland conditions where the moisture in receding, may be a factor in the lack of response to soil-applied nutrients. We therefore investigated different methods of foliar fertilization.

The presence of a very acidic exudate prompted us to use rock phosphate or superphosphate as dust on chickpea foliage; P would then become available for growth of the plants. The experiment was conducted over 2 years, and there was a significant but small increase in one year and not in the other.

Response to foliar applications of N, P, and N + P in liquid solutions was also investigated. Interestingly, individually N and P and the two together in the spray increased yield significantly (21.6%). Singh et al. (1971) found that a three-fourth dose of the phosphorus applied as spray was equivalent to the full dose of P through the soil and concluded that P uptake efficiency in foliar applications was high. Srivastava and Singh (1975) did not find a response to foliarly applied P up to 60 kg P_2O_5/ha.

Intercropping of Chickpea Cultivars of Different Durations

Observations at ICRISAT Center indicate that considerable moisture is left behind in the soil profile, even after harvest. To make better utilization of moisture in the profile, intercropping of chickpea cultivars varying in growth duration (early, medium late, and late), either as alternate rows or as a mixture, was investigated at ICRISAT Center and at Hissar. No marked beneficial or detrimental effect of intercropping with cultivars of the same species was observed. However, when cultivars of varying duration were grown in alternate rows, there was a tendency for yield to be about 6% greater at ICRISAT Center and 4% greater at Hissar.

Effect of "Nipping" on Yield

In northern India and Pakistan, nipping of the young shoots during vegetative growth and grazing of the young plants by sheep in Rajasthan causes an increase in auxillary branches, which sometimes leads to increased yields. The effect of nipping in shorter growth duration condition at ICRISAT Center (peninsular India) was investigated. Nipping treatments tended to reduce yield, but the reduction was not statistically significant.

Effect of Row Direction

Orientation of rows in some crops has been shown to increase yields, while in others it has no effect. Trials were conducted at ICRISAT Center and at Hissar to find the effect of east-west or north-south row directions on yield of chickpea. There was no effect on yield at either location.

Effect of Planting Geometry

Geometry of planting has been shown to influence the yield of many crops. Under conditions where water is limiting, square planting of dryland crops such as sunflower (Krishnamoorthy 1972) results in earlier development of moisture stress than does rectangular planting. This was investigated with chickpea at ICRISAT Center.

Three rectangularities were studied at two densities of population, 33 and 50 plants/m². At normal population densities (33 plants/m²), square planting yielded less than rectangular planting. At higher population densities (50 plants/m²), the difference between square and rectangular planting was statistically insignificanct, although the square planting tended to produce higher yields.

Response to Plant Population

Response to increasing plant density was investigated at ICRISAT Center and at Hissar. Optimum plant population depended upon the location and choice of cultivar.

In general, yields of chickpea at both locations were fairly plastic over a range of plant densities. Total dry-matter production and yield did not reach a plateau at ICRISAT Center at population densities of less than 80 and 20 plants/m², respectively, compared to 20 and 4 plants/m² at Hissar.

The idea of increasing yield by increasing the plant density of nonbranching erect cultivars was also investigated and found to be not promising. Branching of a normal cultivar is automatically suppressed when it is grown at high population densities, and a normal branching type tailors itself into a nonbranching type.

Effect of Seed Size

In some crops, larger seeds have been shown to produce vigorous plants and high yield. This was investigated in chickpea. Narayanan et al. (in press) reported that there is a close relationship between the weight of seeds and seedlings in graded seeds of a given cultivar, which may result in better seedling vigor. The greater seedling vigor of larger seeds may be related to greater seed reserves. This could be of practical importance in overcoming problems of emergence from crusted soils.

Saxena et al. (in press) investigated the effect of graded seed size within a given cultivar on yield of chickpea at three locations in India. Large seed gave larger seedlings, but there was no significant effect on final yields.

Physiological Aspects of Yield Improvements

For directed efforts to improve yield levels through plant breeding, yield enhancing factors and genetic sources of these need to be identified. On the other hand, yield-reducing factors need to be identified and sources of tolerance found so they can be utilized by breeders to increase yields under growth-limiting conditions.

Double-Podded Character

In chickpea, the dominant component of yield is the number of pods produced per unit area. Where growth duration is short — as at ICRISAT Center (peninsular India) — there is a great limitation imposed on the production of pods and, consequently, on yield. Sheldrake et al. (1979) reported that the double-podded character (cultivars with more than one pod per node) can confer an advantage in yield, ranging between 6 and 11% under conditions in which the character is well expressed. The character is well expressed under normal short growth duration at ICRISAT Center and in late plantings at Hissar. The double-podded character can be exploited to make yield gains under such conditions.

Cultivaral Difference in Plasticity

Ability of cultivars to yield nearly the same at suboptimal populations as at normal plant population is a measure of plasticity of cultivars. Chickpea cultivars in general are very plastic, but cultivaral differences have been noted in yield reduction below a critical plant population (Saxena and Sheldrake, unpublished data). Those with reduced yield at low populations were considered to be nonplastic. The yielding ability of these nonplastic cultivars was similar to that of the plastic cultivars at normal plant populations. Plastic cultivars could be very important in stabilizing and improving yields in farmers' fields where the populations are often nonuniform and suboptimal. A simple screening procedure has been developed in which plants are grown at a suboptimal population and at the recommended normal population (actual populations depending upon the location). The ratio of suboptimal/normal population in yields indicates the plasticity of the cultivar.

Cultivaral Differences in Germination with Limited Water

Cultivaral differences in germination of chickpea with limited available water were noted in laboratory studies on soils brought to different moisture tensions and in osmotic solutions (Saxena and Sheldrake, unpublished data). Germination studies were also carried out under field conditions where emergence is influenced by variation in soil moisture, depth of sowing, soil compaction, and so on. Seed size within a cultivar seems to influence germination to some extent. Under limited soil moisture conditions, small seed (within and between cultivars) had some advantage, which might be expected because of a larger surface/volume ratio and requirement of smaller amounts of water per seed. The reverse was observed when water was not limiting.

Cultivaral Differences in Susceptibility to Iron Chlorosis

Some of the chickpea cultivars exhibited iron chlorosis on Vertisols high in pH (Table 1) at ICRISAT Center. The symptoms are yellowing of the younger leaves with severe deficiency, reduction of size of younger leaves and dropping of pinnae. Agarwala et al. (1971) reported differences in cultivar reaction to iron deficiency in sand culture experiments.

In our studies, we found that iron chlorosis in the field can be easily corrected by a single spray of 0.5% $FeSO_4$. The recovery is very uniform, probably because of the presence of acid exudate on the foliage, which keeps the iron in an available and mobile form. The yield of nonsprayed susceptible cultivars was 41–44% lower than the sprayed cultivars (Saxena and Sheldrake 1980b). Expression of the symptoms appears to be under genetic control, and susceptible plants can be picked out and discarded from segregating populations.

Cultivaral Differences in Susceptibility to Salinity

Some of the chickpea-growing areas in India are saline. Though chickpea is more susceptible than wheat, barley, or other cereals to salinity, cultivar differences in response to salinity, as it affects germination and growth, were noticed in artificially salinized soil. Salinity tolerance at germination is important in ensuring plant stand, which also is an important factor in determining yield. Susceptibility to salinity may change depending upon the stage of plant development. Brick chambers (above ground) have been constructed and are being used to grow chickpea at different salinity levels until harvest to identify cultivaral differences in yield.

Cultivaral Differences in Heat Tolerance

Early planting soon after the end of the rainy season should ensure better germination and plant stands, as the moisture supply is good. However, temperatures are higher at this time and have been reported to affect early growth (Sheldrake and Saxena 1979a). Numerous studies have shown reduced yields result from planting too early (Saxena and Yadav 1975). Plants planted early are also affected by disease. We investigated cultivaral differences in heat tolerance at ICRISAT Center by planting at the normal time (October) and in February when temperatures are rising. We planted late, when the season was dry, rather than early at the end of the rainy season, to avoid the effect of differential disease pressure from year to year. Relative growth rates (RGR) and net assimilation rates (NAR) were calculated. Significant differences among cultivars were noted both with respect to NAR and RGR, and there was a significant interaction between RGR sowing date (Table 10). The significant interaction between cultivar and sowing date suggests that some cultivars may be more heat tolerant than others. Bengal gram, Annigeri, 850-3/27, H-208, and Radhey are some of the cultivars that had high RGR values in the February planting.

Screening for Cultivaral Differences on Limited Water

By withholding irrigation, severe water stress

Table 10. Variance ratios for relative growth rate (RGR) and net assimilation rate (NAR) from heat stress trial at ICRISAT Center (1977–78).

Source of variation	RGR	NAR
Sowing dates	10.03	446 177.2
Cultivars	3.33**	4.98**
Interaction	3.33**	2.8

**Significant at 1% level.

can be created in Alfisols (red soils), which are poor in water holding capacity. A simple field screening technique was developed to compare relative yield performance of cultivars under stress and nonstress treatments. The three irrigation treatments included no irrigation, once a month irrigation and once every 15 days irrigation. Cultivars differed in their drought tolerance (avoidance and/or tolerance). A drought tolerance index (DTI) was calculated as follows:

DTI = nonirrigated yield/irrigated yield

On the basis of the drought tolerance index, drought tolerant cultivars were early, but not all early cultivars were drought tolerant. Drought tolerance index was positively correlated with yield of nonirrigated plants (r = +0.40**, n = 70). Some degree of drought tolerance also appeared in cultivars of medium maturity. The ranking of cultivars in irrigated and nonirrigated treatments changed, suggesting that it may not be possible to select cultivars for nonirrigated conditions by growing them with irrigation.

References

Agarwala, S. C., Sharma, C. P., Bisht, S. S., Mehrotra, S. C., and Afzal, A. 1971. Genotypic differences in susceptibility of some legumes to iron chlorosis. *In* Abstract of papers presented at the Second International Symposium on Plant Pathology, 27 Jan–3 Feb 1971, New Delhi, India.

Argikar, G. P. 1970. Gram. Pages 54–136 *in* Pulse Crops of India. ICAR, New Delhi, India.

Dahiya, B. S., Singh, K. B., Brar, H. S., and Brar, J. S. 1976. Identification of physiologically efficient genotypes in chickpeas (*Cicer arietinum* L.). Pages 19–20 *in* Tropical Grain Legume Bull. No. 4.

Krishnamoorthy, C. H. 1972. Discussion *in* Sorghum in seventies. N. G. P. Rao and L. R. House (ed.), Oxford and IBH Publishing Co., New Delhi. 370 pp.

Kumari, P. S., and Sinha, S. K. 1972. Variation in chlorophylls and photosynthetic rate in cultivars of Bengal gram (*Cicer arietinum* L.). Photosynthetica 6: 189–194.

Lindoo, S. J., and Nooden, L. D. 1977. Studies on the behavior of senescence signal in Anoka soybeans. Plant physiology 59: 1136–1140.

Manjhi, S., and Chowdhury, S. L. 1971. Response of Bengal gram (*Cicer arietinum* L.) to four levels of phosphorus applied alone and in combination with nitrogen and potassium. Indian Journal of Agronomy 16: 247–249.

Narayanan, A., Saxena, N. P., and Sheldrake, A. R. 1980. Cultivaral differences in seed size and seedling growth of pigeonpeas and chickpeas. Indian Journal of Agricultural Sciences (in press).

Rao, S. B. P., Ramnath, B., and Sam, M. J. 1973. Response of gram to fertilizer application in the black cotton soils of Bellary under dryland farming. Mysore Journal of Agricultural Science 7: 360–365.

Rathi, S. S., and Singh, D. 1976. Effect of nitrogen and phosphate fertilization on the growth and yield of gram (Ev). Indian Journal of Agronomy 21(3): 305–306.

Saxena, M. C., and Yadav, D. S. 1975. Some agronomic considerations of pigeonpeas and chickpeas. Pages 31–62 *in* Proceedings of the International Workshop on Grain Legumes (13–15 Jan 1975), ICRISAT, Hyderabad, India.

Saxena, N. P., and Sheldrake, A. R. 1980a. Effect of pod exposure on the yield of chickpeas (*Cicer arietinum* L.). Field Crops Research 3: 189–191.

Saxena, N. P., and Sheldrake, A. R. 1980b. Iron chlorosis in chickpea (*Cicer arietinum* L.) grown in high pH calcareous Vertisol. Field Crops Research 3: 211–214.

Saxena, N. P., Narayanan, A., and Sheldrake, A. R. 1980. Effect of seed grading on yield of chickpea and pigeonpea. Indian Journal of Agricultural Sciences (in press).

Sheldrake, A. R., and Saxena, N. P. 1979a. The growth and development of chickpeas under progressive moisture stress. Pages 465–483 *in* Stress Physiology in Crop Plants, by H. Mussel and R. C. Staples, J. Wiley, New York, 1979.

SHELDRAKE, A. R., and SAXENA, N. P. 1979b. Comparison of earlier and later formed chickpeas (*Cicer arietinum* L.). Annals of Botany 43: 467–474.

SHELDRAKE, A. R., SAXENA, N. P., and KRISHNAMURTHY, L. 1979. The expression and influence on yield of the double-podded character in chickpeas (*Cicer arietinum* L.). Field Crops Research 1: 243–253.

SINGH, K. B., TOMER, P. J., and JAIN, M. K. 1971. Effect of spray fertilization of phosphorus in gram. Annals of Arid Zone 10(2/3): 199–202.

SINGH, K., TRIPATHI, H. P., and RAHEJA, H. R. 1972. Response of gram (*Cicer arietinum* L.) to nitrogenous and phosphatic fertilization under different crop rotations. Haryana Agricultural University Journal of Research 2(1): 19–24.

SINGH, R. G. 1971. Response of gram (*Cicer arietinum* L.) to the application of nitrogen and phosphate. Indian Journal of Agricultural Sciences 41(2): 101–106.

SINGH, R. S., and YADAV, S. C. 1971. Effect of number of cultivation and increasing levels of N and P on yield and quality of gram (*Cicer arietinum* L.). Indian Journal of Agricultural Research 5(1): 51–54.

SINHA, S. K. 1974. Yield of grain legumes. Problems and prospects. Indian Journal of Genetics 34A: 988–994.

SINHA, S. K. 1977. Food legumes distribution, adaptability and biology of yield. FAO. Plant Production and Protection, Paper 3.

SRIVASTAVA, S. P., and SINGH, A. P. 1975. Phosphorus fertilization in gram under dry-land conditions. Science and Culture 41(11): 527–528.

SUBRAMANIA IYER, P. R. V., and SAXENA, M. C. 1975. Preliminary studies on root distribution pattern of some gram varieties. Journal of Nuclear Agriculture and Biology 4(2): 46–48.

The Effects of Photoperiod and Air Temperature on Growth and Yield of Chickpea (*Cicer arietinum* L.)

R. J. Summerfield, F. R. Minchin, E. H. Roberts, and P. Hadley*

From a cultivated area which exceeds ten million hectares, the average seed yield of chickpea (*Cicer arietinum* L.) is small, probably about 700 kg/ha, and varies greatly between both sites and seasons, from about 190 to 1600 kg/ha. Most crops are of ancient land races grown on poor fertility soils in rainfed conditions (Auckland and Singh 1976). Chickpeas are grouped into 2 basic types — the small-seeded desi varieties grown mainly as a winter crop planted in October or November from Pakistan eastward, and the large-seeded kabuli varieties characteristically grown as a summer crop planted in March or April from Afghanistan to the Middle East. Clearly, crops of this species which cover such a wide range of latitude, longitude, and altitude are subject to a tremendous variety of environments; with our present knowledge, however, it is impossible to assess reliably the significance of various environmental factors or of genotype × environment interactions in varietal adaptability. For example, chickpea breeding at ICRISAT is divided between field sites at Hyderabad (17°N) and at Hissar (29°N); crops generally mature within 110 days after sowing in the warmer (southernmost) environment and within 160 days in the cooler environment. Crosses between cultivars "adapted" to southern India produce short-duration segregants, which produce greater yields at Hyderabad than at Hissar, whereas crosses between cultivars "adapted" to northern India produce long-duration segregants, which yield best at Hissar (Auckland, personal communication 1977). Clearly, the different aerial environments in these localities are likely to contribute markedly to variations in phenotypic expression.

As with other grain legumes, physiological data on chickpea are rife with confusion and contradiction, and conclusions are often based on unreliable methodology. As a consequence, the chickpea breeder, without clear guidelines from the plant physiologist, primarily uses final seed yield as a criterion for selection in the field. Even if components of yield are also used (traditionally, the number of pods per plant and seeds per pod and the weight of individual seeds), there is little, if any, information available as to the phenological or physiological bases for their variations.

Seed yield in grain legumes depends upon both vegetative and reproductive components, which are markedly affected by environmental factors (Summerfield and Minchin 1976). As is true of other species, the number of pods that reach maturity has a major effect on seed yield in chickpea (Sandhu and Singh 1972), but we know little of either how or at which stage during development variations in this yield component arise. Without doubt, the environment in which chickpea grows and matures has a major effect on the realization of yield potential, as many time-of-planting studies have shown (Eshel 1968). In order to elucidate the environmental factors that show these effects, it is usually necessary to use controlled environments. Although some work has been done in controlled-environment conditions, however, we still know little about the effects of environ-

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mental factors or their interactions on chickpea growth because orthogonal treatment combinations have not been used, and environmental factors have been poorly controlled or have been studied in isolation (Sandhu and Hodges 1971; van der Maesen 1972). An essential prerequisite to the use of controlled environments as an adjunct to field research is that plants grown to reproductive maturity in artificial conditions should resemble, as closely as possible, plants of the same genotype grown as spaced individuals in the field (Summerfield 1976). We have now successfully adapted plant husbandry and culture techniques developed for other potential tropic-adapted grain legumes and shown that this prerequisite can be satisfied for chickpea (Summerfield et al. 1978).

With experiments on grain legumes, it is imperative to take the widest possible viewpoint of the symbiotic association with *Rhizobium*, otherwise it becomes increasingly difficult to ascribe experimental treatment effects to responses of the host plant, the microsymbiont, or both. For example, just as a selection objective such as increased net photosynthesis rate in chickpea (e.g., Kumari and Sinha 1972) may be irrelevant unless the reproductive behavior of a legume crop is well adapted to the local environment (Evans and King 1975), so is the evaluation of environmental adaptability if the role of the microsymbiont in the realization of yield potential is ignored (Summerfield et al. 1978).

Growth, Phenology, and Yield

Seasonal changes in photoperiod and in day (mean maximum) and night (mean minimum) temperature become progressively more pronounced as latitude increases, and although changes in air temperature lag behind those in photoperiod, the two measurements also tend to be closely correlated. The correlation between temperature and photoperiod, however, is not inevitable since temperature varies markedly with altitude. The relative magnitude of these changes in selected localities within important areas of chickpea cultivation are shown in Figure 1. Not only do average absolute values differ markedly between photothermal regimes, but also there are major chronological

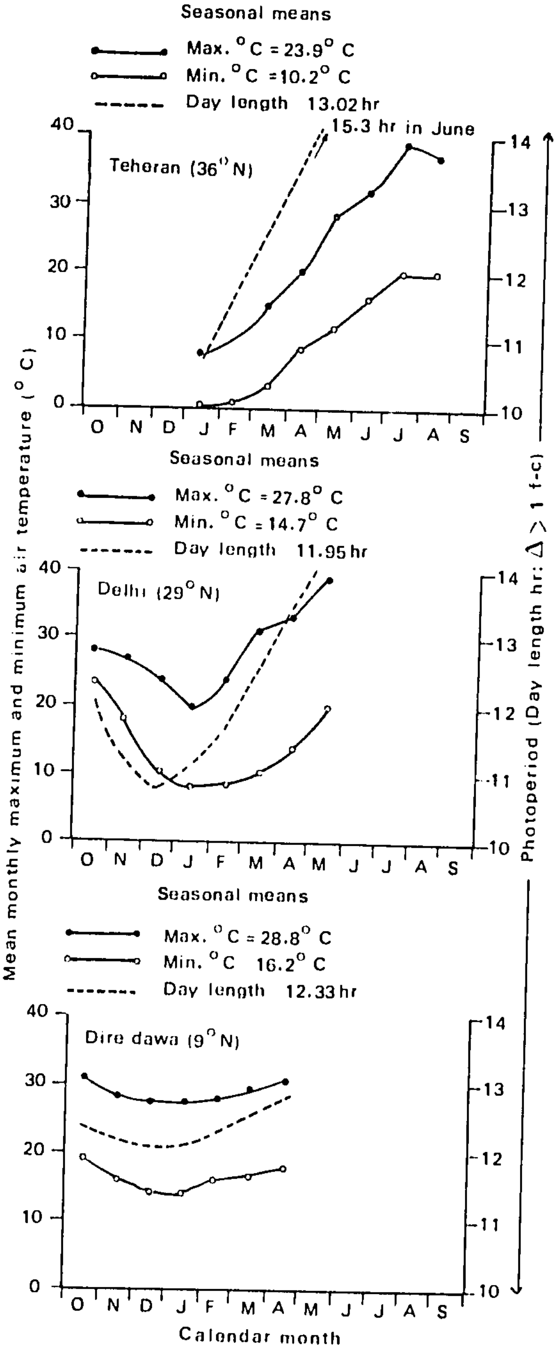


Figure 1. Seasonal changes in mean monthly maximum and mean monthly minimum air temperature and in photoperiod at three locations within important areas of chickpea cultivation (photoperiods from Francis 1972).

variations in both the rates and direction of change in these climatic factors.

Many studies with chickpea are severely limited because it is assumed or inferred that a single combination of values of environmental factors is optimal for all stages of growth. Such an assumption may be erroneous since the effects of warmer temperatures on growth, at least in the temperate range, may be positive during vegetative development because the effects on a plant organ (e.g., the initiation and expansion of leaves) can reasonably be expected to be positive; but the effect may well be negative when the same organ is aging because warmer temperatures accelerate aging and shorten useful life. In the field, the effects of air temperature and humidity are often confounded. In temperate conditions the separate effects may well be in opposition because warm air (which accelerates growth) is usually dry air (which retards growth) and vice versa. On the other hand, in tropical environments, hot and dry atmospheric conditions may combine to limit plant growth.

Response to differences in photoperiod, associated with season as well as latitude, are important components in the adaptation of traditional legume cultivars to their native environments (Wien and Summerfield 1979). Although this climatic factor changes in an exactly predictable manner throughout the calendar year at any one location, climatologists pay little attention to it. Temperature affects not only the rates but also the durations of many processes that affect growth. The adaptations of local populations of grain legumes and their progeny to environment depend on differences between genotypes in the separate effects of day and night temperature and of photoperiod, and in the interactions between them, all of which may vary with the phenological and developmental stage of the genotype. Understanding these effects and interactions makes it possible to predict reliably the times of phenological features such as onset of flower initiation, appearance of first flowers, duration of flowering, physiological maturity, and harvest ripeness (Nix et al. 1977). Such knowledge is a necessary basis for constructing realistic predictive models of crop growth and yield (Monteith 1972), models which at present become less reliable as flowering and reproductive growth become preponderant over vegetative growth, since we know relatively little about the time course of fruit-to-total growth ratios and the effects on them of environment and genotype.

A plant species can realize its full genetic growth potential or complete its genetically programmed phasic development only within certain ranges of environmental factors. Growth and development apply to components as well as whole plants and involve important changes in morphology and reproductive state. In nonleguminous plants, phenotypic variations are the consequence of a combination of genetic differences, the effects of environment on the rate or duration of vegetative growth and reproductive development, and of genotype × environment interactions. However, in marked contrast, a nodulated legume can obtain at least part of its nitrogen requirements from symbiotic fixation, and its economic yield (leaves and seeds) is composed not only of carbohydrate but also of protein and sometimes of oil. Studies of phenotypic variability in legumes should therefore consider the additional contribution of the *Rhizobium* genotype upon which plants may partly depend for their nitrogen supply, and the likelihood of *Rhizobium* × host, Rhizobium × environment, or indeed second-order interactions (Fig. 2A). The more a legume depends upon symbiotically fixed rather than inorganic nitrogen, the most common situation in chickpea cultivation (Table 8 van der Maesen 1972), the more significant these potential sources of variation become. The chickpea-*Rhizobium* symbiosis is extremely specific (Vaishya and Sanoria 1972), and *Rhizobium* strain differences in efficacy of nitrogen fixation are common (Okon et al. 1972). Strains differ in their ability to tolerate salinity and warm soil temperatures and significant host × strain interactions can occur (Dart et al. 1976). Significant correlations have been established between effective inoculation and seed yield of chickpea in locations where the crop has not been previously grown (Corbin et al. 1977). In view of these observations, it is unfortunate that the symbiotic relationship has all too frequently been ignored in studies of interactions between genotypes and environment in this species (Gupta et al. 1972; Malhotra and Singh 1973).

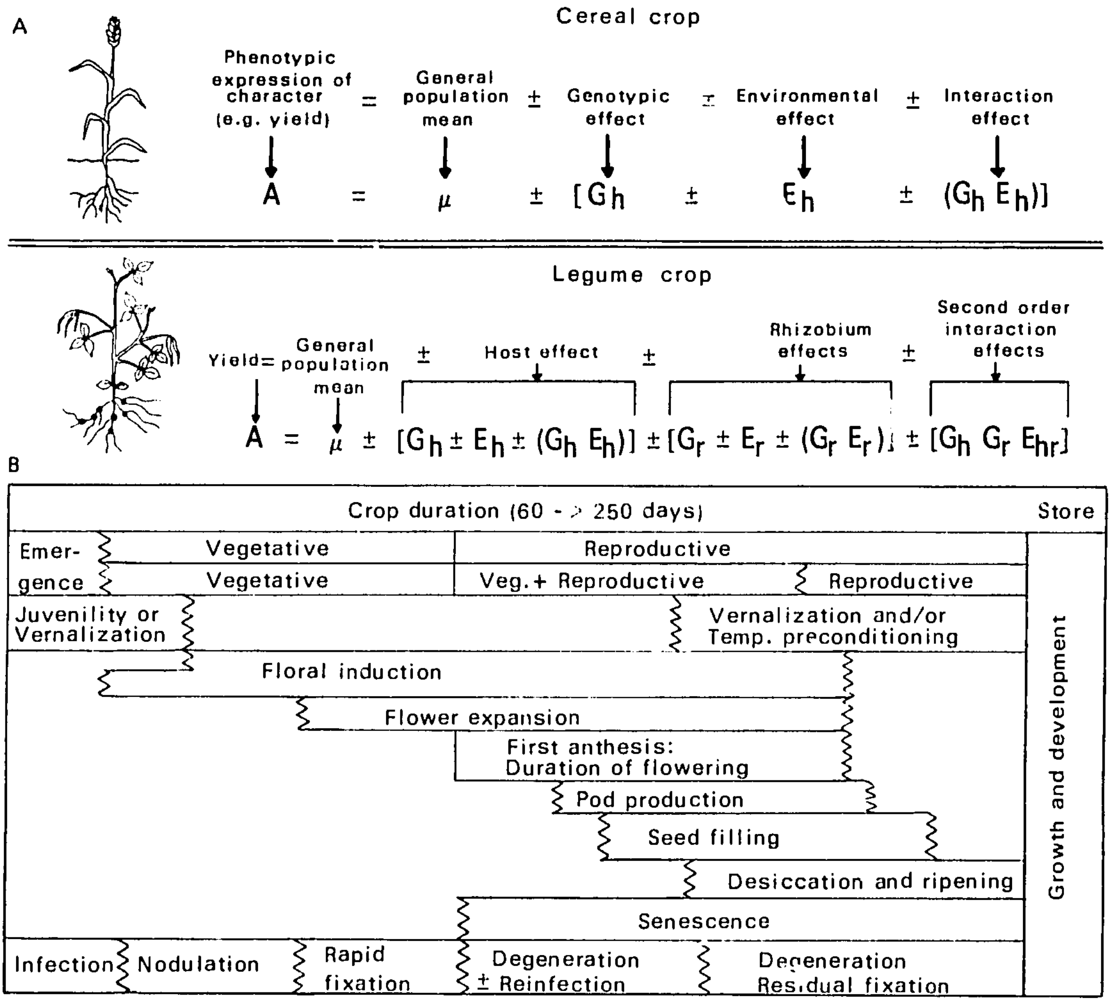
It is convenient to consider the growth and development of an annual legume as a number of consecutive phases: vegetative (which includes juvenility), mature (ripeness to flower), reproductive (flowering and setting of fruits), and senescent (which includes maturation of fruits). The quantitative performance of plants throughout each stage of development (Fig. 2B) is often determined or limited by those environmental factors which also initiate phase changes. A traditional components-of-yield analysis equates legume seed yields to the product of three components only, that is, the number of pods that reach maturity, the average number of seeds in them, and the mean weight of individual seeds (Fig. 2C). However, as we have argued before (Summerfield et al. 1978), these aggregated data alone are of limited value in furthering our comprehension of the physiological limitations to legume seed production. We cannot hope to identify with confidence the main effects and interactions of climatic factors on the more responsive components that contribute to significant variations in yield until these relations have been studied more carefully.

Growth: Increase in Size and Formation of New Vegetative Organs

Variation in both the number and size of a particular plant organ can be analyzed in terms of two variables, which may or may not be independent, i.e., the rate and the duration of growth (Monteith 1977). When the size or number of organs is fixed genetically, a change in growth rate associated with warmer or cooler temperatures may be offset by a proportional change in duration, so that the net effect may be small. However, if the rate of growth is limited by some nongenetical factor(s), such as the supply of carbon or nitrogen, a change in growth rate in association with change in temperature may not be compensated for by differences in growth duration. Indeed, it is difficult and dangerous to make general statements from "first principles" about the effects of photoperiod and air temperature on the growth (and development) of legumes, and many data cannot be sensibly interpreted because of the poor experimental designs and cultural practices that have been adopted.

Within chickpea cultivars, individual seed size depends on pod location (mean seed weight decreases acropetally), the number of seeds produced by mother plants (seed size and number per plant are often inversely related), and maturation environment. For example, when parent plants mature in the hot and dry environment of Hyderabad, medium- and late-maturity cultivars (e.g., 850-3/27 and G-130, respectively) produce fewer but individually heavier seeds with smaller nitrogen, and presumably protein concentrations than in the cooler climate of Hissar (Saxena and Sheldrake 1977). These differences could influence crop performance not only in the current but also in the subsequent generation, since small seeds of a given cultivar may germinate more rapidly and result in better stand establishment than larger seeds when soil water status is poor. However, in contrast to some other legumes, (e.g., the sensitivity of large-seeded Virginia groundnuts to drought during embryogenesis and the associated loss of germinability (Palls et al. 1977), the agronomic significance of "environmental preconditioning" of chickpea seeds on mother plants remains to be demonstrated.

After planting, the rates of germination, emergence (hypocotyl elongation), and seedling growth are very temperature-dependent with marked differences between genotypes. Chickpea seeds can germinate over a wide range of temperatures (10–45°C), but they do so most rapidly at either a constant temperature of 20°C or in diurnally fluctuating regimes of 15–25°C (van der Maesen 1972) or 20-30°C (ISTA 1966). Some cultivars are responsive to cold-temperature vernalization (Pal and Murty 1941). It is claimed that the vernalized plants have more rapid anatomical development — e.g., vascular differentiation and cessation of cambial activity (Chakravarti 1953) — and flower earlier, and at lower nodes, than plants produced from nonvernalized seeds (Pillay 1944; Chakravarti 1964). Vernalization can also influence chickpea morphology by hastening stem elongation and suppression of branch formation, although there are complex interactions between vernalization treatment and the photoperiodic regimes to which plants are subsequently exposed (Nanda and Chinoy 1960a, 1960b); however, some cultivars do not respond by flowering earlier when grown from vernalized seed (Kar 1940), and Mathon (1969) has classified *Cicer arietinum* as "having no obligate cold requirement."



C

1. Number of nodes/plant (N_0) ⟶ Vegetative growth rate x Duration of preflowering period
2. % of N_0 that becomes reproductive
   (1 x 2)=Phenological potential
3. Number of flowers per reproductive node (F) } Number of pods per reproductive node (P)
4. % of F that set pods
5. % of P that are retained
6. Number of seeds per pod (S)
   (3 x 4 x 5 x 6) = Reproductive efficacy
7. % of S that attain maturity ⟷ Carbon supply / Nitrogen supply
8. Mean seed weight ⟶ Mean seed growth rate x Duration of pod-fill
   (7 x 8)=Yield culmination

∴Yield /plant = (1 x 2) x (3 x 4 x 5 x 6) x (7 x 8)

Figure 2. (A) Factors that contribute to variations in seed yield of a cereal and a legume crop; (B) Diagrammatic representation of growth and development in annual legumes; (C) Components of seed yield in determinate legumes.

Vernalization response in plants is commonly controlled by a single or few genes and can be readily modified by selection (Evans and King 1975); however, a modest vernalization requirement may be advantageous in Mediterranean climates in order to prevent the appearance of flowers before winter. Likewise, for crops grown throughout the Indian winter, requirement for vernalization may enhance yields by delaying flower initiation until plants are well established. Then again, in southern Australia such a cold requirement may permit early autumn sowings without the risk of late winter flowering (Corbin 1976).

Many different cultivars have been used in experiments on seed vernalization. Even if genetic diversity for "cold requirement" exists in cultivated chickpea, it may normally be masked in areas to which particular cultivars are adapted because of the frequent occurrence of cool temperatures. This illustrates a fundamental principle — the chance of detecting genetic differences is increased when plants are grown in environmental conditions that maximize the difference in response between genotypes (Murfet 1977).

Young plants of chickpea cultivars commonly grown in Mediterranean climates are tolerant of cool springtime temperatures, and genotypic differences in seedling growth rate in cool conditions have been identified in Australia (Corbin 1976). Young seedlings can withstand temperatures as cold as −8°C (Ivanov 1933) or even −13°C (Koinov 1968), and cultivar differences in frost tolerance have been reported (Whyte et al. 1953; FAO 1959).

At the other climatic extreme, ensuring adequate stand establishment is a major problem in some legume production systems (e.g., soybean) in the tropics. However, chickpea seeds seem able to tolerate warm soils at planting, at least when adequate water is available. For example, van der Maesen (1972) recorded 84% germination after 9 days at 35°C in laboratory tests. Nevertheless, chickpea stands in farmers' fields are often poor, and, while limited availability of water in the seed bed may be a major factor (Saxena and Sheldrake 1977), other factors may interact with this, such as seed maturation environment, storage conditions, depth of planting, soil compaction, and soil temperature.

It seems logical to consider nodule initiation and development at the seedling stage, but unfortunately, this is seldom done even though in chickpea significant differences are known in the ability of *Rhizobium* strains to establish an effective symbiosis and, in the subsequent rate of nitrogen fixation, in different thermal regimes. For example, the formation and function of nodules by *Cicer rhizobium* can be restricted in warm soils (Sen 1966). A temperature of 30–33°C had drastic effects even when imposed for only a few hours each day (Dart et al. 1976). When chickpea is grown as a summer crop at latitudes between 30 and 40°N in Lebanon, Italy, Spain, Iran, and Turkey, the vegetative plants will experience long days (to more than 14 hours) and average maximum and minimum air temperatures of about 25° and 8–10°C, respectively. For winter crops in India and Pakistan, however, the daylengths at this stage of development will be only 10–12 hours, and mean maximum air temperature will be about 18°C while nights can be as cool as 0–2°C (Sinha 1977).

We have used controlled-environment growth cabinets to investigate the effects on chickpea growth and development of factorial combinations of long and short days, which are either warm or cool and which are followed in each diurnal cycle by warm or cool nights. The temperatures chosen were selected to typify the range of each climatic factor experienced by chickpea crops throughout their geographical distribution. Evidence to date (Summerfield et al. in press) for three cultivars (Chafa, Rabat, and G-130) has established that the rate of seedling emergence from a homogeneous and hydrated rooting medium is more obviously positively correlated with weighted mean temperatures throughout the range 14.5–24.5°C than any other aspect of temperature (when treatments comprised nights of 10° or 18°C alternating with days of 22° or 30°C). Seedlings emerged within 4–6 days after sowing at 24.5°C, compared with 6.5–9 days at 14.5°C (Fig. 3). The subsequent vegetative performance of young plants, however, is far more dependent on the separate effects of day and night temperature than on the mean value of the diurnal fluctuation. These responses are typified by Chafa plants harvested after 28 days from sowing (Figs. 4, 5). In daylengths characteristic of the Indian growing season (11–12 hours), the dry weight of vegetative plants (Fig. 4A) depends largely on whether

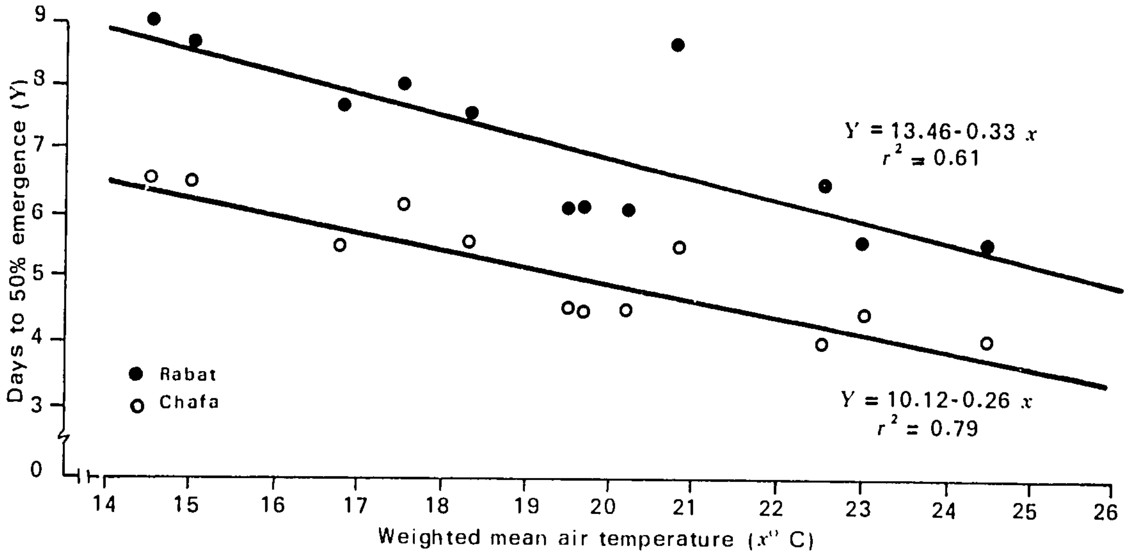
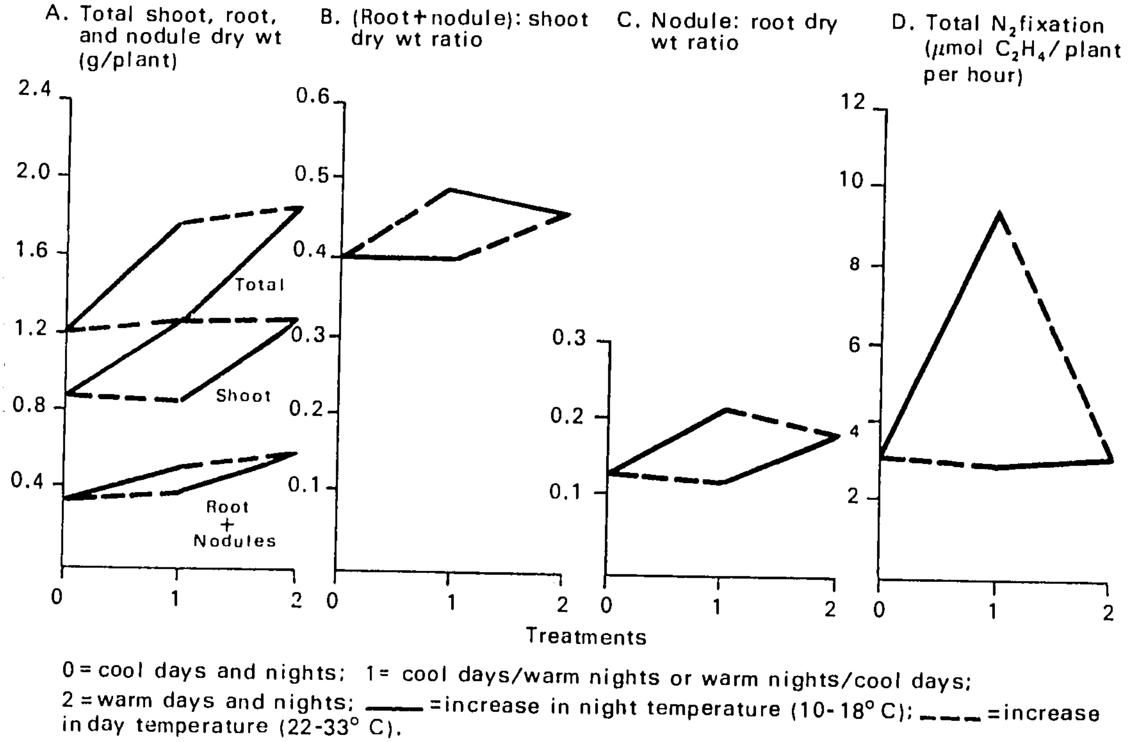


Figure 3. Relationship between days to 50% emergence and weighted mean air temperature for chickpea cultivars Rabat and Chafa. Cultivar G-130 showed a response almost identical to Chafa and has been omitted for clarity.

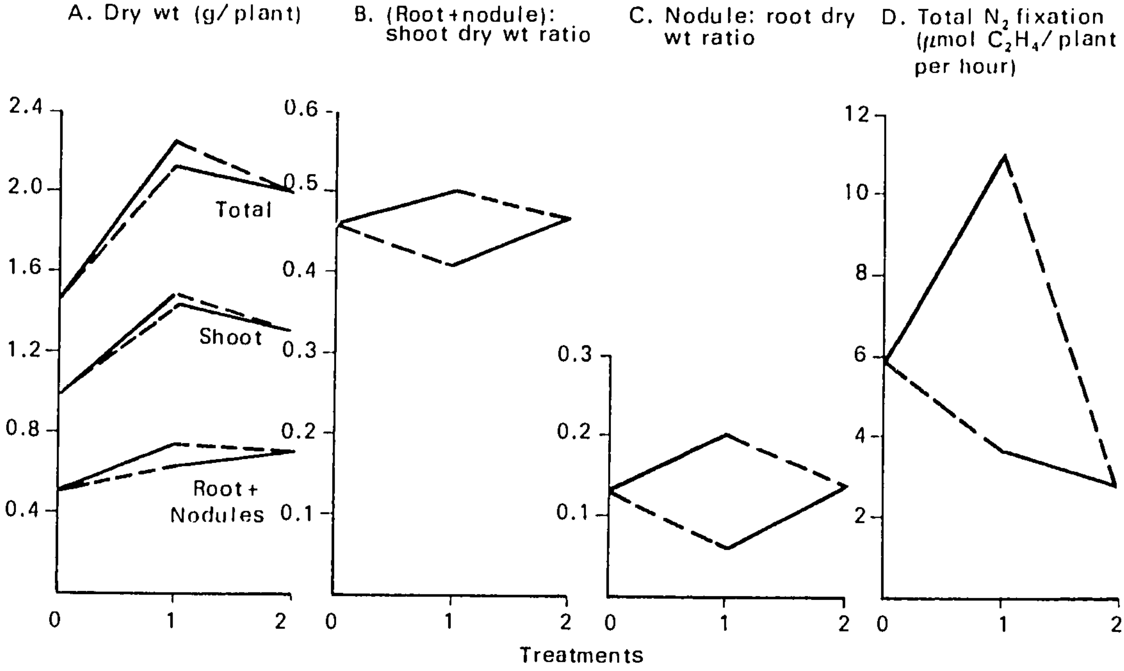


0 = cool days and nights; 1 = cool days/warm nights or warm nights/cool days; 2 = warm days and nights; ——— = increase in night temperature (10-18° C); – – – = increase in day temperature (22-33° C).

Figure 4. Richards' diagrams (1941) illustrating the effects of day and night temperature on the production and distribution of dry matter, and on nitrogenase activity, of young Chafa plants grown in controlled-environment growth cabinets. Mean values of three replicates per treatment combination in 11- and 12-hour day lengths, respectively (i.e., six replicates in total). Plants harvested 28 days after sowing.

the nights are warm (18°C) or cool (10°C), and neither above- nor below-ground dry-matter production is significantly affected by whether or not days are warm (30°C) or cool (22°C). Warm nights promote shoot growth more so than below ground dry-matter production, which in all treatments, represents at least 28% of the total dry weight produced at this stage of development. While they do not affect dry-matter production per se, warm days do favor dry-matter allocation to organs below rather than above the ground (Fig. 4B), and warm nights favor nodule production and growth rather than root growth (Fig. 4C). Hence, vegetative plants grown in cool days and warm nights (22–18°C) are equally the largest, and they invest about one-half of their total dry matter into root plus nodule growth and about 20% of this to the nodules themselves. Indeed, the nodules (formed by *Rhizobium* strain CC 1192) in this regime are especially active, whereas a night temperature of 10°C and (as also shown by Dart et al. 1970) a day temperature of 30°C are clearly sub- and supraoptimal, respectively (Fig. 4D).

In a 15-hour daylength regime characteristic of the growing season in more northerly latitudes, warm days and cool nights or cool days and warm nights (30–10°C or 22–18°C) are best for dry-matter production (Fig. 5A). Warm nights favor dry-matter allocation below the ground (Fig. 5B) and again, to nodules rather than to roots (Fig. 5C), and they stimulate symbiotic activity if day temperatures are not supraoptimal (Fig. 5D). Since many chickpea crops are grown without addition of large amounts of nitrogenous fertilizer and, in India and Pakistan, on moisture conserved in the soil after preceding rains, a combination of cool days and warm nights (22–18°C) seems likely to produce plants best equipped to tolerate such practices. It may prove worthwhile however, to screen genotypes for their ability to grow and nodulate in cool nights (10°C) — a site at high

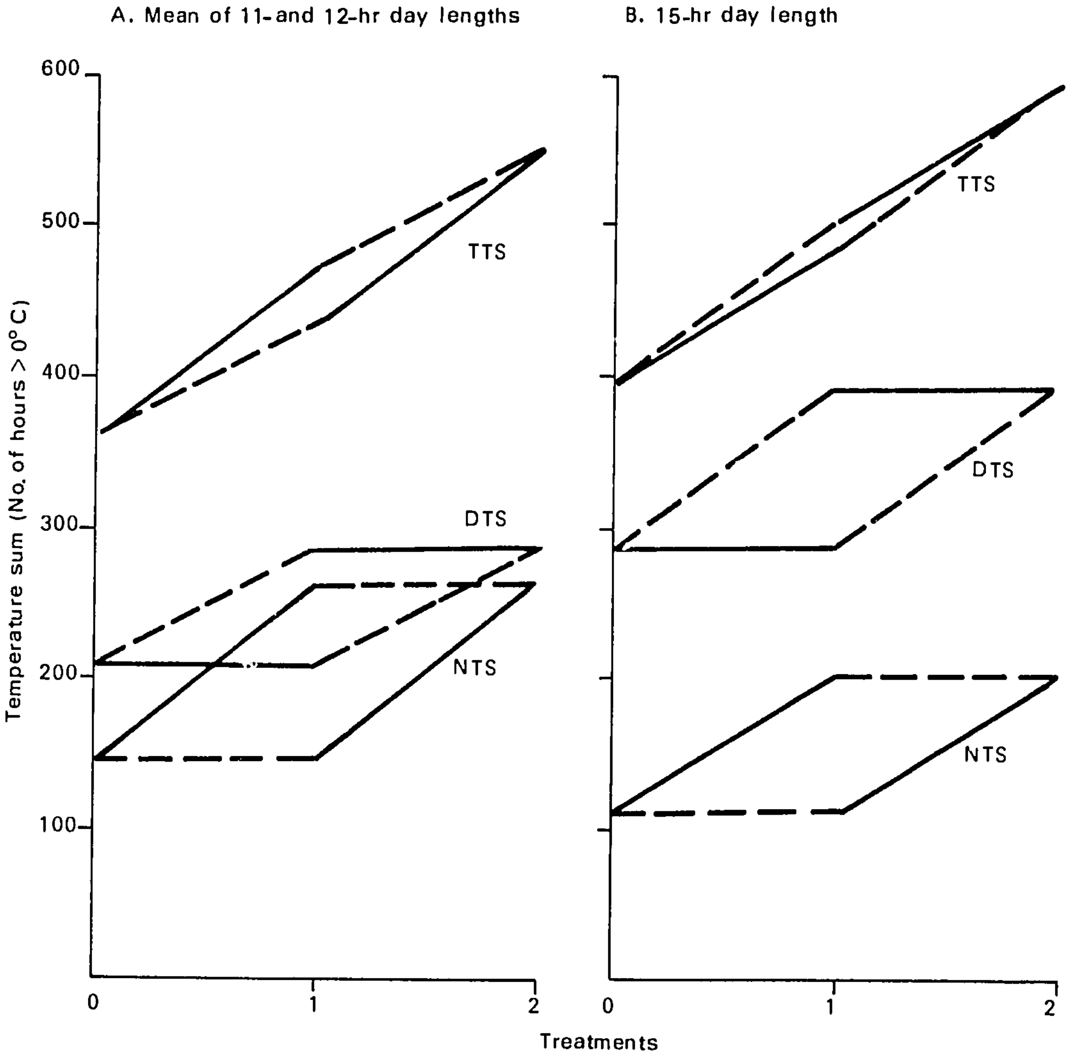


0 = cool days and nights; 1 = cool days/warm nights or warm nights/cool days; 2 = warm days and nights; —— = increase in night temperature (10-18°C); – – – = increase in day temperature (22-30°C).

Figure 5. Same as for Figure 4 except that each value is the mean of three replicates per treatment combination and in a day length of 15 hours. Plants harvested 28 days for sowing.

altitude may suffice — and for nodulation and fixation activity in warm days (30°C).

Figure 6 shows the diurnal distribution of temperature sum (centigrade hours above a base temperature of 0°C) within the various treatment combinations and highlights just how easily erroneous conclusions could be drawn if plant responses were related only to mean temperature or, as is commonly done with grain legumes, to average day tempera-



0 = cool days and nights; 1 = cool days/warm nights or warm nights/cool days; 2 = warm days and nights; ——— = increase in night temperature (10-18° C); – – – – = increase in day temperature (22-30° C).

Figure 6. Distribution of temperatures sum within various day and night temperature combinations: DTS, NTS, and TTS denote day, night, and total temperature sum, respectively. Note especially that treatment combinations which provide more or less the same temperature sum to plants each diurnal cycle (e.g., 22-18°C and 30-10°C) can have drastically different consequences, depending on the relative distribution of the temperature sum between hours of daylight and darkness (see Figs. 4 and 5).

ture. These data are presented and discussed more fully elsewhere (Summerfield et al., in press).

Others have investigated the effects on vegetative attributes of chickpea when plants are grown in a range of nonfactorial combinations of temperature (van der Maesen 1972) or even constant temperatures (Sandhu and Hodges 1971). A plethora of responses have been described (Table 1), usually for plants dependent on inorganic nitrogen rather than symbiotic fixation but which may or may not have been nodulated. It is difficult to relate these data either to each other or to extrapolate from them to predict field performance. It is also difficult to anticipate how such data will relate to the performance of nodule-dependent plants in different aerial environments. However, it is noteworthy that two of the temperature combinations that others have described as "optimal" for dry-matter production have a mean value close to that of the cool day, warm night environment (19.56°C), which was so favorable to the early vegetative growth and symbiotic activity of cv Chafa (Figs. 4 and 5).

The longevity of individual chickpea leaves is more prolonged in areas of cool temperatures (18°-19°C) than in warmer regimes (26°C), a fact which, in time, could counteract their slower rates of photosynthesis (23.2 and 26.1 mg CO_2 dm^{-2}, per hour, van der Maesen 1972). Furthermore, the rate of dry-matter production of a cultivar does not necessarily closely reflect the rate of foliar photosynthesis of the same cultivar in other trials (van der Maesen 1972). The photosynthetic capacity of chickpea leaves seems neither greater nor less than other grain legumes, is equally variable (Table 2), and presents the same problems with respect to measurement and interpretation of comparative data (Evans 1975). Others have suggested or inferred, that selection for photosynthetic rate per se or some related attribute, such as RuDP carboxylase activity or chlorophyll content (Kumari and Singh 1972; and Sinha 1977), may be a worthwhile objective. This seems unlikely: selection for photosynthetic rate presents very great problems with little surety of return. One major problem is immediately apparent in Table 2 where it can be seen that an enormous range of values has been reported even for the same cultivars of soybean.

The average dry weight of young Chafa plants (28 days after sowing) grown in a 15 hour daylength of intense fluorescent light (Fig. 5) was exactly 30% larger than the average of plants grown in 11 or 12 hour days (1.96 and 1.51 grams $plant^{-1}$, respectively). Plants in the

Table 1. Some effects of air temperature and photoperiod on vegetative attributes of several cultivars of chickpea.

	Optimum environmental combination				
	Temperature (°C)		Photoperiod (hr)		
Vegetative attribute	Day	Night	Length	Light source	Light intensity (lux)
Leaf + stem dry weight (g)	22.5	22.5	12	Fluorescent + incandescent	28 063
Total dry weight (g)	26.0	18.0	12	Fluorescent	?
	32.0	24.0	14	HPL bulbs for 12 hr + 2 hr low intensity	?
	29.0	21.0	14		
No. primary and secondary branches $plant^{-1}$	30.0	30.0	16	Fluorescent + incandescent	28 063
	10.0	10.0	16	Fluorescent	4 000
	23.0	15.0	14	HPL bulbs for 12 hr + 2 hr low intensity	?
Leaf no. on main stem	35.0	27.0	14		
Area $leaf^{-1}$ (cm^2)	26.0	18.0	14		
Leaf area $plant^{-1}$	26.0	18.0	14		

Compiled from Hugon (1967); Sandhu and Hodges (1971); and van der Maesen (1972).

All plants probably dependent on inorganic N; may or may not have been nodulated. Insufficient data presented to calculate N concentration applied.

Table 2. Rates of foliar photosynthesis (mg CO_2dm^{-2} per hr) reported for grain legumes.

Legume	Net photosynthetic rate of fully expanded leaves at saturating light intensity	No. of measurements on different lines/ cultivars/genotypes
Lupin	29.4-34.9	3
P. vulgaris	13.5-32.0	10
Chickpea	19.0-42.5	8
Cowpea	23.0-50.0	2
Groundnut	29.0-41.0	24
Soybean	12.0-41.6	63
Soybean cv Wayne	18.0-50.0	5
cv Chippewa	22.0-35.0	3
cv Hark	20.0-38.3	3
cv Lee	15.0-34.7	3

Data extracted from 23 publications, which involve a total of 113 species, genotypes, cultivars, and breeders' lines.

longer daylength received 30% more total short wave radiation (300–3000 nm) than the average of 11 and 12 hour regimes (15.60 and 11.95 MJ m^{-2}, respectively). Clearly, there is no photoperiodic effect, and differences in dry-matter production reflect those in light-energy receipt.

Others have studied photoperiodic effects on chickpea, either on plants grown in pots in poorly designed experiments in controlled environments or in natural daylengths, which are either shortened by screening plants for a number of hours in each diurnal cycle or extended with dim incandescent light. Incandescent lighting was used to extend a common photosynthetic period of 11 hour duration to 20 hours (Dart et al. 1976), and three varieties were tested. The plants grown in 11 hour daylengths produced many more branches but were only slightly (13.5%) heavier, nodulated better, and fixed between 24 and 27% more nitrogen than those grown in the 20 hour regime. The better branched plants had many more leaves, which probably supplied more photosynthate to the roots. Singh (1958) also recorded a decline in nodulation of chickpea plants in daylengths longer than 12 hours, which too was associated with a decrease in leaf number per plant. These data, coupled with those observations of van der Maesen (1972), which are consistent and can be interpreted logically, lend support to a hypothesis that photoperiod per se has little effect on vegetative attributes of chickpea, except where the duration of the vegetative period is drastically influenced by photoperiodic effects on flower initiation and development (see below). We caution against the sole use of incandescent lighting to provide contrasting photoperiods in controlled conditions, not only because of unwanted photomorphogenetic responses to light quality by the host plant but also because of the complex effects of red/far-red light on nodulation that are already known for other legumes, e.g., Lie (1971).

Chickpea is indeterminate and can continue vegetative growth into the reproductive period. Although relatively few cultivars have been studied in detail, those examined reveal marked differences in the rate of dry matter production and the relative distribution of dry-matter between vegetative and reproductive components, when grown at the same or in different locations. Such differences may well reflect appropriate adaptation to the environment experienced throughout crop duration. For example, Table 3 contrasts the average performance of each of four desi and kabuli types grown at Hyderabad (Fig. 7). Kabuli cultivars seem far better adapted to the environmental conditions that prevail during the early growing season: they first flower slightly later but by then they have produced more than double the dry weight (and presumably a correspondingly larger number of nodes) of desi cultivars. However, the earlier flowering desi types produce most of their vegetative dry matter (68%) after flowering, so that by final harvest (100 days

Table 3. Comparison of the production (g plant^{-1}) and distribution (%) of dry matter by four cultivars of each desi and kabuli types at Hyderabad.

Mean values of	Desi (D)	Kabuli (K)	Relative difference (%) between kabuli and desi (100 [K-D]/D)
Days from sowing to first flower	44.3	53.8	+21
Plant dry weight at first flower	1.46	3.15	+116
Total dry weight at harvest (100 days)	10.73	11.74	+9
Fruit dry weight at harvest	6.14	5.98	−3
Vegetative dry weight at harvest	4.59	5.76	+25
Proportion (%) of total dry weight produced by first flower	14	27	+93
Proportion (%) of vegetative dry weight produced by first flower	32	55	+72
Proportion (%) of dry weight produced after first flower in			
(a) Fruits	66	70	+6
(b) Vegatative	34	30	−12
Fruit weight ratio	0.57	0.51	−10

Calculated from Saxena and Sheldrake (1976).

from sowing) both types have similar biological and almost identical economic yields. Both types allocate remarkably similar proportions of their dry-matter accumulation after first flowering into fruits (about two thirds), but the improved dry-matter production of desi cultivars throughout the latter half of the growing season overcomes the early advantage of kabuli types. This trial (Saxena and Sheldrake 1976) was sown between November 6 and 12 and experienced average maximum and minimum air temperatures of 30 and 10°C, respectively, throughout the first 60–70 days. This combination of temperatures has already been shown not to favor vegetative growth of cv Chafa (a desi type) in Indian daylength conditions (Fig. 4).

A Comparison of the performance of short- and long-duration cultivars in different environments can provide information on the adaptability of these types to time and to the environmental conditions that prevail (Table 4). In both Hyderabad and Hissar, the onset of flowering in the long-duration cultivar (G-130) was delayed to the same relative extent (54–59%) as was the short-duration cultivar (JG-62), and this resulted in a dramatic, more than threefold, increase in dry-matter production. However, in the warmer environment at Hyderabad this represents almost all the vegetative dry matter produced by the crop (83%) and more than half (62%) of the total dry-matter production. At Hissar, these values correspond to less than half and less than 20%, respectively (Table 4). Even though the durations of the reproductive period and overall crop growth are significantly longer in G-130 than in JG-62 at Hyderabad, the long-duration cultivar produces slightly less total dry matter and only about one-third the fruit yield than the short-duration type does. Clearly, the long-duration cultivar is poorly adapted to the environmental conditions that prevail throughout the latter part of crop duration at Hyderabad.

In contrast, a delay in the onset of flowering between sites, again to the same relative degree in both cultivars (a delay of 33–37% at Hissar), reduces plant dry weight at this stage of development by an identical porportion (19%) in both cultivars. The duration of the reproductive period and overall crop growth (sowing to harvest) is drastically extended in the short- but not the long-duration cultivar when grown at Hissar, and by maturity, both cultivars have produced more or less the same total dry matter — about three times more than at Hyderabad (Table 4). Fruit yields are also similar but represent a six- and threefold increase in the

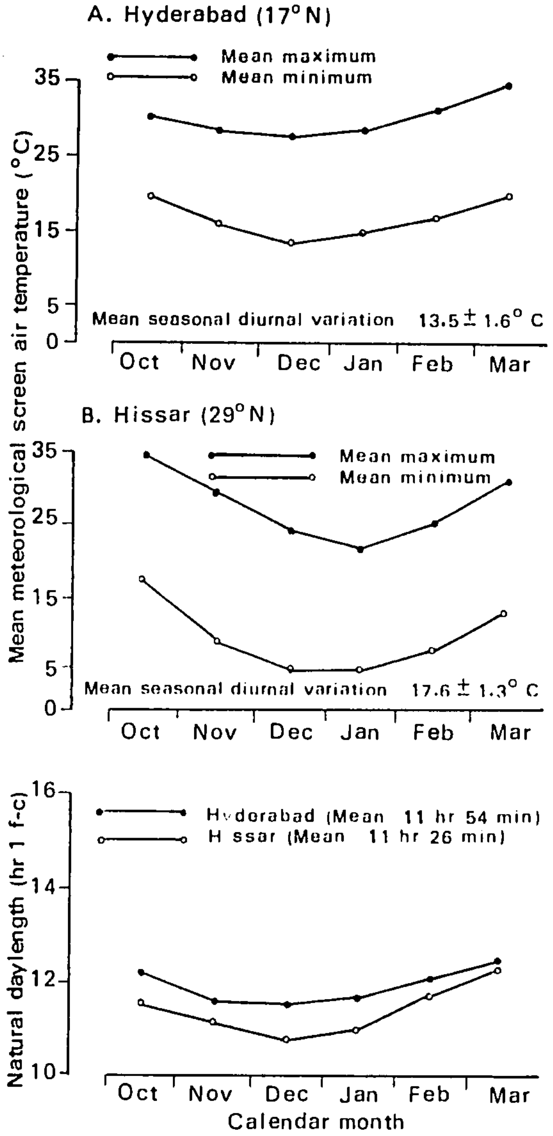


Figure 7. Mean monthly maximum and minimum meteorological screen air temperatures at Hyderabad (17°N) and Hissar (29°N), and mean monthly day length in both locations (hr ≥1 Ft–c) throughout the main chickpea-growing seasons.

long- and short-duration cultivars over their respective performances at Hyderabad. It seems likely that the cold nights at Hissar are suboptimal for vegetative growth of these two desi cultivars (Figs. 4, 7). Both cultivars had produced only a minor proportion of their vegetative (and total) dry matter by the onset of flowering at Hissar, but the later flowering of G-130 allowed four times greater dry-matter production (and presumably improved node production and nitrogen accretion) than did JG-62. At Hyderabad, the short-duration cultivar allocated about three times more dry matter into fruits than into vegetative components than did G-130, and this ratio was identical at Hissar (Table 4). Clearly, the short-duration cultivar is less well adapted to Hyderabad conditions during vegetative growth than is G-130 (at least with respect to dry-matter production), but early flowering, rapid maturation and a more efficient distribution of dry matter into fruits ensure far greater economic yields at harvest. The long-duration cultivar grows little after flowering, produces fruits when air temperatures are warming rapidly (see below), and has an abysmal harvest index. It is inappropriately adapted to both time and environment; the short-duration cultivar, while better adapted in time, is poorly adapted to the environment that prevails during early growth. At Hissar, adaptation in time is less critical, but both cultivars are poorly adapted to cold nights. It is pertinent to note the contrasting "strategies" of the short- and long-duration cultivars at Hissar: they have identical crop durations, which however, result from relatively long vegetative and short reproductive periods in G-130 and vice versa in JG-62; dry matter is produced mainly after the first flowering by JG-62, but a far larger proportion is generated during the vegetative period of G-130, which then allocates a larger proportion (of the relatively smaller amount) of dry matter produced after flowering into fruits than does JG-62 (Table 4).

Overall, these data pose the following questions that merit investigation: (1) what is the potential value of kabuli germplasm to the improvement of chickpea adaptability to cold nights?; (2) what is the potential for earlier sowing of long-duration cultivars in southerly locations?; (3) what is the potential value of long-duration germplasm to the improvement of vegetative growth rates of progeny material (dry-matter production being far greater than expected if time to flowering and dry weight at flowering were linearly related)?; (4) what is the potential value of short-duration parents to the improvement of harvest index of longer duration cultivars?

The translocation of photosynthates accumulated before flowering from vegetative organs to seeds is probably small in chickpeas (inferred from defoliation experiments); typical values in other grain legumes range from 8 to 15% (Summerfield and Wien 1979). On the other hand, the nitrogen nutrition of vegetative plants is often neglected even though the probability of adequate nitrogen accumulation before flowering is of critical importance to final seed yield.

Table 4. Comparison of the production (g plant^{-1}) and distribution (%) of dry matter by a short- (JG-62) and long-duration (G-130) desi cultivar at Hyderabad and at Hissar.

Mean values of	Cultivar (desi)	Hyderabad (A)	Hissar (B)	Relative difference (%) between sites (100[B-A]/A)
Days from sowing to first flower	JG62	46	63	+37
	G130	73	97	+33
Relative difference between cultivars*		+59	+54	
Plant dry weight at first flower	JG62	1.6	1.3	−19
	G130	5.3	4.3	−19
Relative difference		+231	+231	
Crop duration (days)	JG62	107	172	+61
	G130	150	172	+15
Relative difference		+40		
Duration reproductive period (days)	JG62	61	109	+79
	G130	77	75	−3
Relative difference		+26	−31	
Total dry weight at maturity	JG62	9.3	27.5	+196
	G130	8.5	22.9	+169
Relative difference		−9	−17	
Fruit dry weight at maturity	JG62	5.9	14.9	+152
	G130	2.1	12.3	+486
Relative difference		−64	−17	
Vegetative dry weight at maturity	JG62	3.4	12.6	+271
	G130	6.4	10.6	+65
Relative difference		+88	−16	
Proportion (%) of total dry weight produced by first flower	JG62	17	5	
	G130	62	19	
Proportion (%) of vegetative dry weight produced by firstflower	JG62	47	10	
	G130	83	41	
Proportion (%) of dry weight produced after first flower in				
a) Fruiting stage	JG62	77	57	
b) Vegetative stage		23	43	
a) Fruiting stage	G130	66	66	
b) Vegetative stage		34	34	
Fruit weight ratio	JG62	0.63	0.54	
	G130	0.24	0.54	

Calculated from Saxena and Sheldrake (1977).

* For all items, relative difference is 100(b-a)/a.

Indeed, large quantities of nitrogen are mobilized from vegetative organs as chickpea seeds fill (Table 5).

We urgently require more detailed quantitative data on environmental regimes that significantly influence the amount of nitrogen accumulated by different symbiotic associations before the onset of reproductive growth. It is surprising that the majority of studies on vegetative growth in chickpea have concentrated exclusively on carbon metabolism and that only in a small minority of investigations has attention been focused on the formation of potential reproductive sites or on nitrogen nutrition. Clearly, such studies should receive research priority. An example of symbiotic response to environment is shown by some preliminary data in Figure 8.

For symbiotic associations which involve *Rhizobium* strain CC 1192, there are marked differences in average symbiotic performance with different hosts and subtle differences in response to environmental factors. The most obvious, consistent, and dramatic effect on symbiotic N_2 fixation, however, is the adverse consequences of warm (30°C) days (Dart et al. 1976). These symbiotic combinations are ill adapted to warm days and cool nights (30–10°C) and to the warmest diurnal regime (30–18°C) — conditions that prevail at the beginning and end of crop duration in many Indian locations (e.g. see Fig. 7). The optimum environment for fixation (22–18°C) was also optimal for vegetative growth (Figs. 4, 5), but the temporal relationships between improved growth and more rapid fixation have yet to be resolved. For the two desi cultivars, the longer the daylength, the more adverse are warm days; however, it may be significant that, although symbiotically inferior, the kabuli cultivar Rabat (strain CC 1192 association) shows identical absolute responses in long (15 hour) and short (11–12 hour) days (Fig. 8). These preliminary data indicate the magnitude of the effects of environmental factors on symbiotic potential and demonstrate to the plant breeder that not only does the host genotype contribute to symbiotic performance but also responses to environmental factors differ between symbiotic partnerships. Attempts should be made to select not only the host but also the *Rhizobium* genotypes, and the agronomic management of breeders' plots will require careful regulation.

Table 5. Sources of N to seeds in chickpea. (All values expressed as a percentage of total seed N content at harvest.)

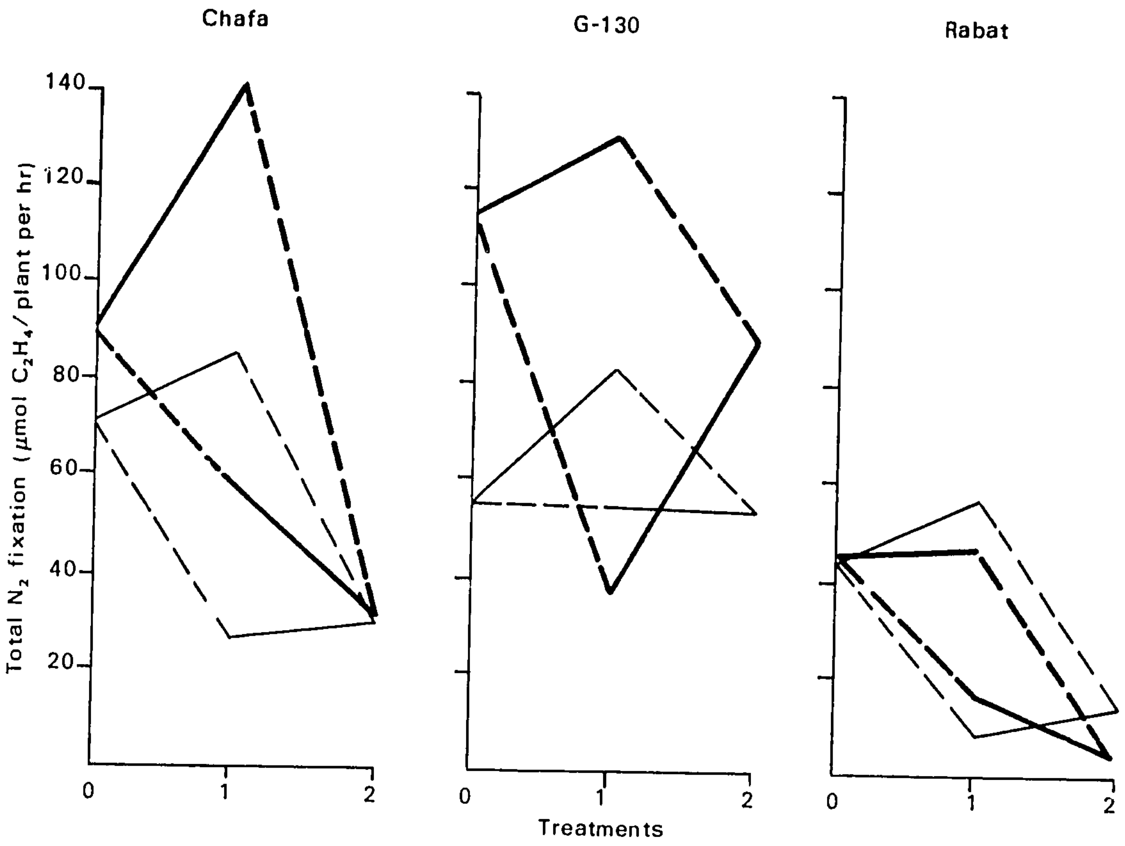
Source	Contribution to seed N
Mobilization from:	
Leaves + petioles	31.8
Main stem + lateral axes	8.0
Root + nodules	3.0
Pod walls	ND[a]
Total	42.8
Assimilation of N_2 and/or NO_3 uptake during seed fill	57.2

Calculated from Saxena and Sheldrake (1977).

a. Not determined.

Clearly, the rates at which nodes, leaf initials, and branches are differentiated and expand, the pattern of branching, and the height of plants depend on temperature, but, unless there is a marked effect on the duration of vegetative growth, differences in photoperiod seem generally less important. Leaf area per plant, or per unit area (leaf area index), however, depends not only on the rate of leaf growth but also on the rate of leaf death, about which little is known in chickpea. The rate of foliar senescence will change during the ontogeny of the crop, and the effects of temperature (frequently progressively warmer in many natural growing conditions) are likely to become more acute as individual leaves age. Furthermore, the rate of senescence will certainly depend on the number and size of the fruits, and the rate at which they grow, and on nitrogen nutrition both before and after flowering begins. We should not pretend to have more than a cursory knowledge of these relationships in chickpea.

Only in a few studies have the separate effects of day and night temperature been investigated. Already, we find that night rather than day temperature determines the vegetative dry-matter production of cultivars examined in factorial experiments. In other legumes, cool nights can limit water uptake but they may favor root rather than shoot growth, and they may lessen dark respiration of whole plants and so promote vegetative growth. Alternatively, with warmer temperature ranges than those investi-



0 = Cool days and nights; 1 = cool days/warm nights or warm nights/cool days; 2 = warm days and nights; ——— = increase in night temperature (10-18° C); — — — = increase in day temperature (22-30° C).

Figure 8. Richards' diagrams (1941) illustrating the effects of day and night temperature and day length on total plant nitrogenase activity of 45-day old chickpea cultivars grown in controlled-environment growth cabinets. Mean values of three replicates. Day lengths are differentiated by relatively thick (15 hr) or thin (11-12 hr) solid lines and dashes.

gated with chickpea, leaf expansion, branching, and the accumulation of vegetative dry matter in cowpea and soybean are promoted in warm nights (24° compared with 19°C) but are little affected by day temperature (33° and 27°C). Then again, more nodules may be formed in warm nights and they may also fix nitrogen more rapidly than in cool nights (Summerfield and Wien 1979). Clearly, we are far from being able to classify chickpea genotypes as to their adaptability to relatively warmer or cooler conditons: field observations at this time can offer no more than tentative proposals.

Reproductive Development

Our current approach to and comprehension of environmental adaptation in all grain legumes has been largely influenced by the discovery, more than 50 years ago, that photoperiod markedly affects the induction of flowering in soybean. The effects of other environmental factors, and especially of their interactions with photoperiod, on reproductive development have been seriously neglected even though it was observed 40 years ago that cool temperatures, particularly at night, can modify the response of soybean to inductive photoperiods (Steinberg and Garner 1936). Chickpea provides the classic example of the myopic preoccupation with photoperiodic effects on reproductive development.

Juvenility and Vernalization

A pronounced juvenile phase, during which plants are insensitive to normally inductive conditions, has not been reported in chickpea. Cultivars responsive to cool temperature vernalization are known but, in general, only relatively small positive and negative effects have been reported, as we discussed earlier in this review.

Floral Initiation and Flower Development

Air temperature and photoperiod and their interaction markedly affect the time of initiation of flower buds in legumes and their subsequent expansion into open flowers. In contrast to many nonleguminous species, where the initiation of flowers is the reproductive stage most sensitive to environmental regulation, in legumes the expansion of flower initials seems equally, if not more sensitive to external control. It is very difficult to generalize from published data because so few experiments on the effects of these environmental factors have been designed factorially or have continued through successive periods of reproductive development.

Chickpea has been variously described as a long-day plant (Pal and Murty 1941; Singh 1958; Nanda and Chinoy 1960a, 1960b; Moursi and Gawad 1963; Eshel 1968; Mathon 1969; Pandey et al. 1977), quantitative long-day plants (Sandhu and Hodges 1971; van der Maesen 1972), day-neutral plants (Allard and Zaumeyer 1944; Mateo Box 1961), and in one case, as short-day plants (Bhardwaj 1955). Evidence has been summarized as showing "chickpeas are only moderately sensitive to photoperiod" (van der Maesen 1972) whereas others have described cultivars of this species that "display tremendous variation in photoperiodical response" (Ladizinski and Adler 1975). Several workers report that long days suppress branching but increase dry-matter production, while others report that early flowering leads to small yields. Cultivars may flower earlier in warm days, in warm nights, with warmer average temperatures, or with warmer constant temperatures; but they can also flower later with warmer average or constant temperatures (Summerfield and Wien 1979).

Collectively, these conflicting data provide little information to enable the prediction of cultivar responses in the field, to identify potentially broad or narrow adaptation to climate, or to arrange that the durations of vegetative and reproductive growth coincide with the most efficient utilization of the available growing season.

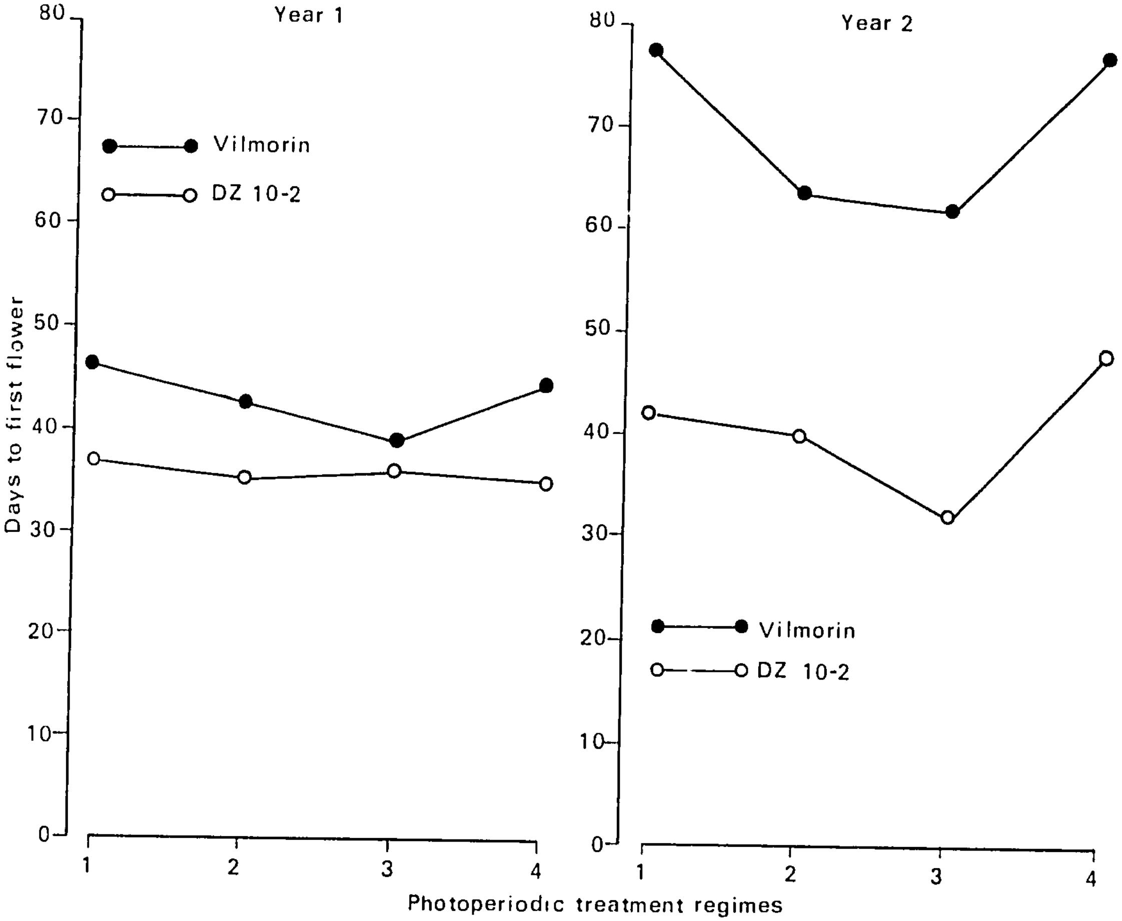
We have discussed earlier some of the reasons why this unsatisfactory situation has arisen, but a number of other reasons need to be borne in mind in the future. For instance, there are likely to be important differences among chickpea cultivars with respect to:

1. The optimum photoperiod (that at which the course of events at a particular stage of reproductive ontogeny is most rapid);
2. Photoperiod sensitivity (the delay in a particular developmental sequence per unit change of photoperiod);
3. The critical photoperiod (that above or below which a given developmental sequence is arrested);
4. Separate effects of day and night temperature on successive stages of development; and
5. Temperature effects on (1), (2), and (3) above.

Furthermore, from experience gained from other legumes, we should now attempt to quantify for chickpea:

1. Whether cool temperatures, particularly at night, can substitute for longer photoperiods;
2. The effects of temperature on the shape of daylength response surfaces;
3. Whether genetic indifference (neutrality) to daylength with respect to the onset of flowering is available:
4. Whether daylength requirements become progressively more stringent after flower initiation; and
5. The separate temperature effects on successive stages of reproductive ontogeny.

To illustrate the care that is needed if controlled environment studies are to be used effectively to resolve some of these problems, we have replotted some data from van der Maesen (1972), which indicate that large differences between occasions may occur when the environment is not closely controlled. Four photoperiodic regimes (simulated sowing dates) were imposed in each of 2 years in a glasshouse in which air temperature was not closely controlled. Although the differences were not discussed, the two cultivars tested responded markedly differently in each year (Fig. 9). From our results in controlled environments it is clear that both day and night temperature and photoperiod can have large effects on chickpea behavior such that, as Table 6 shows, a cultivar classified as early flowering is not necessarily destined to mature early and to enjoy only a short reproductive period. Conversely, cultivars taking twice as long to come into flower can have shorter reproductive periods and so come to maturity in more or less the same time, depending upon environmental conditions. The shorter the daylength and the cooler the air



	Year 1		Year 2	
	Mean	Range	Mean	Range
Vilmorin	43	39-46	70	62-77
DZ 10-2	36	35-37	41	32-48

Figure 9. The large differences in two consecutive years in days to the appearance of first perfect flowers that were obtained in identical photoperiodic regimes in glasshouse experiments. These differences were probably the result of poor temperature control (replotted from van der Maesen 1972).

Table 6. Range of durations (days) of vegetative growth (sowing to the appearance of first perfect flower), reproductive period (first perfect flower to final harvest), and crop duration (sowing to final harvest) of chickpea cultivars classified according to their relative maturity in the field at Hyderabad.

	Cultivar		
Attribute	Chafa (early-maturing)	Rabat (medium)	G-130 (late-maturing)
Duration of vegetative growth	26–48	46–81	42–89
Duration of reproductive period	67–130	49–111	46–95
Crop duration	98–181	113–181	99–181

Data from controlled environment studies of Summerfield et al. (1979a).

temperature (over the range tested; see text), the more protracted and equable are the overall crop durations. Conversely, in longer days and in warm temperatures, all plants mature equally rapidly (98–113 days from sowing), but the earliest flowering cv Chafa had by then enjoyed a reproductive period far longer than did cvs Rabat and G-130 (67 and 46-49 days, respectively).

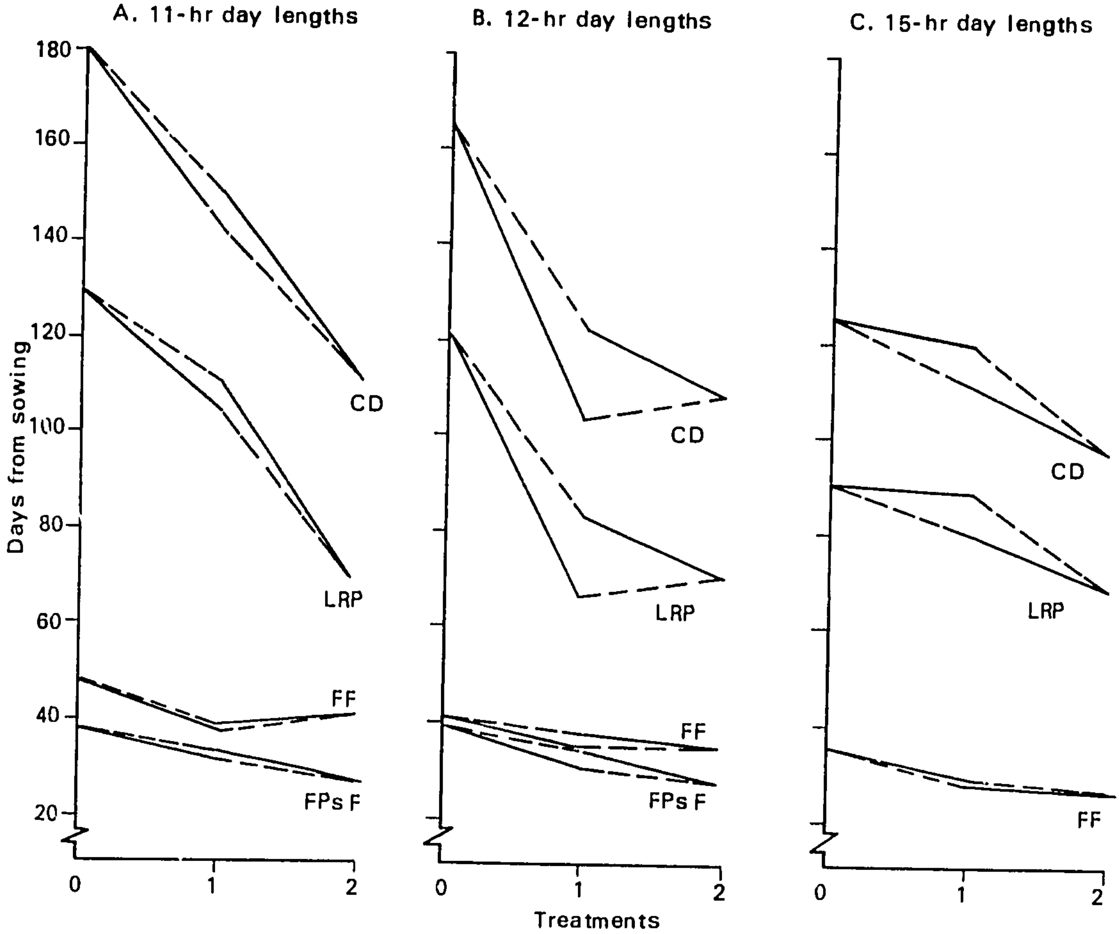
Although photoperiod has a major effect on the duration of vegetative growth (defined here as "the period from sowing to the appearance of the first perfect flower with clearly visible corolla coloration"), plants can be induced to flower after exactly the same time in different photoperiods by changes in air temperature (e.g., for cv Chafa, see Fig. 10). Pseudoflowers (Aziz et al. 1960) appeared first and were produced for the longest period in less inductive conditions (for 9 and 4 days in 11 and 12 hour daylengths, respectively). None were recorded in the 15 hour daylength. In any given temperature regime, Chafa plants produced their first perfect flowers progressively earlier as daylengths increased from 11 to 15 hours.

Warmer day and/or night temperatures also promoted earlier flowering; hence, the earliest plants to flower were those grown under 15 hour, 30° to 18°C conditions (26.5 days) and the latest ones were grown under 11 hour 22° to 10°C conditions (48.0 days). Short days contributed about one-half to this delay (12 days), and cooler day and night temperatures each delayed flowering by an average of 3 to 4 days (Fig. 10). Clearly, the opposing effects of longer days, which hasten flowering, and of cooler temperatures, which delay it, can exactly offset each other!

Longer days and warmer temperatures also reduced the length of the reproductive period, and hence overall crop duration, especially in suboptimal photoperiods.

Of the 12 treatment combinations tested, the 12 hour, 30° to 18°C regime most closely approximates the average of seasonal changes in the climatic factors at Hyderabad (Fig. 7A). Indeed, the durations recorded for cv Chafa in controlled environments (Fig. 10) and those reported from the field studies of Saxena and Sheldrake (1977) are remarkably similar (Table 7). Plants of the long-duration cultivar G-130 also had cropping "timetables" very similar to those recorded in the field.

Seasonal profiles of the activity of nodules in fixing nitrogen suggest that "flowering" is a critical period for the symbiotic system. In several legume species, symbiotic nitrogen-fixing activity reaches a peak toward the end of vegetative growth, and then it declines very sharply sometime during the flowering period. In some chickpeas, bacteroids degenerate, and leghaemoglobin content declines after flowering (Chopra and Subba Rao 1967), whereas in other cultivars, the onset of flowering has no immediate effect on symbiotic performance (Fig. 13, Dart et al. 1976). There are also marked variations in other grain legumes in the effects of flowering on nodule functioning and longevity of bacteroid tissue (e.g., for soybean, compare Brun 1976 with Hardy et al. 1971). We know of few data (Dart 1973; Dart et al. 1976) from studies designed to evaluate the effects of



0=Cool days and nights; 1= cool days/warm nights or warm nights/cool days; 2=warm days and nights; ——— =increase in night temperature (10-18°C); - - - - - =increase in day temperature (22-30°C).

Figure 10. Effects of photoperiod and day and night temperatures on the time from sowing (days) to the appearance of first pseudoflowers (FPsF), first perfect flower (FF), length of reproductive period (LRP), and crop duration (CD) for chickpea cv Chafa grown in controlled-environment growth cabinets. (See Summerfield et al. 1979a.)

daylength and temperature on the consequences of flowering for symbiotic nitrogen fixation. However, the potential importance of these environmental factors has been demonstrated in other legumes (e.g., Summerfield et al. 1978), and diurnal variations in fixation activity are known to be markedly affected by air temperature, with complex interactions between solar radiation, atmospheric humidity, and the water status of host plants.

Anthesis and Seed Set

Economically important grain legumes are predominantly self-pollinated; perhaps obligatorily so in chickpea since pollination is effected at the hooded-bud stage (van der Maesen 1972). Chickpea seems atypical among the grain legumes in that some cultivars produce abnormal, poorly developed flowers that become yellow and desiccate without opening, that is, pseudoflowers (Aziz et al. 1960). They are

Table 7. Duration (days) of vegetative growth (sowing to the appearance of first perfect flower), reproductive period (first perfect flower to final harvest), and crop longevity (sowing to final harvest) for selected chickpea cultivars in the field and in growth cabinets.

Cultivar/location	Vegetative period	Reproductive period	Crop duration
Chafa at Hyderabad[a]	36	71	107
Chafa in 12 hour, 30-18°C controlled environment	35	71	108
G-130 at Hyderabad[a]	73	77	150
G-130 in 12 hour, 30-18°C controlled environment	73	61	134
G-130 at Hissar	97	75	172
G-130 in 11 hour, 30-10°C or 22-10°C controlled environment	89	91	180

[a] Data from Saxena and Sheldrake (1977).

produced before perfect flowers; but the time from sowing to their appearance, and the duration for which they are produced, depends not only on the cultivar but also on the air temperature and the daylength (e.g., Fig. 10). Whether this floral abnormality is a form of cleistogamy or partial sterility is a topic for debate. Floral biology and phenology have been reviewed for chickpea (Meimandi-Nejad 1977); seed set is reduced in poor light intensities (Howard et al. 1915; Aziz et al. 1960), but contrary to popular belief, seems little affected by atmospheric humidity (van der Maesen 1972). Pollen is equally viable at 20° and 30°C but germinates and produces longer pollen tubes more rapidly in the warmer regime (van der Maesen 1972). It is not uncommon for between 55 and 95% of flowers and immature chickpea pods to abort. The extent of flowering and seed set varies not only within inflorescences but also between the nodes on a parent plant: flowers produced early in reproductive development are more likely to produce pods (containing more and individually heavier seeds) than those produced later (Saxena and Sheldrake 1975). The sequestering of a large proportion of available assimilates from mother plants and an increased production of endogenous hormones (e.g., ABA) by flowers or fruits, which promotes the abortion of distal reproductive structures, have both been implicated as the main causes of premature abscission. However, Sinha (1977) lists 8 possible factors and their numerous combinations which could be significant and the role of ABA as a primary controlling factor of flower abscission (in lupin) has been questioned (Porter 1977). Genotypes of most species examined in detail differ markedly in their ability to retain flowers and young pods, and chickpea genotypes should be screened in these respects also.

We obviously require detailed studies of both the effects of climate on flower and podsetting in chickpea and the mechanisms involved before the major limitations to reproductive efficacy, and their major effects on yield, can be alleviated.

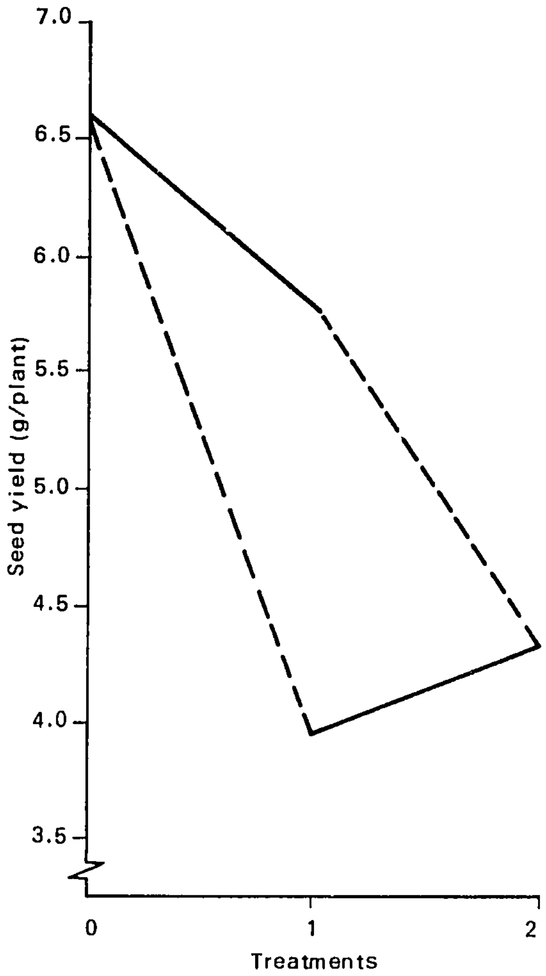
Fruit Development

Embryogenesis has been studied in relatively few grain legumes, the seeds of which commonly attain their maximum dry weight between 30 and 70 days after anthesis (e.g., *Phaseolus vulgaris*, *Pisum sativum* and *P. arvense*, *Glycine max*, and *Vicia faba*). The developmental pattern of seed formation is so similar among these species that it is possible to generalize about many major events. For example, final cell number in the embryo is attained early in its ontogeny, the subsequent increase in embryo weight being the result of cell expansion and the concomitant synthesis and deposition of starch and thereafter, storage proteins Furthermore, in each of these species, the seeds derive a large proportion of their carbon from photosynthesis by foliar organs at the parent node (Dure 1975; Summerfield and Wien 1979). Furthermore, provided that certain conditions are satisfied (Gallagher et al. 1976), as they are for those legumes which have been studied in detail (Dure 1975), mean maximum seed weight can be equated to the product of mean growth rate per seed during the linear phase of growth and the duration of this phase. From the limited data available (Sinha 1977), we can postulate that chickpea too will show similarities with those species mentioned above: the fruit wall grows to a large extent before seed development proceeds. A lag period that lasts about 15 days after anthesis is followed by a linear period of growth of about 20 days duration, during which the individual seeds accumulate the vast proportion of their dry matter. Indeed, maximum seed growth rates for chickpeas are among the fastest recorded for grain legumes (Table 3, in Summerfield and Wien 1979). However, in contrast with the species mentioned above, chickpea seeds seem to sequester assimilates effectively from nodes within a branch (whether reproductive or vegetative nodes), and pods at nodes with leaves have no preferential advantage to those at nodes without leaves. On the other hand translocation of assimilates between branches seems less effective (Saxena and Sheldrake 1976). Moreover, we know little for chickpea of the effects of environmental factors on the rate or duration of seed fill; when, during fruit ontogeny, seed number is determined; at which loci within fruits and at what age abortion is most prevalent; or the consequences of maturation environment on the biochemical composition of ripe seeds.

Although the ontogeny of field crops was predicted with remarkable accuracy from controlled environment experiments (Table 7), the seed yields of both cv Chafa and G-130 were increased in warm days typical of average seasonal values at Hyderabad (30°C) as compared with cool (22°C) days. These responses do not reflect agronomic reality at this site (cf. Table 4). Indeed, the late-muturing G-130 responded particularly favorably, and yields were increased by 183% (from 9.2 grams plant^{-1} at 22°C to 26 grams at 30°C): yields of cv Chafa increased by 86% (from 7.2 to 11.4 grams). However, day temperatures after about 90 days from sowing average about 35°C at Hyderabad and may have important effects on the realization of yield potential, especially in long-duration cultivars.

In order to investigate whether or not chickpea is affected by heat stress when vapor pressure deficit — a better indication of the drying power of the air than relative humidity (Hughes 1962) — and soil-water status are maintained at values equivalent to those at cooler temperatures (i.e., in the absence of water stress), we have screened 15 cultivars of contrasting crop durations in controlled environment glasshouses. Plants were grown in factorial combinations of two daylengths (11 and 12 hours of natural light), warm and cool nights (18° and 10°C), and warm and hot days (30°C throughout or 30°C for the first 90 days and 35°C thereafter). These data are reported fully elsewhere (Summerfield et al., in press). The average yield of all cultivars in all eight environments (the population mean) was 5.2 grams seed plant^{-1}, and the environments can be ranked according to their suitability for expression of yield potential in chickpea on the basis of average yield of all genotypes in each situation (Fig. 11). Differences in daylength and night temperature had little effect on the average yield of all cultivars, but hot days (35°C after 90 days) were deleterious and reduced average yields by 33% (Fig. 11). Clearly, plants that experience diurnal variations of either hot days (35°C) and cool nights (10°C) or hot days and warm nights (35–18°C) during reproductive development produce only small yields. However, not all cultivars respond in a similar manner, and it is possible to classify cultivars according to whether they yielded greater or less than the average in each environment.

The scatter diagrams presented in Figures 12 and 13 show the relationships between seed yield of individual cultivars to each combination of day and night temperature and each photoperiod, and the mean responses over the range of conditions tested of both the individual cultivar and the population of cultivars from which it was drawn. Thus, it is possible to deduce for each cultivar: first, its relative stability (or variability) in yield over a wide range of temperature conditions; and second, in the case of a variable response, to which temperature condition it is best suited (Finlay and Wilkinson 1973). Although there are some statistical disadvan-



0 = Cool days and nights; 1 = cool days/warm nights or warm nights/cool days; 2 = warm days and nights; ——— = increase in night temperature (10-18° C); – – – = increase in day temperature (30-35° C).

Figure 11. Richards' diagram (1941) showing the effect of day and night temperatures on average seed yield of 15 chickpea cultivars grown in day lengths characteristic of Indian growing seasons (11-12 hr). (See Summerfield et al. 1979b.)

tages in this approach (Freeman 1973), the method produces simple visual displays which, if they are interpreted with care, provide the best preliminary comparison of the data.

The difference in response of any pair of genotypes to a given change in environment measures GE, the genotype × environment interaction (Figs. 12, 13). The sum of the responses measures E, the overall effect of environment as revealed by the genotypes as a group (Fig. 11). Since GE depends on differences in response, it must reflect the properties of only those genes by which the genotypes differ. On the other hand, E, the summed response of genotypes as a group, reflects not only those genes by which the genotypes differ but also other genes that affect response to environment but which are alike in many, if not all, genotypes.

The long-duration cultivar G-130 yields best when day temperature is maintained at 30°C throughout growth, but it is poorly adapted to hot days during the reproductive period (Fig. 12A). The short-duration cultivar Annigeri has a similar response, but, by maturing most of its pods before the days become really hot, it produces larger-than-average yields by escaping the potentially adverse conditions (Fig. 12B). Cultivars L-550, Rabat, and RS-11 show very similar responses to G-130, whereas cvs 850-3/27 and P 222-1 are very similar to Annigeri. Other short- and intermediate-duration cultivars are less responsive to more ideal environments but more tolerant of adverse climates (Fig. 13, and see the response of cv Chafa in Table 4). Although these two examples produce average yields slightly less than the population mean, others (e.g., C-235) have similar trends but produce above-average yields. These responses support the general principle that early-maturing genotypes are least susceptible to environmental influence (Murfet 1977). Of course, these cultivars are selected from a very small number of the total chickpea germplasm now available and represent data from just one trial. However, they demonstrate to the chickpea breeder some of the responses of his material which may influence his selection of parents in seeking progeny adapted to given environmental situations.

Prospect for the Future

Although economic yields in chickpea are poor in farmer's plots, and vary widely between sites

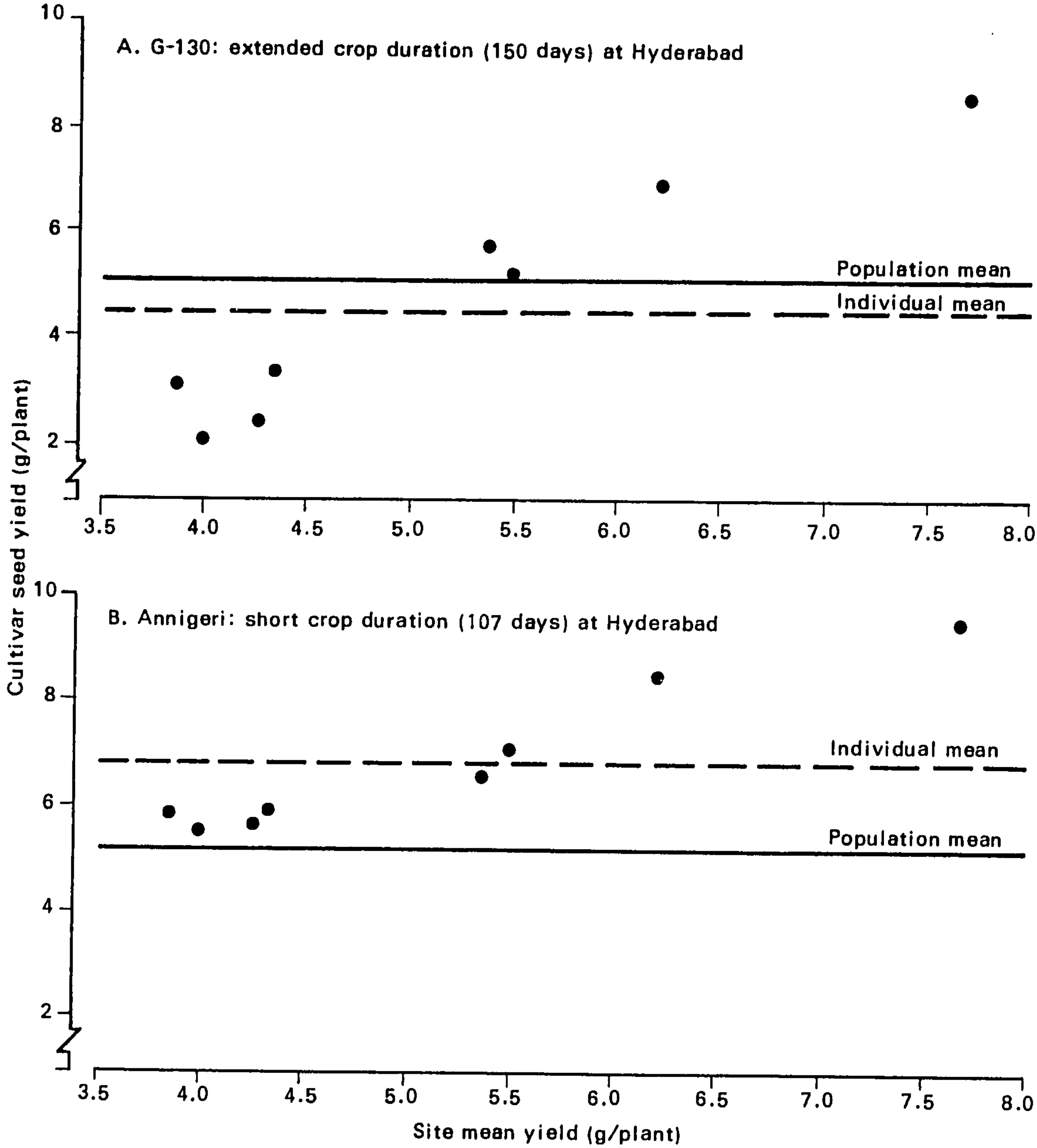


Figure 12. Scatter diagrams illustrating the yield of a long-duration and a short-duration chickpea cultivar in a range of aerial environments; average of 15 cultivars (Summerfield et al. 1979b.)

and seasons, the plants grown are usually of primitive land races selected (probably unconsciously) for performance in conditions of agronomic neglect and environmental stress. Only recently have extensive germplasm resources become available, and multiple selection criteria have been applied to progeny material. Without doubt, seed yields in this legume are largely dependent on pod and seed number per unit area and, as we have argued before (Summerfield et al. 1978), multiple components, whether morphological, physiologi-

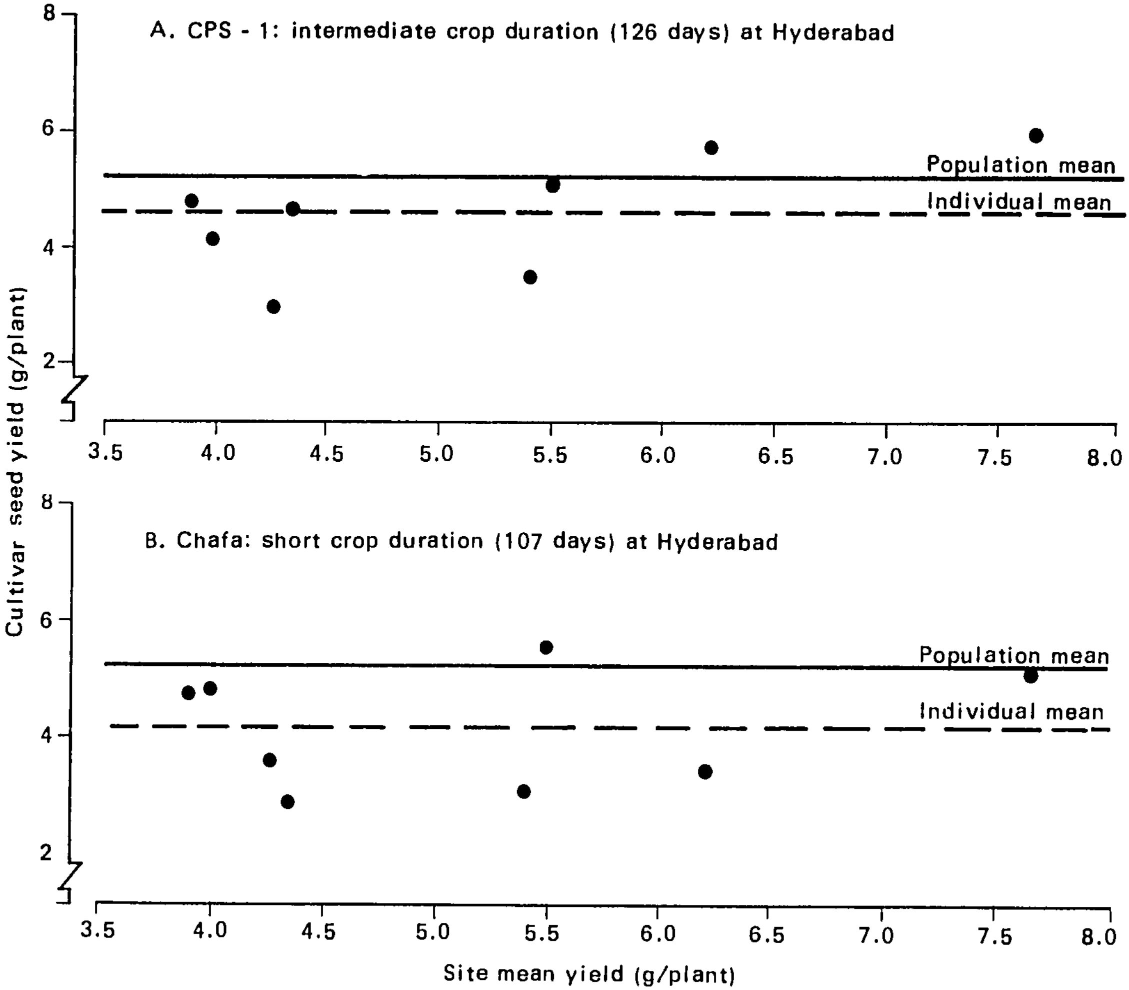


Figure 13. Same as for Figure 12 for an intermediate and a short-duration chickpea cultivar. Note that both of these examples are less responsive to favorable environments but are more stable in adverse climates.

cal, or temporal, contribute to variations in yield. Certainly, chickpea is capable of large yields; 4800 kg/ha is a commonly quoted maximum value, which was produced at Karaj in Iran (36°N, 1220 m; RPIP 1968) in conditions drastically different from those in India and Pakistan (Sinha 1977).

Adaptation in chickpea will, of course, involve appropriate resistance to disease and insect pests (particularly to wilt and *Heliothis*, respectively). Then again, water stress is undoubtedly a significant selection force and will be affected by air temperature and vapor pressure deficit. However, there is little evidence that it has any direct regulatory effect on flower initiation (Murfet 1975), although flower abscission seems especially sensitive to water stress — a pertinent example of the response of yield components to a stress factor (adaptability).

Plant breeders have usually selected for adaptation to particular sites, chosen to represent particular regions, rather than to specific combinations of temperature and photoperiod. This traditional approach requires that selections be grown and tested for a number of seasons at a particular site (to take account of climatic variations between seasons) and, ideally, also at a number of other sites. However, both researchers in the field and those employing controlled environments must become more aware of the critical aspects of the climates to which chickpea crops must adapt if breeders are to be provided with more critical selection criteria and so ensure that the reproductive behavior of improved genotypes is appropriately adapted to the environments for which they are intended.

Up to now, research on chickpea has concentrated on dry-matter production and has neglected morphology and phenology; researchers have also looked into carbon metabolism but have neglected nitrogen nutrition. In addition, there has been much research on environmental regimes that bear little relevance to the seasonal changes and complex interactions between factors, which are so characteristic of natural situations. Where a species such as chickpea has colonized a range of habitats, we might expect to find a range of genetic adaptations to those environments. However, these adaptive responses have yet to be quantified in chickpea, let alone exploited by breeders. We should seek to explain how environmental variations in time affect physiological and morphological processes — and hence, growth, development, and yield — rather than merely to describe the outcome by statistical procedures such as correlation or curve-fitting (Bunting 1975).

References

Allard, H. A., and Zaumeyer, W. J. 1944. Response of beans (*Phaseolus*) and other legumes to length of day. United States Department of Agriculture (USDA), Technical Bulletin 867. 24 pp.

Anon. 1968. Page 6 *in* United States Regional Pulse Improvement Project Progress Report (Iran and India). USDA-USAID, Washington, USA. 232 pp.

Auckland, A. K., and Singh, K. B. 1976. Chickpea breeding. *In* ICRISAT Annual Report, 1975-1976. ICRISAT, Hyderabad, India. 18 pp.

Aziz, M. A., Khan, M. A., and Shah, S. 1960. Causes of low seed setting in gram (*C. arietinum*). Agriculture Pakistan 11: 37-48.

Bhardwaj, S. N. 1955. Effect of long and short photoperiods on incidence of flowering in wheat and gram. Page 256 *In* Proceedings of the Indian Scientific Congress 42.

Brun, W. A. 1976. The relation of N_2 fixation to photosynthesis. Pages 135-143 *in* World Soybean Research, L. D. Hill, ed. Interstate Press, Illinois, USA.

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

Chakravorti, S. C. 1953. Anatomical studies in relation to vernalization. Indian Journal of Agricultural Science 23: 289-300.

Chakravorti, S. C. 1964. Vernalization and growth. Indian Agriculture 8: 68-70.

Chopra, C. L. and Subba Rao, N. S. 1967. Mutual relationships among bacteroid, leghaemoglobin and N content of Egyptian clover and gram. Archives Mikrobiologie 58: 71-76.

Corbin, E. J. 1976. Present status of chickpea research in Australia. Pages 87-94 in Proceedings of the International Workshop on Grain Legumes, ICRISAT, Hyderabad, India.

Corbin, E. J., Brockwell, J., and Gault, R. R. 1977. Nodulation studies on chickpea (*Cicer arietinum*). Australian Journal of Experimental Agriculture and Animal Husbandry 17: 126-134.

Dart, P. J. 1973. Root nodule symbiosis and tropical grain legume production. Pages 185-197 *in* Proceedings of the first IITA Grain Legume Improvement Workshop, IITA, Ibadan, Nigeria.

Dart, P. J., Islam, R., and Eaglesham, A. R. J. 1976. The root nodule symbiosis of chickpea and pigeonpea. Pages 63-83 *in* Proceedings of the International Workshop on Grain Legumes, ICRISAT, Hyderabad, India.

Dure, L. S. 1975. Seed formation. Annual Review of Plant Physiology 26: 259-278.

Eshel, Y. 1968. Flower development and pollen viability of chickpea (*Cicer arietinum* L.). Israel Journal of Agricultural Research 18: 31-33.

Evans, L. T. 1975. The physiological basis of crop yield. Pages 327-355 *in* Crop Physiology: some case histories, L. T. Evans, ed. Cambridge University Press, London and New York.

Evans, L. T., and King, R. W. 1975. Report on the TAC working group on the biology and yield of grain legumes. Publication number DDDR: IAR/75/2, Food and Agriculture Organisation of the United Nations, Rome.

FAO (Food and Agriculture Organisation of the United Nations). 1959. Pages 78–87 *in* Tabulated information on tropical and sub-tropical grain legumes. Food and Agriculture Organisation of the United Nations, Rome.

FINLAY, K. W., and WILKINSON, G. N. 1963. The analysis of adaptation in a plant breeding programme. Australian Journal of Agricultural Research 17: 269–280.

FRANCIS, C. A. 1972. Natural daylengths for photoperiod .sensitive plants. Centro Internacional de Agricultura Tropical (CIAT), Technical Bulletin 2. 32 pp.

FREEMAN, G. H. 1973. Statistical methods for the analysis of genotype-environment interactions. Heredity 31: 339–354.

GALLAGHER, J. E., BISCOE, P. V., and SCOTT, R. K. 1976. Barley and its environment. VI. Growth and development in relation to yield. Journal of Applied Ecology 13: 563–583.

GUPTA, S. P., LUTHRA, R. C., GILL, A. S., and PHUL, P. S. 1972. Variability and correlation studies on yield and its components in gram. Journal of Research of the Punjab Agricultural University 9: 405–409.

HARDY, R. W. F., BURNS, R. C., HEBERT, R. R., HOLSTEN, R. D., and JACKSON, E. 1971. Biological nitrogen fixation: a key to world protein. Pages 561–590 *in* Biological Nitrogen Fixation in Natural and Agricultural Habitats, T. A. Lie and E. G. Mulder, ed. Plant and Soil, Special Volume.

HOWARD, A., HOWARD, G. L. C., and KHAN, A. R. 1915. Some varieties of Indian gram (*Cicer arietinum* L.). Memoirs of the Department of Agriculture in India. Botanical Series 7: 213–235.

HUGHES, A. P. 1962. The interpretation of thermohygographs. Journal of the Australian Institute of Agricultural Science 28: 52–55.

HUGON, E. 1967. Observations on branching and inhibitory correlations between buds in chickpeas, *Cicer arietinum* (In French). Revue Générale de Botanique 74: 251–272.

ISTA (International Seed Testing Association). 1966. Page 57 *in* International rules for seed testing. Proceedings of the International Seed Testing Association 31.

IVANOV, N. N. 1933. The causes of chemical variability in the seeds of chickpea in different geographical areas (in Russian). Trudў po Prikladnoi Botanike, Genetike i Selektsii 3: 3–11.

KAR, B. K. 1940. Vernalization. Current Science 9: 233–234.

KOINOV, G. 1968. Optimum sowing rates for chickpea (In Bulgarian). Nauchni Trudone. Vissh Selskostopanski Institute Vasil Kolarov 17: 65–69.

KUMARI, P. S., and SINHA, S. K. 1972. Variation in chlorophylls and photosynthetic rate in cultivars of Bengal gram (*Cicer arietinum* L.). Photosynthetica 6: 189–194.

LADIZINSKI, G., and ADLER, A. 1976. The origin of chickpea *Cicer arietinum* L. Euphytica 35: 211–217.

LIE, T. A. 1971. Symbiotic nitrogen fixation under stress conditions. Pages 117–128 *in* Biological Nitrogen Fixation in Natural and Agricultural Habitats, T. A. Lie and E. G. Mulder, ed. Plant and Soil (Special Volume).

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 Landbouwhogeschool Wageningen. 342 pp.

MALHOTRA, R. S., and SINGH, K. B. 1973. Genetic variability and genotype-environment interaction in Bengal gram. Indian Journal of Agricultural Science 43: 914–917.

MATEO BOX, J. M. 1961. Pages 69–84 *in* Leguminosus del Grano, I. Era, ed. Barcelona, Salvat.

MATHON, C. C. 1969. Photoperiodic reactions and sensitivity to vernalization in four hundred species of Spermatophyta: eight years of research into the ecological analysis of development (In French). Bulletin de la Société Botanique de France 116: 311–321.

MEIMARDI-NEJAD, M. J. 1977. Crop Botany. Pages 27–62 *in* Food Legume Crops: Improvement and Production. E. S. Bunting, ed. Food and Agriculture Organization of the United Nations, Plant Production and Protection Paper Number 9, FAO, Rome.

MONTEITH, J. L. 1972. Solar radiation and productivity in tropical ecosystems. Journal of Applied Ecology 9: 747–766.

Monteith, J. L. 1977. Climate and the efficiency of crop production in Britain. Philosophical Transactions of the Royal Society of London, Series B 281: 277–294.

Moursi, M. A., and Abdelgawed, A. A. 1965. Legume photoperiodism. 2. Formative and photoperiodic reaction to light duration. Annals of Agricultural Science of the University of Ain Shams (1963) 8: 297–304.

Murfet, I. C. 1977. Environmental interactions and the genetics of flowering. Annual Review of Plant Physiology 28: 253–278.

Narda, K. K., and Chinoy, J. J. 1960. Effect of vernalization and photoperiodic treatments on *Cicer arietinum*. 1. Phasic development in relation to its photo and thermic quanta. Indian Journal of Plant Physiology 3: 32–44.

Narda, K. K., and Chinoy, J. J. 1960. Effect of vernalization and photoperiodic treatments on *Cicer arietinum*. 2. Stem elongation and branching of *Cicer arietinum* and their correlation with flowering under varying photoperiodic treatments. Indian Journal of Plant Physiology 3: 45–55.

Nix, H., McMahon, J., and Mackenzie, D. 1977. Potential areas of production and the future of pigeonpea and other grain legumes in Australia. Pages 50–62 *in* The Potential for Pigeonea in Australia, E. S. Wallis and P. C. Whiteman, ed. University of Queensland, Australia. Special Publication.

Okon, Y., Eshel, Y., and Henis, Y. 1972. Cultural and symbiotic properties of *Rhizobium* strains isolated from nodules of *Cicer arietinum* L. Soil Biology and Biochemistry 4: 165–170.

Pal, B. P., and Murty, G. A. 1941. Vernalization of Indian crops. 1. Preliminary experiments on gram, wheat, chilli and soybean. Indian Journal of Genetics and Plate Breeding 1: 61–85.

Pallas, J. E., Stansell, J. R., and Bruce, R. R. 1977. Peanut seed germination as related to soil water regime during pod development. Agronomy Journal 69: 381–383.

Pandey, R. K., Saxena, M. C., and Singh, V. B. 1977. Genotypic differences in photoperiodic response in chickpea (*Cicer arietinum* L.). Pantnagar Journal of Research 2: 123–126.

Pillay, K. P. 1944. A short note on vernalization of gram. Current Science 13: 185.

Porter, U. G. 1977. The role of abscisic acid in flower abscission of *Lupinus lutens*. Physiologia Plantarum 40: 50–54.

Richards, F. J. 1941. The diagrammatic representation of the results of physiological and other experiments designed factorially. Annals of Botany 5: 249–261.

Sandhu, S. S., and Hodges, H. F. 1971. Effect of photoperiod, light intensity and temperature on vegetative growth, flowering and seed production in *Cicer arietinum* L. Agronomy Journal 63: 913–914.

Sandhu, T. S., and Singh, N. B. 1972. Correlation, path coefficient analysis and discriminant function selection in *Cicer arietinum*. Journal of Research, Punjab Agricultural University 9: 417–421.

Saxena, N. P., and Sheldrake, A. R. 1975. Chickpea physiology. *In* Pulse Physiology Annual Report 1974–75, Part II. ICRISAT, Hyderabad, India. 51 pp.

Saxena, N. P., and Sheldrake, A. R. 1976. Chickpea physiology. *In* Pulse Physiology Annual Report 1975–76, Part II. ICRISAT, Hyderabad, India. 176 pp.

Saxena, N. P., and Sheldrake, A. R. 1977. Chickpea physiology. *In* Pulse Physiology Annual Report 1976–77, Part II. ICRISAT, Hyderabad, India. 179 pp.

Sen, A. N. 1966. Inoculation of legumes as influenced by soil and climatic conditions. Indian Journal of Agricultural Science 36: 1–7.

Singh, A. 1958. The effect of clipping shoot tips on nodulation in *Cicer arietinum*. Proceedings National Academy of Sciences of India, Series B 28: 231–241.

Sinha, S. K. 1977. Food legumes: distribution, adaptability and biology of yield. Food and Agriculture Organisation of the United Nations, Plant Production and Protection Paper Number 3, FAO, Rome. 124 pp.

Steinberg, R. A., and Garner, W. W. 1936. Response of certain plants to length of day and temperature under controlled conditions. Journal of Agricultural Research 52: 943–960.

Summerfield, R. J. 1976. Vegetative growth, reproductive ontogeny and seed yield of selected tropical grain legumes. Pages 251–271 *in* Crop Protection Agents: Their Biological Evaluation, N. R. McFarlane, ed. Academic Press, London.

Summerfield, R. J., and Minchin, F. R. 1976. An integrated strategy for daylength and temperature-sensitive screening of potentially tropic-adapted soyabeans. Pages 186–191 *in* Expanding the use of soyabeans in Asia and Oceania, R. M. Goodman, ed. INTSOY, Illinois, U.S.A.

Summerfield, R. J., and Wien, H. C. 1980. Effects of photoperiod and air temperature on growth and yield of economic legumes. Pages 17–36 *in* Advances in Legume Science, R. J. Summerfield and A. H. Bunting, ed. Her Majesty's Stationery Office, London.

Summerfield, R. J., Minchin, F. R., and Roberts, E. H. 1977. Growing chickpeas (*Cicer arietinum* L.) in controlled environment growth cabinets. University of Reading — ICRISAT, Internal Communication Number 1. 20 pp.

Summerfield, R. J., Minchin, F. R., Roberts, E. H. 1978. Realisation of yield potential in soyabean (*Glycine max* (L.) Merr.) and cowpea (*Vigna unguiculata* (L.) Walp.). Pages 125–134 *in* Opportunites for Chemical Plant Growth Regulation. British Crop Protection Council, Monograph Number 21, BCPC, London.

Summerfield, R. J., Minchin, F. R., Roberts, E. H., and Hadley, P. 1979. Effects of daylength, day and night temperature on growth, reproductive development and seed yield of chickpea (*Cicer arietinum* L.). University of Reading — ICRISAT, Internal Communication Number 2. 29 pp.

Summerfield, R. J., Minchin, F. R., Roberts, E. H., and Hadley, P. 1979. Variation in adaptation to contrasting aerial environments among selected cultivars of chickpea. University of Reading — ICRISAT, Internal Communication Number 3. 20 pp.

Vaishya, U. K., and Sanoria, C. L. 1972. Specificity and efficiency of *Rhizobium* cultures of Bengal gram (*Cicer arietinum* L.). Indian Journal of Microbiology 12: 133–144.

Whyte, R. O., Nilsson-Leissner, G., and Trumble, H. C. 1953. Legumes in Agriculture. Food and Agriculture Organization of the United Nations, Agricultural Study Number 21, FAO, Rome. 367 pp.

Wien, H. C., and Summerfield, R. J. 1980. Adaptation of cowpeas in West Africa: effects of photoperiod and temperature responses in cultivars of diverse origin. Pages 405–417 *in* advances in Legume Science, R. J. Summerfield and A. H. Bunting, ed. Her Majesty's Stationery Office, London.

Session 3 — Chickpea Agronomy and Physiology

Discussion

Saxena Paper

B. M. Sharma

Why are there good responses to the foliar application of DAP in comparison to single superphosphate? In DAP, is the response mainly due to the P component or to both N and P?

M. C. Saxena

Studies in the All India Coordinated Research Project on Pulse Improvement at various locations where N and P sprays were applied separately, along with treatments involving DAP spray, reveal that whenever increases have occurred, they are generally because of the phosphate component. Spray of single superphosphate has the problems associated with the dissolution of phosphate in the spray solution.

R. B. Singh

1. It is often said that legumes are hard on soils, particularly the micronutrients. You showed varietal differences for tolerance to low Zn and Fe availability. Are the cultivars that are unaffected by low Zn and Fe levels more efficient nitrogen fixers than those that are affected by low Zn-Fe conditions?
2. You made a case for one to two irrigations. This may be a location-specific recommendation. In the All India Coordinated Varietal Chickpea Trials in North India, under irrigated and unirrigated conditions, the average yields when rainfed were higher than when irrigation was applied, and based on this, the coordinated irrigated trial has been dropped. As a matter of fact, it is the soil moisture (at varying profiles) available that would determine whether or not to irrigate.

M. C. Saxena

1. No studies have been conducted by us on N fixation of the genotypes tested for differential susceptibility to Zn and Fe deficiency. We do know, however, that they make excellent growth under normal conditions with sufficient zinc supply. Good growth is a reflection that N fixation was going on well in all these genotypes. Reduction in nodulation and vegetative growth with zinc deficiency has been observed by us.
2. Irrigation recommendations are by no means universal. In fact, the response to irrigation is entirely dependent on the soil moisture available to the crop in the season. Depending upon the amount of moisture present in the profile, there may or may not be any response. However, in many areas in North India where the water-holding capacity is low, the atmospheric conditions are conducive to increased evapotranspiration, and thus good responses have been obtained to supplemental water supply early or late in the vegetative growth stage and at early pod filling.

R. B. Singh

Please clarify the relationships among Zn and Fe deficiency and nodulation and N_2 fixation.

P. J. Dart

There are differences between cultivars of legumes (e.g., soybean) in ability to use zinc, and their yields could reflect N_2-fixation rates . In large tracts of southern Australia, legumes respond to zinc application, but this does not appear to have a specific effect on the nodulation process. Increased N_2 fixation probably results from increased photosynthesis in the plants with better Zn nutrition. Zinc is not a component of the nitrogenase enzyme complex, molybdenum and iron are, and there is a specific requirement of molybdenum for N_2 fixation over and above that required by the plant for growth on an inorganic nitrogen source. There are no reports on the effect of iron chlorosis on nodulation, but obviously, decreased yields almost certainly mirror a decrease in N_2 fixation. Chickpeas with iron chlorosis have nodules containing leghaemoglobin (Lb), so that nodules are able to sequester some of the limited iron supply for Lb synthesis. As the chlorotic plants age, there is an apparent decrease in the amount of Lb, probably because the reduced photosynthate supply to the nodules induces premature nodule senescence. The turnover time for iron in Lb in lupin nodules is relatively slow.

K. G. Shambulingappa

Was there any relationship between date of planting and pest infestation?

M. C. Saxena

The susceptibility to foliar diseases, as well as to root rot and wilt pathogens, seems to be related to some extent, to date of planting. Because of the effect of date of planting on canopy development, susceptibility to foliar diseases changes. Higher temperatures in early plantings in some location have been associated with higher wilt damage. The insect infestation of the crop is also related to planting date. Dr. H. P. Saxena might like to comment on this.

H. P. Saxena

1. The trials carried out at some centers of the All India Project on Pulses have revealed that there were more caterpillars of *Heliothis armigera* Hubn. in the irrigated chickpea crop.
2. Early-sown crops of chickpea attract pod borers, and more caterpillars are seen. The pest builds up, and later the pod borer severely damages the late-maturing crops.

D. C. Erwin

Is there any information on the mycorrhizal fungal flora on chickpea and the response of the crop to phosphorus and zinc uptake?

M. C. Saxena

Mycorrhizal associations have been observed by Dr. Sheldrake at ICRISAT. He might like to comment on this. But we have hardly any information on the effect of this association on the phosphorus and zinc uptake in chickpea.

S. C. Sethi

Dr. M. C. Saxena's data on planting density show continuous increase in yield with increase in density, whereas Dr. N. P. Saxena's data show that there is an appreciable compensating mechanism because of plasticity. It would be worthwhile to resolve this difference.

M. C. Saxena

As was mentioned by me during the course of my presentation, the effect of population density seems to be related to growth conditions (both aerial and edaphic). In situations where conditions are ideal, there is apparently no conspicuous yield difference over a wide range of population density as has occurred in Pantnagar, in Hissar, and in some trials in Kanpur. When the aerial environment is such that the vegetative period is rather short, the population response is observed when moisture supply is not limiting. If the moisture supply is limiting, again the population responses become limited.

S. S. Lateef

1. What are the common pests on chickpea that bring about great losses in yield at Aleppo?
2. Have you observed any delay or earliness in maturity of chickpea plants, because of pesticide sprayings on the crop?

M. C. Saxena

1. Chickpea is not damaged much by insects at Aleppo, except for the damage from leaf miners to some extent in the vegetative and early reproductive growth and from *Heliothis* spp in the podding stage.
2. We have not observed any conspicuous earliness because of the endosulfan spray.

A. S. Gill

1. The histogram showed the following varieties for your studies: G-130, C-235, K-468, P-61, and PB-7. Please confirm that the cultivar used is P-61, not F-61. I am of the opinion that it is F-61 and not P-61.

2. Dr. Saxena has chosen five cultivars for his studies, but four of them belong to one region, Punjab. It would have been better if he selected cultivars from five different regions or zones to depict a good picture of zinc uptake. Most of these cultivars have common parents, as in the case of G-130 and F-61.

M. C. Saxena

1. You may perhaps be right; but we had this line with us under the number P-61, at Pantnagar.
2. No, we had 18 cultivars in this study. Only the ones with large contrast were shown in the histogram. There are eight of these (T-2, G-130, NP-100, P-61, C-235, 742-7, BEG-482, and Pb-7) and represent a fairly wide range.

M. V. Reddy

What is the possibility of date of planting interrelating with some root rot diseases at Hudeiba, which could also be responsible for low stands in addition to the factors you have mentioned?

M. C. Saxena

The authors did check for this possibility, and we were of the opinion that the mortality was primarily due to accumulation of salts. We did isolate *Fusarium orthoceras* var *ciceri* from the affected plants, but the pathogenicity of the isolated organism was not confirmed.

Jagadish Kumar

When we irrigate chickpeas at ICRISAT Center after flowering, we get quite a bit of flower drop and the plants look sick, although they recover later on.

M. C. Saxena

This is a common observation, particularly on heavy soils having high pH. Several times, such plants show induced iron deficiency also. It seems that soil-packing associated with irrigation leads to a temporary situation of restricted aeration, which results in this type of response.

Irrigation during flowering encourages vegetative growth and thus should increase competition between the reproduction and vegetative sink for the assimilates, resulting in flower drop. Irrigation during flowering is therefore not recommended. Instead, the pod-filling stage is considered good for irrigation to get good response.

S. Sithanantham

You have indicated that there have been instances of irrigation during flowering leading to reduced yields. Could we have additional information on the type of irrigation and whether the observed reduction in yield was due to flower drop or to other components?

M. C. Saxena

The studies at Pantnagar and Ludhiana have shown that irrigation at flowering stage encourages vegetative growth at the expense of reproductive growth, which results in reduced yield. Part of this is because of the flower drop that occurs due to this type of competition.

C. L. L. Gowda

In your radial planting experiments, the plant growth near the base (high density) is better than low density (end). This is in contrast to experiments conducted at ICRISAT where better growth and branching is observed at the lower densities. Could you comment?

M. C. Saxena

I did mention in my talk that there seems to be some synergistic effect of increased plant population on the early vegetative growth of the winter-planted chickpeas, which are exposed to long periods of low temperature. We do not know which factors are involved, but there is the possibility that local temperature effects in the microenvironment in the canopy might be playing a role.

S. Chandra Paper

J.S. Kanwar

1. What critical limit of salinity did you use for screening the genotypes?
2. What salt did you use to create salinity conditions?

S. Chandra

1. The level of salinity used was 5.8±0.2 mmhos/cm of the saturation extract for screening genotypes. These genotypes were not used for screening under sodic soils.
2. The salts used were NaCl, Na_2SO_4, $CaCl_2$ in the ratio of 7:1:2 to build up the desired level of salinity.

Rajat De

In North India we encounter two types of salinity — one confined to the soil surface and the other in which the salinity permeates the profile to some depth. Will you clarify as to which type of salinity you referred in your paper and with which you have screened your cultivars.

S. Chandra

The salinity status of the profile is a dynamic one and would undergo changes with rainfall or irrigation. Our concern at the moment is to try to improve chickpea with regard to a level of salinity since this crop has a very low salt tolerance. We screened varieties in pots having a uniform salinity of 5.8±0.2 mmhos/cm.

Y. S. Tomer

1. What is the mechanism of salt tolerance in chickpea?
2. Is there any relationship between salt tolerance and agronomic characters or morphological characters?

S. Chandra

1. We cannot say anything at this moment about this mechanism because we are still identifying tolerant ones. However, it may not be possible to identify a simple mechanism because salt tolerance is a complex response.
2. Again, we have no definite answer yet.

J. S. Sidhu

In the Indo-Gangetic plains of India, chickpea crops cannot be grown successfully under assured irrigation conditions, whereas chickpea could be grown under rainfed conditions before the irrigation facilities were made available. What could be the possible edaphic factors for this failure?

S. Chandra

It would be necessary to examine local conditions before a reason could be assigned. However, generally speaking, the availability of irrigation in certain conditions in the Indo-Gangetic plains has led to development of salinity and sodicity. This might be one of the possible reasons.

M. V. Reddy

1. What are the external symptoms of salinity and sodium in soil on chickpea? Do they cause any vascular symptoms also?
2. Is there any information on temperature on salinity-sodium interaction?

S. Chandra

1. There are different types of responses by different genotypes. However, leaf browning and leaflet shedding of older leaves with progressive growth are associated with saline as well as sodic soils and would vary in extent with the degree of soil affectedness. Vascular symptoms were not studied over the range of varieties.
2. Higher temperatures are more conducive to the adverse effects of salinity, but detailed information on chickpea is not yet available in this regard.

S. Sithanantham

In one of your illustration slides, you showed a picture of a field crop of chickpea in which you suggested that brown leaves indicated response to sodic soils. Could you eliminate the involvement of "stunt" disease, which might also end up in "reddish"-brown foliage.

S. Chandra

The symptoms indicated were found in

known sodic conditions and nowhere else in adjacent improved fields or normal fields. This makes us believe that stunt was not involved because that would occur irrespective of type of soil. However, we did not proceed to establish that stunt was not involved.

E. J. Knights

Which genotypes show the least effect of salinity on establishment and final yield? What are the main symptoms attributable to salinity?

S. Chandra

Of the genotypes tested by us, H-75-36 appeared to do well on these scores. The main symptoms attributable, in the absence of other effects, are browning of leaflet tips, which moves down through the leaflet pregressively, culminating in leaflet drop after browning has completed. While this is happening to the older leaves, new leaves are being put up and appear normal except for some restricted elongation and sometimes even growth. Meanwhile, plant mortality continues at a slow to rapid pace, depending on relative tolerance.

H. S. Nagaraj

Are nodules present in the chickpea plant in sodic soils? If so, what is the number? Is it not possible to isolate *Rhizobium* strains from these nodules? What is the color of the nodules inside?

S. Chandra

The nodulation studies are important in sodic soils, and some data have been presented in the paper. Further studies, which are now being done by us, will give us data to answer your questions. At the moment, it is difficult to provide quantitative data.

C. L. L. Gowda

Among the sensitive crops, chickpea is highly sensitive to salinity. Is this because chickpea is grown in the postrainy season when salt begins to seep up and thus affects rabi crops such as chickpea (with its deep root system) more than others?

S. Chandra

The relative tolerances of crops generally reflect how much accumulation of salts in the soil they could withstand. Those that withstand increasing levels are progressively more tolerant. Chickpea shows sensitivity at very low levels of salt in soils. Thus, their sensitivity would not appear to be related to changes in the soil profile before the crop is planted. That would, however, determine the performance of the particular cultivar of chickpea that is grown in such soils.

Jagdish Kumar

I wonder if you have anything to say about the effect of salinity on protein content of chickpea or any other crop.

S. Chandra

Nitrogen content in leaves of salt-stressed plants has been reported to go up on a per-unit dry matter basis and, in certain cases, on a per-unit grain weight basis. In chickpea, however, these data have not yet been estimated by us.

Saxena and Sheldrake Paper

K. B. Singh

Production and area statistics on chickpeas have been circulated. I am interested to know (1) what is the proportion of kabuli chickpea in whole chickpea production; (2) what proportion of the area under chickpea receives irrigation; and (3) what are the reasons for year-to-year fluctuations in production and area?

B. M. Sharma

1. There are no separate statistics available on the area of kabuli chickpea, but kabulis are grown on a restricted area in Punjab, in Haryana, in the Ganganagar area of Rajasthan.
2. About 10% of the chickpea area is irrigated.
3. The area under chickpea mainly depends upon the late rains during the end of September or early October, while production depends upon the winter rains. Again, heavy winter rains invite

diseases and stimulate insect infestation and thereby lower yields.

B. M. Sharma

If bold seeds produce healthier plants, what is their effect on grain yield?

N. P. Saxena

Bold-seeded cultivars produce larger seedling, but with time, the effect fades away and there is no advantage in yield. In fact, very bold-seeded cultivars tend to be low yielding.

A. S. Tiwari

Which cultivars responded best to irrigation application in the experiment on cultivaral differences on limited water?

N. P. Saxena

The results on cultivaral responses to irrigation are available in the Pulse Physiology Progress Report 1977–78. These are data based on 1 year's experience, which need to be confirmed.

Rajat De

In screening genotypes of chickpea to drought tolerance, will it not be better to take into consideration the leaf water potential at various phenological stages of the crop?

N. P. Saxena

We are measuring water potential in a set of cultivars varying in growth duration. The objective of the field screening is to keep it as simple as possible so that it is an effective and useful technique. Measurement of water potential is a cumbersome process and is unlikely to be as useful in yield as a criterion for drought tolerance. However, it may be used in a limited way for the identification of drought-tolerant parents.

K. G. Shambulingappa

Have any laboratory studies been initiated to screen the varieties against drought conditions.

N. P. Saxena

No, we have so far not commenced any laboratory studies on drought tolerance.

Mohamed Bouslama

Do you think that cultivars with high carbohydrate content perform better under drought-stress conditions?

N. P. Saxena

We have no information on this aspect. It is known in other crops that carbohydrate accumulates when plants are under stress.

Y. S. Tomer

Please comment on whether production of dry matter is more important after or before flowering.

N. P. Saxena

Chickpeas are indeterminate in nature and consequently dry-matter production continues after flowering. Dry matter at flowering and continued dry-matter production after flowering both seem to be important in determining yield.

J. M. Green

Did you not think it necessary to conduct a balanced test on the effect of double pods? You should have added a second pod to the single-podded cultivar in addition to removing one from the double-podded cultivar.

N. P. Saxena

A balanced test would be desirable, but the absence of isogenic lines presents certain technical problems. Adding flowers by grafting does not work; adding already-filled second pods increases yield, but is perhaps somewhat unphysiological. Doubling the pod numbers by means of mirrors has so far failed to influence yields significantly under Hyderabad conditions.

V. P. Gupta

How do you feel about screening the germplasm for root growth and root dry matter and relating the data on root dry matter with growth and the phenological and yield components. What I feel is that most of the studies have been conducted above the ground, but there is a need to study in detail what is happening below the ground. We have found genotypic differences for root dry matter and strong association with the physiological attributes.

N. P. Saxena

Quantitative studies on root growth are difficult. Also, they are greatly influenced by soil environment factors, such as availability of water, compaction, and nutrient availability. As we are interested in the differences in biological productivity, and more so in yield, a better root system should be reflected in the cultivar's dry-matter production in above-ground parts, which are easy to monitor.

S. S. Lateef

We know that chickpea plants mature early (2-3 weeks) under sprayed conditions. Have you taken this factor into consideration when interpreting your results on delay and earliness in maturity of chickpea because of three other factors, as you mentioned in your talk?

N. P. Saxena

The results on flower removal indicate delay in senescence when pod set is prevented. Insect damage to pods and flowers could be analogous to this in a nonsprayed condition and could delay senescence.

I do not know if the early senescence in sprayed plants is in response to an internal signal in response to pod set that triggers senescence or whether it is a sole effect of the chemical used as an insecticide.

H. S. Nagaraj

What is the state of nodulation when the flower buds are removed and the plants remain green. Do the nodules senesce or continue to be active.

N. P. Saxena

Nodule regression is delayed in response to flower removal. The nodules continue to grow and accumulate a greater mass.

M. V. Redey

What could be the effect of low and high plant stands on the stability of yields?

N. P. Saxena

Chickpeas are fairly plastic and give stable yields over a range of population densities. At low plant stands the yield of cultivars is reduced, depending upon the plasticity of the cultivar; there seem to be distinct cultivaral differences in this respect.

B. M. Sharma

In the States of Madhya Pradesh, Uttar Pradesh, and Gujarat, chickpea plants show a bronzing of leaf color and symptoms of forced maturity. What is the reason for this type of appearance?

N. P. Saxena

We observe in desi cultivars that the bronzing of leaves occurs in response to any stress, such as water and salt. Disease or insect stress could also be involved.

R. C. Misra

You mentioned that providing shade cuts off sunlight and temperature to some extent. Dr. M. C. Saxena of ICARDA, while presenting the slides, mentioned that in late sowing the yield is lower than that of early sowing, probably due to high temperature and full sunlight. Will it not be possible to increase the yield of chickpea in late sowing by using it as an intercrop with safflower or sugarcane to provide shade to cut off sunlight and temperature? Please comment.

N. P. Saxena

In fact, in the cropping system group, an intercrop of chickpea and safflower has led to an increase in yields of chickpeas. The intercrop advantage is suggested to be due to the partial shading effect.

Summerfield et al. Paper

K. B. Singh

1. You mentioned that long days and warm temperatures induce early flowering and probably result in high yields. Exactly similar conditions exist at Aleppo and result in lower yields. Probably moisture and heat stress are quite important. Could you comment on this?
2. Your literature review indicated that chickpea has been reported variously as

day-neutral, long-day, and short-day. What is your own experience?

R. J. Summerfield

1. For the few cultivars for which we have data, longer days and warmer day and night temperatures are more inductive. I was at pains to point out that warmer days to 30°C increase yield, compared with cooler days (22°C), but that 35°C is supraoptimal even when experienced for only the latter part of the reproductive period.

2. Chickpeas are probably mainly quantitative long-day plants; genotypes differ in degree of sensitivity; some may be insensitive, the single report in the literature of a short-day response is unreliable.

L. J. G. van der Maesen

1. There is only a single aberrant report extant on chickpea as a short-day plant.
2. Obviously there exists a range of responsiveness to daylength between chickpea cultivars. We would learn more if many representatives of geographical groups were screened together. With breeding, germplasm gets mixed, and which probably also mixes this response.

R. J. Summerfield

1. I know of this single reference and do not believe it.
2. I entirely agree with these sentiments. We have made only a small start. Genotypes could fairly easily be screened for photoperiod sensitivity in the field, but materials of interest to the breeder should subsequently be tested for the effect of day and night temperature on successive stages of reproductive development.

N. P. Saxena

The shoot growth in the environmental cabinet was similar to the field-grown plant. Do you expect similar results in roots.

R. J. Summerfield

doubt it! Rooting depth is restricted in pots, and the medium is defined and mainly inorganic rather than heterogenous and more organic as in natural soils. Different shapes and sizes of containers could be used, but would we need to recreate the soil profile (e.g., bulk density) to produce realistic data? I can foresee many problems.

N. P. Saxena

As senescence seems to be governed more by internal physiological factors, early planting of early cultivars may not get the advantage of extending growth duration. The plants will mature in response to internal signals, even though the conditions continue to be conducive for continued growth.

R. J. Summerfield

On the basis of studies so far completed, we cannot assess reliably which internal factors are involved or which environmental stimuli trigger or modify their manifestations. Undoubtedly, it may prove to be a combination of endogenous and external control, and it will be pertinent to note the "strategy" of cultivars that do not conform.

A. R. Sheldrake

In the field, sensescence is affected by three main factors: water stress, heat stress, and internal physiological factors. I find it very interesting that in the growth chambers when the plants were well watered and grown at constant temperatures they matured normally in comparable times to those in the field, emphasizing the role of internal factors in senescence.

R. J. Summerfield

These nodule-dependent plants completed their phasic development in times (days from sowing) closely similar to those in the field. Certainly, the role of internal factors (such as the mobilization of nitrogen from vegetative to reproductive structures and, perhaps, changes in endogenous hormone balances) must be important in this respect. There is likely to be a progressively larger effect of water stress on longer duration cultivars in the field, and you will notice that predictions are less precise (Table 7) for this line. Furthermore, these plants were harvested when more than 95% of the fruits were mature, although all their leaves had not senesced. Crop duration in cultivar Chafa corresponds to all fruits mature and all leaves senesced.

M. C. Saxena

You seem to maintain the relative humidity in your cabinets at a constant level, whereas in the field there is not only a diurnal fluctuation in this but also a seasonal pattern. Would you care to comment on the effect of relative humidity on flower retention and yield build up.

R. J. Summerfield

To establish a "baseline" from which to build, we control at single values (CO_2) Vpd, (vapor pressure deficit), light intensity, and quality, frequency of irrigation, nodulation, and volume of nutrient solution applied. We can then elect "key" combinations of daylength and air temperature and vary also Vpd or any other factor. We are likely to investigate factorial combinations of Vpd and temperature in future experiments.

Session 4

Chickpea Microbiology

Chairman : M. C. Amirshahi
Co-Chairman: D. F. Beech

Rapporteur: O. P. Rupela

Research on Symbiotic Nitrogen Fixation by Chickpea at ICRISAT

O. P. Rupela and P. J. Dart*

Nodulation in Farmers' Fields

The *Rhizobium* strains nodulating chickpea (*Cicer arietinum*) are very specific, nodulating only *Cicer* species readily (Raju 1936) and rarely and non-reciprocally with *Sesbania bispinosa* and *S. sesban* (Gaur and Sen 1979). Surveys of nodulation of chickpea in farmers' fields in India, Syria, and Lebanon indicate a wide range in the extent of nodulation. Within India, fields were found in the states of Andhra Pradesh, Maharashtra, and Madhya Pradesh where chickpea plants were not nodulated; in other fields in Haryana and Rajasthan nodulation and plant growth were poor. This may reflect low chickpea *Rhizobium* populations in the soils or poor soil moisture conditions. Large differences in growth between plants were associated with differences in nodulation.

The increase in the area of wheat and rice cultivation in the northern States of India (Punjab, Haryana, Uttar Pradesh, Bihar, West Bengal) since the introduction in 1965 of new, fertilizer-responsive cereal varieties has resulted in a decreased area of chickpea cultivated in these states, from 52.89 to 34.3% in 1972–75, and decreased yields per hectare, probably because the better land was taken out of chickpea production and there was an associated movement of production to more marginal areas where chickpea may previously have been grown infrequently, if at all. Chickpea production has increased in the states of Rajasthan, Gujarat, Madhya Pradesh, Maharashtra, Andhra Pradesh suggesting that some production is being taken up in new areas for chickpea growth (M. von Oppen, personal communication). In such new lands for chickpea, one would expect low populations of chickpea *Rhizobium* to occur naturally in the soil and responses to inoculation with *Rhizobium* would also be expected.

At ICRISAT Center, there is a sharp transition from a Vertisol field, where chickpea is grown, to an Alfisol field where chickpea is not normally grown. Chickpea nodulates readily in the Vertisol field, but poorly, if at all, 150 metres away in the Alfisol field, where marked responses to inoculation occur. The prevailing winds blow from the Vertisol to the Alfisol field so that transfer of *Rhizobium* would have occurred through the dust. The poor saprophytic development of chickpea *Rhizobium* in this Alfisol soil is intriguing.

Counting *Rhizobium* in Soil

We have now developed a suitable technique using a most-probable number method based on growing chickpea plants axenically in 22 × 200 mm test tubes, and inoculating them with an aliquot of solution from a dilution series. The plant will nodulate if chickpea rhizobia are present in the aliquot.

We have achieved consistent nodulation of chickpea in test tubes by transplanting seedlings in which the cotyledons were excised 3 days following germination. The rooting medium can be either sand or a sand/vermiculite mixture.

Nodules appear at about 20 days after inoculation. The plants will nodulate in natural light if the temperature inside the test tube is kept below 30° C, but nodulate more reliably when they are grown with lateral illumination from fluorescent tubes in a temperature controlled room (Toomsan et al. 1980 in press). This counting technique now enables us to determine chickpea *Rhizobium* populations in soil and in *Rhizobium* inoculants containing contaminating organisms. This will be helpful in understanding nodulation patterns in the field, and in monitoring the quality of inoculants used in field experiments.

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* Microbiologist and Principal Microbiologist, respectively, ICRISAT.

Response to Inoculation

We have a collection of several hundred *Rhizobium* strains isolated from chickpea nodules collected mainly in India, but also some from Bangladesh, Iran, Syria, Jordan, Turkey and wild *Cicer* species from Israel. There is a wide range of symbiotic characteristics among the strains (Table 1). Strains from this collection are available for research workers and inoculant manufacturers; ICRISAT offers to maintain characterized chickpea strains in its collection for any who wish to deposit them.

Responses to inoculation have been obtained with some of these strains in field experiments. Table 2 shows the response in one such trial in a Vertisol field at ICRISAT Center. The previous cultivation history of the field was not known, but the uninoculated control plants formed some nodules (Fig. 1). Nodulation, nitrogenase activity, dry-matter production, and yield were significantly increased by inoculation with no advantage of the multistrain over the single strain inoculm.

At ICRISAT Center in the dry winter season of 1977, interactions between *Rhizobium* strains and host cultivars were found for nodule formation in a Vertisol field with a low population of native rhizobia. Inoculation increased nodulation with most nodules formed by strain

Table 1. Range of symbiotic characteristics[a] for *Cicer Rhizobium* strains screened on cv JG-62, ICRISAT Center, 1977.

Character	Range	Overall mean	Median
Nodule (no./plant)	7–48	21	25
Nodule dry wt (mg/plant)	13–74	30	32
Nitrogenase activity: (μmol C_2H_4/plant per hour)	0.2–3.25	1.2	1.3
μmol C_2H_4/g nodule dry wt per hour	3–100	36	41
Root dry wt (g/plant)	0.08–0.29	0.15	0.14
Top dry wt (g/plant)	0.15–0.92	0.37	0.42
Colony growth rate[b]	3–15	9.3	ND

a. Testing done during the rainy season when the ambient temperature range was above optimum for chickpea growth. Plants grown in Leonard jars watered with N-free nutrient solution, harvested around 45 days after planting. Values are means of four replications with three plants.

b. Days taken for an isolated colony to reach 2 mm diameter on yeast extract, mannitol agar plate.

N D = No data.

Table 2. Effect of *Rhizobium* inoculation on nodulation and yield of chickpea.

Treatment	Nodulation/plant No.	Nodulation/plant Dry wt (mg)	Nitrogenace activity (μmol C_2H_4/plant per hr)	Dry matter (kg/ha)	Yield (kg/ha)
Uninoculated	4	11	0.3	2890	1560
Strain CC 1192[a]	17	42	2.2	3740	2140
Multistrain[b]	15	53	2.6	3440	2010
SE ±	2.7	13	1.1	390	252
CV (%)	21	29	67	12	13

a. Single strain inoculum in peat carrier.

b. Multistrain inoculum prepared from 20 strains grown separately on large agar slants and suspension of this growth used to inoculate the peat carrier.

Cultivar used — Annigeri.

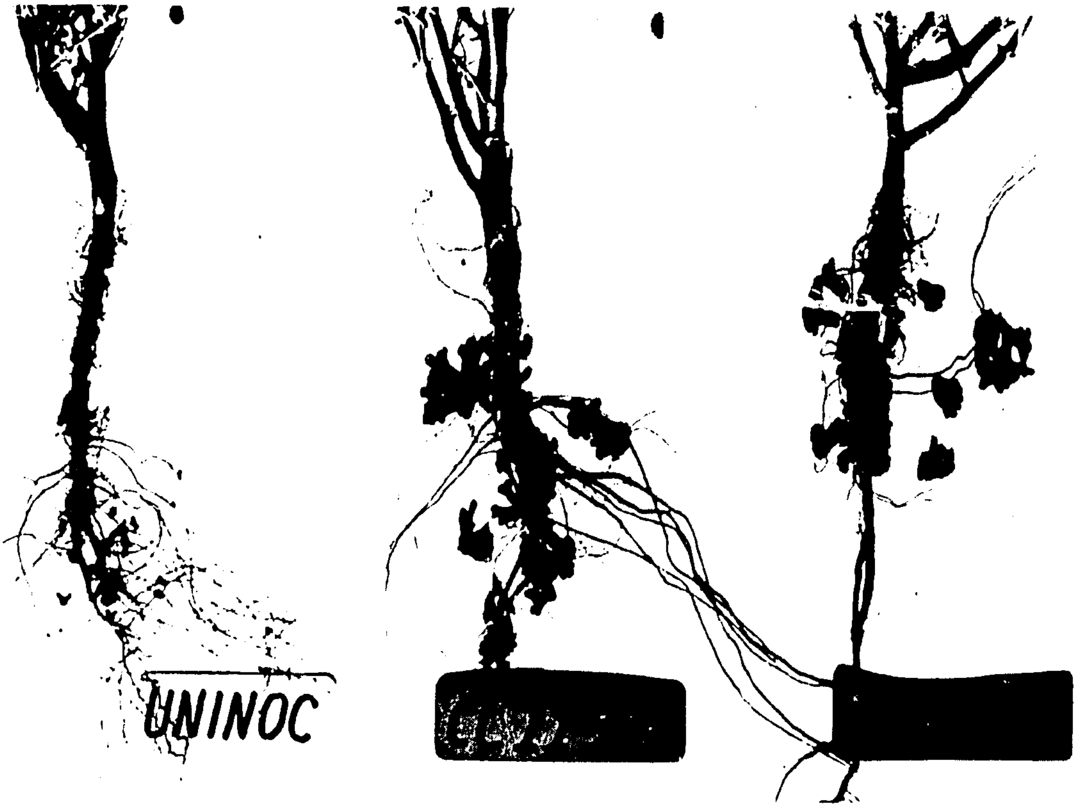

Figure 1. Response of chickpea to inoculation with Rhizobium *strain CC 1192 or a multistrain inoculant. Few nodules are formed on noninoculated plants.*

DNRa-1. Among the five cultivars, 850–3/27 was best nodulated, followed by JG-62, with significantly fewer nodules formed on Rabat and C-235, and the fewest were formed on G-130. Inoculation significantly increased grain yields for some strain-cultivar combinations. Nitrogen fertilizer application (150 kg N/ha) produced the highest yields indicating that the symbiotic system was unable to provide enough nitrogen for maximum yields. No response to inoculation was obtained in another trial in a Vertisol field where chickpea nodulated readily without inoculation.

A similar, rainy-season trial was planted in an Alfisol field (also with low numbers of *Cicer Rhizobium*) to examine the possibility for field screening *Rhizobium* strains in the off-season. There was again a significant response to inoculation in nodulation and plant growth with a cultivar × strain interaction in nodulation. Mean nodule number and weight per plant were generally greater than for similar treatments planted in a Vertisol in the dry winter (postrainy) season. This experiment indicated that chickpea can be grown in the rainy season-although *Colletotrichum* blight disease did kill some plants. The temperature regime was not unfavorable for chickpea growth.

A large response to inoculation has also been obtained when chickpea followed paddy (Table 3). It is estimated that in India some 2 million ha of pulses are grown after a rainy season crop of paddy, and much of this is sown to chickpea. We are studying the survival of chickpea *Rhizobium* in paddy soil.

Another trial was conducted in a saline field containing no native chickpea *Rhizobium* at Hudeiba Research Station in the Sudan by Dr. Mohammed El Habib and Dr F. A. Salih. Strain IC 53 isolated from a saline field at ICRISAT produced three times as many nodules per plant, more than double the nodule weight and a 63% increase in grain yield over another inoculum strain CC1192, of similar effectiveness in nitrogen fixation under non-saline conditions (Table 4).

This experiment suggests that selecting specific strains for saline conditions would be rewarding.

Our experiments suggest that there are situations where responses to inoculation can be obtained with chickpea, but little response may be obtained where the soil already contains a large population of chickpea rhizobia. Our work is now directed towards developing methods of identifying *Rhizobium* strains so that we can follow the competitiveness of our inoculum strains in forming nodules in different environments.

Nitrogen Fixation

There are large effects of location on nodule longevity on chickpea. At Hyderabad in the postrainy season, using residual stored water in the soil, the nitrogen-fixing activity of chickpea nodules virtually ceases by 89 days after planting with final grain harvest at 110–130 days. At Hissar in North India, nodules remain active much longer, even up to 145 days after planting or 3 weeks before final harvest.

Table 3. Yield of chickpea after paddy.

Treatment	Dry matter (kg/ha)	Grain yield (kg/ha)
Control	1480	1090
Inoculated + N[a]	2390	1760
Inoculated	2680	1800
SE±	161	123
CV%	7	8

a. Fertilizer (Calcium ammonium nitrate) added at rate of 150 kg N/ha).

Nodulation, nitrogenase activity and yield were followed for five cultivars grown in a Vertisol soil at ICRISAT. Highly significant correlations were found between grain yield and nodulation parameters, particularly for nodule number and nodule weight at 61 days after planting when there were large differences between cultivars, and nodule development and nitrogenase activity were greatest (Tables 5, 6; Fig. 2). At 89 days after planting, only cultivar 850–3/27 retained some nitrogenase activity as measured by acetylene reduction (5μ moles/C_2H_4/plant per hr) while less than 0.2μ moles/C_2H_4/plant per hr was measured for other cultivars.

Differences between cultivars in their pattern of nodulation were apparent at 17 days after planting (Fig. 2). The cultivar 850–3/27 formed more nodules per plant, a greater mass of nodule tissue and had much greater nitrogenase activity per plant than any of the other cultivars. Nodule tissue developed rapidly between 27 and 61 days, with big differences in growth rate between cultivars. The specific nitrogenase activity (per g dry weight nodule) was most for the youngest nodules (17 days after planting) and declined similarly and rapidly for all cultivars except 850–3/27 where the nodule tissue retained its activity until 61 days after planting.

Table 4. Effect of *Rhizobium* inoculation on yield of chickpea in a saline field at Hudeiba Research Station, Sudan[a].

Rhizobium strain	Nodule no./plant	Nodule dry wt/plant (mg)	Seed yield (kg/ha)
Uninoculated	0.3	8	680
CC 1192	45	149	860
IC 53	143	34	1400
LSD			480

a. Experiment conducted by Mohamed El Habib Ibrahim & F. A. Salih.

b. Nodulation measured 57 days after planting.

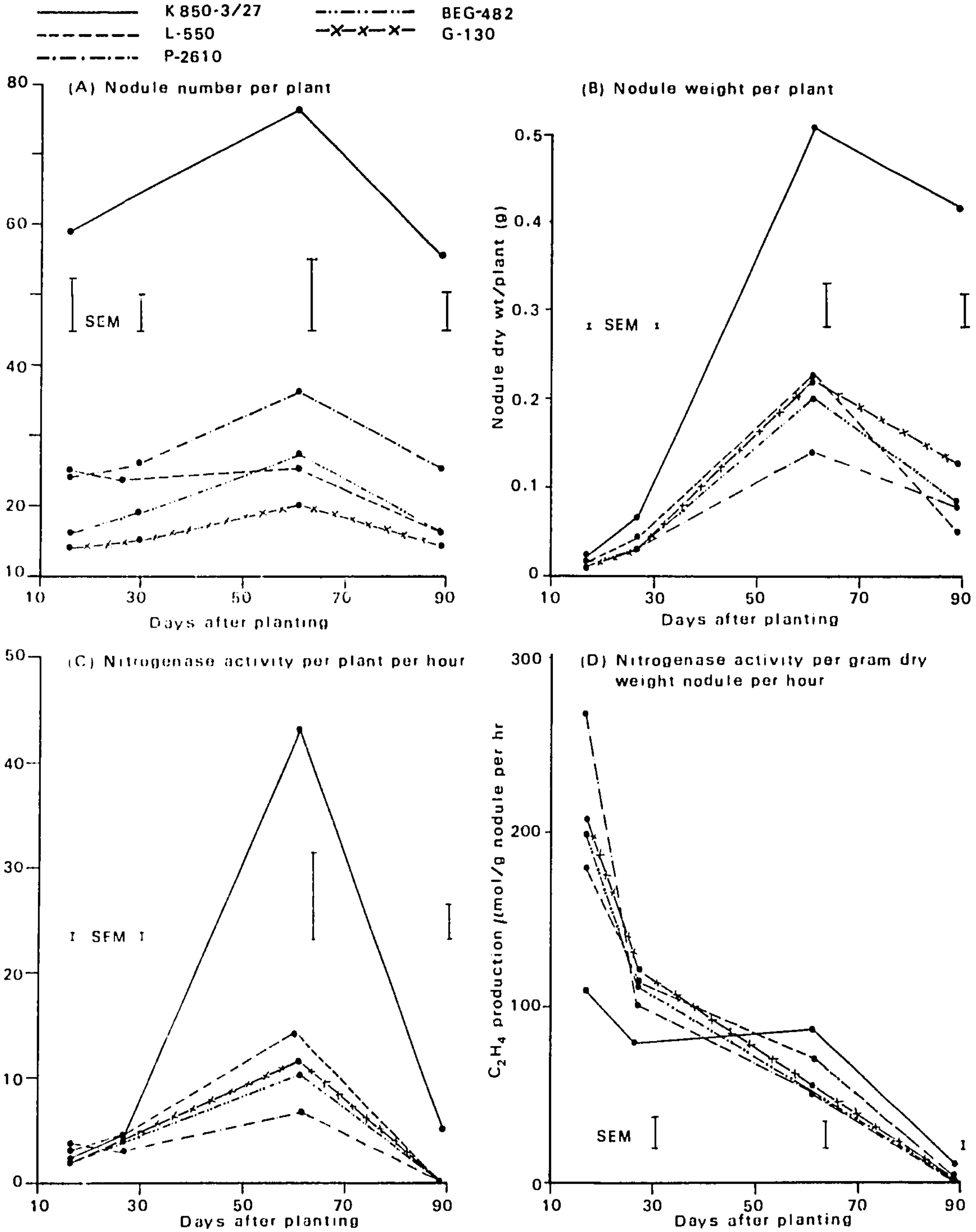

Figure 2. Symbiotic performance of five chickpea cultivars grown in a Vertisol field at ICRISAT Center, dry winter season 1976–77; (A) Nodule number per plant. Bars represent the standard error of the mean (SEM); (B) Nodule weight per plant; (C) Nitrogenase activity, μmoles C_2H_4/plant per hr; (D) Nitrogenase activity, μmoles C_2H_4/g dry weight nodule per hr.

This experiment indicates that there are lagre differences in nodule development and nitrogen fixation between cultivars, and that this may influence final yield.

Symbiotic Variability in Germplasm Lines

We screened 251 lines of chickpea, including those used by breeders for crossing, for symbiotic characteristics in the postrainy season of 1977 and 1978 in a Vertisol soil at ICRISAT Center, and 100 lines in a silty loam soil at Hissar in North India. There is a wide range for all three parameters examined at three different growth stages (Table 7). There were large effects of location and year on the nodulation pattern.

Nodule number for the 30-and 50-day harvests in 1977–78 was less than half that observed in 1976–77. Nodule weight per plant was even more reduced. Nodules continued to form between 30 and 50 days in 1976–77 but not in 1977–78 at Hyderabad. The decline in nodule number between the 50 and 75 day harvests in 1977–78 reflects both nodule senescence and difficulty in recovering nodules from this heavy clay soil as it dries out.

Table 5. Correlations between nitrogen fixation parameters at 61 days after planting and yield.

	Nodule weight	Nitrogenase activity/plant	Grain yield
Nodule no.	0.788***	0.778***	0.761***
Nodule wt.		0.763***	0.813***
Nitrogenase activity/plant			0.668**

n = 20.
** Significant at 1%; *** Significant at 0.1%.

In both seasons and at both locations, nodule tissue growth continued after 50 days so that nodule weight per plant was greatest at the 70–75 days harvest. Nodule growth at Hissar was much greater than at Hyderabad with more than double the nodule mass per plant at 70 days. Plant top growth reflected these differences in nodule development between Hyderabad and Hissar, but not between seasons at Hyderabad suggesting that other factors than nitrogen supply may be determining plant development at Hyderabad. Even though the entries were variable in plant type, for the Hyderabad sowing in 1977–78 there was a significant correlation between nodule weight and top weight at the 45–50 day harvest ($r^2 = 0.313$, $p<0.01$) and between top weight at 45–60 day and nodule weight at 25–30 day ($r^2 = 0.278$, $p<0.01$).

Some lines were consistently high and others low in nodulation over seasons and location. For other cultivars there was an interaction with location.

We also observed differences between cultivars in their ability to form nodules on newly formed roots after rain rewetted the top 10 cm soil. Since rain during the season is a common occurrence in North India, this is likely to be a valuable trait.

Table 6. Nodulation and nitrogen fixation at 61 days after planting and yield of chickpea.

Cultivar	Nodule no. per plant	Nodule wt. (mg/plant)	Nitrogenase activity (μ mol C_2H_4/plant per hr)	grain yield (kg/ha)
850-3/27	77	448	43	1510
L-550	24	101	14	1180
G-130	23	205	12	1190
BEG-482	21	127	10	890
P-2610	31	89	7	1030
SE ±	6	24	8	87
CV %	17	13	47	7

Nodulation and nitrogenase data are averages of 32 plants over 4 replications.

Table 7. Range of symbiotic parameters and yield of chickpea cultivars.

Parameter	Harvest days after planting	Hyderabad		Hissar
		1976–77	1977–78	1977–78
Nodule no./ plant	25–30	4–48	2–18	0–27
	45–50	10–76	1–20	1–24
	70–75	1–20	4–28	2–34
Nodule dry wt. mg/plant	25–30	0.3–55	1–13	0–21
	45–50	2–105	2–34	2–108
	70–75	1–195	3–82	1–472
Top wt. g/plant	25–30	ND	0.2–1.7	0.2–1.5
	45–50	0.7–6.2	1.1–9.2	0.6–11.4
	70–75	1.8–39.2	10.5–36.5	2.8–65.4

Two hundred and fifty-one cultivars were grown in the postrainy season 1976–77 at ICRISAT Center, without inoculation and replication. Nodulation was observed 25–30, 45–50, 70–75 days after planting (DAP). Thirty plants per cultivar were scored at each harvest date. In the 1977–78 postrainy season the same cultivars were planted at Hyderabad and 100 of these with specific nodulation characteristics were selected for planting at Hissar. At both locations seeds were inoculated with *Rhizobium* strain CC 1192. Observations are means for 30 plants from 3 replicates in Hyderabad and 20 plants from 4 replicates in Hissar. ND = No data.

The experiment at Hissar was conducted in collaboration with Dr. A. L. Khurana and Dr. P. Tauro.

We have made crosses between some of these cultivars to examine the heritability of nodule number and weight per plant as a prelude to a breeding program aimed at increasing nitrogen fixation by chickpea.

References

Gaur, Y. D., and Sen, A. N. 1979. Cross inoculation group specificity in *Cicer–Rhizobium* symbiosis. New Phytologist 83: 745–754.

Raju, M. S. 1936. Studies on the bacterial plant groups of cowpea, *Cicer* and dhaincha. I. Classification. Zentralblatt fur Bakteriologie, Parasitekunde, Infection — Skrankheiten and Hygiene, Abteilung II, 94–249.

Toomsan, B., Rupela, O. P., and Dart, P. J. 1980. Counting chickpea *Rhizobium* using a plant infection technique. Soil Biol (in press).

Session 5

Plant Protection

Chairman : D. C. Erwin
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Rapporteur: M. V. Reddy

Diseases of Chickpea

Y. L. Nene*

About 50 pathogens have so far been reported on chickpea from different parts of the world (Nene 1978). While some reports are mere records of occurrence, many diseases are widespread and a few are devastating. A survey of the literature reveals that only a few diseases have been investigated in detail (Nene et al. 1978). The objective of this paper is to summarize the present status of our knowledge of those diseases which cause losses every year and of those which have the potential to do so.

Fungal Diseases

Wilt Complex

History

Chickpea wilt was first mentioned by Butler (1918). In 1923, McKerral, working in Burma, considered the disease to be soilborne. He sent specimens to India, which yielded *Fusarium* sp. Narasimhan in 1929 reported an association of *Fusarium* sp and *Rhizoctonia* sp with wilted plants. Later, Dastur (1935) found *Rhizoctonia bataticola* producing "wilted" plants, and he called the disease *Rhizoctonia* wilt. Although he isolated *Fusarium* from several wilted plants, Dastur could not produce the disease artificially. Since his description of symptoms (he did not look for vascular discoloration) and field pattern of incidence is almost identical to that of typical wilt caused by *Fusarium oxysporum* f sp *ciceri*, it is a mystery why he failed to prove pathogenicity of the *Fusarium* he isolated. He concluded that the wilt was due to physiological reasons and called it physiological wilt. In 1939, Prasad and Padwick published a detailed account of their studies and reported *Fusarium* sp to be the cause of chickpea wilt. The fungus was named later by Padwick (1940) as *F. orthoceras* var *ciceri.* Erwin (1958) reported *F. lateritium* f *ciceri* to be the cause and questioned the name *F. orthoceras* var *ciceri*. Following the classification of Snyder and Hanson (1940), Chattopadhyay and Sen Gupta (1967) renamed *F. orthoceras* var *ciceri* as *F. oxysporum* fsp *ciceri*. This change has been accepted by Booth (1971).

While some workers considered chickpea wilt to be caused by *Fusarium*, several workers were not convinced. In addition to other fungi reportedly found associated with wilt, high temperatures at the time of sowing and flowering, deficient soil moisture, and "bad soil" were considered to be the cause (Bedi and Pracer 1952; Anonymous 1953). The State of Punjab in India had a project on chickpea wilt from 1947 to 1954 (J. S. Chohan, personal communication), and it was concluded that soil and weather factors, not fungi, were the cause. It seems that the use of the term "wilt complex" began after all these investigations and any dead or dried chickpea plant was considered wilted due to the "wilt complex."

A report on virus-induced wilts in chickpea from Iran (Kaiser and Danesh 1971) further contributed to the confusion in India. In the literature we find the term "wilt" used loosely or root rots and even blights. So much confusion has existed since then, that it prompted Dr. H. K. Jain, now Director of the Indian Agricultural Research Institute, New Delhi, to organize a symposium in 1973 on "problems of wilt and breeding for wilt resistance in Bengal gram." Several Indian pathologists and breeders participated, and a part of one of the conclusions, reproduced below, pointed out the problem clearly:

> The participants concluded that considerable confusion exists with regard to the causation of the wilt disease of Bengal gram. Most workers have tended to emphasize a wide variety of factors including those of physiological, agronomical, environmental and pathological nature, which in one way or the other contribute to the development of

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wilt symptoms (Jain and Bahl 1974).

This was the status of the problem when we initiated our investigations at ICRISAT. It was clear that various causal agents were responsible for the drying of plants, and the foremost need was to understand the characteristic symptoms produced by each. Once the diagnosis of the cause based on host symptoms became possible, there would be no room for confusion.

I have gone into the details above mainly to ensure a proper understanding of the problem itself and the reason why we devoted considerable time to investigate the so-called "wilt complex." Although the term "wilt complex" has been used mainly in India, similar situations in some other chickpea growing countries have been noted.

ICRISAT Work

We initiated a project in 1974 to understand the "wilt complex." After many critical observations of symptoms, hundreds of isolations of fungi in pure cultures, pathogenicity tests, and visits to research stations and farmers' fields in India and other chickpea-growing countries, it was concluded that what has generally been referred to as the "wilt complex" is actually a number of distinct diagnosable diseases. In order to assist workers in identifying the main disorders of chickpea, a bulletin with colored plates has been prepared. An attempt to develop a key to diagnose the common, but confusing disorders has also been made.

I wish to make a special mention of chickpea stunt. I feel that this particular disease, which is observed at most places in India and also many other chickpea-growing countries, contributed in a major way to the confusion in diagnosis. Very frequently it is possible to isolate *Fusarium* spp from the root system of the stunt-affected plants, but no one could produce typical stunt symptoms with any *Fusarium*. It is pertinent to cite here the observations made by Prasad and Padwick (1939). They divided the wilt-affected plants into the following three groups on the basis of symptoms: Those in which (1) the first symptom was drooping of the upper leaves followed soon by the lower leaves, the plants withered and died within about a week; (2) the leaves gradually turned yellow and then began to drop, the remaining leaves rapidly withering and the plant dying; and (3) the leaves became red. In the later stages these plants resembled those of group (2).

Whereas the symptoms of the first group above are of typical wilt (*Fusarium oxysporum* f sp *ciceri*), the symptoms in the second group can also be of wilt in certain genotypes. The symptoms of the third group, however, are never seen in wilt, and I feel certain that those are symptoms of stunt. Further, Prasad and Padwick (1939) mentioned phloem browning as a symptom of wilt, but in the results of their pathogenicity tests they did not mention red leaves nor phloem browning. Obviously they were unable to produce those symptoms through inoculations with *Fusarium*. It seems, therefore, that chickpea stunt was present but not identified earlier and was confusing to workers.

Wilt (*Fusarium oxysporum* f sp *ciceri*)

The disease has been reported in Burma, India, Mexico, Pakistan, Peru, and the United States (Nene 1978). From several other countries *Fusarium* spp have been reported, and it is possible that the vascular wilt exists in those countries too. No precise information on losses caused by this disease is available from any country. According to a rough estimate, about 10% loss in yield due to wilt was considered to be a regular feature in chickpea-growing states of India (Singh and Dahiya 1973). At ICRISAT, we made attempts to estimate loss in yield on a per plant basis. We found that earlier wilting caused more loss than late wilting, although the latter also resulted in substantial loss. Seeds harvested from wilted plants were lighter, rougher (wrinkled surface), and duller in color than were healthy ones (Haware and Nene unpublished).

Typical symptoms of wilt are (1) sudden drooping of leaves and petioles (some genotypes die gradually); (2) no external rotting of roots; and (3) black internal discoloration involving xylem and the pith.

The fungus is soilborne and survives through chlamydospores in seeds and in dead plant debris in the soil. The primary infection is through chlamydospores or mycelia. Optimum temperature for the fungus and for infection is around 25°C. Alkaline soils seem to favor the wilt. As far as we know, the fungus attacks *Cicer* spp only.

The seedborne inoculum can be eradicated by seed dressing with Benlate T (benomyl 30% + thiram 30%) at 0.15% rate (Haware et al. 1978). A massive screening program for wilt resistance is being carried out at ICRISAT. Both laboratory- and field-screening procedures have been developed and standardized. The following lines have been identified as resistant: ICC-202, -391, -658, -858, -1443, -1450, -1611, -3439, -4552, NEC-790, WR-315, CPS-1, JG-74, and BG-212.

Evidence indicating the presence of physiologic races of the fungus in India has also been obtained (Haware and Nene unpublished).

Dry Root Rot (*Rhizoctonia bataticola*)

The disease has been reported in Australia, Ethiopia, India, Iran, and the United States (Nene 1978). It has also been seen in Lebanon, Syria, and Turkey. It is relatively more serious in central and southern India where the crop gets caught in higher ambient temperatures (around 30°C) in the postflowering stage.

Symptoms are (1) dry root rot, making the roots brittle; (2) sudden drying of the plant without drooping of leaves and petioles; and (3) presence of ash-colored mycelium and sclerotia in the pith cavity in the collar region.

The fungus survives as sclerotia in the soil, and the primary infection is by sclerotia. Low soil moisture and temperatures between 25° and 35°C are favorable. Vertisols seem to favor the disease more than Alfisols.

No specific source of resistance is known. Since the fungus can attack a large number of crops, rotation will not help in reducing the disease incidence.

Root Rot (*Rhizoctonia solani*)

The disease has been reported in Argentina, India, Iran, and the United States (Nene 1978), but it has not been considered serious. Most of the incidence is in the seedling stage when soil moisture content is usually high. In irrigated chickpea the disease may occur at any time. I have seen this disease more frequently in chickpea planted after the harvest of paddy when the soil moisture content is high. Typical symptoms include root rotting with discoloration extending above the ground level and gradual yellowing and wilting of plants. The fungus survives as sclerotia and as mycelium in colonized organic matter, and these propagules are responsible for primary infection. The disease occurs in a temperature range of 18–30°C, in a soil moisture range of 30–80%, and at high nitrogen levels. Avoiding high fertility should reduce the disease. No specific source of resistance is known.

Collar Rot (*Sclerotium rolfsii*)

Although the disease has been recorded in Ethiopia, India, and Syria (Nene 1978), it is logical to assume that it exists elsewhere because of the presence of this fungus in almost all tropical and subtropical countries. Incidence is associated with high soil moisture content, presence of undecomposed organic matter near the soil surface, low soil pH, and temperatures of 28–30°C. It is normally a problem in the seedling stage, but in irrigated crops the disease can occur at any stage provided temperatures are not low. Chickpea following paddy shows more incidence. Fungus sclerotia and colonized organic matter serve as the primary inoculum. Our multiple-disease sick plot at ICRISAT shows some incidence of collar rot every year. Resistance to *Sclerotium rolfsii* is difficult to obtain.

Stem Rot (*Sclerotinia sclerotiorum*)

The disease has been reported in Australia, Chile, India, and Iran (Nene 1978). The problem is more serious where cool weather, relatively more rain leading to more vegetative growth than normal, and heavy dew, occur. The disease causes substantial damage if the crop canopy is thick. No attempt to identify resistance to this disease has so far been made.

Foot Rot (*Operculella padwickii*)

Kheswalla (1941) described this disease first from Punjab and Delhi in northern India. Although the fungus has been isolated from several locations in central and northern India, the disease seems to be location specific. At Gurdaspur in northern India, this fungus is the dominant one in the sick plot. We feel wet soil is conducive to this disease. From Gurdaspur, Singh and Bedi (1975) reported that G-543 is a resistant cultivar and F-61 is moderately resistant.

This fungus has been reported only from India.

Root Rot (*Fusarium solani*)

Kraft (1969) first reported that *F. solani* f sp *phaseoli* can infect chickpea. Westerlund et al. (1974) reported it to be one of the root-rotting fungi of chickpea in California. The same year Grewal et al. (1974) reported it from northern India. Although the fungus has been isolated from diseased chickpea plants from different areas of India, it is restricted mainly to northern India. The chickpea plots at New Delhi usually show more incidence of *F. solani*, and screening against this pathogen should be possible there.

No specific resistance sources have yet been identified.

Ascochyta Blight (*Ascochyta rabiei*/ *Phyllosticta rabiei*)

The disease has been reported in North America, southern Europe, North and East Africa, West Asia, southern Russia, and the Indian subcontinent (Nene 1978). The earliest report of its occurrence is from the "North-West Frontier Province" of India (now in Pakistan) where it was observed in 1911 (Butler 1918).

The disease causes heavy losses fairly frequently. All the green parts of the plant are attacked. Dark lesions appear on the stems and leaves first and then on pods. Oval or elongated lesions are produced on the stem, and round lesions occur on leaves and pods. When well developed, the margin of the lesion is dark brown and the center is light brown and full of small pycnidia of the fungus. In severe cases, lesions surround the stem, causing blighting of the parts above. As the stems are frequently attacked near the ground level, death of whole plants is common. The young shoots are also prone to infection, and the infection may spread from top to bottom in a plant. Developing seeds are infected and may show lesions.

As far as I know, this fungus attacks *Cicer* spp only. The fungus survives in infected seed and may also survive in dead plant debris. Dead plant debris, if buried more than 5 cm in moist soil, may not serve as a source of primary infection (Luthra et al. 1935). Kaiser (1973) found that the fungus survived over 2 years in naturally infected tissue at 10–35°C, provided the relative humidity was between 0–3%, an unlikely situation under natural conditions. Infected seed is the main source of primary infection. Kaiser (1972) isolated the fungus from infected seed which had been stored for more than 117 weeks at Safiabad (Iran) under summer temperature exceeding 45°C. The secondary spread of the fungus is through spores produced in pycnidia. Under prolonged wet and windy spells with temperatures around 20°C, the fungus spreads rapidly, causing mass mortality and epidemics.

While Luthra et al. (1939) did not find evidence of the existence of physiologic races, Bedi and Aujla (1969) reported 11 races, and Satya Vir and Grewal (1974b) reported 2 races (races 1 and 2) and 1 biotype of race 2.

Control measures suggested are (1) seed treatment with benomyl (Kaiser et al. 1973), organomercurials (Askerov 1968), thiram (Khachatryan 1961), or pimaricin (Zachos et al. 1963); (2) foliar sprays with Bordeaux mixture (Kovachevski 1936), zineb (Solel and Kostrinski 1964), or captan (Satya Vir and Grewal 1974a); (3) removing infected plant debris or burying it deep in soil (Luthra et al. 1935); (4) obtaining seed from disease-free areas (Luthra et al. 1935); and (5) planting resistant varieties. A review of the literature reveals reports of several "resistant" cultivars. With the annual operation of the International Chickpea *Ascochyta* Blight Nursery, it should be possible to identify stable sources of resistance.

Other Blights

Two blight diseases that occasionally cause serious losses are *Botrytis* gray mould (*Botrytis cinerea*) and the *Stemphylium* blight (*Stemphylium sarciniforme*). The former has been reported in Argentina, Australia, Colombia, and India, and the latter in India, Iran, and Syria (Nene 1978; K. B. Singh, personal communication). Prolonged cool and wet spells are favorable for the incidence of these two blights. Both the pathogens are present worldwide and have a wide host range. *Stemphylium* survives on seed and on infected plant debris and *Botrytis* on infected plant debris. Conidia (spores) of these two fungi are responsible for the disease spread. No information on control measures is available, except that kabuli types are generally less susceptible than desi to the *Botrytis* gray mould.

Another blight called *Colletotrichum* stem blight (*Colletotrichum capsici*) has been reported from India (Ramakrishnan 1947) on a chickpea crop raised during a relatively warmer season. At ICRISAT Center we have observed it in August-September plantings, but not in October plantings (October is cooler).

Rust (*Uromyces ciceris-arietini*)

Since weather conditions favorable for the occurrence of rust are similar to those for *Ascochyta* blight, rust has been reported from many of those countries where blight is a problem. Among the foliar diseases, rust can be considered as the second most widespread disease after *Ascochyta* blight.

Rust appears first chiefly on the leaves as small, round or oval, chinnamon-brown, powdery pustules. These pustules tend to coalesce. Sometimes a ring of small pustules can be seen around a larger pustule. Pustules occur on both surfaces but more frequently on the lower surface. Occasionally, pustules can be seen on stems and pods. Severely infected plants may dry prematurely. The complete life cycle of the fungus is not known; only uredial and telial stages are seen on chickpea. The telial stage cannot survive in hot weather. It is possible that a weed, *Trigonella polycerata*, which grows in hills up to 6000 feet and which is attacked by the uredospores of the chickpea rust, serves as a reservoir of the rust fungus (Payak 1962; Saksena and Prasada 1956). Bahadur and Sinha (1970) have suggested the possibility of the existence of physiologic races.

No control measures are known. Gallegos et al. (1965) were unsuccessful in controlling rust with foliar sprays with fungicides. Cultivar IP-82, susceptible in the seedling stage, was only mildly attacked in the adult stage (Mehta and Mundkur 1946).

Mildews

Downy and powdery mildew have both been reported on chickpea. Downy mildew caused by *Peronospora* sp has been reported in Israel and Mexico (Nene 1978; Jose Cosme Guerrero-Ruiz, personal communication). Powdery mildew caused by *Erysiphe* sp has been reported in Iran, and another mildew caused by *Oidiopsis taurica* has been reported in India, Pakistan, and Sudan. In Mexico, downy mildew has been reported to be serious in certain areas; powdery mildews are not considered to be important. Work carried out at ICRISAT has revealed that the powdery mildew (*Oidiopsis taurica*) is not seedborne (Haware and Nene unpublished).

Viral Mycoplasmal Diseases

Stunt

The disease was reported by Nene and Reddy in 1976. The virus has not yet been identified, but preliminary findings indicate that it may be the pea leaf roll virus (PLRV). If the identity of the virus is confirmed as PLRV, then I would say that the stunt was first reported on chickpea by Kaiser and Danesh (1971) from Iran. The disease has been observed in India, Ethiopia, Iran, Lebanon, Pakistan, Sudan, Syria, and Turkey (Nene 1978). PLRV has been reported from Iran and New Zealand. Although the disease incidence is generally less than 5%, I have occasionally come across farmers' fields with 50–90% incidence.

The characteristic symptoms are stunting, yellowing or browning (yellowing in kabuli and browning in desi cultivars), proliferation, and phloem browning, particularly in the collar region.

The virus is transmitted by several aphid species. Mechanical transmission has not been successful. It has a wide host range and therefore one would expect spread to chickpea from other hosts through viruliferous aphids.

No control measures are known. We have initiated a resistance screening program at Hissar in northern India, taking advantage of the high natural incidence of the disease. We have identified over 20 promising lines.

Phyllody

The disease has been reported only from India. Vasudeva and Sahambi (1957) reported that the sesame phyllody causal agent could be transmitted to chickpea. Venkataraman (1959) subsequently reported natural occurrence of phyllody. *Orosius albicinctus*, the vector of sesame phyllody was considered to be the vector for chickpea phyllody (Kandaswamy and Natarajan 1974). The disease is seen in farmers' fields but never showed more than 1% infection. The disease is possibly caused by a mycoplasma.

Other Viruses

Other viruses, including the alfalfa mosaic virus (India, Iran, and the United States), bean yellow mosaic virus (Iran, and the United States), cucumber mosaic virus (Colombia, Iran, and Russia), lettuce necrotic yellow virus (Australia), and pea enation mosaic virus (United States) have been reported on chickpea (Nene 1978). None of them can be considered serious at present. At ICRISAT, we have established that the mosaic of chickpea, which we observe in Hyderabad, is caused by the alfalfa mosaic virus.

Bacterial Diseases

Seedling Rot/Blight

This disease caused by *Xanthomonas cassiae* has been reported only from India (Ranagaswamy and Prasad 1960). Normally it is not a problem, but if chickpea is planted early when temperatures are higher, like *Colletotrichum* blight, this disease can cause substantial damage.

Nematode Diseases

Root-Knot Nematodes (*Meloidogyne incognita* and *M. javanica*)

Root-knot has been reported only from India (Ahmad Jamal 1976), where the problem has been seen mainly in irrigated chickpea. More incidence has been noted in northern India. The symptoms are stunting and yellowing with galls on roots. Roots become black.

Although the disease has been reported only from India, there is no reason why it must not be prevalent in other chickpea-growing areas, particularly where the crop is irrigated.

At Ludhiana in India, a good nematode-infested plot exists, and this offers an excellent opportunity to screen for resistance.

Other Nematodes

Besides the root-knot nematode, eight species belonging to 6 plant parasitic nematode genera have been found associated with the root system of chickpea. All these have been reported from India and none are considered serious at present.

References

AHMAD JAMAL. 1976. Studies on the relationship between *Meloidogyne incognita* and behavior of *Cicer arietinum* roots. Current Science 45: 230–231.

ANONYMOUS. 1953. Gram wilt and its control. Indian Council of Agricultural Research, New Delhi, and Indian Farming 3: 7.

ASKEROV, I. B. 1968. Ascochytosis of chickpea (in Russian). Zashch. Rast., (Moscow) 13(3): 52–53.

BAHADUR, P., and SINHA, S. 1970. Physiologic specialization in *Uromyces ciceris-arietini*. Indian Phytopathology 23: 626–628.

BEDI, K. S., and PRACER, C. S. 1952. Gram wilt disease and its control in Punjab. Punjab Farmer 4: 296–301.

BEDI, P. S., and AUJLA, S. S. 1969. Variability in *Phyllosticta rabiei* (Pass.) Trott., the incitant of blight disease of gram. Journal of Research Punjab Agricultural University 6: 103–106.

BOOTH, C. 1971. The genus *Fusarium*. Commonwealth Mycological Institute, Kew (Surrey), England. 1–137 pp.

BUTLER, E. J. 1918. Fungi and disease in plants. M/s Bishen Singh Mahendra Pal Singh, New Connaught Place, Dehra Dun and M/s Periodical Experts, 42-D, Vivek Vihar, Delhi-32. 547 pp. (reprinted 1973).

CHATTOPADHYAY, S. B., and SEN GUPTA, P. K. 1967. Studies on wilt diseases of pulses. I. Variation and taxonomy of *Fusarium* species associated with wilt disease of pulses. Indian Journal of Mycological Research 5: 45–53.

DASTUR, J. F. 1935. Gram wilts in the Central Provinces. Agr. Livestock. India 5: 615–627.

ERWIN, D. C. 1958. *Fusarium lateritium* f *ciceri*, incitant of *Fusarium* wilt of *Cicer arietinum*. Phytopathology 48: 498–501.

GALLEGOS, H. M. L., REYNOSO, E. L., and ORTEGA, J. 1965. Observations on chickpea rust in Central Mexico. Phytopathology 55: 125.

GREWAL, J. S., PAL, M., and KULSHRESTHA, D. D. 1974. A new record of wilt of gram caused by *Fusarium solani*. Current Science 43: 767.

HAWARE, M. P., NENE, Y. L., and RAJESHWARI, R. 1978. Eradication of *Fusarium oxysporum* f sp *ciceri* transmitted in chickpea seed. Phytopathology 68: 1364–1367.

JAIN, H. K., and BAHL, P. N. 1974. Recommendations of symposium on gram wilt. Indian Journal of Genetics and Plant Breeding 34: 236–238.

KAISER, W. J., and DANESH, D. 1971. Etiology of virus-induced wilt of *Cicer arietinum* Phytopathology 61: 453–457.

KAISER, W. J. 1972. Occurrence of three fungal diseases of chickpea in Iran. FAO Plant Prot. Bull. 20: 74–78.

KAISER, W. J. 1973. Factors affecting growth, sporulation, pathogenicity, and survival of *Ascochyta rabiei*. Mycologia 65: 444–457.

KAISER, W. J., OKHOVAT, M., and MOSSAHEBI, G. H. 1973. Effect of seed treatment fungicides on control of *Ascochyta rabiei* in chickpea seed infected with the pathogen. Plant Disease Reporter 57: 742–746.

KANDASWAMY, T. K., and NATARAJAN, C. 1974. A note on phyllody disease on Bengal gram (*Cicer arietinum* L.). Madras Agricultural Journal 61: 1019–1020.

KHACHATRYAN, M. S. 1961. Seed transmission of ascochytosis infection in chickpea and the effectiveness of treatment (in Russian). Sbor. nauch. Trud. nauch. issled. Inst. Zemledel. Armyan S. S. R. 2: 147–155.

KHESWALLA, K. F. 1941. Foot rot of gram (*Cicer arietinum* L.) caused by *Operculella padwickii* nov gen nov sp. Indian Journal of Agricultural Science 11: 316–318.

KOVACHEVSKI, I. C. 1936. The blight of chickpea, *Mycosphaerella rabiei* n sp. (in Russian). Issued by Min. Agric. Nat. Domains, Sofia, 80 pp.

KRAFT, J. M. 1969. Chickpea, a new host of *Fusarium solani* f sp *pisi*. Plant Disease Reporter 53: 110–111.

LUTHRA, J. C., SATTAR, A., and BEDI, K. S. 1935. Life history of gram blight (*Ascochyta rabiei* [Pass.] Lab. = *Phyllosticta rabiei* [Pass.] Trot.) on gram (*Cicer arietinum* L.) and its control in the Punjab. Agr. Livestock. India 5: 489–498.

LUTHRA, J. C., SATTAR, A., and BEDI, K. S. 1939. Variation in *Ascochyta rabiei* (Pass.) Labr., the causal fugus of the blight of gram (*Cicer arietinum* L.). Indian Journal of Agricultural Science 9: 791–805.

MCKERRAL, A. 1923. A note on *Fusarium* wilt of gram in Burma and measures taken to combat it. Agr. J. India 28: 608–613.

MEHTA, P. R., and MUNDKUR, B. B. 1946. Some observations on the rust of gram (*Cicer arietinum* L.). Indian Journal of Agricultural Science 16: 186–192.

NARSIMHAN, R. 1929. A preliminary note on a *Fusarium* parasitic on Bengal gram (*Cicer arietinum*). Madras Agr. Dep. Year Book 1928: 5–11.

NENE, Y. L. 1978. A world list of pigeonpea (*Cajanus cajan* [L.] Millsp.) and chickpea (*Cicer arietinum* L.) pathogens. International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, India, Pulse Pathology Progress Rep. 3: 1–15.

NENE, Y. L., MENGISTU, A., SINCLAIR, J. B., and ROYSE, D. J. 1978. An annotated bibliography of chickpea diseases 1915–1976. International Crops Research Institute for the Semi-Arid Tropics, Hyderabad, India, Information Bull. No. 1: 1–43.

NENE, Y. L., and REDDY, M. V. 1976. Preliminary information on chickpea stunt. Tropical Grain Legume Bull. No. 5: 31–32.

PADWICK, G. W. 1940. The genus *Fusarium* III. A critical study of the fungus causing wilt of gram (*Cicer arietinum* L.) and of the related species of the subsection *Orthocera*, with special relation to the variability of key characteristics. Indian Journal of Agricultural Science 10: 241–284.

PAYAK, M. M. 1962. Natural occurrence of gram rust in uredial stage on *Trigonella polycerata* L. in Simla Hills. Curr. Sci. 31: 433–434.

PRASAD, N., and PADWICK, G. W. 1939. The genus *Fusarium* II. A species of *Fusarium* as a cause of wilt of gram (*Cicer arietinum* L.). Indian Journal of Agricultural Science 9: 371–380.

RAMAKRISHNAN, T. S. 1947. Studies in the genus *Colletotrichum*-III. Proceedings of the Indian Academy of Science Sect. B: 15–27.

Rangaswamy, G., and Prasad, N. N. 1960. A bacterial disease of *Cicer arietinum* L. Indian Phytopathology 12: 172–175.

Saksena, H. K., and Prasad, R. 1956. Studies in gram rust, *Uromyces ciceris-arietini* (Grogn.). Jacz. Indian Phytopath. 8: 94–98.

Satya Vir and Grewal, J. S. 1974a. Evaluation of fungicides for the control of gram blight. Indian Phytopathology 27: 641–643.

Satya Vir and Grewal, J. S. 1974b. Physiologic specialization in *Ascochyta rabiei* the causal organism of gram blight. Indian Phytopathology 27: 355–360.

Singh, G., and Bedi, P. S. 1975. The perpetuation of *Operculella padwickii*, the cause of foot blight (rot) of gram in the Punjab. Indian Phytopathology 28: 546–548.

Singh, K. B., and Dahiya. 1973. Breeding for wilt resistance in chickpea. Symposium on wilt problem and breeding for wilt resistance in Bengal gram. September 1973 at Indian Agr. Res. Inst., New Delhi, India, pp. 13–14 (Abstr.).

Snyder, W. C., and Hanson, H. N. 1940. The species concept in *Fusarium*. American Journal of Botany 27: 64–67.

Soel, Z., and Kostrinski, J. 1964. The control of *Ascochyta* anthracnose of chickpea. Phytopath. Mediterranea 3: 119–120.

Vasudeva, R. S., and Sahambi, H. S. 1957. Phyllody diseases transmitted by a species of *Deltocephalus* Burmeister. Pages 359–360 *in* Proc. IV International Congress of Crop Protection, Hamburg.

Venkataraman, K. 1959. Phyllody in Bengal gram. Madras Agricultural Journal 46: 97–98.

Westerlund, F. V. Jr., Campbell, R. N., and Kimble, K. A. 1974. Fungal root rots and wilt of chickpea in California. Phytopathology 64: 432–436.

Zachos, D. G., Panagopoulos, C. G., and Makris, S. A. 1963. Researches on the biology, epidemiology, and the control of anthracnose of chickpea (in French). Annls. Inst. Phytopath. Benaki, N. S., 5(2): 167–192.

Insect Pest Management on Chickpea

W. Reed, S. S. Lateef, and S. Sithanantham*

Integrated pest management is a fashionable phrase, but unlike most fashions it is unlikely to disappear or diminish in importance with time. It is a concept that is essential for the continuing progress of man's twin needs to produce more food while at the same time to avoid deterioration of the enviornment and ecosystem. The concept has been forced upon us largely as a consequence of the overuse of, and overdependence on, chemical pesticides since 1950. The ecological disasters following overdependence upon chemical pest control are well documented (Carson 1962; Apple and Smith 1976), and although they have on occasion been overemphasized to a point where the integrated pest-management movement has "acquired the impetus and characters of a religious revival" (Price Jones 1970), there can be few specialists in plant protection now who do not acknowledge that chemicals should be used to supplement cultural and other methods of pest control rather than to replace them.

Integrated pest management has been aptly described as the optimum mix of elements of pest-damage reduction and crop improvement that will give us the best returns, taking into account not only the economics and yield of the current crop but also the effects on the environment and on the future potential of the area. The approach does not preclude the use of chemicals; indeed, insecticides will have an increasingly important role in pest management, particularly in the semi-arid tropics. To date, the chemical pesticides are underutilized on most crops in countries such as India, and ecological disasters as a result of overuse of chemicals are not of immediate concern in most of our areas. Hopefully, however, we can learn from the mistakes elsewhere and develop pest management on crops such as chickpea to include chemical pesticide as one element within an optimum mix of other measures.

Survey of the Insect Problems on Chickpea

It is obvious, both from the literature and from our observations and those of others, that chickpea has remarkably few insect pest problems. The great exception is that of *Heliothis*, the larvae of which feed voraciously on the crop from the seedling stage to crop maturity. Throughout the Old World *H. armigera* is the major pest of chickpea, while in the Americas, *H. virescens* takes over the leading role. Further, *Heliothis* appears to be increasing as a problem on many crops in areas where agricultural production is being intensified.

ICRISAT's extensive surveys of the pest situation on chickpea in farmers' fields show that *Plusia* spp, *Spodoptera* spp, and *Agrotis* spp can be locally important lepidopteran pests and that termites and aphids are of concern in some localities. Birds and small mammals can also cause substantial loss in some localities. But *Heliothis* is undoubtedly the most damaging pest on the crop in most areas and in most years, so chickpea entomology research at ICRISAT is concentrating on this pest.

Insecticide Use

Our surveys in India have indicated that less than 20% of chickpea farmers use insecticides on their crops. Of those, many use insecticide dusts, and almost all use the persistent chemicals DDT, BHC, and endrin. A similar situation appears to hold in the chickpea-growing areas of the Middle East. Recommendations to use pesticides, such as endosulfan, that are less persistent and less harmful to the beneficial insect complex appear to be generally ignored. The reasons for this are very probably the relatively high cost of such pesticides and their restricted availability in the local markets. The relative costs of effective doses of DDT and endosulfan, expressed in kilograms of chickpea

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* Pulse Entomologists, ICRISAT.

per hectare, are illustrated in Figure 1. It can be seen there is a wide disparity in cost, which has not been reduced over the last few years. It is unlikely that many chickpea farmers will choose to pay three times as much to control *Heliothis* in response to concern about the environment or beneficial insects!

Preliminary results at ICRISAT indicate little, if any, net economic benefit from pesticide use even when severe *Heliothis* infestations are controlled, largely because of the marked compensation for early losses observed in the cultivars tested. Elsewhere, the observed returns from insecticide use have varied greatly. A benefit: cost ratio of at least 3:1 is probably needed before chickpea farmers should be encouraged to embark upon pesticide use, given the variable responses and attendent risks. All too often pesticides are obtained and used after much of the pest damage has been done. Use of pesticides on large larvae can be detrimental, killing more beneficial insects than *Heliothis*. Correct timing of pesticide use is essential if it is to be of value; the larvae should be controlled when they are in the early instars and before they have eaten their fill. Such timing will only be possible if pesticides and application equipment are readily available for use as soon as the eggs or small larvae are noticed in densities that will cause economic injury levels on the crop. This requires a level of preparedness, knowledge, and observation that is not available with most farmers, but may be supplied by local extension workers.

As chickpea is grown as a postrainy season crop in semi-arid areas, it is often difficult for the farmer to obtain water for spraying at the critical *Heliothis* attack period during and after flowering. Dusting is seldom as efficient as spraying, partly because it is difficult to distribute dusts evenly with cheap applicators. Developments in controlled-droplet application of insecticides at ultra-low volume may alleviate the application problems on this and other crops in the near future.

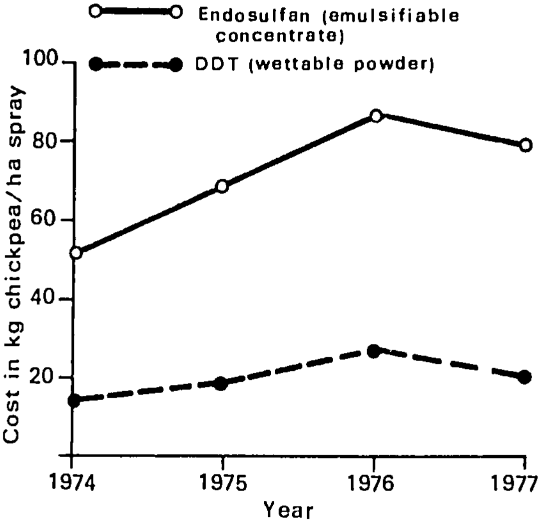

Figure 1. The costs of pesticides expressed in kilograms chickpea per hectare spray for the effective control of Heliothis armigera *in India.*

Resistant Plants

It is clear that most available chickpea cultivars are resistant to most potential insect pests. We must not be complacent about this situation, for we can undoubtedly breed more susceptible plants, if we continue to select and test under insecticide umbrellas on our research stations. At ICRISAT, we have embarked upon a project to select genotypes that are less susceptible to losses caused by insect pests, particularly *Heliothis armigera*.

In a preliminary trial we tested the effect of plot size on the evaluation of susceptibility to *Heliothis* among cultivars in open-field screening with natural infestations, with the results shown in Table 1.

The results from this trial were encouraging, for highly significant differences were recorded among cultivars, and the small plots appeared to be at least as efficient as the larger plots. In screening very large numbers of germplasm entries, however, we cannot afford the space, seed, and recording time required for adequate replication. In such tests, the major problem is uneven distribution of *Heliothis* infestations in space and time that allow chance escapes from damage. As an example of this, in 1976–77 we tested 8629 germplasm lines in unreplicated plots, of which 955 had no borer damage. However, the check cultivars, which were grown after each 20 plots of germplasm, gave higher proportions of borer-free samples (Table 2).

From these results, we concluded that the germplasm lines were generally more susceptible to *H. armigera* than were the well-adapted check cultivars, and that escape from attack by chance was likely to be a problem in unreplicated small-plot testing.

Analysis of the yields from this screening trial showed that the borer-free plots had produced less seed than the mean for the trial (Table 3). Observations during the green-pod period indicated greater *H. armigera* larval populations in the better grown areas. Thus, much of the escape from *H. armigera* was probably associated with relatively poor growth.

Subsequent testing of the borer-free germplasm entries in replicated trials in the

Table 1. Evaluation of plot size for testing the susceptibility of chickpea cultivars to *H. armigera*. Two trials were conducted, one with plot size 4.8 m², the other 20 m². Each was of randomized block design with 13 treatments and 4 replications, ICRISAT Center, 1976–77.

Cultivars	Mean percentage of pods damaged by *Heliothis* Small plots	 Large plots
L-345	3.0 (9.4)[a]	2.6 (7.6)
C-235	4.9 (12.7)	3.4 (10.2)
ICP-6037	4.9 (12.8)	6.6 (14.8)
RS-11	6.1 (14.4)	7.1 (14.8)
L-2937	7.0 (15.5)	6.9 (15.1)
BR-70	4.4 (11.9)	10.6 (18.6)
JGC-1	7.5 (15.7)	8.3 (16.3)
ICP-682	9.5 (17.7)	9.3 (16.0)
NP-34	12.0 (19.9)	8.1 (16.4)
NEC-143	13.3 (21.5)	11.0 (19.2)
Rabat	13.6 (21.9)	14.5 (21.6)
850-3/27	18.1 (25.2)	12.6 (20.3)
P-3090	19.2 (25.8)	16.6 (22.7)
SE	± 1.85	± 1.80
CV%	21.5	22.0

a. Numbers in parentheses are arcsin √%.

Table 2. Screening chickpea germplasm for susceptibility to *Heliothis armigera*. Plots found to be free from damage in harvested samples, ICRISAT Center, 1976–77.

	No. of entries harvested	No. without borer damage	% without borer damage
Germplasm lines	8629	955	11.1***
Check BEG-482	221	43	19.5*
Check C-235	219	61	27.9*

Differences significant at * p = 0.05, *** p = 0.001

Table 3. Screening chickpea germplasm for susceptibility to *Heliothis armigera*. Yield comparisons of all entries with the borer-free entries; ICRISAT Center, 1976–77.

	Single-plant mean yields (g) All entries	 Borer-free entries
Germplasm lines	6.7 (8629)[a]	3.5 (955)
Check BEG-482	7.5 (221)	4.8 (43)
Check C-235	6.4 (219)	4.7 (61)

a. Number in parentheses is number of entries screened.

1977–78 season showed that none was immune to *H. armigera* attack, but that some had relatively little damage in all replicates. There were substantial differences in susceptibility among the cultivars and comparisons of 2 years' results indicated that these differences were inherited.

So far, our attempts to utilize field cages and inoculation of trials with laboratory-bred *Heliothis* eggs and larvae have not been successful in obtaining even pest distributions that would enable us to improve on our open-field screening. In the absence of any better method, we are now rejecting cultivars that are clearly more susceptible and yield less than the relevant checks in our unreplicated tests within which the entries are grouped according to maturity. The others are carried forward to replicated testing; the greater the replication, the less the chance of escape. In cooperation with the breeders, we have already started a crossing program with some interesting lines thrown up by this testing. We have also started single-plant selection from within promising selections, with some early indications of possible success. Tests at ICRISAT and elsewhere have indicated that the kabuli types are generally more susceptible to *Heliothis* and some other pests than are the desi types. We have found substantial differences in susceptibility and tolerance to, and recovery from attacks by *Heliothis* within the available materials, particularly among desi cultivars.

Acid Exudate

One obvious factor that may be involved in the comparative resistance of chickpea to insect pests is the very acidic exudate (pH = 1.4). The acidic fraction has been reported to consist of 94.2% malic, 5.6% oxalic, and 0.2% acetic acids, (van der Maesen 1972). We are now studying the composition of exudates in cooperation with the Max Planck Institute for Biochemistry in Munich. Preliminary observations indicate that the concentration of the exudate varies from cultivar to cultivar. We are analyzing the acids and other contents of the exudates from more- and less-susceptible cultivars and are studying the effects of varied concentrations of exudates and malic acid upon *Heliothis* moths and larvae in laboratory tests.

Cultural Practices

Pest attacks can be modified by a variety of cultural practices. If it is known that *Heliothis* attacks are likely to be severe at a particular time, then it may be possible to adjust the sowing date or to utilize a cultivar of appropriate flowering and maturity timing to ensure that the flowering and podding stage does not coincide with the peak *Heliothis* attack period.

There is usually a pool of *Heliothis* in any area that may be supplemented or depleted by migration. By synchronous sowing of the crop in any area, the available pest population will be diluted by dispersion across the whole crop area. Early sown fields will probably act as magnets for the pests and may act as multiplication sites for a subsequent dispersal to the main crop. Late-sown crops may bear the brunt of the pest dispersal from the maturing main crop.

Poor plant stands are commonly said to be a major factor in the poor yields obtained from this crop by many farmers, but we have indications that close spacing harbors more *Heliothis* larvae per unit area (Table 4), so increased yields may be obtained only if the closer-spaced crop is protected by pesticide use. Thus, optimum spacing probably varies not only according to the cultivar used and to edaphic and climatic factors but also to the degree of pest control afforded.

Natural Enemies of *Heliothis*

Heliothis attacks on chickpea are generally accompanied by fairly heavy parasitism, particu-

Table 4. Counts of *Heliothis armigera* larvae and yields recorded from an unprotected spacing trial of chickpea. Four-replicate, randomized block design trial, ICRISAT, 1977–78.

	Spacing			
	Close	Medium	Wide	SE
Plants/m^2	33.0	8.3	2.8	
Mean no. *H. armigera*/m^2	15.3	5.5	4.2	±1.29
Yield (kg/ha)	396	626	645	±60.0

larly by the hymenopteran parasitoids. There appear to be relatively few arthropod predators within fields of this crop; perhaps they are deterred by the acid exudate. However, birds are not greatly discouraged, and several (often the mynahs and crows) are commonly seen enjoying a meal of *Heliothis* larvae in heavily infested fields. Unfortunately, the birds are not always beneficial, for some have been observed to feed on the seed from ripening pods.

We are looking at ways of augmenting the natural control of *Heliothis* on this crop. It may be possible to increase the native parasitoid populations by breeding in laboratories and inoculating the fields with booster populations early in each season. We are studying the possibility of introducing exotic parasitoids. A virus disease that kills *Heliothis* is one possibility for use on farmers' fields, but much more work on this is required.

Integrated Pest Management

Integrated pest management is unlikely to be a real success if applied only to an individual field or plot. There is a much greater chance of success if all fa·mres of the crop in an area coordinate in united action. Ideally the concept should apply not just to a single crop, but to all the crops in any area, particularly if the threat from a polyphagous pest such as *Heliothis* is to be reduced.

The timing of the differing crops and their juxtaposition should be considered in relation to pest buildup and dispersion. We do not yet have enough knowledge to design the ideal mix of pest-management factors and probably never will, for the pest complexes and timings will soon change to take maximum advantage of the changed systems. Nor can we pretend that the pests are of such overriding importance that agricultural systems should revolve around pest-management considerations! Pest-management planning in the distant future will undoubtedly be in the hands of specialists armed with a great deal of basic knowledge of the crop, its pests, their natural enemies, and computer simulations of the economics of management strategies. We cannot wait for such developments, and we have to suggest measures that we are confident will economically reduce pest losses now and not cause problems of pollution in the future.

The basic approach to any pest management system will undoubtedly involve group action along the following lines:

1. All farmers should sow synchronously at the optimum time and spacing.
2. All farmers should use a cultivar that is less susceptible to the problem pests.
3. If nonpolluting pesticides are known to be of undoubted economic value, then they should be applied as efficiently and as timely as possible, according to counts of eggs and young larvae.
4. The crop should be harvested as soon as it is ripe, and crop residues should either be removed or plowed in.
5. There should be a closed season during which the crop and, if feasible, the alternative hosts of the damaging pests are not grown in the area.

Additional measures, including attempts to augument natural control of the pests, can be incorporated into the system as our knowledge and expertise increase. We should not wait for the ideal; the sooner we start in farmers' fields, the faster we will make progress. We can pretend to look at integrated pest management in our research farm fields and computers, but we know that the only worthwhile testing and development will take place at the village level. When do we start?

References

Apple, J. L., and Smith, R. F. (ed.). 1976. Integrated Pest Management. Plenum Press, New York and London. 200 pp.

Carson, R. 1962. Silent Spring. Hamish Hamilton, London. 304 pp.

Price Jones, D. 1970. Applied biology as an evolutionary process. Annals of Applied Biology 66: 179–191.

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. Medelelingen Landbouwhogeschool, Wageningen, The Netherlands, 72–10, 342 pp.

Session 5 — Plant Protection

Discussion

Y. L. Nene Paper

M. C. Saxena

Colletotrichum blight has been suggested to appear in the early planted crops, when day temperatures are high. Is the loss of seedlings observed in early plantings in North India, to be attributed to this disease?

Y. L. Nene

I have never seen the blight caused by *Colletotrichum capsici* in northern India. I have seen it at Hyderabad and down south. In northern India, mortality in seedlings in early-sown crops is due to cutworms and collar rot by *Sclerotium rolfsii.*

Solomon Tuwafe

Concerning the rust sample from Ethiopia, I would like to know from what type of soil and time the sample was taken; our experience is that generally the incidence is observed on light, sandy soils, early planting, and with wider canopy spp. Do you think soil type, plant type, and type of planting would improve or control rust?

Y. L. Nene

The slide of the rust that I showed was taken at Arussi Negeli in Ethiopia. I do not remember the soil type over there. I also do not know if soil type influences any rust fungus. High humidity and cool temperatures are favorable for the rust. Early planting may lead to the situation where plants reach the rust-prone stage when the fungus inoculum and favorable weather are present.

S. Lal

Several diseases attacking chickea have been reported. It is a difficult task for the breeders to combine resistance into one genotype for several diseases. Are there genotypes possessing resistance to three or four diseases, so that the breeders' task of resistance breeding could become easier?

Y. L. Nene

I agree that it is difficult to combine resistance to several diseases in a genotype, but efforts must be made. In the field trip yesterday you saw good performance of several lines in the root rot/wilt nursery. When we identify lines promising to other diseases such as stunt or *Ascochyta* blight, we test them in the root rot/wilt nursery to see if some of these carry multiple disease resistance. International testing of lines against root rot/wilt is also a part of the same objective.

Geletu Bejiga

You said that *Ascochyta* inoculum can be stored for 2 years if the affected tissues are collected. For how long will it survive in the field planted to chickpea in previous cropping season and is it followed by a cereal crop?

Y. L. Nene

Ascochyta inoculum in infected tissues cannot survive until the next season if these tissues are buried 5 cm or deeper in the soil and if the soil becomes wet between the two chickpea seasons. However, if the infected tissues lie on the surface and go through a dry period until the next chickpea season, it is possible that the fungus will survive and serve as primary inoculum. If a cereal crop is planted in between the chickpea, I doubt that the *Ascochyta* inoculum will survive in the soil until the next season.

V. P. Gupta

To add to the information of Dr. Nene, we have screened 58 diverse germplasm lines representing more than 15 countries against *Ascochyta* blight and chickpea rust at Lahaul (12 000 ft above sea level) and we found that 1528-1-1 and E-100, which were free from blight, were also free from rust under field conditions.

Y. L. Nene

I appreciate the information given by you. We will make a note of it.

Reed et al. Paper

J. P. Yadavendra

1. In the western parts of India where early cultivars are cultivated, the incidence of *Heliothis* is very low. May I request Dr. Reed to give his opinion?
2. Do you have some information on whether or not *Prodenia* affects chickpea?

W. Reed

1. *Heliothis* populations are reduced by cold nights from December to February. Thus, early-maturing chickpeas may escape partially.
2. *Prodenia* is now called *Spodoptera litura* and is a major pest of tobacco and barbadense cotton. We have recorded a few small larvae thought to be of this species on chickpea, but it is not generally considered to be a pest of this crop.

A. R. Sheldrake

Is the earlier maturity of the insecticide-treated plots due to phytotoxicity? Have any experiments been done comparing insecticide-sprayed and unsprayed plants in the absence of insects, that is, with plants grown in mesh cages?

W. Reed

We have checked on the possibility of phytotoxicity in trials this year. The results from this trial are not yet at hand, but the indications are that phytotoxicity is not an important factor in the early maturity of the sprayed plots. Perhaps Dr. Sithanantham can comment further.

S. Sithanantham

We are looking into this possible superimposing effect of pesticide phytotoxicity this season, by keeping comparable plots in which *Heliothis* infestations are suppressed by mechanical removal of the insects. The trials are yet to come to harvest, and we don't feel that it will be a pesticide-toxicity effect. However, we should shortly be able to elucidate the role of factors leading to differences between sprayed and unsprayed crops at the end of this season.

S. Chandra

A reference was made yesterday to date of planting in reference to incidence and damage by *Heliothis armigera.* I was expecting to see some information on this aspect in Dr. Reed's paper. Could he give a comment on the extent of this relationship and its utilization in manipulation of chickpea cultivation?

W. Reed

This relationship is rather complex, with the winter in the north slowing down *Heliothis,* and the dry season in the south starving *Heliothis* where irrigated hosts are not available. We are looking at the annual incidence of this pest through light traps and surveys. We do not yet have sufficient reliable data to comment upon the effect in differing areas and with differing sowing dates.

Y. S. Tomer

What were the spacings under close, medium, and wide planting?

W. Reed

Spacings were 33, 8.3, and 2.8 plants per square meter, respectively.

E. J. Knights

From a very limited sample I have observed a relationship between *Heliothis* resistance and apparent pod thickness. Have you tried to relate pod thickness to resistance?

W. Reed

Yes, we have recently been looking at pod thickness and hardness. We are also looking at lines with a high proportion of pods where the outer layer of the pod wall is eaten by *Heliothis* larvae but the inner layer is not penetrated. Clearly, pod-wall characteristics play an important role in susceptibility, and we are in the early stages of evaluating these.

Ewert Aberg

During the field trip yesterday you stated that it would not be possible to obtain immunity to *Heliothis* if you also want a chickpea suitable for food. Your statement makes me ask: Did you refer to increased fiber content or to chemical substances as essential for hindering the insect but at the same time making the products unsuitable for food?

W. Reed

I was referring to the fact that *Heliothis* is polyphagous and that we would probably need chemical antibiosis to make plants immune to *Heliothis*: such chemicals would be most likely to render the chickpeas unpalatable to man! We are looking for any means of reducing susceptibility to *Heliothis* both in chickpea and pigeonpea. In pigeonpea relatives (*Atylosia*), some species are much less susceptible to *Heliothis* but are also inedible for man. We are looking at crosses of these with pigeonpea.

H. P. Saxena

1. I am in agreement with the speaker, Dr. Reed, that insecticides such as endosulfan and others with low toxic residues should be preferred and popularized over DDT which has long residual toxicity and now is known to cause the worst environmental pollution.
2. The difference in the cost of DDT and endosulfan spraying is not in the ratio of 1:3, and this point needs precise clarification.
3. A variety more susceptible to the pest may be kept as a check in the screening trial and not a variety which is resistant like C-235, as the former would attract the insects and there may be more uniform spread of the pest all over the field.
4. Study on acid exudate appears to be a good approach for determining the mechanism of resistance. Perhaps more entomologists, plant breeders, and biochemists would be necessary for developing insect-resistant cultivars.

W. Reed

1. We quoted the costs of 0.7 kg endosulfan and 1 kg a.i. DDT in our calculations.
2. We use C-235 as a check because it is less susceptible, and we are looking for cultivars even less susceptible. We do not think that infector rows of more susceptible cultivars would help in the even distribution of the pest.
3. I agree that a more intensive study of the exudate and other chemicals in the chickpea plant may pay dividends in our understanding of the relative susceptibility of plants. We would welcome further cooperation in this.

D. F. Beech

I would like to pass a comment on the problem of *Heliothis* experienced in Australia. In growing cotton using the ratoon method, we had a carryover of *Heliothis* pupae. The broadbed method is being used by the Land Systems Groups to grow chickpeas on a zero-tillage basis, which will be adding to the increase of *Heliothis* populations. Will this *Heliothis* population be monitored?

W. Reed

We are monitoring *Heliothis* across ICRISAT fields, but we have not yet looked at the pupal survival in the minimum-tillage fields. This could be an important point, and we will look into it.

H. P. Saxena

Early-sown crops attract insects, and we find more caterpillars in these crops. The pest builds up and again we find a late-maturing crop being damaged more severely by the gram caterpillar.

B. M. Sharma

Cutworm is quite a serious pest and results in serious losses to plant stand in initial stages. The usual recommendation is to treat the soil with dust formulations of some insecticide. In some parts of India, seed treatment with aldrin at 150 to 160 kg per liter is being adopted by the farmers and provides quite satisfactory control.

W. Reed

"There are several species of Lepidopteran larvae known as cutworms; of these the *Agrotis* spp are known to be locally important in some areas of northcentral India.

The use of concentrated aldrin on seed sounds very dangerous. It might well be effective, provided phytotoxicity does not occur. I would not like to commend such a practice however!

Session 6

Chickpea Breeding at the National Level

Chairman : G. Ladizinsky
Co-Chairman: M. C. Saxena

Rapporteur: K. B. Singh

India accounts for more than 80% (8.5 million ha) of the world's chickpea-growing area (10.5 million ha). Another 10% of chickpea is grown elsewhere in Asia (Pakistan, Burma, and Bangladesh). The remaining 10% is largely distributed in Ethiopia, Mexico, Spain, Morocco, Turkey, and Iran.

For the most part, cultivars with small- to medium-sized (12–20 g/100 seed), brown, wrinkled seed, which are adapted to marginal growing conditions, are planted. Average yields over the past two decades have fluctuated between 550 and 650 kg/ha. Grains that may have accrued as a result of availability of better seed, application of phosphate, one or two irrigations per season, and use of pesticides for control of *Heliothis*, have been offset by moving the crop to less favorable production areas when it was displaced by high-yielding wheat cultivars in expanded irrigated areas of northern India.

Though some of the well-adapted land races and improved cultivars developed during the last decade yield up to 1500 to 2000 kg/ha, even under rainfed conditions, these yield levels could not be translated to a substantial increase in average productivity.

These yield levels were not stable over the years even at a given location. So it became clear that, besides striving for high yield levels, stability of production was an important consideration in chickpea-improvement programs. With the potential yielding capacity of existing improved cultivars (1500–3000 kg/ha), it should be possible to raise and stabilize average yields from 700–800 kg/ha to 1000 kg/ha in northern India and from 300–500 kg/ha to 700 or 800 kg/ha in southern India by managing the yield-reducing factors. Some of the more important factors contributing to instability in yields are given below.

Plant Stand. Early seedling mortalities caused by *Sclerotium, Rhizoctonia*, and *Fusarium*; prevailing high temperatures at sowing time; and lack or excess of moisture at sowing time. These factors, combined or individually, cause considerable reduction in plant stand each year in some regions or in individual fields in all the chickpea-growing regions.

Soil and Weather Factors. Poor or marginal soil fertility; salinity or alkalinity; undulating topography; variable rhizobial population; moisture stress or excess of soil moisture; and frost damage.

Diseases and Pests. Wilts, blight, *Heliothis*, cutworm, and nematodes.

Cultivars tolerant or resistant to some of the unstabilizing factors, capable of still higher yields under rainfed and irrigated conditions, and responsive to phosphatic nutrition are major targets of the all India chickpea-improvement programs. With these objectives, the All India Coordinated Pulse Improvement Project (AICPIP) has developed multidisciplinary research programs for chickpea improvement.

In order to rationally discuss the programs and achievements in chickpea improvement work, it will be necessary to understand the organization and infrastructure developed and being further developed under AICPIP.

Organization of All India Coordinated Chickpea Improvement Programs

The All India Coordinated Pulse Improvement

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Project was launched in 1966–67 with the mandate to strengthen and stimulate pulse crop improvement programs in the country. Seventy-five percent of the recurring cost and all nonrecurring costs are met by the Indian Council of Agricultural Research; the remainder is met by the respective agricultural universities. The Project direction and coordination center is located at Kanpur; 15 main centers and 13 subcenters (including off-season nurseries) are located at various agricultural universities throughout India. Recently, certain centers have been designated to conduct strengthened improvement programs for a specific pulse crop; this step is to save dilution of resources and efforts caused by handling too many crops simultaneously. Chickpea-improvement work is being strengthened at a few centers, keeping in view the agroclimatic coverage and work already developed. Based on broad agroclimatic considerations and specific problems of cultivation found in each, six major zones of chickpea cultivation can be identified. Brief descriptions of growing conditions, agroclimatic variations, and location of chickpea improvement centers are presented in Table 1.

At each of the research centers, a team of scientists in the disciplines of breeding, agronomy, entomology, pathology, and microbiology operate a multidisciplinary program of chickpea improvement. The objectives of improvement, however, depend on the problems specific to the region with that of overall yield gains.

Programs and Achievements

Varietal improvement of chickpea, along with other pulse crops, was initiated in some Indian states in the early to mid-1940s through several short-term, ad hoc schemes financed by ICAR. Most of these terminated by the mid-1950s. During this period, land races were collected in each region where a research center was located, then through single-plant selections or limited biparental crosses, several lines were identified and released as improved varieties. During the mid-1950s to mid-1960s, the pulse improvement program was almost at a standstill. It got a fresh impetus in the mid-sixties with the launching of AICPIP. Improved varieties developed before the launching of the coordinated project are listed in Table 2. Since these varieties had been tested within the respective state boundaries during the first phase of the coordinated project, this elite material from different states was pooled and tested throughout the country in multilocation, uniform, coordinated varietal tests. Realizing that much of earlier improvement work depended on selections from locally adapted land races or hybridization between elite selections, a large collection of intraspecific variability was made. By 1968, more than 6500 accessions (including more than 4500 exotics) representing 21 countries were available and distributed to several of the Indian centers for evaluation and utilization in improvement programs. The programs were recently strengthened by exchange of material and information with ICRISAT.

Varietal Improvement since 1969

The uniform coordinated trials for improved strains in new areas of adaptation revealed wide adaptability in some of them. C-235 and T-3 proved to be significantly superior to the prevalent cultivars in the northern and parts of the central belt, and Annigeri-1 and Chafa were superior in parts of the central and peninsular belts. These cultivars are by far the choicest genotypes, even though two decades have passed since their development. C-235 and T-3 in the northern zone and Annigeri-1 and Chafa in the southern zone were used as check entries during the first 5 years of uniform testing.

Then appeared the new crop of genotypes, which were an improvement in yield and adaptability over the checks. They were Hima, H-355, and H-208 from Hissar (Haryana); L-550, L-345, G-130, and G-543 from Punjab; K-468 and K-850 from Kanpur (Uttar Pradesh); Pant G-110, Pant G-114, and Pant G-115 from Pantnagar; JG-62, JG-221, and JG-74 from Jabalpur (Madhya Pradesh); BDN 9-3 from Badnapur (Maharashtra); and BG-200 and BG-203 from IARI, New Delhi. On the basis of their performance at individual locations for 3–4 years, these cultivars were identified for release in specific areas of adaptation. On the basis of their mean performance over several locations and years, they were identified for broader agroclimatic zones.

Table 1. Agroclimatic zones of the major chickpea cultivation and improvement centers in India.

Zone	States covered	Chickpea area covered (%)	Characteristic features of the zone	Research centers in the region	Proposed testing centers to cover agroclimatic variations
Northwest plains	Western Rajasthan; southern Punjab; western Haryana	20–25	Arid to semiarid; light, sandy loam soils; severe winters; rainfall less than 100 cm; moisture stress; response to irrigation; salinity/alkalinity; blight, wilt, cutworm, *Heliothis*, nematodes.	Hissar, Ludhiana; Durgapur	Sriganganagar, Ambala; Faridkot; Gurdaspur
North central plains	Delhi; parts of Punjab; Haryana; North and Central Uttar Pradesh; North Madhya Pradesh	20–25	Fertile alluvial soils; rainfall 100 cm or more; severe winter; September rains uncertain; variable sowing temperature and moisture; wilt, *Heliothis*.	N. Delhi; Kanpur; Pantnagar	Etawah; Gwalior; Rewa
Bundelkhand highlands	Parts of Uttar Pradesh and Madhya Pradesh	15–20	Shallow to medium; black soils to skeletal soils; undulating topography; low fertility; kharif fallows; rainfall adequate; moisture stress; sowing temperature and moisture variability; early cessation of winters; wilt, *Heliothis*.	None; proposed in Jhansi	Chattarpur; Banda
Central plateau and plains	Parts of Madhya Pradesh; adjoining areas of Maharashtra, Gujarat, and Rajasthan	15–20	Highly variable, deep black to shallow black to skeletal soils; rainfall 100–150 cm; sowing temperature and moisture variable; kharif (rainy season) fallows; root rots, wilts, *Heliothis*, cutworm; pink-seeded types grown in some pockets.	Jabalpur; Rahuri (proposed); Junagadh	Vidisha; Khandwa; Durg; Chhindwara; Indore; Mandsaur; Dohad; Osmanabad
Eastern area	Eastern Uttar Pradesh; Bihar; West Bengal	5–10	Moderate winters; adequate moisture; grown on rice fields; variable symbiosis; wilt, *Heliothis*.	None; (strengthen at Sabour)	Varanasi; Berhampore; Dholi; Faizabad
Peninsular	Parts of Maharashtra, Karnataka, Andhra Pradesh, and Tamil Nadu	5–10	Mild winters; short growing season; moisture stress; medium to shallow black soils; wilt, *Heliothis*.	Gulbarga	Bidar; Guntur; Ananthapur; Adilabad; Raichur; Coimbatore

Thus, within less than a decade, the chickpea improvement work of the All India Coordinated Project led to the development and identification of several genotypes superior by 10–15% in yield and more widely adaptable than the best available checks. Performance of some of the recently developed cultivars is presented in Tables 3 and 4. Chickpea breeders

Table 2. Improved chickpea cultivars developed before 1969.

State	Cultivars
Punjab (including present Haryana and Himachal Pradesh)	S 26, G 24, C 235, C 104
Gujarat	Dohad yellow, Dohad 206-8 Dohad 1597-2-1
Rajasthan	RS 10, RS 11
Uttar Pradesh	T 1, T 2, T 3, T 87, K 4, K 5, Radhey
Madhya Bharat	Adt.V, No.10, EB 28 (Dacca),
C.P. and Berar	Warangal, A-1-8, D8, Gwalior 2 Ujjain 21, Ujjain 24 Ujjain Pink 2
Maharashtra	Chafa, N 29, N 30, N 59, N 68, N 74
Madras	Co. 1
Mysore	Kadale 2, Kadale 3, Annigeri-1
West Bengal	B 75, B 98, B 108, B 110

have more material in the pipeline, some was tested in multilocation tests during the 1977 growing season in all India initial evaluation tests and showed promise of further yield improvement and a fair amount of broader adaptability within a zone. The mean of over 15 locations spread over all the zones when compared with common check cv H-208 point out the following lines:

	Seed yield (kg/ha)	100-seed weight (g)
H-208	2180	13.3
GNG-16	2280	14.7
GG-549	2310	14.5
ICC-4	2390	15.9
BG-216	2390	12.9
H-76-49	2410	12.4

Pedigree selection of plants and progenies from single, intervarietal crosses among parents chosen on the basis of performance, and in some cases on combining ability, has been the more common method of improvement.

Seed Size and Quality

Even though the bulk of the land races and improved desi (brown to darkbrown, wrinkled seeds) types in the major North Indian chickpea-growing belt have smaller seed size (10–15 g/100-seed weight), a price premium for bolder seed size is often obtained. Observations have shown that yield gains and a seed size range of 18–20 g/100 seeds could be well combined. Further increase in seed size leads to reduction in yield. The seed size range of 18–20 g/100 seeds with higher yields had been successfully combined in cv T-3 and cv Radhey bred in the northern alluvial belt. In none of the new material has this optimum range of seed size and higher yields been successfully combined, particularly in late northern zone types. K-850 does have bolder seed, but would not compete in yield with small-seeded types, such as H-208, BG-203, and Pant-114.

It appears that seed size of 18–20 g/100 seeds should be acceptable and optimum for combining higher yield levels and stability, though present high-yielding material is below this range. In peninsular commercial types, however, seed size range is between 14 and 18 g/100 seeds, but yield levels are low in the shorter growing season. Seed color in desi types also has some bearing on local preferences. For instance, the yellowish color referred to as "Malida" in central and western India fetches a somewhat better price. However, in selecting for yield, this factor had not been considered. Brown-seeded desi types are more widely consumed as "besan" (ground flour) rather than "split pulse." The parameters for flour quality have not been considered in improvement programs, nor has protein content. However, the percentage of protein content in improved types remained the same as that of check entries (18–20%).

Kabuli (white, bold, round-seeded), gulabi (pink, round-seeded), and green-seeded types are referred to as culinary types and used as whole seed in curries (kabuli and green) and as puffed or parched grains (pink types). Improvement work for kabuli types is being strengthened at Ludhiana and for pink types at Jabalpur. Yield improvements over cv L-550 (kabuli) and JG-5 (pink) are being worked on at Ludhiana and Jabalpur, respectively. The parameters to be used for selecting for quality in these types will be worked out at these centers. High ascorbic acid content has been reported in green- and black-seeded types; pink-seeded types have less ascorbic acid con-

Table 3. Mean yield (kg/ha) of recently developed chickpea cultivars in multilocation uniform cooperative tests.

Cultivar	1975–76 (12 locations)	1976–77 (13 locations)	1977–78 (11 locations)	Mean
North plains (west zone)				
Pant G-114[a]	2940	2730	1940	2530
Pant G-115[a]	2880	2650	1890	2470
BG-203	2510	2630	1330	2320
H-208 (check)	2510	2580	1610	2230
	1975–76 (3–5 locations)	1976–77 (6–8 locations)	1977–78 (7 locations)	Mean
North plains (east zone)				
Pant G-114	2370	2380	2250	2330
Pang G-115	2530	2380	2190	2360
BG-203	1780	2720	1970	2150
K-468	1990	2560	2060	2200
RSG-2		2830	1710	
H-208 (check)	1740	2010	1820	1850
	1975–76 (7 locations)	1976–77 (5 locations)	1977–78 (6–7 locations)	Mean
Central zone				
K-468	1730	1350	1260	1440
BG-200	1830	1390	1140	1450
BG-203	1580	1320	1280	1390
JG-221	1590	1080	1180	1280
H-208 (check)	1460	1320	1140	1300
	1975–76	1976–77	1977–78	Mean
Peninsular zone				
JG-62	1570	1300	1590	1480
Annigeri-1 (check)	1490	1750	1520	1580
9–3	1350	1490	1740	1520
JG-221	1400	1670	1500	1520

a. 4–5 locations only.

tent. The yield improvement, while retaining culinary characteristics, will continue to be a major breeding objective. These types have relativelv more susceptibility to soft seed rots, seedling rot and collar rots, *Fusarium* wilts, and *Heliothis* damage. Resistance to wilt is being transferred from desi backgrounds.

Screening of genetic stock collections and segregating populations for reaction to major diseases under national and artificial epiphytotics forms a continuing program of All India Chickpea Improvement efforts.

Sowing Time

The optimum time of planting for each agroclimatic zone is fairly well known to farmers; it usually falls in October to November. Under rainfed conditions, early cessation of rains will

Table 4. Performance of chickpea cultivars in All India Coordinated Tests in 1977–78 (seed yield in kg/ha).

Cultivar	Mean	High yield/location		Low yield/location	
North plains (west zone)					
Pant G-114	1940	3350	Sriganganagar	1020	Etawah
BG-209	1990	3240	"	880	Hanumangarh
H-208	1610	3150	"	850	Ludhiana
North plain (east zone)					
Pant G-114	2250	2710	Kanke	1030	Shillongini
BG-209	2270	2770	Patna	1270	"
H-208	1820	2500	Sabour	1020	"
Central zone					
BG-209	1510	2430	Kota	1140	Anand (Guj)
Pant-122	1430	2200	"	850	Jabalpur
BG-290	1390	2120	"	1050	"
H-208	1140	1740	"	730	Anand
Peninsular zone					
BDN-9-3	1740	3040	Rahuri	950	Parbhani
JG-62	1590	3000	"	960	ICRISAT-Hyderabad
Phule G-1	1550	2740	"	750	ICRISAT-Hyderabad
Phule G-2	1500	3120	"	690	Parbhani
Annigeri-1	1510	2010	"	920	"

warrant plantings in September or early October, when high day temperatures (above 35°C) often cause mortality of seedlings, excessive vegetative growth, and subsequent moisture stress late in the season.

Late plantings in December and January become necessary on wet lands after paddy harvest. In multiple cropping systems under irrigation, January planting with early-duration types may help in raising cropping intensity. This explains our emphasis on the need for developing genotypes capable of high production under diverse cropping systems.

For 2 years, several cultivars of chickpea were tested in mid-December plantings at Dholi (Bihar) and Waraseoni (Madhya Pradesh). Some were identified as being consistent in giving significantly higher yields than others, although generally, yield levels were low.

Cvs C-235 and Pant G-110 at Dholi produced, on average, between 1000 and 1500 kg/ha. At Waraseoni, cv JG-74 and strain 76 had mean yields of 1200 to 1500 kg/ha.

Breeding for Other Characters

Resistance to soil salinity and selection for multiseeded pods (more than two seeds/pod) were also objectives of chickpea improvement at Hissar.

Studies on plant type and desi/kabuli introgression have been discussed by Dr. P. N. Bahl in the second session of this workshop.

Chickpea Improvement at Pantnagar

B. P. Pandya and M. P. Pandey*

Chickpea (*Cicer arietinum* L.) occupies a unique position in Indian agriculture by virtue of its high protein content and its capacity for fixing atmospheric nitrogen. It is now widely recognized that the only practical means of solving the protein malnutritional problem in the developing countries — where, as in India, the majority of the population depends for its protein requirement on grain legumes — is to increase greatly the production of chickpea. Chickpea grains have nearly three times more protein than do cereals, for example. The per hectare yield of protein from chickpea can be greatly increased through evolution and distribution of seed of high-yielding varieties.

Area and Production

India is the leading chickpea-producing country of the world; it grows 76% of the world acreage and produces 80% of the total grain. No other single crop grown in India has this privileged position in the world. Chickpea is widely cultivated in Asia, Africa, Europe, and Latin and Central America, and the most important chickpea-producing countries, in order of acreage, are India, Pakistan, Ethiopia, Mexico, Burma, Spain, Morocco, Turkey, and Iran (Table 1). In the Indian Union, chickpea ranks fifth in area and fourth in production among the food grain crops. Madhya Pradesh has the largest acreage followed by Uttar Pradesh, Rajasthan, and Haryana (Table 2).

In spite of the very high yields of chickpea among pulse crops in India, the acreage and production have shown a decline since 1959–60 (Fig. 1), mainly due to substitution of wheat as a crop. It is clear that the acreage has been reduced to the extent of 23.9%, but production has declined only 4.5%. Thus, a portion of reduction in area was partly compensated by higher yields (8%). Even as population increases, the per-capita availability of chickpea has dwindled to a level well below the one physiologically needed for a healthy individual.

Location and Weather Conditions

Improvement work on chickpea reviewed in this paper has been carried out at the crop research center of G. B. Pant University of Agriculture and Technology, Pantnagar. This station is located around 29°N latitude, in the foothills of the Shivalik range of the Himalayas. This is a highly fertile belt with plenty of water available from natural precipitation and from the spring-fed streams. The area is characterized by a humid, subtropical climate with an average annual precipitation of 133 cm. Almost three-quarters of the total precipitation is received during the

Table 1. Area, production, and yield of chickpea in the world in 1972.

Country	Area (000 ha)	Production (000 tonnes)	Yield (00 kg/ha)
India	8 027	5106	636
Pakistan	970	516	532
Ethiopia	302	194	642
Mexico	215	180	837
Burma	168	91	542
Spain	145	82	566
Morocco	130	110	846
Turkey	115	170	1478
Iran	100	50	500
Others	156	39	250
Total	10 543	6718	637

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* Professor and Head, and Assistant Professor, respectively, Department of Plant Breeding, G. B. Pant University of Agriculture and Technology, Pantnagar, India.

monsoon period from July to September. In the end of December and the first week of January, frost may occur. The weather conditions in terms of mean, maximum, and minimum temperatures; weekly rainfall; relative humidity; open-pan evaporation; and day length during the winter season averaged over 1961 to 1974 are given in Table 12.

The soils of this tract are alluvial, fairly deep, and rich in organic matter, and they range from clay loam to sandy loam in texture. The soil pH ranges from highly acidic to highly alkaline. The water table in this area is low enough so that it does not interfere with the normal growth of the crop.

The Improvement Program

Improvement work on chickpea started in 1970 as one of the subcenters of the All India Coordinated Project during the Fourth Five-Year Plan and was further strengthened and raised to the status of main center during the Fifth Five-Year Plan

The immediate objective has been the collection of a wide range of genetic stock and its evaluation for immediate use as varieties or as suitable parents for specific characters in the crossing program. Emphasis has been on evolving high-yielding varieties of different maturity durations, meeting resistance with such varieties, and improving various aspects of seed quality.

Several studies were also made at this center in development of superior varieties. Some results on genetics of important growth characters and yields are very interesting. The projects in hand may be discussed as follows:

Table 2. Area, production, and yield of chickpea in various states of the Indian Union (1976–77).

State	Area (000 ha)	Production (000 tonnes)	Yield (00 kg/ha)
Andhra Pradesh	72.8	25.7	353.0
Assam	2.7	1.3	NA
Bihar	221.4	141.4	639.0
Gujarat	76.8	49.0	638.0
Haryana	1040.0	830.0	798.0
Himachal Pradesh	29.3	21.1	72.0
Jammu & Kashmir	2.9	1.6	NA
Karnataka	145.0	45.3	312.0
Kerala	NA	NA	NA
Madhya Pradesh	1946.1	998.1	513.0
Maharashtra	427.9	134.8	315.0
Manipur	0.1	0.1	NA
Meghalaya	0.1	0.1	NA
Nagaland	NA	NA	NA
Orissa	23.5	9.5	404.0
Punjab	349.0	311.0	891.0
Rajasthan	1175.3	1364.7	769.0
Tamil Nadu	8.3	4.8	NA
Tripura	0.2	0.1	NA
Uttar Pradesh	1630.9	1344.7	825.0
West Bengal	98.7	78.6	796.0
Delhi	4.9	4.5	NA
Total	7855.9	5366.4	683.0

NA = Not available.

Table 3. Variability for some chickpea characters, 1972 and 1974.

Character	Range
Days to 50% flowering (no.)	72–96
Days to complete maturity (no.)	126–156
Seeds per pod (no.)	1.1–2.2
100-seed weight (g)	7.43–42.57
Canopy width (cm)	31–105
Plant height (cm)	21–57
Seed yield per 3-m row (g)	5–1015

Collection and Evaluation of Genetic Stock

Evaluation of 1353 genetic stocks consisting of indigenous and exotic lines was done in 1972 and examined further in 1974. Data on foliage color, flower color, plant type, vigor, disease-pest reaction, and certain quantitative traits were taken. The range by quantitative traits taken is given in Table 3. It is obvious that enough genetic variability exists for the characters noted, but there are several characters for which we do not have the desired genetic stock, for example, good plant type and resistance to wilt, blight, and pod borers. Good plant type in grain is highly theoretical and, in our opinion, this denotes an erect, nonlodging and compact plant, which is early maturing, photoinsensitive,

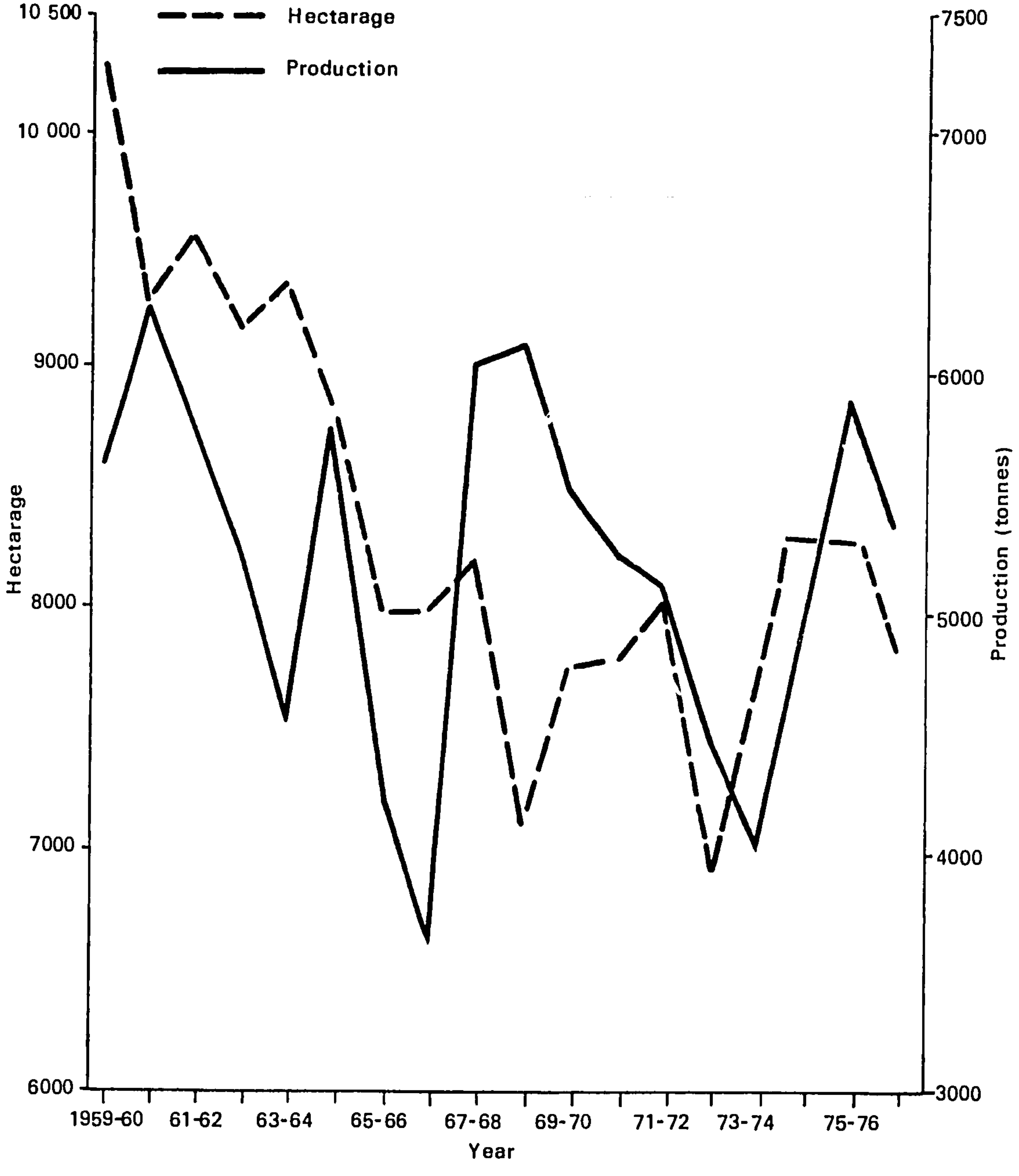

Figure 1. Hectarage and production of chickpea in India, 1959–60 to 1976–77. Source: Agricultural Situation in India.

and highly responsive to nutrients, with a high harvest index, high photosynthetic activity, and multiple resistance to diseases and stress.

Two selections from the germplasm bank, which were entered into the All India Coordinated Varietal Trial for multilocation testing during 1972–73 and tested over several years have shown wide adaptability and have given fairly high yields (Table 4). Pant G-110 gave 19.4% higher yields than the standard check H-208 over 3 years in rainfed conditions in the north plains east zone of the country.

Table 4. Performance of chickpea varieties in All India Coordinated Varietal Trials in northern plains (rainfed) of India, 1973–76.

	North plains (west) zone				North plains (east) zone			
Variety	73–74	74–75	75–76	Mean	73–74	74–75	75–76	Mean
Pant G-110	NA	20.78	23.26	22.02	NA	18.38	21.87	20.12
Pant G-104	19.29	19.78	20.06	19.71	15.87	18.20	17.45	17.17
H-208	18.53	20.10	24.64	21.09	15.08	18.98	16.42	16.83
C-235	17.88	NA	NA	17.88	15.48	NA	NA	15.48
T3	16.83	NA	NA	16.83	15.87	NA	NA	15.87

NA = Not available.

Evolving Varities of Different Maturity Durations

Around 1970 in the Tarai belt of the submountainous Himalayan region, farmers used to grow chickpea in late September as a mixed crop with sugarcane. Since sugarcane is grown as an irrigated crop with high N applications, more vegetative growth occurred in chickpea, resulting in high pod number and, therefore, very poor chickpea yields. Experiments at this station show that plantings delayed till the middle of November checked incidence of blight and excessive growth caused by prevailing heavy fertility and moisture conditions. Varietal differences have been observed and late-maturing varieties such as T-3 (160–165 days) and H-355, which are susceptible to *Sclerotinia* blight, show higher reduction in yield under early planting. This necessitates development of early-maturing varieties. In addition, in certain areas, chickpea is taken after the late paddy harvest where short-duration varieties are expected to perform better. Keeping these factors in view, Pant G-113, Pant G-116, and several strains with good yield potential and a maturity period of 140–150 days duration have been developed through our hybridization program. Efforts are under way to evolve good-yielding types of 4 months' durations suited for the northern plains of India for early- as well as late-planting conditions

Wilt Resistance

Chickpea wilt is complex and, because of its pathogenic and physiologic nature, is considerably affected by soil and moisture conditions during growth. *Fusarium oxysporum* f sp *ciceri* and *F. solani* have been shown to be the main causes of wilt. The wilt syndrome can start at varying stages of the life cycle of the crop, sometimes even after flowering and fruiting has started. Keeping these problems in mind, donors resistant to chickpea wilt were crossed with good-yielding cultivars in 1971–72. One of the selections, Pant G-114 from cross G-130 × 1540, remained completely free from *F. oxysporum* and showed less than 4% infection of *Sclerotium rolfsii* in the multiple-disease sick plot at Jabalpur. This variety has also shown wider adaptability. Another source, WR-315, is being exploited extensively in various cross combinations to combine disease resistance and seed yield. Recently, we have commenced detailed investigations for the inheritance of wilt caused by *F. oxysporum*. During 1980–81, F_1, F_2, and backcrosses, along with their parents, will be tested in artificially inoculated plots in a replicated experiment. This should greatly help in understanding the nature of inheritance of this serious disease. Resistance sources included in the study are WR-315, P-496, and CPS-1.

Botrytis Gray Mold

Work to incorporate gray mold resistance of P-1528, a black-seeded gray mold resistant material from Morocco, into adapted and otherwise susceptible variety G-130 started in 1971. This program was further expanded in 1972 with the availability of several resistant sources, namely, P-1447, 539A, P-6613, 100, 101, 106, 6001, 6002, and P-6612. Four good agronomic bases chosen for incorporation purpose were T-3, G-130, C-235, and JG-62. In 1973,

F_1s involving resistant sources and good yielding lines were grown, and F_1 seed of three double crosses — (G-130 × 100) × (T-3 × P-1447); (G-130 × 6001) × (T-3 × 106); and (G-130 × 539A) × (T3 × 100) — was also obtained in 1972. Also, F_2 and subsequent generations of these crosses were raised. Since in Pantnagar conditions, natural incidence of gray mold is very severe, and there are hardly any chances for escape, plants that were completely free from disease with profused podding were selected and advanced to the next generation. A total of 258 F_5 families of cross G-130 × 1528, selected on the basis of disease reaction, seed size, and seed color, were evaluated in observation plots (nonreplicated) during 1975-76. In remaining crosses, 478 single plants completely free from disease with profuse podding were selected and evaluated for yield.

High Podding and Erect Types

One of the major potential components of yield in chickpea is pods per plant. This character seems to be much influenced by the environment. The germplasm available in the country offers very little variation for number of pods per peduncle. We initiated a program to incorporate this feature as early as 1970. A single flower per peduncle appeared to be dominant over two flowers per peduncle. In the F_2 generation of cross G-130 × 1540, a large number of plants was studied. The range of paired pods per plant was 1–78, and it accounted for 0.4 to 32% of the pods/plant. A total of 44 families with the tendency of producing two pods per peduncle derived from cross (JG-62 × 106)F_4 and (G-130 × 1540)F_7 were yield tested in a replicated 7 × 7 lattice design during 1975–76. A number of families yielded better than the best standard H-208 (Table 5). Two pods per peduncle are likely to produce better yields through photosynthesis. Moreover, though some of the erect types yielded better than H-208, the semi-spreading double-podded types gave still better yields. Observations reveal that in paired flowers, one flower has a purple-pigmented peduncle and sets pod while the other flower has a green peduncle and does not set pod. This finding is very important in a crossing program where only buds with the purple-pigmented peduncle should be selected for emasculation and pollination purposes.

Table 5. Performance of the top ten families with two pods per peduncle in a replicated experiment at Pantnagar, 1975–76.

Strain	Yield (q/ha)[c]
(JG-62 × 106)-51sp[a]	26.45
(JG-62 × 106)-9sp	26.42
(JG-62 × 106)-6sp	26.31
(JG-62 × 106)-48sp	26.29
(JG-62 × 106)-52sp	25.88
(JG-62 × 106)-58sp	25.25
(JG-62 × 106)-7sp	24.73
(JG-62 × 106)-38Er[b]	24.42
(JG-62 × 106)-10Er	24.12
H-208	23.79
CV (%)	20.27
CD at 5%	6.10

a. sp = semi-spreading plant type.
b. Er = erect plant type; *c.* 1 quintal = 100 kg.

Component Analysis in Yield Breeding

In order to initiate a successful hybrid breeding program it is necessary to understand the components of yield. This information has been lacking in chickpea. As early as in 1972, a study was initiated at this University with 49 diverse genotypes. Results are presented in Table 6. This suggests that the number of pods per plant and the 100-seed weight were the main contributors toward yield. All other characters had less direct effects. Indirect effects of these other characters via number of pods and 100-seed weight were large. The number of branches per plant had a negative direct effect, but its indirect effect via number of pods was positive.

Seed yield had a positive and high association with number of pods per plant, number of branches, and days to flowering, and low association with 100-seed weight. Plant height was negatively correlated with yield.

Character association among yield components suggests that 100-seed weight was significantly correlated with seeds per pod. There was also a negative association of pod number with seed weight and plant height. Bahl et al. (1976) also reported similar results in chickpea. Thus, it is evident that number of pods, number of branches, and days to flowering are important yield-contributing characters in Bengal

Table 6. Genotypic and phenotypic (in parentheses) correlations of different characters with grain yield in chickpea, 1972.

Character	Correlation with yield
Plant height	−0.3907 (−0.2481)
Days to flowering	0.4271 (0.3226*)
Branches per plant	0.5824 (0.5506*)
Pods per plant	0.6820 (0.7571**)
Seeds per pod	−0.1659 (−0.1427)
100-seed weight	0.2216 (0.1887)

*Statistically significant at 5% level.
**Statistically significant at 1% level.

Table 7. Heritability estimates for certain quantitative characters in chickpea.

Character	Heritability (%)
Plant height	29.67
Days to flowering	85.71
Branches per plant	32.60
Pods per plant	52.51
Seeds per pod	79.23
100-seed weight	95.95
Seed yield per plant	57.77

Table 8. Good combiners for specific characters in a chickpea crossing program.

Character	Variety
8 × 8 diallel (kabuli)	
Primary branches	K-4, C-104, K-1071
Secondary branches	JG-5
Pods per plant	JG-5
Seeds per pod	K-4, HYB-16-3, K-1071
100-seed weight	C-104, JG-12, L-550
Seed yield per plant	JG-5
9 × 9 diallel (desi)	
Earliness	JG-62, 1868, 940
Plant height	BRG-8, K-468
Primary branches	K-468, JG-62
Secondary branches	K-468, H-208, T-3, JG-62
Pods per plant	K-468
Seeds per pod	H-208, T-3, K-468, PG-72-271
Whole plant weight	T-3, 1868
100-seed weight	T-3, 1868, BRG-8, K-468
Seed yield per plant	1868, T-3
Harvest index	H-208

gram. It also suggests that combined selection for high yield and good seed size will also be effective in increasing yield. These characters may be given equal weightage in a selection program.

Heritability Estimates

Heritability estimates (Table 7) suggest that 100-seed weight had the highest heritability (95.95%) and is closely followed by days to flowering and seeds per pod. Seed yield and number of pods per plant had medium heritability. Number of branches and plant height had low heritability.

Genetic Analysis for Selection of Desirable Parents

The choice of parents is very crucial in any hybridization program. Our earlier procedure was to select one parent on the basis of its adaptation, dependability, and yield and the other parent to complement the weakness of the first parent. Recently, combining ability is being employed by breeders in selecting parents, but there has been very limited information on this procedure. A number of studies were begun at this University to provide the basis for choosing parents for hybridization, and the results are presented in Table 8.

Exploitation of Heterosis

Heterosis in chickpea, first reported by Pal (1945) and subsequently by Ramanujam et al. (1964), has never been fully appreciated. We studied heterosis in desi and kabuli types and results for desi are given in Table 9. It may be seen that an appreciable amount of heterosis for yield is present and may be exploited for development of high-yielding varieties. Some of the crosses showing significant heterosis over the standard variety include 1868 × 940, T$_3$ × 1868, 940 × PG-72-271, K-468 × 940, H-208 × 1868, H-208 × T-3, H-208 × BRG-8, and T-3 × K-468. These are being exploited

Table 9. Heterosis for certain characters in chickpea (desi).

	Range (%)	
Character	Over better parent	Over mid parent
Days to flowering	− 0.29 to 16.53	− 0.25 to 9.25
Plant height	−40.90 to 30.67	−18.18 to 45.27
Plant width	−33.41 to 28.40	−38.42 to 58.05
Primary branches per plant	−53.24 to 75.38	−41.81 to 85.36
Secondary branches per plant	−63.76 to 14.44	−42.10 to 35.29
Seeds per pod	−38.80 to 10.03	−28.62 to 24.61
Whole plant weight	−43.34 to 165.78	−77.13 to 278.81
100-seed weight	−46.25 to 19.08	−19.17 to 32.82
Seed yield	−55.27 to 101.77	−31.65 to 257.81
Harvest index	−36.18 to 28.17	−20.36 to 65.99

further for isolating high-yielding pure lines or initiating a recurrent-selection program.

Screening Sources of Resistance to Pests

Chickpea crops suffer greatly from attacks in the field by pod borer (*Heliothis* spp) and in storage by beetle (*Callosobruchus* spp). Emphasis has been on chemical control of these pests up to now; simultaneous efforts are also being made to screen sources of resistance against these pests. None of the entire germplasm collection screened against pod borer showed resistance during 1976–77. This study is being repeated during 1978–79. One of the selections developed at this University (Pant G-112) has shown tolerance to beetle and is being used in the crossing program.

Stability

In chickpea improvement it has been found that varieties do not perform consistently better across environments and years. This is because breeding strategies for crop improvement, both in and outside India, have been toward the evolution of varieties, either through directional selection from indigenous genetic stock or through hybridization programs utilizing very narrow genetic base parents. This has resulted in a marginal yield advance. Studies made at this station reveal no parallelism between genetic diversity and geographical distribution. Desi and kabuli types seem to be different from each other and, therefore, crossing among these two types may give useful segregants. To make worthwhile improvements in chickpea, test weight, pods per plant, flowering period, harvest index, and yield, in that order, should be taken into account. Our studies also identify K-4, Pant G-110, Kaka, NEC-240, and Pink-2 varieties for use in crossing programs.

Multiline Mixtures for Higher Yields

An experiment carried out at this University in this direction revealed very interesting results. Six improved varieties, pure as well as blended in varying proportions, have been tested in a replicated trial during 1976–77 and lead to the conclusion that mixtures can give better yields than the standard varieties taken as pure stand. The original proportion of varieties in the mixture does not remain the same through successive generations; there is also a shift in yields. A comparison of different generations of a particular mixture within the same environment will be begun in 1979–80 and continued through later years to determine the kind of intergenotypic competition, if any, that may be responsible in the shift of performance of mixtures.

Breeding Approach

A twofold breeding approach, short and long term, was begun in 1970 to solve the need for high-yielding varieties of chickpea. The short-term approach was to collect and evaluate the indigenous and exotic germplasm collections and to select certain stocks for immediate use as varieties. This approach paid a good dividend and led to identification of a number of such genotypes. This also led to the identification of parents to be included in breeding programs. Biometrical studies on component analysis, heritability, combining ability, heterosis, phenotypic stability, top cross, and several others helped to devise suitable methods of breeding.

Almost simultaneously, intensive hybridization work was started for isolation of high-yielding pure lines from elite crosses. A few but well planned multiple crosses were attempted among parents, one having good yield and adapted, while the second complemented the weaknesses of the first. The pedigree method of breeding was adopted in the F_2 generation and onward. In the F_4–F_5 generations, most of the families became uniform with respect to most of the simply inherited characters. Such families, which are vigorous and profusely podded and which have resistance to major diseases, are evaluated, along with the check, for seed yield in observation plots of several rows. Those yielding better than the check are evaluated further in replicated trials. Seed of such advance lines is simultaneously multiplied separately for possible testing into national and international trials.

We also follow the sib-pollinated line-selection technique as suggested by Palmer (1953) in wheat and later improved by Andrus (1963). In this method there are three steps: (1) a preliminary sampling of the most productive superior recombining crosses; (2) selection of individual plants in F_2; and (3) intermating of the best sib to provide a new cycle of selection. Each cycle could be long or short and can be repeated many times until the improvement seems to be forthcoming. This procedure is based on the assumption that the chances for a single individual to carry all or most of the potentially coadapted genes are very small, and therefore, pure line selection in F_2 will hardly produce the best-balanced genotype, while recombining of two or more partly balanced genotypes will enhance the chance that the maximum number of harmoniously functioning coadapted genes will be assembled together and, through subsequent inbreeding, will emerge as relatively stable and well-adapted varieties.

In the last few years, with the availability of extra finances from the Indian Council of Agricultural Research (ICAR), an extensive hybridization program has been started. A large number of single three-way, and double crosses are made and advanced to the F_5 generation by the single-seed descent method, as suggested by Brim (1966) in soybean. This method has the advantage of handling a large number of crosses, which is otherwise very labor-consuming and expensive. Selection to single plants is delayed in F_5 generations when most of the plants are fixed for most of the characters. The second advantage is that the same genetic variability is carried over through the F_2 to the F_5 generation.

Recently, we planned to initiate the use of the biparental technique for the accumulation of additive genes and breaking the undesirable linkages. This method has been suggested by Joshi and Dhawan (1966). In this method, two or three crosses are selected out of several that have shown enough heterosis in F_1 over the best variety and, in the F_2 generation, have shown a considerable amount of residual heterosis and have given yields equal to or better than the check varieties for the isolation of superior-yielding pure lines. In such selected crosses, biparental crosses should be made and their performance determined in the next generation. This process may be repeated as long as advances are made. This is followed by isolation of high-yielding pure lines.

Our breeding approach to date has utilized the classical methods of breeding, but we propose to investigate the diallel selective-mating system (Jensen 1970) as a means of creating diverse and dynamic gene pools from which to select high-yielding cultivars. We propose to initiate this work on a diallel involving 16 × 16 cultivar combinations. The parents for this diallel will be chosen in their morphological variability, genetic and geographical diversity and would include both kabuli and desi types.

Varietal Development

Based on some of the concepts and breeding approaches described above, new varieties of chickpea have been developed at this station and other stations in the country during the last decade. None of these varieties, however, shows the efficiency of plant types as has already been achieved in presently available varieties of wheat and rice. The new varieties of chickpea, however, show that significant progress is being made in this direction. Most plant breeders in India and in other countries continue to work with a limited number of genetic stocks. This represents a much more serious limitation to the progress of its improvement than anything inherent in the genetic potential of chickpea. The rate of this progress should greatly increase, therefore, as more and more

Table 10. Estimates of stability parameters for cultivars tested in the northern plains (east zone) of India, 1977–78.

Cultivar	Mean yield (q/ha)[a]	Mean yield Rank	Regression coefficient (b)	Measured deviation (S^2d)
H-208	18.16	7	1.052	0.674
Pant G-110	16.44	11	0.813	11.599**
Pant G-114	20.89*	2	0.395+	4.159
Pant G-115	20.40	3	1.056	6.174
BG-200	13.16	7	0.919	5.910
BG-203	18.96	6	0.996	2.147
BG-209	21.48	1	1.221	5.893
K-468	19.00	5	1.074	9.466
K-295	19.02	4	0.929	9.355
KE-30	17.86	9	0.926	1.782
BG-290	16.99	10	0.991	7.668
LSD	2.27		0.414	

a. 1 quintal = 100 kg; + Indicates 'b' value significantly less than one.

*, ** Indicate significant difference from zero at 0.5 and 1% levels of probability, respectively.

Table 11. Chickpea varieties evolved at Pantnagar and tested in national and international trials since 1971.

Variety	Pedigree	Year of development	Mean yield (q/ha)[a]	Highest yield recorded (q/ha)[a]
Pant G-101	P-1656	1971	15.92	27.59
Pant G-102	P-70	1971	17.80	36.64
Pant G-104	P-1262	1971	19.03	39.44
Pant G-107	P-1214	1971	17.37	36.57
Pant G-110	P-6056	1971	23.34	35.43
Pant G-111	P-691	1971	15.22	23.30
Pant G-112	P-1475	1971	16.72	25.31
Pant G-113	G-130 × 1881	1971	24.81	33.33
Pant G-114	G-130 × 1540	1974	25.37	34.88
Pant G-115	G-130 × 1540	1974	24.75	36.62
Pant G-116	G-130 × 1540	1974	21.17	28.54
Pant G-117	G-130 × 1162	1974	24.00	31.32
Pant G-121	JG-62 × 106	1976	21.31	40.30
Pant G-122	JG-62 × 106	1976	21.19	43.37

a. 1 quintal = 100 kg.

genetic variability is injected into the breeding program.

In Uttar Pradesh, T1 was the first variety to be released in 1958 for general cultivation for trap soils of Bundelkhand and for the eastern region of the state. Subsequently, T2 and T3 were released in 1959 for the central and western regions of the state, respectively. T1 was replaced in 1968 by the release of the still superior variety Radhey. Recently, in 1977, K-468 was released for general cultivation in the eastern part of the state. Pant G-114 has been identified for final release by the All India Rabi Pulse Workshop held at Orissa University of Agriculture and Technology, Bhubaneshwar in September 1978.

The estimate of adaptability parameters for 11 varieties in the national trial over 16 locations during 1977–78 is given in Table 10. Looking to the mean of Pant G-114 over the locations, Pant G-114, and BG-209 significantly yielded higher than the check H-208. Pant G-114 was stable ($S^2d = 0$), and its regression value was significantly less than unity. This cultivar will also do well under poor environmental conditions. This cultivar has also shown similar adaptability

Table 12. Weather conditions at Pantnagar, India; weekly mean temperatures, rainfall, relative humidity, open-pan evaporation, and daylength during chickpea growing season at Pantnagar; average of 1961–74.

Months	Standard weeks	Temperature (°C)		Rainfall (mm)	Relative humidity		Open-pan evaporation (mm)	Mean daylength (hr)
		Max.	Min.		A.M.	P.M.		
Oct	40	31.8	19.1	24.2	89	56	3.9	10.16
	41	31.6	18.0	6.9	92	56	3.8	9.98
	42	30.9	16.5	11.3	84	47	3.9	9.84
	43	30.7	14.7	0.0	85	42	3.8	9.65
	44	29.4	12.8	4.9	86	43	3.4	9.53
Nov	45	28.6	11.2	0.0	86	39	3.1	9.37
	46	27.9	10.2	0.03	89	39	2.9	9.19
	47	26.4	8.8	0.04	89	38	2.7	9.13
	48	25.2	7.1	1.8	90	39	2.4	9.01
Dec	49	24.3	6.3	1.4	84	39	2.1	8.93
	50	23.2	5.7	2.6	85	40	2.1	8.87
	51	21.4	5.4	4.0	95	42	1.7	8.83
	52	21.6	5.0	1.6	85	42	1.7	8.83
Jan	1	21.7	4.7	8.7	94	58	1.9	8.85
	2	21.7	4.3	1.9	93	45	2.0	8.93
	3	21.1	4.1	4.6	90	44	2.1	8.98
	4	21.0	5.7	10.5	93	51	2.2	9.08
	5	21.2	6.2	12.3	92	43	2.3	9.21
Feb	6	22.3	5.8	4.8	90	44	3.6	9.37
	7	23.9	7.6	4.1	89	44	3.8	9.53
	8	25.5	8.3	5.4	88	42	3.6	9.70
	9	26.8	8.7	3.9	89	37	4.0	9.84
Mar	10	27.8	9.1	3.7	87	39	4.7	10.01
	11	30.3	11.6	3.07	82	37	5.2	10.16
	12	30.1	12.5	3.7	83	34	5.4	10.35
	13	32.8	13.7	0.9	76	28	6.3	10.53
	14	34.1	14.4	1.5	69	25	8.0	10.71
Apr	15	35.9	16.5	5.1	64	23	9.2	10.87
	16	36.0	16.8	4.3	62	22	9.9	11.03
	17	37.3	19.4	1.0	55	24	10.0	11.17

during 1975–76 and 1976–77. Similarly, Pant G-115 has also shown higher adaptability during the last 3 years (1975–76 to 1977–78) in the northern plains of India.

A list of the chickpea varieties evolved by this University during the last 8 years, along with their pedigree year of development, average yield, and maximum yield in the national trials, is given in Table 11. It can be seen from the table that the yield level of these varieties is practically two to three times higher than the state average, whereas their potential is four to five times higher than the state average. This clearly shows a wide gap between the state average and yield of these improved varieties and their potential. It suggests that if a proper extension program were begun, there would be a great possibility for a considerable increase in yields of chickpea.

References

ANDRUS, C. F. 1963. Plant breeding systems. Euphytica 12: 205–228.

BAHL, P. N., MEHRA, R. B., and RAJU, D. B. 1976. Path analysis and its implications for chickpea breeding. Zeitschrift fuer Pflanzenzuechtung 77: 67–71.

BRIM, C. A. 1966. A modified pedigree method of selection in soybeans. Crop Science 6: 20.

JENSEN, N. F. 1970. A diallel selective mating system for cereal breeding. Crop Science 10(6): 629–635.

JOSHI, A. B., and DHAWAN, N. L. 1966. Genetic improvement of yield with special reference to self-fertilizing crops. Indian Journal of Genetics 26A: 101–113.

PAL, B. P. 1945. Studies in hybrid vigour, notes in the manifestation of hybrid vigour in gram. Indian Journal of Genetics 5: 106–121.

PALMER. 1953. Progressive improvement in self-fertilized crops. Heredity 7: 124–129.

RAMANUJAM, S., ROHEWAL, S. S., and SINGH, S. P. 1964. Potentialities of heterosis breeding in *Cicer*. Indian Journal of Genetics 24(2): 122–129.

SINGH, K. B., MALHOTRA, R. S., and KUDHRA, R. C. 1973. Heterosis in Bengal gram. Indian Journal of Agricultural Sciences 43(5): 459–463.

Chickpea Breeding Program at Hissar

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Among grain legumes grown in India, chickpea ranks first with annual acreage and production of 7.9 million ha and 5.4 million tonnes respectively (Anonymous 1977). It contributes as high as 34.39 and 47.88% to the total area and production, respectively, of pulses in the country. In Haryana, where it is cultivated throughout, chickpea enjoys a special position and the economy of the rainfed agriculture mainly depends on it. It shares 92% of the total production and 90% of the total acreage under pulses in the state. However, Hissar and Bhiwani are major chickpea-growing districts (Table 1), which together account for 39.64 and 38.04% of the total area and production of chickpea in the state, respectively (Anonymous 1978). Raised mainly as a rainfed crop, chickpea accounts for as high as 28.4% of the total rainfed-cultivated area in the state; only 8.2% of the total irrigated area is under chickpea, however. The districts of Sonepat and Karnal, which have better irrigation facilities, have minimum areas in chickpea cultivation.

Statistics on chickpea in Haryana (Table 2) show clearly that both area and production have declined since 1960–61. The main reason is a shifting of the area under chickpea to high-yielding varieties of wheat in irrigated areas and barley in rainfed areas and planting chickpea in less-favored areas. The main reasons for low production of chickpea in the state are given below:

1. Low yield potential of the varieties.
2. Susceptibility to diseases, particularly wilt complex, blight (*Ascochyta rabiei*), and chickpea stunt (Phloem necrosis).
3. Susceptibility to insect pests, such as cutworm (*Agrotis* spp) and pod borer (*Heliothis armigera* Hub.).
4. Poor response of varieities to management inputs such as fertilizers and irrigation.
5. Growing of the crop in marginal lands and using poor management practices.
6. Physiologically inefficient plant.
7. Lack of stability in the performance.
8. Poor production technology.

In view of the importance of chickpea in the agricultural economy of the state and its decline in production, the state government sanctioned a program for "Improvement of Gram at Hissar" in 1971. However, meager facilities (in terms of technical staff) were provided, and improvement work was started only on breeding and agronomic aspects. Due to inadequate facilities, much headway could not be made. In 1975, the Indian Council for Agricultural Research (ICAR) started a project on "Intensification of Research on Improvement of Pulses." Under this project, research work following a multidisciplinary approach was begun to increase the production of major pulses, including chickpea. As chickpea is the major pulse of this state, efforts were directed to solving problems on all fronts. The breeding work for evolving high-yielding types had the following objectives:

1. Breeding for high yield: Present-day varieties of chickpea are inherently low yielding. To make this pulse more competitive with cereals, breeding of high-yielding types by combining yield-contributing characters into a single genotype is the foremost objective.
2. Breeding for stability of yield and regional adaptability: Chickpea is generally grown under varying situations, such as rainfed and irrigated areas; fertile and marginal lands; from humid climates of submountainous, hilly areas to the drybelt of the state. Present-day varieties are of narrow adaptability and are suitable only for a certain pocket of land; their performance also varies from year to

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Table 1. Area, production, and yield, by district, of chickpea in Haryana State, 1975–76.

District	Area (000 ha)	Production (000 t)	Percentage of total:		Yield (kg/ha)
			Area	Production	
Hissar	182.7	155	16.52	17.09	849
Sirsa	146.8	133	13.27	14.66	905
Bhiwani	255.8	190	23.12	20.95	743
Gurgaon	62.4	51	5.64	5.62	815
Jind	101.4	102	9.17	11.25	1006
Mohindergarh	127.4	83	11.52	9.15	652
Ambala	39.1	26	3.53	2.87	673
Karnal	21.5	21	1.94	2.32	959
Kurukshetra	42.4	40	3.83	4.41	963
Rohtak	109.0	90	9.93	9.92	819
Sonepat	16.8	16	1.52	1.76	934
Total	1105.3	907	100.00	100.00	

Table 2. Area, production, and yield of chickpea in Haryana since 1960–61.

Year	Area (000 ha)	Production (000 t)	Yield (kg/ha)
1960–61	1543.0	1274	826
1965–66	868.0	385	444
1966–67	1062.0	531	500
1967–68	1160.0	1267	1092
1968–69	577.0	421	729
1969–70	1084.0	1173	1082
1970–71	1063.0	789	742
1971–72	1119.1	647	578
1972–73	969.7	551	568
1973–74	993.9	448	451
1974–75	704.4	343	487
1975–76	1106.2	907	820

year. It is essential therefore, to develop genotypes that would give consistantly high yields year after year and under varying soil and climatic conditions.

3. Breeding for resistance to diseases: Chickpea is the victim of several diseases, but wilt complex and blight (*Ascochyta rabiei*) are the major ones in Haryana. It is estimated that wilt complex alone causes from 5–15% loss every year in Haryana. The incidence of blight is not regular. During the years that blight is most prevalent, however, it wreaks havoc, as happened during 1968. Thus it is essential to incorporate resistance to these diseases.
4. Breeding for resistance to insect pests: Cutworm (*Agrotis* spp) and pod borer (*Heliothis armigera* Hub.) are the major pests. Though the sources of resistance to these pests are not available, efforts should be made to find such sources and incorporate them in existing varieties.
5. Breeding for drought resistance: More than 90% of the area under chickpea is rainfed. In the near future this pulse will continue to be grown under rainfed conditions. It is essential therefore, to breed varieties that thrive under rainfed situations.
6. Breeding varieties resistant to salinity: In Haryana there is a large saline area, and present-day varieties of chickpea are highly sensitive to such soils. Therefore, in order to extend the cultivation to such soils, the breeding of varieties resistant or tolerant to salinity is most important.
7. Breeding for responsiveness to fertilizers and irrigation: For making chickpea competitive to cereals, such as wheat, development of varieties that could give high yields under better management, such as fertilizers and irrigation, is most important.
8. Breeding varieties suitable for late planting: A sizable area has come under paddy cultivation in Haryana. The most com-

mon rotation in such areas is paddy-wheat. The soils cannot sustain such a rotation for long. It is essential therefore, that chickpea alternate with wheat, at least in some areas. Since paddy is generally harvested at the end of November, and present-day varieties of chickpea do not give good yields when planted during December, it is essential to breed short-duration varieties that could be sown later.

9. Breeding for high harvest index: In order to get better partitioning of photosynthates between vegetative and reproductive parts (grains), breeding for high harvest index is important for developing high-yielding varieties.
10. Breeding for efficient plant type: The present day varieties do not efficiently utilize soil and solar energies. The nitrogen-fixing and photosynthesis processes are not uniformly distributed throughout the life span of the plant, with the result that the pod and grain settings are not uniform. It is essential therefore, to design a plant type that could fix atmospheric nitrogen and synthesize the food material throughout the growth and development periods.
11. Breeding for better grain quality: Bold grain, attractive color, good recovery of dal and good cooking quality are the characters that should be combined into one variety.
12. Breeding for high protein content and balanced amino acid profile: The protein content in the present day varieties of chickpea is fairly low, as compared to soybean and other pulses. It is important to increase the protein content and essential amino acids.

Breeding Projects and Achievements

Selection from local cultivars has been the only breeding method for chickpea improvement in the pest. Recently, however, the breeding approach has been shifted from selection to hybridization. The breeding strategy has been organized along the following lines.

Collection, Maintenance, and Evaluation of Germplasm

It is well known that only a small fraction of genetic variability has been utilized by pulse breeders for the improvement of chickpea in India. This has probably been one of the factors that have resulted in the lack of success in improving chickpea. An attempt has been made therefore, to collect a wide spectrum of germplasm of chickpea. A total of 6620 cultivars, 1803 from within the country and 4817 from 21 other countries, has been collected. These cultures were grown at IARI and Hissar and, after evaluation, were distributed among centers of the All-India Coordinated Pulses Improvement Project. In addition to these cultures, 300 other cultivars were received from ICRISAT. Although none of the collections has been found suitable for direct use as a variety, this program has provided useful parental material with considerable divergence for broad-based hybridization. The germplasm lines that were found desirable for the following characters are:

1. Wilt resistance: G-24, C-214, H-355, H-208, P-426, P-5054, CPS-1, F-61, P-82, P-199, P-336, P-1447, K-315
2. Blight resistance: C-235, P-1528-1, P-6625, 12-071-05093, 12-071-10054, P-180-1, C-727
3. Salinity resistance: E-100
4. Double poddedness: P-271, JG-62, P-3111, P-1482
5. Multiseededness: HMS lines (30), NEC-989, P-6, P-82, P-99, P-431, P-1198-1, P-2774
6. Bold seededness: T-3, 850-3/27, Rabat, L-144
7. Upright growth habit: G-130, Caina, NEC-249, P-336, P-345-1, P-6099, P-6308
8. Drought tolerance: C-214, H-208, G-24
9. Frost tolerance: C-214

The above genotypes have been used in the crossing program.

Selection

Visual selection is useful in the early generations of a breeding program for elite material to select desirable plants from the heterogeneous populations. For improving yield, the characters with direct association with yield should be given due attention. In order to determine the magnitude and direction of association between yield and other characters, correlation studies are very important. The coefficients of genotypic and phenotypic correlations between yield and other characters found in chickpea are presented in Table 3.

From Table 3 it is clear that the number of pods, primary branches, and secondary branches per plant and grain weight have positive and significant associations with grain yield. Therefore, improvement in yield can be effected if selections are directed for large numbers of pods, primary branches, secondary branches, and bold grains. There are several factors that might upset the effectiveness of the selection, however, such as seasonal variation, biological factors, and uneven plant stand. These factors should be taken into account in a selection program.

As a result of selection, the following varieties of chickpea have been developed in the area that is now Punjab and Haryana states.

1. G-24: This variety, released in 1958, is resistant to wilt and is most suitable for cultivation in sandy soils and rainfed areas. The plants are dwarfed, bushy, and profusely branched. The foliage is small and dark green. The grains are small and reddish or chocolate. Since it matures a week earlier than other varieties, this cultivar escapes the hot winds and moisture stress late in the season. The average yield of this variety is 1500 kg/ha.
2. S-26: This variety was developed through pure-line selection and released in 1958 for cultivation throughout the state of Haryana under rainfed conditions. It is also tolerant to wilt and is relatively early maturing. It is profusely branched and has attractive bright yellow grains. The average yield is 1500 kg/ha.
3. Pb-7: This is an old variety released as early as 1934 and recommended for cultivation under irrigated conditions in Haryana. The grains are attractive and yellow colored. The average yield is 1800 kg/ha.

Table 3. Genotypic and phenotypic correlations between grain yield and its components in chickpea.

Character	Correlation coefficient	
	Genotypic	Phenotypic
No. of pods per plant	1.1037	0.7230**
No. of primary branches	0.0429	0.7365**
No. of secondary branches	0.9298	0.5279**
No. of grains per pod	0.5486	0.1394
100-grain weight	−0.4138	0.3484**

** Denotes significance at 1% level.

Hybridization

In order to exploit the genetic variability and combine characters scattered among different genotypes, hybridization was started. A large number of single and double crosses were made, and their segregating populations were handled through the pedigree system of breeding. The following varieties were developed through this method (Table 4).

1. C-235: Developed from the cross IP-58 × C-1234. It is resistant to blight and is suitable for cultivation in blight-prone areas, particularly sub-mountainous humid regions of the country. It has been released for cultivation in the north plains, west and east, and in the central zones of the country. The plants are medium tall, vigorous, and semi-erect in growth habit. The grains are medium bold (135 g/1000 grains) and brownish yellow. The average yield is 1900 kg/ha.
2. C-214: Selected from a three-way cross G-24 × (G-24 × IP-58). This variety is tolerant to wilt, frost, and drought and has been released for cultivation in Haryana, Punjab, Delhi, and Rajasthan. The plants are medium tall and semi-erect in growth habit. The grains are medium bold (137 g/1000 grains) and browish yellow. The average yield is 1750 kg/ha.
3. G-130: Developed from the cross 708 × C-235 and released in 1971 for irrigated or adequate rainfall areas of Haryana. It has replaced an old variety, Pb-7, and has given about 18% higher yield. The plants are medium tall and upright in growth habit with vertical orientation of the leaves. Fruiting is very profuse and pods are generally two-seeded. Grains are medium bold (131 g/1000

Table 4. Details of the varieties of chickpea developed through hybridization.

Variety	Pedigree	Growth habit	100-grain weight (g)	Grain color	Resistance	Mean yield (q/ha)	Area adaptability in India
C-235	IP-58 × C-1234	Semi-erect	12.5	Brownish yellow	Blight resistant	19.0	North plain west and east, and central zones of India.
C-214	G-24 × (G-24 × IP-58)	Semi-erect	13.7	Brownish yellow	Wilt resistant	17.5	Haryana, Punjab, Delhi, and Rajasthan
G-130	708 × C-235	Erect	13.1	Brownish yellow	Wilt tolerant	20.0	Adequate rainfall areas of Haryana.
H-208	(S-26 × G-24) F_3 × C-235	Semi-erect	11.6	Brownish yellow	Wilt tolerant	20.0	North plain, west and east, and central zones of India
H-355	V-140 × S-26	Semi-erect	12.5	Brownish yellow	Wilt tolerant	22.5	Irrigated areas of north plain and central zones of India
C-104	Pb-7 × Rabat	Semi-erect	24.5	Salmon-white	ND	12.0	Irrigated areas of Haryana.
L-144	S-26 × Rabat	Semi-erect	30.0		ND	12.0	Irrigated areas of Haryana.

ND = No data.

grains) and brownish yellow. The average yield is 2000 kg/ha.

4. H-208: Developed from the cross (S-26 × G-24) F_3 × C-235 and released for cultivation in 1977. It is widely adaptable in the northern, eastern, and central zones of the country. It is most suitable for drier, rainfed, and wilt-prone areas as it is tolerant to wilt. It also does well in irrigated areas. It is tall and semi-erect and bears a large number of fruiting branches. The leaves are medium in size and green in color. The stem is pinkish green with a purple spot at the leaf axil. The pods are comparatively small and two-seeded. The grains are small (115 g/1000 grains) and brownish yellow. The average yield is 2000 kg/ha.
5. H-355: Developed from the cross V-140 × S-26. It has been released for general cultivation in irrigated or adequate rainfall areas of northern parts of the country. It is also tolerant to wilt. The plants are tall, profusely branched, and semi-erect in growth habit. The grains are medium bold (128 g/1000 grains) and brownish yellow in color. The average yield is about 2200 kg/ha.
6. C-104: A kabuli variety developed from the cross Pb-7 × Rabat. It has been released for cultivation in irrigated areas of Haryana except humid regions where blight is a serious problem. The plants are vigorous and tall. The grains are bold 245 g/1000 grains) and salmon white. The average yield is 1200 kg/ha.
7. L-144: A kabuli variety developed from the cross S-26 × Rabat and released for general cultivation in 1975 for irrigated areas of Haryana. The plants are tall (65–70 cm), vigorous with broad and light green foliage, and sparsely branched; the flowers are white, the pods bold, and the plant is generally single-seeded. The grains are very bold (300 g/1000 grains) and are salmon white with thin testa and high water-imbibing capacity. The grains swell rapidly when soaked in water and take considerably less time for cooking. They are comparatively sweeter than desi and other kabuli varieties. The variety has wide adaptability, and the yield potential is 1200 to 1500 kg/ha.
8. Newer varieties: A total of 16 newer varieties (H-376, H-457, H-192, H-519, H-531, H-75-33, H-76-49, H-76-62, H-75-35, H-75-36, H-73-28, H-72-4, H-73-10, H-76-2, and H-76-67) developed through hybridization and selection, have given higher yield than the existing varieties (Table 5). These varieties are being tested at different centers in the country. In addition to high yield, they hold promise for bold grains (H-75-35, H-75-36), long fruiting stalk (H-75-35, H-75-36), attractive grain color (H-376, H-75-18, H-76-2), and tolerance to wilt (H-75-18, H-75-33, H-76-49). These varieties are also being tested under late planting conditions and various agronomic practices.
9. Multiseeded varieties: The number of seeds per pod is one of the most important yield components. In order to increase the yield, an intensive crossing program was initiated. A large number of genotypes were developed and tested against the existing recommended varieties. A set of 30 varieties was found, with 1.75–2.37 grains per pod on the average, as against 1.46 in the recommended variety H-208. Besides retaining multiseeded and normal grain size, 13 have given higher yield than the existing recommended varieties (Table 6). These genotypes will be grown under various situations, such as late planting, variable row spacings, and different fertility and irrigation levels for testing their stability, particularly for number of grains per pod and yield.

Irradiation Breeding

For the first time, Raja Ram (1973) reported increased yield in varieties Pb-7 and Rabat from this center on treatment with 2, 5, 10, and 20 krad of irradiation. Both varieties gave high genetic variance, much of which was accounted for by the additive component. Therefore, the possibility of improving the yield of kabuli varieties has been indicated. On the other hand, in varieties S-33 and HM-9, the irradiation did not bring any changes in yield performance. The genetic variance and additive genetic component were not increased in the desi as in the kabuli varieties.

Table 5. Characteristic features and yield performance of newly developed varieties of chickpea.

Variety	Pedigree	Habit of growth	100-grain weight (g)	Grain color	Special features	Mean Yield (q/ha)[a]	
						1976–77	1977–78
H-376	(S-26 × V-114) × (G-24 × V-114)	Semi-erect	12.5	Yellow brownish	Drought tolerant	26.78	16.19
H-457	H-432 × C-214	Semi-erect	12.8	Yellow brownish	Drought tolerant	29.31	17.02
H-519	H-432 × H-214	Spreading	12.7	Brownish yellow	Drought tolerant	31.90	17.72
H-531	H-432 × C-214	Spreading	13.6	Yellowish brown	Drought tolerant	30.67	15.48
H 75-18	C-214 × P-6195	Spreading	12.3	Yellowish brown	Wilt tolerant	26.23	16.78
H 75-33	(C-214 × H-435) × (H-214 × H-432)	Semi-erect	11.9	Yellowish brown	Wilt tolerant	26.47	12.98
H 76-49	H-214 × P-6195	Semi-erect	11.3	Dark brown	Wilt tolerant	30.19	19.40
H 76-62	H-214 × P-6224	Spreading	13.9	Brown	Drought tolerant	32.27	14.05
H 75-35	C-235 × E-100Y	Semi-erect	21.5	Yellowish brown	Salinity tolerant	37.14	22.92
H 75-36	H-208 × E-100Y	Semi-erect	20.4	Brown	Salinity tolerant	35.43	19.61
H-192	(C-214 × V-114) × (S-26 × V-156)	Semi-spreading	16.0	Brownish yellow	Drought tolerant	21.23	20.95
H 73-28	Selection	Semi-spreading	15.3	Brownish yellow	Drought tolerant	25.47	20.76
H 72-4	Selection	Semi-spreading	15.2	Brownish yellow	Drought tolerant	27.30	24.10
H 73-10	Selection	Semi-spreading	14.9	Brown	For irrigated areas	25.59	24.63
H 76-2	G-130 × P-1347	Semi-spreading	12.4	Yellowish brown	For irrigated areas	26.58	16.13
H 76-67	P-6224 × T-3	Semi-spreading	13.3	Yellowish brown	Drought tolerant	27.21	20.99
H-208 (check)	(S-26 × G-24) F_3 × C-235	Semi-erect	12.0	Brownish yellow	Drought tolerant	20.30	18.40

a. 1 quintal = 100 kg.

Breeding for Drought Resistance

Among the varieties released from this University, G-24, C-214, and H-208 are tolerant to drought. Since neither precise information about the mechanism of resistance to drought nor the standard techniques for evaluation for drought resistance are available, efforts were made to improve the yield and tolerance to drought of present varieties. Certain morphological characters (such as small foliage, stiff stem and foliage, dwarf and bushy plant type, slow growth during stress and quick recovery during favorable conditions) have been considered as contributing to drought tolerance. The culture P-6224 (Delhi Dwarf), which possesses most of these characters, has been intensively used in the crossing program. Progenies in the F_5 and F_6 stages, isolated from the crosses involving this culture, have been found promising. A set of 217 genotypes is under evaluation, grouped into different plant types, namely (1) tall, erect, broad foliage, and bold seeds, (2) semi-spreading and profuse podding and branching, (3) very short statured, spreading, and small foliage, and (4) short stature, spreading, and small foliage.

Breeding for Disease Resistance

Diseases are the limiting factors for realizing the expected yield in chickpea. Though there are several diseases that attack chickpea, wilt complex and blight are the most devastating. Therefore, the resistance breeding program has been confined to those diseases.

Breeding for Wilt Resistance.

Rhizoctonia bataticola and *Fusarium* species have been reported responsible for wilting in chickpea in Haryana. The earlier variety G-24, though fairly resistant to wilt, has low yield potential and nonattractive small grains. For developing high-yielding types possessing re-

Table 6. Characteristic features and yield performance of 13 multiseeded varieties of chickpea at Hissar (1977–78).

Variety	Pedigree	Growth habit	Grains/ pod (no.)	100-grain weight (g)	Mean yield (q/ha)[a]
HMS-6	C-214 × H-432	Semi-erect	2.19	13.4	24.59
HMS-30	(H-432 × H-214) × (H-214 × C-214)	Semi-spreading	2.28	14.7	23.95
HMS-27	(H-432 × H-214) × (H-214 × C-214)	Semi-spreading	1.75	13.0	22.69
HMS-24	(H-432 × H-214) × (H-214 × C-214)	Semi-erect	1.71	17.7	21.59
HMS-25	(H-432 × H-214) × (H-214 × C-214)	Semi-spreading	2.19	15.7	21.48
HMS-2	(H-432 × H-214) × (H-214 × C-214)	Semi-erect	2.17	15.4	21.12
HMS-5	(H-432 × H-214) × (H-214 × C-214)	Semi-spreading	2.37	12.2	20.95
HMS-21	(H-432 × H-214) × (H-214 × C-214)	Semi-spreading	1.80	11.9	20.95
HMS-23	C-214 × H-432	Semi-erect	1.78	15.0	20.78
HMS-15	(H-432 × H-214) × (H-214 × C-214)	Semi-erect	2.28	17.0	20.00
HMS-16	(H-432 × H-214) × (H-214 × C-214)	Semi-spreading	1.95	14.8	19.21
HMS-19	C-214 × H-432	Semi-erect	1.75	16.4	19.21
HMS-17	(H-432 × H-214) × (H-214 × C-214)	Semi-spreading	1.87	15.6	18.74
H-208	(S-26 × G-24) F_3 × C-235	Semi-erect	1.46	12.5	18.09

a. 1 quintal = 100 kg.

sistance to this disease, the wilt-sick plot has been developed for effective screening of the cultures and segregating material. As a result of screening, the cultures P-426, P-5054, G-543, P-6229, P-1447, P-539A, P-6612, P-6613, and K-315 were found to possess a fair degree of resistance. Some of these cultures have been used in the crossing program involving agronomic bases C-214, H-208, H-355, C-235, Hima, and G-130. Six genotypes were found to possess a fair degree of resistance or tolerance to wilt and high yield (Table 7). These genotypes are being intensively tested for wilt resistance and yield.

Breeding for Blight Resistance

Chickpea blight is a fungal disease caused by *Ascochyta rabiei*. Symptoms appear first on growing tips in the form of black dots that encircle the stem and result in drying. This process is repeated on other branches and is intensified until the whole plant appears to be burnt up.

Breeding work for blight resistance was started as early as in 1941. Of the 392 cultures received from the United States and from different parts of India, only three lines — F8, F9, and F10 — were found resistant to blight. The cul-

Table 7. Performance of wilt-resistant varieties of chickpea (1978–79).

Variety	Pedigree	Growth habit	Incidence of wilt (%)
H 78-91	C-235 × E-100Y	Semi-erect	0.0
H 78-77	H-208 × E-100Y	Erect	0.0
H 78-94	P-1129 × E-100W	Semi-erect	0.0
H 78-100	H-208 × E-100W	Semi-erect	0.0
H 78-96	P-1404 × E-100W	Semi-erect	10.0
H 78-92	P-1129 × E-100W	Erect	0.0
H 78-97	P-1404 × E-100W	Semi-erect	0.0
H-208	(S-26 × G-24) F_3 × C-235	Semi-erect	5.0
K-315	100 × 106	Semi-erect	0.0

ture F8 was also high-yielding and was released for cultivation in what was then part of Punjab. By using this variety as a donor for resistance, the variety C-1234 was developed and released in 1949. Subsequently, C-235 was developed from the cross C-1234 × IP-58 and released for cultivation in 1960. This variety is still holding its place in the field as a resistant variety. Recently the cultures P-6625, P-1528-1, C-227, 12-071-05093, 12-071-10054, and P-180-1 were found resistant to blight and were used as donors in the crossing program with G-130, C-235, G-130, and H-355 as agronomic bases. The segregating material is being evaluated at Kaul (Kurukshetra), which is suitable to such screening.

Breeding Varieties Responsive to Inputs

While chickpea is grown in India under conditions of neglect and in localities not suitable for cash crops, it commands good inputs in several other countries, such as Iran, where it is grown during the March–September season and receives ample fertilizers and irrigation. The yield levels of chickpea under such conditions are reported to be as high as 5000 kg/ha. Therefore, it was planned to isolate some fertilizer- and irrigation-responsive genotypes. A set of 60 cultures received from Iran was tested under two fertility levels, (0 kg N + 40 kg P_2O_5/ha and 25 kg N + 80 kg P_2O_5/ha), during 1969–70 and 1970–71. None of the cultures excelled the recommended varieties G-130, C-214, and C-235.

During the current season (1978–79), 100 germplasm lines are being tested under three irrigation levels (25, 50, and 75% moisture depletion) and two fertility levels (40 and 80 kg P_2O_5/ha) for isolating input-responsive cultures for use in the crossing program. In addition to these cultures, 50 F_2 bulks (40 from ICRISAT and 10 from Haryana Agricultural University [HAU], Hissar) are being evaluated under these situations for selecting the input responsive recombinations (Table 8).

Breeding for Salinity Resistance

There is no specifically known source of resistance to salinity. However, a relatively resistant strain, E-100Y, which tolerates salinity up to 4 mmho electrical conductivity, was received from Greece in 1970. Intensive crossing involving this culture was carried out. Though the performance of this culture was very poor, it appeared to be a good combiner for number of fruiting branches and pods per plant, number of grains per pod, and seed size. The breeding material was screened for resistance to salinity at the Central Soil Salinity Research Insitute (CSSRI), Karnal, and the yield performance was assessed at HAU. A set of 11 varieties, which showed tolerance up to pH 9.4 at CSSRI, was tested for yield performance at HAU during 1977–78 (Table 9).

Breeding for Stability

Stable varieties of chickpea are most important

Table 8. List of F_2 bulks being tested during 1978–79 at two fertility levels at Hissar.

Cross
From ICRISAT
T-103 × NEC-143
P-517 × F_5 (H-208 × GW-5/7)
WR-315 × P-1179
F_2 (F-61 × T-103)-3 × F_2 [(P-502 × P-9623) × P-4235]-3
7389-18-5-B × 7358-7-2-B
C-214 × JG-74
73114-15-3-B × 73126-6-2-B
P-2264 × F_5 (850-3/27 × Radhey)
NEC-1196 × P-3482
P-3552 × F_5 (850-3/27 × F-378)
G-130 × 12-071-05093
F_2 (P-1286 × 850-3/27)-2 F_2 (P-2571 × P-3090)-2
7389-15-1-B-B × 7330-10-4-B-B
73143-5-1-B × 73111-8-3-B
P-6099 × P-1179
T-103 × B-110
850-3/27 × (P-1214 × 12-071-04244)
850-3/27 × F_2 (NEC-1639 × NEC-1640)
73143-5-1-B-B × 7376-15-2-B-B
WR-315 × 73111-8-3-B
7389-18-5-B × 73111-8-2-B
F_5 (JG-62 × F-378) × F_5 (RS-11 × GW-5/7)
7389-18-5-B-B × (P-1363-1 × Jam)
850-3/27 × (P-1231 × GL-629)
73114-15-3-B × 7378-7-2-B
C-104 × 73105-7-1-B
GW-5/7 × (P-30 × NEC-249)
F_2 (NEC-249 × P-3090)-3 × F_2 (JG-39 × P-4235) × C-214)-3
850-3/27 × 7330-10-4-B
7389-18-5-B-B × 7330-10-4-B-B
Annigeri × C-214
JG-62 × F_5 (850-3/27 × N-59)
F_2 (12-071-04244 × P-1100)-3 × F_2 (P-481 × GW-5/7)-3
No. 22 × 7389-21-1-B
WR-315 × 73114-15-3-B
850-3/27 × 7332-7-2-B
73143-5-1-B-B × JM-460/A
P-1238 × F_5 (850-3/27 × F-378)
73114-15-3-B × 73111-8-3-B-B
7332-7-2-B-B × (WR-315 × GL-629)
From Hissar
Pant-113 × P-1081
H-355 × No. 5
C-214 × P-3284
H-355 × P-726-2
H-208 × T-3
H-214 × No. 3
Pant-113 × E-100Y
F-61 × T-3
C-214 × P-726-2
F-61 × 850-3/27
H-208 (check)

for a country such as India where environmental fluctuations are very high. As a result of several years' testing of the varieties under the All-India Coordinated Program, 2 varieties — H-208 and H-355 — continued to be the top-yielding at Hissar. The varieties Hima, BG-203, F-61, F-378, K-295, and K-468 have also been found stable and fairly high-yielding. These varieties are being used in a broadbased hybridization program.

Selection of Good Combiners for Hybridization

The selection of suitable parents for hybridization is the most important step. In the past, parents were selected on the basis of performance, which does not always give good recombinants. Selection on the basis of general combining ability has been proved beneficial in many crops. There are several techniques (such as line × tester, diallel, and partial diallel) that may be employed for the evaluation of the parental material for general combining ability. Through these techniques, the genotypes given in Table 10 have been found to be good general combiners for different characters and therefore, can be used successfully in hybridization programs (Chowdhary 1973; Singh 1973; Tomer 1977; and Sikka 1978).

Special Breeding Techniques

Disruptive Selection

Generally there is lack of desirable recombinations in the segregating populations, particu-

Table 9. Performance of 11 varieties of chickpea at Hissar and Karnal during 1977–78.

Variety	Pedigree	Growth habit	100-grain weight (g)	Mean Yield (q/ha)[b]	Reaction to salinity[a]
H 76-101	C-235 × E-100Y	Semi-erect	17.6	25.32	A
H 76-109	P-539 × E-100Y	Semi-spreading	23.0	24.05	B
H 76-106	Addis Ababa × E-100Y	Spreading	24.0	23.96	C
H 76-105	G-130 × E-100Y	Spreading	16.5	22.86	C
H 76-102	H-214 × E-100Y	Semi-erect	17.3	22.54	B
H 76-103	H-214 × E-100Y	Semi-erect	15.5	22.46	B
H 76-110	P-1447 × E-100Y	Semi-spreading	18.3	20.71	B
H 76-108	P-539A × E-100Y	Semi-spreading	21.9	20.16	B
H 76-104	G-130 × E-100Y	Spreading	21.8	19.36	A
H 76-111	P-1440 × E-100Y	Spreading	18.9	17.06	C
H 76-107	Addis Ababa × E-100Y	Semi-erect	19.5	16.67	D
C-235 (check)	IP-58 × C-1234	Semi-erect	12.2	20.48	C

a. Ratings are as follows:
A = Resistant, B = Tolerant, C = Moderately tolerant,
D = Susceptible under pH 9.1 and 5 E.C.

b. 1 quintal = 100 kg.

Table 10. Good general combiners for different characters in chickpea.

Character	General good combiners
Seed yield	G-130, P-1387, No. 502, E-100Y, C-727, P-1129, P-1528-1, T-3, P. No. 1, F-8, Hima
No. of pods/plant	H-208, P-1387, B.D. Local, NEC-721, C-235, E-100Y, T-3, P. No. 1, Hima, L-345, H-214
No. of primary branches	G-130, H-208, T-3, Hima, L-345, F-8
No. of secondary branches	H-208, F-61, P-82, P-436, P-3083, E-100Y, BG-482, T-3, Hima
No. of grains/pod	G-130, P-1129, P-1387, P-1113, H-214, C-23, EC-26414
Grain size	G-130, P-3083, NEC-721, Caina, E-100W, H-214, S-26, Addis Ababa, E-100, T-3
Protein content	H-208, F-61, P-861
Pod setting	F-378, P-3387, No. 502, H-214, Hima, E-100

larly for quantitative characters, due to linkage between desirable and undesirable traits. By selecting populations of two extreme types, followed by intermating between the individuals of these two populations, chances of breaking linkages and consequently the release of variability and new desirable recombinations are increased. Considering the imporatnce of this technique, a large number of progenies in single and double crosses were selected by number of days to flowering and number of grains per pod. Very encouraging results were obtained, and the number of grains per pod was increased to two to three without adversely affecting the size. One of the lines (HMS 6) developed by this procedure has outyielded the best check (H-208) by a significant margin (35%). This technique is also being extended for improving the other characters, such as seed size, number of branches, number of pods, and so on.

Biparental Crossing Technique

Joshi and Dhawan (1966) suggested the use of the biparental crossing technique for accumulating genes having additive effects and breaking of undesirable linkage. According to them, out of several crosses, only a few exhibiting considerable heterosis both at F_1 and F_2 levels are selected. In these selected crosses, biparental mating among the individuals both within and between crosses is made for further isolating the superior lines. This process may be repeated so long as improvement is forthcoming. This technique is being followed for selecting crosses and effecting improvement in yield.

Diallel Selective Mating System

In chickpea, both additive and nonadditive genetic variances have been reported important for the expression of most of the quantitative characters (Singh 1973; Tomer 1977; Sikka 1978). Under such a situation, breeding for a homozygous variety by the conventional pedigree method would only partially exploit the genetic variance. In order to exploit different types of gene actions, it is desirable to use breeding procedures that will take care of the fixable gene effects and at the same time maintain considerable heterozygosity for exploiting the dominance or nonadditive gene effects; these procedures may prove most efficient in improving the population. Under such a situation — when on the one hand, the conventional breeding methods have almost failed to make further improvement and on the other, heterosis breeding is faced with several serious difficulties — only some refined technique, which also retains the advantages of the conventional system, can be effective. Jensen (1970) proposed a new crossing system known as "diallel selective mating" to serve as a supplement to the conventional breeding system for self-pollinated crops like chickpea. In this method, all possible biparental crosses are made among the selcted parents and, depending upon the number of F_1s, a diallel or partial diallel set of crosses is made among F_1s. Such crosses thus provide the material for initiation of a breeding population. The population is propagated into F_2 where some form of mass or visual selection is applied; subsequently, many random crosses are made among selected F_2 individuals. This process of mass and visual selection, followed by intercrossing among the selected individuals, should be continued either in every generation or every second generation to maximize heterozygosity, crossing over, and recombination among alleles at linked loci. In this way, this system forces simultaneous involvement of multiple genotypes into a central population, indicating thereby broad use of germplasm, breaking of linkage blocks, freeing of genetic variability, and releasing of desirable genetic recombinations.

Considering its importance, this technique is being followed by involving 14 parents — C-214, H-208, H-362, H-354, H-370, H-534, G-24, K-315, F-378, BG-2, H-75-1, P-6224, T-3, and P-3083. All possible biparental crosses — C-214 × H-208, H-362 × H-354, G-24 × K-315, H-75-1 × P-6224, F-378 × BG-2, H-370 × H-534, and T-3 × P-3083 — were made during 1975–76. A complete diallel set among these seven crosses was made during 1976–77. During the subsequent year, the 21 crosses were advanced, and an F_2 population is being grown during the current season for selecting desirable plants for further crossing.

References

ANONYMOUS. 1977. Agricultural situation in India 32(8): 541.

ANONYMOUS. 1978. Statistical abstracts of Haryana, 1976–77: p. 11.

CHOWDHARY, D. S. 1973. Studies on heterosis and combining ability in Bengal gram (*Cicer arietinum* L.). M.Sc. thesis of Haryana Agricultural University, Hissar, India.

JENSEN, N. F. 1970. A diallel selective mating system of cereal breeding. Crop Science 10(6): 629–634.

JOSHI, A. B., and DHAWAN, N. L. 1966. Genetic components in yield with special reference to self-pollinated crops. Indian Jouranal of Genetics 26A: 101–113.

RAJA RAM. 1973. Irradiation studies in diploid and tetraploid varieties of gram (*Cicer arietinum* L.). Ph.D. thesis of Haryana Agricultural University, Hissar, India.

SIKKA, V. 1978. Heterosis and combining ability studies in *Cicer arietinum* L. M.Sc. thesis of Haryana Agricultural University, Hissar, India.

SINGH, K. P. 1973. Genetic divergence and quantitative inheritance studies in gram (*Cicer arietinum* L.). Ph.D. thesis of Haryana Agricultural University, Hissar, India.

TOMER, Y. S. 1977. Studies on inheritance of some quantitative characters in chickpea (*Cicer arietinum* L.). Ph.D. thesis of Haryana Agricultural University, Hissar, India.

Session 6 — Chickpea Breeding at the National Level

Discussion

Laxman Singh Paper

M. P. Haware

Through the All India Pulse Program, the chickpea cultivars are bred on the basis of agroclimatic zones. Since disease problems can be identified locally, why not breed for disease resistance on the basis of need of a particular zone? This way, a cultivar that may be susceptible at Kanpur but performs well at Gurdaspur or Delhi may not be rejected.

Laxman Singh

I agree that cultivars showing resistance at a particular location (though susceptible at another) should not be rejected. After ascertaining their genetic resistance, these cultivars should be utilized in disease-resistance programs at that location, but we should not lose sight of a wider spectrum resistance.

J. S. Sindhu

We developed a variety of chickpea, named K-315, which is completely resistant to wilt disease but has small seed size. Knowing that consumers favor bold-seeded types, we crossed it with variety T-3, a bold-seeded variety. The material is now in an advanced stage and may be made available on demand.

Laxman Singh

This is a good attempt to combine seed size optima with yield and wilt resistance.

Jagdish Kumar

If multilines can protect against different races of pathogens, they can be equally effective against different pathogens.

R. B. Singh

Dr. Pandya has chosen cultivars with varying seed sizes (e.g., 850-3/27 and H-208) and varying maturity. It would adversely affect the performance of these mixtures. I do not see any advantage of including a kabuli type in these mixtures.

K. B. Singh

1. ICRISAT and other institutions in India have been working for the development of (1) genotypes suitable for late planting in North India and (2) genotypes suitable for early planting in southern India. ICARDA has been working on development of a kabuli type for winter planting. Would you please comment?
2. ICARDA is generating kabuli material and can furnish trials to people in India, if desired.

Laxman Singh

1. We in India plan to develop in the very near future a program of joint evaluation of genotypes under early and late plantings at a few centers in the country.
2. If more material is forthcoming, we would initiate uniform cooperative varietal testing of kabuli types.

Umaid Singh

I have a small comment regarding the aspect of crop quality as mentioned by you. It is good that you intend to start some work on high-protein lines of chickpea. But in addition to work on protein quality, I feel there should be considerable emphasis on cooking quality of chickpea. While saying this, I mean a cultivar that takes a shorter time to cook would be a consumer preference and it is also of importance in the context of saving fuel. As we have observed in our laboratory, large differences occur in the cooking time of different cultivars. So I think there is a point that work to evaluate the chickpea cultivars for their cookability values should be undertaken.

Laxman Singh

The trade quality parameters often are seed size, shape, and color, which tend to get premiums in the market, depending on preferences in different regions. Chickpea is more widely consumed as *besan* (ground flour) than as whole seed, so perhaps flour quality would deserve attention. Breeding for less time to cook or high protein is not on our priority list in the national program, but advanced materials should be monitored lest they fall below prevalent types. However, we should endeavor to generate information on parameters of quality of flour, culinary types, and genetic and nongenetic factors affecting them through a cooperative program at two or three centers.

Pandya and Pandey Paper

J. Kannaiyan

What is the causal organism of the blight you mentioned in your paper?

B. P. Pandya

This is actually *Botrytis* gray mold.

Jagdish Kumar

You mentioned an experiment on multiline mixtures in chickpeas. I am interested in knowing the names of the cultivars that were used and their seed sizes and maturity durations. What is the yield advantage?

B. P. Pandya

The parents were as follows: 850-3/27, JG-62, WR-315, Rabat, L-550, Pink 2, and H-208 (check) for a total of 64 treatments; 6 genotypes, 57 mixtures and 1 check. There was a total of 120 seeds, which were tested in three locations and in 1 year at two dates of planting. Information on seed size and maturity is not available at the moment. Although statistically not significant, the yield advantage was 13.7% over the check. The best combination was found to be 850-3/27 + L-550.

P. N. Bahl

During the last 2 days we have learned that coadaptation in chickpea is very important. We also know that the breeder would like to break repulsion phase linkages. In the light of these remarks, will you elucidate whether the breeder should go in for two-way, three-way, or multiple crosses?

B. P. Pandya

I have no experience with three-way crosses. We had made certain double crosses but could not get good segregants. In fact, I would prefer to go for two-way crosses (both adapted parents having good yield potential), because (1) we may get transgressive segregates, and there may be (2) more variability (population improvement) and ultimately selection of better recombinants.

Laxman Singh

As I see it, there is no way of predicting whether we would get desired recombinations in single, two-way, three-way, or multiple crosses. Certainly, multiple crosses would help in breaking linkages; the need, however, is to choose the right type of parents, grow an adequate population, and exercise adequate selection pressure for desired results.

G. C. Hawtin

The problems associated with the breakdown of coadapted gene blocks may be minimized through the selection of adapted parents, but of diverse botanic origin. Thus, in making multiple corsses for western Asia, parents could be chosen to include both well adapted kabulis and well adapted desis. Where some of the parents are nonadapted, it may be better to concentrate on crossing selected F_2s.

J. M. Green

On what genetic evidence do you base your recommendation for intercrossing in F_2? Parents (plants) for crossing would have to be chosen in the early flowering stage. Would random crosses (with respect to yield) be of value?

B. P. Pandya

In fact, my observation is based on random, cross-pollinated crops such as maize, which creates the possibilities of throwing out more and more recombinants. In the spaced-planted F_2 material, we follow selection at three stages: (1) flowering time, (2) podding, (3) ripening when leaves have fallen and only pods are there. Resources permitting, a large number of crosses could be made; then, at the final selection, few of the plants would have to be discarded because of undesirable characters, such as disease.

Lal and Tomer Paper

R. B. Deshmukh

The bushy types have better plasticity, branching, and drought tolerance and, hence, they need more consideration before we shift our preference for the erect habit of growth in chickpea.

Advancing the planting of chickpeas in the month of September may not be possible as the crop is generally grown after the harvest of kharif crops such as sorghum and pearl millet.

It is my experience that the crosses between desi × desi types can give very high heterosis in F_1 and transgressive segregants in F_2, provided the selection of parents is based on genetic diversity, combining ability, and the desirable yield components. The crosses between desi × kabuli may result in the transference of susceptibility to establishment of plants and to heat stress in central and peninsular India.

S. Chandra

When the kabuli × desi crosses were discussed yesterday, I recalled some of the past achievements of this approach. I would just like to mention that an additional advantage of that program was the isolation of some high-yielding, multiseeded lines like H-432, which just failed to get released for cultivation because they were not stabilized until F_{13} and their characteristics could not be described to a seed-producing agency to produce true-to-type certified seed. However, this material in its genetically diverse background was crossed onto the locally adapted types, which resulted in the development of some of these multiseeded types. These multiseeded types have a potential that cannot be ignored.

S. Lal

The suggestion of Dr. Chandra is quite good. These multiseeded lines are being properly evaluated and multiplied for seed increase. These are also being used in crossing programs and for studying inheritance of multiseededness.

S. Chandra

After listening to the three speakers, a case very clearly seems to be emerging for development of prolific types in chickpea. ICRISAT and IARI seem to have tall, stiff-stalked materials; HAU has stable two-pod genotypes. There is an inescapable conclusion that emerges from this situation, that is, a very effective program must be formulated to exploit these new generations of chickpea materials by additionally incorporating disease-resistant sources from Indian and international programs. I also presuppose that this infrastructure shall be based on reasonably extensive intermating mechanisms and will not be wasted in a drive for single-plant progeny selection.

S. Lal

This is a good suggestion. Although it is a huge task to combine all these characters, we should follow this procedure in order to encourage breakthroughs in the production of this important pulse. We are keeping this point in mind and will expand our crossing program involving the materials suggested by Dr. Chandra.

S. C. Sethi

What difference do you observe in the number of seeds/pod in case of your multiseeded lines in lower and upper pods in a branch?

S. Lal

The multiseeded lines are unstable for seed setting within the plant. Generally, the lower pods set a larger number of seeds than the pods on the top, which set grains when the weather is not good for seed setting.

M. P. Haware

Are you screening for wilt resistance? What is the method? Most of the cultivars you mentioned, such as G-24 and H-208, are highly susceptible to wilt.

S. Lal

In the evaluation program where six genotypes were found resistant to wilt, H-208 was used as local standard variety, not G-24. In fact, WR-315 has been used as a resistant check. All these varieties have been sown in wilt-sick plots.

S. Sithanantham

Among the objectives of breeding for resistance to pests, it might be interesting to consider termites also, since considerable importance is given to this pest in Haryana because this pest is as polyphagous as are cutworms and *Heliothis.*

S. Lal

This is a suggestion which will be considered in our breeding program.

P. N. Bahl

Can you tell us if data are available on stability and heritability of multiseeded habit?

S. Lal

The multiseeded types are sensitive to proper seed setting. Generally, the lower pods set larger number of seeds than the upper pods on the same plant. The information on the heritability of this character is not available at the moment. However, we have segregating material at the F_2 and F_3 levels involving multiseeded lines as one of the parents. The information from such material will be derived.

Sessions 7 and 8

Country Reports

Chairmen :	**J. M. Green** **G. C. Hawtin**	**Rapporteurs:**	**C. L. L. Gowda** **K. B. Saxena**
Co-Chairmen:	**M. H. El-Sherbeeny** **G. Bejiga**		

Chickpea in Afghanistan

A. Q. Samet*

Afghanistan, located between 29° 30′ and 38° 30′ N latitude and 60° 30′ and 75° 50′ E longitude has a dry and healthy climate with four distinct seasons. Summers are hot with plenty of sunshine; winters are cold with snow in most areas. During fall and spring, temperatures are mild. The average annual precipitation is 300–350 mm/year, but amounts vary greatly in different areas of the country. The Hindu Kush Mountains dominate most of Afghanistan's 653 000 km². There is great variation in agroclimatic conditions and soil types within the country, and so far, agroecological zones for crop research programs have not been demarcated. Important crops are wheat, rice, cotton, sugarbeet, maize, oilseeds, and pulses, including chickpea.

Area, Production, and Distribution

Chickpea is of secondary importance among the food legumes, and exact figures for its area and production are not available. The largest chickpea-producing areas located in the north include Takhar, Samangan, and Mazar-i-Sharif provinces; and in the west, it is located in Herat province. In these provinces, chickpea is grown under rainfed conditions during spring. The provinces differ in geographical and climatic conditions, as follows:

Takhar Province has the largest area under chickpeas. It has a temperate type of climate with frequent rains in the spring and in the fall, and frequent snow during the winter. This province is mountainous, and there is less flat area; the soil in the hills is sandy clay loam and sandy loam, but the soils in flat areas have high salt content. Data for this region are as follows:

Location : 36°44′ N lat., 69°30′ E long.
Altitude : 804 m
Average annual precipitation : 548 mm
Frost-free days : 224
Average annual temperature : 27°C max., 2.3°C min.

Samangan Province is the second largest chickpea-producing area. This region is also mountainous with considerable variation in soil type and climate; the relative humidity is high during spring and fall. During spring, there are more showers in the mountainous sites than in the flat areas, and there is more snow here during winter. Most of the chickpea in this province is grown under rainfed conditions, although some farmers have irrigation facilities and grow chickpea under irrigated conditions. Soil in the irrigated areas is fertile sandy loam and sandy clay loam, whereas in dryland areas the soil is a poor sandy clay loam.

Mazar-i-Sharif Province is mostly desert, with a small portion that is mountainous. Relative humidity in the desert area is low during the summer. Chickpea is mostly grown under rainfed conditions in areas adjacent to Samangan province, and this area is relatively warm and dry. Precipitation during the spring is very low, and sometimes the atmospheric temperature suddenly drops so much that it completely kills all vegetation in the area. Yields are thus not as good as those obtained under rainfed conditions because the cultivation practices in such areas are poor. Data relating to Mazar-i-Sharif Province are:

Location : 36°42′ N lat., 67°12′ E long.
Altitude : 378 m
Average annual precipitation : 197 mm
Mean annual temperature : 33.1°C max., 1.1°C min.

Herat Province located in the northwest and western part of the country is another

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chickpea-growing area. Most of the area under chickpea is irrigated; very little is rainfed. Chickpeas are sown during early spring. The climate of this province is warm with frequent showers during spring and fall, but summer is warm and dry due to the wind. The chickpea season starts in mid-spring and ends by the end of September. Data relating to Herat Province are:

Location	: 34 13° N lat., 62 13° E long.
Altitude	: 967 m
Frost-free days	: 228
Average annual precipitation	: 207 mm
Mean annual temperature	: 28.9°C max., 0.6°C min.

The wild species of chickpea grow abundantly under rainfed conditions in areas extending from west to north, through central parts of Afghanistan (Vavilov and Bukinich 1926). Japanese botanists also reported the presence of wild species of chickpea in western parts of Afghanistan, extending from Nooristan to the western part of Jalalabad. Different scientists have reported a great variation within the cultivated and wild species of chickpea; based on such studies, Vavilov believed the primary center of origin of chickpea is central Asia, where maximum diversity in chickpea exists. Scientists working on pulses at ICARDA and ICRISAT reported that both cultivated and wild species of chickpea are found in all parts of Afghanistan, but geographical and climatic conditions of all areas in Afghanistan do not support this statement. There are some areas in the country where agroclimatic conditions are not favorable for chickpea. An intensive and systematic survey of species of chickpea is very necessary if we are to have complete knowledge of the chickpea-producing areas. Such knowledge is essential for development of a germplasm bank of chickpea varieties and species.

Major Uses and Marketing

Chickpeas are mainly consumed as a pulse. Kabuli types are preferred to desi types in this regard. Besides its use as a pulse, chickpea is also commonly consumed roasted (*nakhod-beryan*), boiled (*Shore-nakhod*), roasted and salted (*nakhod-tonned*), and roasted and sugarcoated (*Dohlo-nakhod*). Farmers sell their produce in the markets, from where it is distributed to retail shops. The average price varies from 15 Afghanis to 25 Afghanis per kg of raw chickpeas. There is no export because there is no surplus after local consumption.

Current Status of Production Practices

Chickpea is not a major crop of Afghanistan. Exact statistics to compare the relative status of chickpea in the cropping pattern of the country are not available. Chickpea is sown during early spring (Apr–May) and harvested during mid-June to mid-August. At present, there is no improved variety of chickpea for Afghanistan. Local varieties are grown. Cultivation of chickpeas in Afghanistan is done by indigenous methods. Farmers prepare the field with the help of the local plow, and seed is broadcast. Manure or chemical fertilizers are not used for legume crops. Practically no attention is paid to the use of soil amendments or for inoculation of the seed with cultures before sowing. Except in Herat Province, most of the area under chickpea is rainfed, and very little area is irrigated.

Harvesting is done by hand, and threshing is done either by beating with sticks or by walking over with animals. There is no mechanization in chickpea cultivation.

Major Problems of Production, Protection, and Utilization

The common disease of chickpea is root rot; aphids and borers are also a problem. Chemicals (fungicides and insecticides) are not used to control diseases and insect pests of chickpea in Afghanistan. Very little care is given for weeding.

The following factors limit the production of chickpea in Afghanistan:- (1) nonavailability of improved varieties; (2) inadequate use of manures and fertilizers; (3) lack of irrigation facilities; (4) absence of plant protection measures; and (5) inability of the farmers to purchase inputs.

Research and Extension

Research work on food legumes was initiated during 1974. At present, the plant breeders listed in Table 1 are engaged in research for the improvement of chickpeas in Afghanistan.

There is no provision for extension work in chickpea in Afghanistan because there is no improved variety and no technology has been developed for chickpea.

Seed Production Capability

As there is no improved variety of chickpea, there is no commercial seed production in the country.

Research Review

Regular research projects for the improvement of chickpea were initiated during 1974. To begin, a germplasm collection (including cultivated and wild species) was made by ALAD with the assistance of the Ford Foundation during 1974 and ICARDA/ICRISAT during 1975–1977. Afghan scientists also made a cultivar collection during 1977–78; at present, our germplasm bank includes 350 samples of chickpea.

During the last few years we received from ICARDA and ICRISAT chickpea material for observation and trials, and some of the entities appear to be promising. These trials include preliminary yield trials, national yield trials, and observation nurseries grown at four main agricultural research stations (Darul-Aman, Kunduz, Bulkh, and Herat) located in different agroclimatic zones of the country. From the results obtained at these stations during the last 2 or 3 years, four entries, i.e., 1614, 2161, 2375, and 2620 from trials supplied by ICARDA, yielded an average of 2185, 2212, 2456, and 2192 kg/ha, respectively, and seem to have promise in Afghanistan.

Fourteen wild species of genus *Cicer* have been collected from different parts of Afghanis-

Table 1. Scientists doing chickpea research in Afghanistan.

Organization	Scientist	Time spent on chickpeas (%)
Department of Crop Improvement, Ministry of Agriculture and Land Reforms	Atiqullah	25
	Ghulam Haider	50
	Mohd. Aziz	50
	Abdul Manon	50
	Abdul Wase	50

Table 2. Wild *Cicer* species found in Afghanistan.

Scientific name	Date of flowering	Altitude (m)	Ecology	Province
Cicer acanthophyllum	Jul/Aug	2500–4000	Rubble slopes; dry valleys near lakes	Badakhshan
C. chorassanium	Apr/Jul	1400–3300	Rocky and rubble slope	Kabul, Bamian, Farah, Helmand, Ghazni, Baghlan, Parwan, Nangarhar
C. flexuosum		500–2400	Riverbeds, rocks, scree	Badakhshan c/o Kitimura Fl. Afghanistan 223
C. fedtschenkei	Jun/Aug	2500–4200	Dry stony slopes or valleys, also near lakes and streambeds	Wakhan, Kabul, Farkhar, Parwan
C. macracanthum	Jun/Aug	2200–3600	Dry stream beds, valleys, dry rubble slopes	Badakhshan

Continued

Table 2 *Continued*

Scientific name	Date of flowering	Altitude (m)	Ecology	Province
C. microphyllum (*C. jacquemontii*)	Jun/Aug	2000–5600	Rocky places, dry stream, pastures in open or near trees, rubble sub-alpine	Badakhshan
C. multijugum	Jul/Aug	3000–4200	Mountain slopes, scree	Bamian, Chazni
C. nuristanicum	Jun/Aug	2300–4600	Forest, pasture, shady, humid lime-stone rocks	Paktia, Nuristan
C. oxyoden	May/July	1250–2500	Rocky slopes, rubble, and earth slopes, cultivated fields	Kabul
C. pungens	May/Aug	2300–4200	Stony and rubble slopes, volcanic ashes and limestone, dense alpine meadows	Kabul, Parwan, Wardak, Bamian, Chor
C. rechingori	Jul/Aug	2400–3600	Dry slopes, granite scree	Parwan, Wakhan, Baghlan, Badakhshan
C. yamashitae	May/Jun	900–2800	Large rubble, slopes	Nangarhar

Source: van der Maesen (1972).

tan. Relevant information about these species is given in Table 2, as reported by van der Maesen (1972).

Conclusions

Chickpea is a minor crop in Afghanistan; it is grown commercially in only four provinces. Research work was initiated with the help of ALAD and ICRISAT during 1974. In order to improve chickpea production in Afghanistan, intensive research and extensive programs are absolutely essential, and for this purpose I make the following recommendations:

1. Intensive survey of the country to expand the germplasm bank, including cultivated and wild species.
2. Breeding project to develop high-yielding varieties with high response to manures and fertilizers.
3. Production of breeder seed, foundation seed, and certified seed by the newly formed Afghan Seed Co.
4. Irrigation facilities.
5. Extension facilities to provide guidance and inputs to farmers.

In order to execute the above mentioned recommendations, we need assistance and guidance from international organizations and institutes such as ICRISAT and ICARDA.

References

Solh, M., Rashid, K., and Hawtin, G. 1974. Food legume collection — Afghanistan. An expedition report submitted to Ministry of Agriculture, Government of Afghanistan. 66 pp.

van der Maesen, L. J. G. 1972. *Cicer* L., a monograph of the genus, with special reference to the chickpea (*Cicer arietinum* L.), its ecology and cultivation. Medelelingen Landbouwhogeschool Wageningen, Nederlands, 72–10, 342 pp.

Vavilov, N. I. and Bukinich, D. D. 1926. Agriculture in Afghnistan.

Growth of Chickpea in Chile

Jorge Aeschlimann A.*

Introduction

Chickpea (*Cicer arietinum* L.) is grown in Chile between latitudes of 32° 30′ (Aconcagua) and 39° 0′ S (Cautin). The most important area is located in the province of Colchagua (34° 35′ S).

Chickpea grown in the country is of the kabuli (large-seeded) type; four kinds of grains are usually found — smooth grain (noncommercial), slightly smooth grain globular-ovate; wrinkled globular-shaped grain, and tuberculated. All of them are light in color.

A topographic description of Chile from east to west would start with the Andean Cordillera (Andean Mountains); then the Valle Central (Central Valley), where intensive modern agriculture takes place, mostly under irrigation; then a lower chain of mountains called The Cordillera Central (Coastal Mountains); and finally a dry plain, the Secano de la Costa (Coastal Dryland). Chickpea is grown in the Secano de la Costa under very homogeneous soil and climatic conditions. Small climatc differences exist due to proximity to the coast and to the latitude, but they are unimportant.

The area close to the ocean is characterized by the presence of morning mist during development of the crop. Mist becomes less frequent in the inland areas. This factor has conditioned the development of ecotypes adapted to local conditions, which have evolved through the years into local varieties.

However, the level of technology used, as well as the agronomic an phytopathologic problems are similar in all the areas where chickpea is grown, with the result that only small differences in yields exist between these areas.

Climate

The crop depends on rain for its growth and development (it is unusual to find plantings with late irrigation), which is concentrated mainly in the months of winter (June-Aug), decreasing by fall (Apr-May), and spring (Sept-Nov), and reaching a minimal level in the summer (Jan-Mar). Average precipitation per year in this area is 800 to 1000 mm, depending on the latitude, increasing normally toward the south. The availability of water for the development of the crop is very low if we compare it with the total rainfall throughout the year. However, under these conditions there have been (in experiments) yields between 1500 and 2000 kg/ha, compared to those obtained by good farmers, which normally reach only 800 to 1000 kg/ha.

The mean temperature during the growing season is approximately 18°C — maximum around 27.5 and minimum about 9.5–10°C.

Soils

The most common types of soils found in the chickpea-producing areas are sandy-clay or clay-sandy in texture, with contents of organic matter of around 2.5 to 3% and a pH between 6 and 7.5. Soils with relatively high contents of calcium have been observed in some areas, which makes the grain grown under such conditions hard for cooking.

Area, Production, and Distribution

Statistical data of the cultivated area, production, and yield of chickpea in Chile for the last 5 years are listed in Table 1.

Except for the period 1973–74, the area cultivated averaged about 7500 ha. Variations in

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Table 1. Statistics of area, production, and yield of chickpea in Chile.

Year	Cultivated area (ha)	Production (tonnes)	Yield (kg/ha)
1964–65	8 369	5070	610
1973–74	13 780	5000	360
1974–75	7 820	4930	630
1975–76	7 100	2740	390
1976–77	8 270	4990	600
1977–78	11 010	5470	500

Source: National Institute of Statistics, Chile.

production were due mainly to changes in mean yield of the crop. However, in the period 1977–78, a substantial increase in the cultivated area occurred; this phenomenon is attributed to the increase in agricultural exports and therefore to a greater interest of the farmers for producing chickpea and other crops that may be exported.

Major Practices and Trade

Most of the chickpea produced in Chile is exported; national consumption accounts for only approximately 20% of the total production.

The most common method of consumption is as a legume; grains are processed to remove the skin. Less frequently, the grain is ground into flour for soups or creams. Residues such as straw and empty pods are used normally as fodder, forage, and bedding for animals.

Exportation

According to figures released by the Chilean Central Bank, importers of Chilean chickpea for 1977 were (in order of economic importance) as follows:

Brazil	US $ 512 268
Colombia	259 654
United States	93 969
Uruguay	47 749
Spain	32 740
West Germany	23 505
France	17 857
Japan	15 609
Costa Rica	14 381

According to the 1976 FAO Trade Yearbook, prices of exported Chilean chickpea have not suffered great variations during the last few years; the metric ton is quoted around U.S. $450.

If we consider the evolution of Chilean chickpea exportations between 1973 and 1977, we have the results shown in Table 2.

The considerable increase in exportations during 1977 compared with the preceding years may be a reflection of the economic policy of the Chilean government to encourage agricultural exports.

Present Production Practices

Crop Rotation

The most common crop rotation in the chickpea-producing areas is chickpea followed by wheat and 2 years of natural pastures, which is used basically for sheep raising. This rotation scheme is conducted by farmers with large extensions of land. On small farms, the annual rotation is reduced to chickpea and wheat.

Due to lack of irrigation at the Secano de la Costa, soil preparation must start when the spring rains decrease, with the final objective of planting wheat by the next fall. By doing this, chickpea is cultivated as a way of using the prepared land until it may be used for wheat.

As may be observed, under the above mentioned conditions, chickpea is the only alternative planting the farmer may count on in order to make a crop rotation — although a very primitive one. In order to enlarge this rotation, the inclusion of an improved pasture has been

Table 2. Chilean chickpea exportations between 1973 and 1977.

Year	Exported value F.O.B. (U.S.$)	Variation from preceding year (%)	Variation from 1973 (%)
1973	143 324	NA	NA
1974	57 933	−60	−60
1975	250 027	332	74
1976	23 225	−91	−84
1977	1 017 732	4282	610

Source: 1973–75: Customs Office, Chile, 1976–77: Central Bank of Chile.
NA = Not available.

tested, but this practice is inconvenient due to high prices, which makes it impractical for farmers.

The practice of a short rotation has contributed to the increase of root rot incidence.

Planting Dates and Harvest

The normal planting dates are during the second half of September; harvest period is between 15 and 30 January. Chickpea under Chilean conditions has a vegetative period of approximately 120 days.

Varieties

There are no improved varieties of chickpea in Chile at present. Whatever is planted corresponds to mixtures of local types, and therefore a great variation regarding maturity and growth habit is observed at the commercial level. Crop management becomes difficult, and yields are affected.

The first step of the work conducted by the Grain Legume Program of the Chilean Agricultural Research Institution included selections among the best local types. In the long term, improved varieties should be obtained through artificial hybridization conducted in Chile and at ICRISAT Center in India, using as progenitors material derived from screening of native and foreign material. Some of the selected lines appear to be root rot tolerant, and yields of 2000 kg/ha have been obtained in experimental trials. Basic seed of one of them is now available for farmers.

Soil Preparation Methods

Depending on the extension of the area and the economic resources of the farmer, soil preparation is done mechanically (tractor) or with animal traction, consisting in both cases of a single plowing in April or May when the first heavy rains fall, or by the beginning of September when the winter rains start to decrease. By mid-September the soil is harrowed once or twice and is ready for sowing.

Density of Sowing

Seeding rates used by farmers are between 60 and 100 kg/ha, which is considered low; 160 kg of seed/ha is recommended for a population of 250 000 plants/ha.

Planting Methods

Regardless of the method of soil preparation, planting is done by hand in continuous rows. The method consists of opening a furrow with a plow pulled by horse or bullock and drilling seed into the row. A second row is opened with the plow which covers the row previously seeded. The most common distance between rows is 60 cm.

Fertilization

Normally, farmers do not apply fertilizers on chickpea. Research conducted by INIA has indicated that under Chilean conditions very little response is observed after fertilizer applications. However, a basic fertilization of 40 kg/ha of nitrogen and 40 to 80 kg/ha of phosphorus is recommended.

Weed Control

Weed control is generally carried out manually with hoes, and has to be done twice in order to keep the crop clean during its development. At the experimental level, herbicides have been evaluated and some have given good results. However, the high cost of the products makes this practice uneconomic for farmers.

Harvest

Chickpea is usually harvested by pulling up the plants by hand and stacking them with roots upward to accelerate drying. Harvest usually occurs near the end of January.

Threshing

When plants are dry enough to be threshed, they are taken to a preared place in the lot for threshing by machine or animals. If threshing is by animals, the plants are piled in the yard and the horses run over them. This method requires winnowing to separate the grain from the straw.

Even though there are no statistics, the most common method is mechanical; threshing with horses is conducted only in isolated areas not accessible to machines.

Major Production, Protection, and Utilization Problems

Diseases

As mentioned before, the major diseases affecting the cultivar are root rots, caused by the fungus complex of the soil. Preliminary studies have determined the presence of several species, mainly *Fusarium*.

For the control of this disease, disinfection of the seed with thiram + aldrin is recommended. In addition, crop rotation is needed so that chickpea is planted not more often than every third or fourth year.

Another disease observed, and which has not been identified, is characterized by chlorosis of the plant, which presents a certain degree of fading and alteration in the typical shape of the leaflets. Although now found only in isolated plants, this condition might become a serious problem. Research is being conducted and the disease seems to be caused by a virus, but this information is not yet confirmed.

Insects

A larva that perforates the pods has been observed, and it could perhaps be a species of *Heliothis*. ICRISAT's recommendations, i.e., spraying with endosulfan have been adopted to control this pod borer.

Larvae of an insect are present in considerable numbers in soil when chickpea is planted after a pasture; these are controlled by toxic bait.

Economic Aspects of Chickpea

There are no studies on this, but some general statements may be made, based on personal observations of the problem at the small-farmer level:

1. Considering the farmers' characteristics and environmental limitations (chickpea is one of the few alternatives to wheat, the most important crop), chickpea will be cultivated even though it may be uneconomic.
2. The only input used by the farmer is seed, normally kept from the preceding harvest.
3. Thinking on a long-term basis, if the cultivar productivity is to be raised, it will be necessary to support the farmer economically, by cheap or easily available credit, so that he may be able to adopt and use the technology now being generated.

Problems of Crop Management

The main problem presented in crop management is the low density of plants per hectare observed in most commercial plantings. There are perhaps two reasons for this:

1. Low seeding rates. The chickpea cultivated in Chile is the big-grain type (48 to 50 grains/ounce). The optimum rate is 160 kg/ha of seed; farmers are using only between 60 and 100 kg/ha.
2. The high incidence of root rots, which kill some plants at emergence, and then a later attack (generally at flowering time) causing death of adult plants.

Research and Extension Support

Research in Chile is conducted by the Instituto de Investigaciones Agropecuarias (INIA), through its Grain Legume Program (GLP). The GLP comprises the whole area where edible grain legumes (beans, chickpeas, lentils) are cultivated. At present, six scientists supported by four agricultural technicians are in charge of research on grain legumes in Chile (Table 3).

At present, extension activities are in the hands of these researchers, which they perform through demonstrative plantings, field days, and publications.

During the present year, INIA formalized an agreement of research and development with the local government of the VI Region of the country (Chile's most important chickpea-producing area), by which inspection, evaluation, determination of measurements for disease and insect control, and technological improvement of the crop will be conducted. An information service will be supporting these activities.

An improtant 3-year research project on this legume is intended by the Institute which is interested in all the help ICRISAT may offer.

Seed-Production Capability

The regular procedure for seed production of an

Table 3. Grain Legume Program, Institute of Agricultural Investigations (Casilla 5427, Santiago, Chile).

Station	Scientists	Specialization	% of time on chickpea
La Platina	Gabriel Bascur	Breeding/Agronomy	40
	Jorge Aeschlimann	Breeding/Agronomy	40
	Claudio Cafati	Phytopathology/Breed.	40
	Mario Alvarez	Phytopathology	40
Quilamapu	Juan Tay	Breeding/Agronomy	40
	Mario Paredes	Breeding/Agronomy	40

improved variety in Chile will be described below, taking as an example the new chickpea variety to be released by the GLP this year. The necessary infrastructure for producing good-qulity seed exists, as do the commercialization channels.

The institution developing the variety (in this case GLP of INIA) produces the basic or genetic seed, which is turned over to the seed production program of the same institute for the production of foundation seed.

Foundation seed will be offered to private institutions dedicated to production and commercialization of seeds where the seed will be multiplied to produce Registrated seed, and eventually Certified seed. Certified seed is the type sold to farmers.

It is necessary to emphasize that up to now there has been no plan for chickpea seed production, because there was not a single variety with defined genetic characteristics in Chile. After 4 years of research and selection of local types, the GLP of INIA obtained this variety, which will solve in part the seed problem for chickpea.

Research Review

Germplasm resources of the GLP of INIA consist of 439 introduced chickpea varieties and 1300 local types. We are working with these materials for genetic improvement, through selections or artificial hybridizations. We have the support of ICRISAT to conduct crossings using Chilean progenitors in India, so that we may increase the materials obtained by hybridization. In the agronomic respect, the GLP has worked on determining optimum planting distances, time of planting, and seeding rates.

In addition, some trials have been conducted with the objective of testing different combinations of products used for seed disinfection.

Conclusions

1. In spite of the little technology applied to chickpea in Chile, this crop is attractive to farmers, and the national mean yield (450 to 500 kg/ha) is close to the world mean yield (600 kg/ha).
2. Chickpea production in Chile is mostly destined for export. In order to compete in the international market, productivity must be increased.
3. The expansion potential of chickpea in Chile is great, but has been limited by some problems (especially phytopathological) that make necessary the development of some means of pest and disease control.
4. Another important limitation is the lack of varieties; this problem is being solved by the GLP of INIA, through the release of improved materials.
5. Finally, it is necessary to increase research work in breeding (to obtain improved varieties) and in the generation of new technology with the objective of encouraging farmers to plant this legume.

Chickpea Production in Ethiopia

Geletu Bejiga*

Chickpea (*Cicer arietinum* L.) is one of the most important legumes grown in Ethiopia, ranking first among the pulse crops in hectarage and in production. According to the 1975 Central Statistics report, chickpea occupies about 34% of the total area planted to pulse crops and also accounts for 40% of the total production of pulse crops in the country. Considering all cereal grains and pulse crops, chickpea stands sixth after tef, sorghum, barley, corn, and wheat. A 1973–74 statistical report shows that chickpea covered about 302 800 ha of land with an estimated total production of 236 200 tonnes. All chickpea in Ethiopia is grown under rainfed conditions. The average yield is usually low, ranging from 630 to 790 kg/ha.

Climate and Soils

Ethiopia lies between 3 and 18°N latitude. Chickpea is largely cultivated between 1400 and 2300 m above sea level where annual rainfall ranges from 700 to 2000 mm. It is usually planted on heavy black clay soils with pH ranging from 6.4 to 7.9 (Murphy 1963). Such soils usually swell when wet and crack when dry.

Distribution

Chickpea is mostly produced in the northern highlands (Eritrea and Tigre) and in the central highlands, which include Shoa and Gojam along with southwest Wollo, south Bgemder, and eastern Wellege (Fig. 1). Chickpea is found practically in every market in the country (Murphy 1963). Hectarage and total production of chickpea and other pulse crops grown in Ethiopia for the last 7 years are presented in Table 1.

Chickpea is used as a major rotational crop with wheat, barley, and tef. It is one of the crops that improves soil fertility and is preferred by most of the local farmers since it competes well with most of the annual weeds. Cereals following chickpea are usually relatively free of weeds and are expected to give very good yield in both quantity and quality.

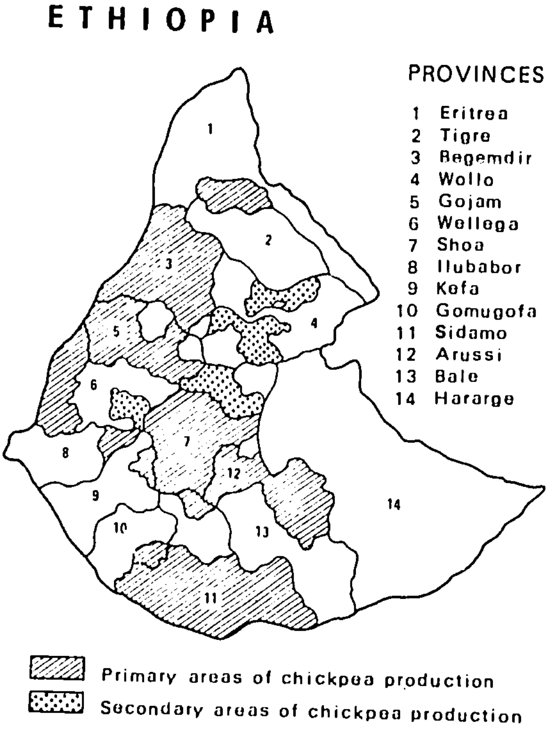

Figure 1. Geographical distribution of chickpea cultivation in Ethiopia. Source: Final Report on Crop Condition Survey for 1972–73, Planning and Programming Unit, Ministry of Agriculture, Ethiopia

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Table 1. Pulse crop production in Ethiopia, 1969–1976.

Year	Chickpea	Fieldpea	Horsebean	Lentil	Beans
1969–1970					
Area (1000 ha)	294	135	144	174	94
Production (1000 t)	85.3	126.4	137.8	106.5	72.3
1970–1971					
Area (1000 ha)	298	133	147	176	95
Production (1000 t)	192	129	145	110.6	75
1971–1972					
Area (1000 ha)	300	140	150	180	120
Production (1000 t)	196	137	148	112	120
1972–1973					
Area (1000 ha)	300	150	137	170	125
Production (1000 t)	231	73.5	116.5	73.1	85
1973–1974					
Area (1000 ha)	301.8	151.4	138	172	132.4
Production (1000 t)	236.2	74.2	118.7	74	90
1974–1975					
Area (1000 ha)	177	108	320	116	70
Production (1000 t)	148	63	294.8	61.1	51.1
1975–1976					
Area (1000 ha)	198	107	259	56	42
Production (1000 t)	109.3	51.8	304.4	55	35.4

Source: Ethiopian Central Statistics Reports.

Major Uses and Marketing

This crop is mainly used as human food in Ethiopia and seeds are consumed either green, cooked, roasted, or germinated. Sometimes the dry seeds are mixed with wheat and/or barley and ground to powder to make "Kiyit Ingera" (a type of local bread). Split seeds (kid) and powdered seeds (Shiro) are also used in making wot (type of sauce) or soup which is usually eaten with Ingera. After threshing, the stem and root (straw) are used as cattle feed (Westphal 1974). Sometimes the straw is also used as firewood by farmers.

Although the bulk of chickpea produced is consumed domestically, quite a considerable quantity is exported. At present, the demand for chickpea in the external markets — especially in the Middle East and Sri Lanka — is very high (Planning and Program Department 1972). However, since its production is at subsistence level and local consumption is relatively high, Ethiopia cannot satisfy the export trade. Other markets, including Europe, may be receptive to chickpea from Ethiopia, particularly if new types (kabuli, or large and white-seeded varieties) can be produced. It is believed that this crop has excellent prospects for both production and marketing in the country. The export situation for chickpea and other pulse crops is presented in Table 2.

Present Status of Production Practices

The chickpea-planting season in Ethiopia depends on the altitude, type of soil, and amount of precipitation. In the northern part of the country — particularly in Tigre and western Wollo — where the soils have been extensively used and eroded for many centuries, chickpea is planted in July. This is because of the poor nutritional status of the soils and shorter rainy

Table 2. Export of chickpea and other pulse crops, 1972–1977.

Year	Chickpea	Lentil	Horsebean	Fieldpea	Haricot
1972					
Quantity (t)	11 795	21 216	17 834	322	25 289
Value (1000 birr)[a]	3 216	7 009	3 346	73	12 261
1973					
Quantity (t)	9 161	22 054	33 548	1901	60 610
Value (1000 birr)	3 891	11 500	8 656	615	41 719
1974					
Quantity (t)	10 813	32 491	27 727	2869	47 923
Value (1000 birr)	5 735	29 654	13 075	1368	53 566
1975					
Quantity (t)	783	36 186	20 632	NA	40 161
Value (1000 birr)	448	30 116	8 490	NA	24 274
1976					
Quantity (t)	211	34 500	29 240	50	30 745
Value (1000 birr)	101	25 954	13 217	29	20 604
1977					
Quantity (t)	10	10 180	28 835	NA	34 739
Value (1000 birr)	6	6 426	14 853	NA	23 342

Source: Ethiopian Grain Agency.
NA = Not available
a. 1 birr = ½ U.S. dollar.

season than in the central highlands of Shoa and Gojam. On the heavy black clay soils, it is usually planted in late August to early September and harvested in February.

In some regions, under excellent rainfall conditions, very high yields are obtained. Under such conditions, early and medium-maturing varieties give good yield. Generally, the earlier chickpea is planted, the higher the yield obtained. But when the rainfall is high enough to cause water logging, the incidence of a root rot disease complex causes considerable loss of plants (seedlings). Seeding rate studies carried out at Debre Zeit Agricultural Experiment Station have indicated 60–80 kg/ha of seed, depending on the size of the seeds, to be optimum.

So far, four varieties of chickpea — Dubie, DZ-10-4, DZ-10-2, and DZ-10-11 (local collections) — have been multiplied and distributed to farmers by Debre Zeit Agricultural Experiment Station through the Extension and Project Implementation Department (EPID). The limitation of varieties Dubie, DZ-10-11, and DZ-10-4 is that they are very susceptible to root rot diseases where the drainage system is very poor. DZ-10-4 is a small white-seeded variety and is recommended not to be planted in areas waterlogged excessively in the months prior to planting (Dagnatchew 1967).

Seed bed preparation for every crop grown in Ethiopia is carried out with oxen and local plows (Marasha). In most cases, chickpea is planted along with grain cereals in the Woyna dega (1800–2400 m) area. In Gojam, Bgemder, and Simen administrative regions, chickpea is planted in mixture with other crops such as sorghum, safflower, noog (*Guzotia abyssinica*). It is planted in pure stand in the Yerer-Kereyu highlands of Shoa, a very important grain-producing region.

Seed inoculation on chickpea is not practiced except for experimental purposes in research stations. The use of fertilizers is limited to cereal grains. Manure and other soil amendments are not applied to chickpea. Instead, chickpea by itself is used in a rotation with tef and wheat as a fertility-improving crop in farmers' fields.

Chickpea can be planted either by using the local plow, which is pulled by oxen, or by using tractors. However, the use of tractors is limited on the heavy black clay, since the soil is very sticky and is not easy to work with, and the residual moisture in the soil is just enough for chickpea seeds to germinate. Generally, poor germination has been observed in the fields where tractors were used for seeding. Therefore, it requires some modifications or adjustment to utilize tractors for the purpose.

Chickpea is usually harvested by pulling out the mature plant by hand and then threshed by driving oxen over it. At the Debre Zeit Agricultural Experiment Station, threshing is done with a combine harvester.

Major Problems of Production

In Ethiopia, chickpea production is limited by many factors. The root rot diseases complex is the major problem; losses of more than 50% occur in some fields where drainage is poor around Debre Zeit (Dagnatchew 1967). There are at least five organisms responsible for root rot and wilt diseases — *Macrophomina phaseolina, Rhizoctonia solani, Sclerotium rolfsii*, and two *Fusarium* spp (Bejiga 1974). *Ascochyta* leaf blight causes heavy damage, especially in research stations where early planting is practiced.

At the seedling stage, cutworm is another problem. The American bollworm also causes considerable damage to green pods and a high percentage of yield loss.

Control of Diseases and Pests

The Department of Crop Protection at Addis Ababa University, Debre Zeit Agricultural Experiment Station, is presently carrying out various field trials on the control of chickpea diseases and insect pests.

Research and Extension Support

Development of high-yielding varieties and improved technology are prerequisites for the high production of any crop. With this view, the National Crop Improvement Committee of Ethiopia (NCIC) selected the Debre Zeit Agricultural Experiment Station to be the coordinator of the National Chickpea Research Program. Since then, this Station has started to make contacts with international agricultural research organizations such as ICRISAT for improvement of the initiated program. This experiment station has been charged with finding solutions to chronic low yields — in spite of the generally favorable ecological conditions; chickpea in Ethiopia averaged only 500–1000 kg/ha. The Debre Zeit Agricultural Experiment Station is located in one of the high potential chickpea-producing areas of Ethiopia. Low yield of chickpea can be ascribed to lack of improved pest-control methods.

Other organizations cooperate with the research activities on this crop. The support of the Institute of Agricultural Research (IAR) of Ethiopia is very substantial.

To maintain the dynamism of the process, it was considered essential to attack the problem with all existing resources, using a strategy that would permit the participation of well-motivated personnel with the ability and interest to achieve the goals of the National Chickpea Research Program. Table 3 lists the researchers and organizations who are cooperators of the National Chickpea Research Program.

Seed Production

The seed corporation was established only recently and has begun seed production and multiciplication of most cereal grains for this cropping season. According to the resolution of the National Crop Improvement Committee of April 1978, this corporation will start to multiply seeds of pulses by the 1979 cropping season, depending on the amount of the basic seeds and recommended varieties that the coordinator of the research work on a crop can supply. Accordingly, Debre Zeit Agricultural Experiment Station is going to provide seeds of varieties CN-17, DZ-10-11, H-54-10, and CADU-54, until promising varieties of wider ecological adaptability are found. Until 1978, there was no organization for seed multiplication in the country; however, the future prospect for distributing seeds of high-yielding varieties seems to be very bright.

Table 3. Cooperators in the Ethiopian National Chickpea Research Program.

Organization	Scientist	Specialization	Approximate time spent on chickpea (%)
IAR (Holleta) P.O. Box 2003 Addis Ababa Ethiopia	Mr. Kiflu Bedane	Agronomy	10
IAR (Mekelle) P.O. Box 14 Mekelle, Ethiopia	Mr. Wolde Amlak Araya	Plant science	10
IAR (Kulumsa) P.O. Box 7 Asella (Kulumsa) Ethiopia	Mr. Asfaw Tilaye	Agronomy	10
IAR (Kobbo) P.O. Box 14 Mekelle Ethiopia	Mr. Kidane	Plant science	5
IAR (Melka Werer) P.O. Box 2003 Addis Ababa Ethiopia	Mr. Gurmu Dabi	Breeding (Oil crop)	5
WADU P.O. Box 3436 Sidamo (Wolayita) Ethiopia	Agronomy Department		5
Yerer and Kereyu Extension & Project Implementation Department P.O. Box 187 Debre Zeit Ethiopia	Agricultural Department		15

Research Emphasis on Chickpea in Ethiopia

The basic need for the advancement of research in any crop is to make germplasm collections. However, in the chickpea program (due to the limitation of staff and financial support) our germplasm collection has been confined to a very narrow area in the vicinity of Debre Zeit. So far, about 3000 germplasm collections are available — a very small percentage of the entire collection that has to be made for the whole nation. The pulse section of the Debre Zeit Agricultural Experiment Station has pressured the Plant Genetic Resource Center (PGRC) to start chickpea germplasm collections from all over Ethiopia.

Screening of Chickpea Strains for Root Rot and *Ascochyta* Leaf Blight

In the 1977 off-season, 1086 lines were planted under irrigation on light soils of the Debre Zeit Agricultural Experiment Station for screening against *Ascochyta* leaf blight where chickpea was severely damaged in the previous crop season. Since infection was low, inoculation based on about 68 000 spores/cc was made. Most of the lines (except for two varieties, NEC-1433 and NEC-1431, which produced seeds) were damaged by heavy infection before pod set. Among the 1986 lines, 160 were selected for further evaluation. These were planted under rainfed conditions in July 1978, where inoculum build-up was high. Generally, all strains were attacked by the disease, but some showed some degree of tolerance. Many lines were also evaluated for resistance against root rot diseases. The ones showing good performance were advanced for further trial.

Chickpea National Yield Trial

Outstanding chickpea varieties are evaluated in different ecological zones in the country. In 1977, most of the varieties included in the National Yield Trial were exotic. They were planted at Debre Zeit, Bako, Awasa, Ajeja, Dubo, and Kulumsa.

Generally, plant emergence and stands were good at most locations; however, the trials at Bako and Awasa were severely affected by *Ascochyta* leaf blight. The trial at Debre Zeit was also affected by waterlogging, and most of the surviving plants were killed by the root rot diseases. Performance of some varieties across some locations is presented in Table 4.

New Activities

In 1976, the program was extended to Awash Valley to carry out chickpea experiments under irrigation. This region was inhabited by nomadic people, but now state farms are emerging; most grow cotton, sugarcane, or fruits. On the other hand, the Settlement Department of the Ministry of Agriculture has started to settle the nomadic people. In this area it is difficult to produce cereal crops because of heavy damage by quolia birds. Therefore, chickpea, and perhaps other pulse crops, may be very important in the vicinity.

A total of 22 exotic varieties of chickpea were included in the Pre-National Yield Trial (Pre-NYT) of 1976. They were planted under irrigation at Melka Worer Research Station, and some were found to be high yielders (2970 kg/ha; Table 5).

Table 4. Mean yield (kg/ha) of chickpea varieties in the 1977–78 National Yield Trial for two locations.

Variety	Ajija	Dubo	Mean of two locations
NEC-1167	1920	NA	1920
NEC-2417	1890	1610	1750
NEC-1719	1670	1690	1680
NEC-167	1690	1640	1670
NEC-249	1640	1690	1670
NEC-756	1580	1420	1500
NEC-Alad-Br	1610	1170	1390
Unknown (exotic)	1360	NA	1360
NEC-764	1500	1110	1310
NEC-1433	1190	1390	1290
NP-50	1390	1030	1210
V-4	1140	1250	1200
NEC-809	1500	860	1180
NEC-231	1530	720	1130
NEC-2438	940	1000	970

NA = Not available.

Constraints

The need for trained manpower to strengthen the chickpea research program is urgent. The meager financial support of the program does not permit utilization of existing manpower due to lack of basic laboratory equipment. Although Ethiopia is the center of diversity for chickpea, there are only a few local germplasm collections. This has been one of the major limiting factors in identifying new varieties with desired agronomical characteristics.

Summary and Conclusion

Ethiopia is one of the major chickpea-growing countries in the world. The genetic variability in the chickpea grown is so great that more collection and evaluation work for different agronomical characteristics will no doubt strengthen the local and international chickpea improvement programs.

Large-seeded chickpea, cream to white in color, are preferred for both local consumption and export trade. So far, such varieties have generally been less resistant to common dis-

Table 5. Yields (kg/ha) and ranks of the 22 varieties of chickpea grown at Melka Werer in the 1976 crop season (Pre-NYT).

Variety	Yield	Rank
NEC-747	2970	1
75TA-5057	2028	2
ICCT-USA613	1983	3
C-214	1923	4
NEC-737	1923	4
NEC-494	1880	5
75TA-5068	1840	6
ICCT-(P-552)	1820	7
75TA-5035	1790	8
ICCT-(T-3)	1720	9
NEC-1431	1695	10
NEC-2382	1665	11
75TA-5012	1612	12
75TA-5158	1598	13
75TA-5109	1495	14
NEC-752	1495	14
ICCT-(P-182)	1470	15
75TA-5125	1353	16
75TA-5079	1300	17
ICCT-(NP 50)	1298	18
75TA-5080	1108	19
NEC-1420	863	20

eases and insect pests, and they are not well adapted to many regions. This will change as more effort is put into the National Chickpea Program.

Future research emphasis will be to (1) develop varieties that are resistant to root rot, wilt, and *Ascochyta* leaf blight; (2) enlarge the chickpea germplasm collection, classification, and evaluation program in Ethiopia; and (3) strengthen the breeding program in order to facilitate the development of high-yielding varieties.

There are some varieties now in the last stage of multiplication. The seeds of these varieties will be available to the Seed Multiplication Corporation (SMC) in 1979 for further increase, and we hope that the seeds will reach the farmers by 1980.

The effectiveness and future development of the Chickpea Research Program in Ethiopia depends on the strong support of the Institute of Agricultural Research of Ethiopia as well as on other organizations (such as ICRISAT) for assistance in funding, staffing, and obtaining materials.

References

DAGNATCHEW, YIRGOU. 1967. Pages 16–17 *in* Plant diseases of economic importance in Ethiopia. HSIU, College of Agriculture, Agr. Exp. Sta. Debre Zeit, Ethiopia.

BEJIGA, G. 1974. Screening of chickpea selections for root resistance and evaluation of some seed dressing chemicals in the control of root rot diseases in chickpeas. College of Agriculture, A. A. University, Agr. Exp. Sta. Debre Zeit, Ethiopia.

ICRISAT. 1975. Pages 95–101 *in* International Workshop on Legumes, Jan 13–16, ICRISAT, 1-11-256, Begumpet, Hyderabad 500 016, A.P., India.

MURPHY, H. F. 1963. Fertility and other data on some Ethiopian soils. Experiment Station Bull. No. 4. College of Agriculture, Haile Sellassie I University.

Planning and Programming Dept., Ministry of Agriculture, Imperial Ethiopian Government. 1972. The feasibility of producing pulse crops for export markets. Report No. 1. 53 pp.

WESTPHAL, E. 1974. Pulses in Ethiopia, their taxonomy and agricultural significance. Joint publication of the College of Agriculture, Haile Sellassie University, Ethiopia, and the Agricultural University, Wageningen, Netherlands.

Development of Chickpea in Iraq

Isam H. Najjar*

Chickpea, or common gram, is cultivated as one of the winter crops in Iraq, mostly under rainfed conditions in the northern region.

Geographical Location

Iraq is situated in southwestern Asia between latitudes 29° 27′ and 37° 23′ N and longitude between 38° 42′ and 48° 25′ E. The total area of Iraq is about 44 million ha, of which 12 million ha are arable; about 3–5 million ha are cropped annually. About 45–50% of the cultivated area is rainfed and the rest is irrigated.

Climate

The climate ranges from arid to semi-arid with absolute minimum and maximum temperatures ranging between 11 and 50°C. The average annual rainfall varies between 500 mm in the northern mountains and most of it is received during the winter and spring months, usually from November through April.

Agroecological Zones

The country can be divided into three zones:- Zone 1, the northern region of the country receives rainfall above 450 mm; Zone 2, receives rainfall between 250 and 450 mm; and Zone 3 receives rainfall of more than 130 mm and less than 250 mm. Major chickpea areas are found in Zone 1, in the governorates of Dhok, Sulaimania, and Arbil, and Nainawa and Karkuk in Zone 2. In Zone 3, little chickpea is grown.

Area, Production, and Distribution

The net cultivated area under legume crops in Iraq is about 49 808 ha (average of 8 years from 1970 to 1977), being 57 135 ha in 1970 and 45 399 ha in 1977. Chickpea occupies about 9445 ha (1970 = 5527 ha; 1977 = 14 956 ha), and 19% of the total area under legumes is in chickpea. While the total area of legume crops has decreased, the area under chickpea has increased from 5527 in 1970 to 14 956 ha in 1977. Production of chickpea has also increased from 3537 tonnes in 1970 to 9167 tonnes in 1977, while yield per hectare has not much changed, averaging 608 kg/ha over the years.

The major area under cultivation of chickpea is distributed in the three governorates of northern Iraq, namely Sulaimania, Dhok, and Nainawa (averages of 4267, 2418, and 3082 ha, respectively). Average grain production in these areas in 2043, 2013, and 1361 tonnes, respectively. Average yield/ha was higher in Dhok (704 kg/ha) than in the other two governorates (429 and 494 kg/ha, respectively).

Major Uses and Marketing

During 1975–76, about 78% of the total production (7200 tonnes) of chickpea was used for local direct consumption; 6% for farmer's consumption; 10% for seed, and 6% for other purposes. For direct consumption, chickpea is used boiled or parched. It is eaten raw, roasted, or cooked or in the form of soup (delicious Baghdad soup stew with pieces of meat and unleavened bread is known as Tashrib in Arabic).

Current Status of Production Practices

Chickpea is generally cultivated as a pure crop. It is grown in rotation with wheat and barley (chickpea — March to June; wheat — October to June). Its cultivation still mainly depends upon manual labor. Land is plowed, and seeds (80 kg/ha) are broadcast by hand in mid-March. Farmers usually do not apply fertilizers. If the

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rainfall is timely and adequate, a good grain production is expected. Harvesting is done by pulling out or by cutting close to the ground, toward the end of June. Local bold-seeded varieties (kabuli) are preferred and grown by the cultivators.

Major Problems of Production

Wilt, a serious disease of chickpea, causes a considerable reduction in yield. Search for wilt-resistant varieties is the prime need. Obnoxious weeds are also a problem. These create great hindrances in mechanical harvesting of the crop. The weeds include *Convolvulus arvensis*, *Amaranthus caudatus*, and *Glycirizha glabra*, as well as others. Attempts are being made to control these by herbicides.

Research-Extension Supports

Research on chickpea is being conducted under the guidance of the Director, Food Legumes, in the Directorate General of Field Crops at Abu-Ghraib.

The extension services organized under the Agricultural Department of the Governorate look after the development of the legume crops in their respective areas working in collaboration with the Legume Directorate.

Seed Production Capabilities

Since the area under chickpea is not very large, seed production is usually controlled by the Department of Agriculture of the respective governorate.

Research Review

Research on chickpea began here a few years ago. The program of research has been much extended since then. So far the work has involved breeding and agronomy.

Breeding

Breeding work started in 1973. Research work in this direction had been undertaken on single-plant selection from local collections of varieties from different parts of the country. The preliminary stage of testing was restricted to parent-progeny testing. Promising lines selected were put under replicated variety testing. Meanwhile, exotic varieties were introduced through the courtesy of ICRISAT and were tested (as was indigenous germplasm) for their adaptability and yield potentialities at different places in the country. Selection work — based on adaptabilities, yield potential, size, and color of the grain — is in progress, keeping in view consumer demands on quality of the grain. In Iraq, consumers prefer the bold-seeded, cream-colored (kabuli-type) varieties.

During 1977, two ICRISAT cooperative yield trials on chickpea, one at Dhok (desi type) and the other at Sulaimania (kabuli type), were conducted.

Results of the cooperative yield trial with 25 desi gram varieties at Dhok revealed that the entries K4, 850-3/27, and Dhok local gave significantly higher yields (524, 524, and 640 kg/ha, respectively). In one observational trial with 101 brown, small-seeded, exotic germplasm entries, P-259 and P-1657 appeared to be promising. Their yields were 680 and 652 kg/ha, respectively, as compared to the local, which had 740 kg/ha. The latter, however, is a kabuli type. In another observation trial with 201 bold-seeded germplasm entries, 1606, 151, 51, and 91 appeared to be promising. Their yields were 1072, 944, 924, and 880 kg/ha, respectively, whereas the Dhok local variety gave a yield of 640 kg/ha.

In a cooperative yield trial with 25 entries of kabuli-type varieties at the Bakrajo research station, the entries Lebanon local P-9800, L-500, B-1411-1, and P-3890 gave significantly higher yields (492, 488, 464, 460, and 436 kg/ha, respectively) than the other varieties, except the local variety, which gave the highest yield (540 kg/ha).

Agronomy Trials

Date of Sowing Trial

In 1975, 1976, and 1977 at Bakrajo and Nainawa, a trial was conducted with five dates of sowing at 15 day intervals starting from mid-February at Nainawa and 10 March in Bakrajo. At Nainawa, the best date of sowing was observed to be between 1–15 April, while that at Bakrajo was 10–30 March.

Fertilizer Trial

During 1976–1977 a fertilizer trial with four rates of nitrogen, i.e., 0, 40, 80, and 120 kg/ha and phosphate at the rate of 40 and 80 kg P_2O_5/ha was conducted. The results, both at Bakrajo and Dhok, showed that rates of 80 kg N and 40 kg P_2O_5/ha gave higher yields than the other treatments, though not significantly. In 1976 this treatment at Bakrajo gave 1348 kg/ha, while in Dhok it gave 700 kg/ha. In 1977 the same treatment in Dhok gave 688 kg/ha, while in Bakrajo it gave 592 kg/ha. These trials will be repeated.

Plant Population Trial

In 1976–77 this trial was conducted at Bakrajo, with spacing of 10, 20, and 30 cm between hills and of 50 cm between rows as compared with the local method of broadcasting 80 kg seed/ha. Spacing of 50 by 10 cm between hills gave a significantly higher yield (1144 kg/ha) over broadcast yields of 980 kg/ha. In the same year at Dhok, a trial was conducted with seeding rates of 40, 60, 80, and 100 kg seed/ha. The best yield (820 kg/ha) was obtained with 80 kg seed/ha; a yield of 676 kg/ha was obtained with 40 kg/ha seeding rate. These trials will be continued.

Mechanical Harvesting Trial

In a pilot project, plowing, seeding, fertilizing, and harvesting was done by mechanical means through different machines in 12.5·ha plots. Three types of combined harvester were used. The results were that:

1. Losses in yield due to mechanical harvesting in different harvesters ranged between 30 and 60%.
2. Yields in high population plots were better.
3. Plant height was an important factor for machine-harvest efficiency.
4. Weed population, especially *Convolvulus*, was a great hindrance in mechanical harvesting.

Summary

Grain legumes research in the country is a new step toward higher food productivity. Though current research on chickpea is being done on a limited scale, its expansion is in view. Collection of germplasm and adaptation testing is the prime need. High-yielding, erect types, 40 to 50 cm in height, will be preferred. Wilt is a severe disease, so screening for wilt resistance is required. Agronomical studies on various aspects need to be intensified. Personnel in the project need to be given adequate research training.

Chickpea in Mexico

Enrique Andrade Arias*

Chickpea in Mexico is planted in two principal areas. Kabuli chickpeas are planted in the northwest (Sonora and Sinaloa) and the desi type in the region known as El Bajio (Jalisco, Guanajuato, and Michoacan).

In the northwest the climate is dry tropical to subhumid tropical (300–600 mm rainfall), and in Bajio the climate is temperate humid (700–1200 mm rainfall). The soils in the northwest are generally sandy clay, while in the Bajio they are mostly clay, with some sand component. The northwest can be considered as one agroecological region with irrigated production on level soils, and with a warm winter and high temperatures at the end of the growing season. In the Bajio, Guanajuato is the driest state with less rainfall at the end of the year, while Jalisco and Michoacan have more rain and consequently a less drought problem for chickpea production.

Area, Production, and Distribution

In the best years (good export market demand and adequate rainfall from October to January), chickpea growers harvest 180 000 ha of desi and about 40 000 ha of kabuli making a total of 220 000 ha. Yields of desis can vary from 600 kg/ha (grown on residual moisture) to 3000 kg/ha (irrigated). Yields of kabuli vary between 1000 and 2000 kg/ha, with the average near 1500 kg/ha (Tables 1, 2, 3, 4).

Uses and Marketing

The principal use of the desi type is in feeding swine. The straw is fed to cattle. The kabuli type is exported to Spain, Japan, and some countries of South America. The lower quality kabulis are consumed in Mexico. Consumption in Mexico is considered low, since with a population of 70 million, only about 7000 tonnes (24% of the production) are consumed annually.

Present Production Practices

Generally chickpeas are sown following maize in Bajio and following soybeans, sesame, and other crops in the northwest. Planting is in October to December, with harvest from March to May. Improved cultivars of desi for planting under irrigation are Cal Grande and Grande-12, which are planted on 90% of the desi irrigated area. Irrigated kabuli acreage is planted to Surutato-77, Culiacancito-860, Union, Sinaloa, and others. In the Bajio, 100% of the area planted on residual moisture is planted to local landraces; no improved cultivars exist. Inoculation has not given any response and is not used. Fertilizer gives some response in the northwest, but not in the Bajio. In irrigated production, two irrigations are given and only land preparation and cultivation is by machine.

Desi chickpeas (improved cultivars) are planted at the rate of 50 kg/ha for irrigation, and kabulis at 80 kg/ha. The landraces on residual

Table 1. Production of desi chickpeas in Mexico.

Year	Area harvested ha	Yield kg/ha	Production tonnes
1971	198 160	746	147 918
1972	205 083	821	168 530
1973	147 212	860	127 193
1974	193 583	876	169 771
1975	195 000	890	173 550

Source: Consumos aparentes 1971–75, SARH/DGEA.

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Table 2. Production of kabuli chickpeas in Mexico.

Year	Area harvested ha	Yield kg/ha	Production tonnes
1971	17 000	1143	19 431
1972	42 000	1405	59 010
1973	69 000	1432	98 808
1974	55 000	1445	79 475
1975	44 000	1576	69 344
1976	13 000	1333	17 329
1977	39 000	1409	54 951

Table 3. State production of desi chickpeas in Mexico, 1974/75.

State	Area harvested ha	Yield kg/ha	Production tonnes
Nayarit	501	1074	538
Jalisco	50 000	900	45 000
Michoacan	39 000	541	21 100
Guanajuato	18 500	932	17 250
Queretaro	2 000	900	1 800
San Luis Potosi	6 000	1000	6 000
Total	116 001	790	91 688

Source: Plan Agricola Nacional, Agosto 1975.

Table 4. State production of kabuli chickpeas in Mexico, 1974/75.

State	Area harvested ha	Yield kg/ha	Production tonnes
Baja California Sur	600	750	450
Sonora	9 000	1650	14 850
Sinaloa	22 000	1442	31 860
Tamaulipas	500	ND	ND
Puebla	100	800	80
Oaxaca	1 250	848	1 034

Source: Plan Agricola Nacional, Agosto 1975. ND = No data.

moisture are planted at 120–150 kg/ha. Under irrigation, rows 76–91 cm apart are used with single rows, or 120–140 cm with double rows. The traditional method of planting desis on residual moisture is after fallow in rows 30 cm apart.

Problems

Major disease problems are root rots caused by *Fusarium* sp, *Macrophomina phaseoli*, and *Rhizoctonia* sp. For *Fusarium orthoceras* var *ciceri* the resistant lines L-41 (black) and L-1186 (brown) are used to incorporate resistance into kabuli cultivars for export, e.g., Surutato-77. This disease is most serious in the northwest.

Damaging insects are pod borers, army worm, cutworms, and leaf miners. In Culiacan, Sinaloa the pod borer problem is serious and the recommended control is 1 kg Dipterex 80% per ha. In Mochis, Sinaloa the army worm problem is most severe, and the recommended control is 1 liter of Azodrin 60% or Dipterex. In Bajio the leaf miner is most serious, especially on the simple leaf cultivars. Recommended control is 1 liter of Dimethoate 40% or Diazinon 25%. In general two applications are used. With ground equipment, 300 liters of water and with aerial equipment, 60 liters water per ha are used. The cutworms in the northwest are controlled with 10–15 kg of Salvadrin dust applied to the soil.

Experiments in the Bajio have shown no advantage in yield from weeding and cultivating.

Production of kabulis for export depends on world demand and largely on prices in Spain. Production of desis depends on the amount of rainfall during the months October to December, since not much of the area is irrigated. Production is also limited by the nonavailability of improved cultivars and improved planting methods. In the Bajio, irrigated land is frequently used for more profitable crops (vegetable) and the hillsides to desi, coffee, and lentils. It is well known that chickpea is a secondary crop in Mexico, since it is for feed, while the basic crops are for food (maize, beans, wheat, vegetables, and others).

Agricultural Extension

The agricultural extension service in each state is under the representative of the Secretaria de Agricultura y Recursos Hidraulicos (SARH). The extension program is divided into districts of irrigated and rainfed agriculture. However, there is still a need for more personnel to give orientation to farmers concerning the recommendations for 10 to 25 crops including chickpeas. There is a need for demonstrations of the new cultivars Carreta-145 (desi) and Surutato-77 (kabuli). At present there is no one specialized in chickpea extension exclusively; there is a need for two persons, one in the northwest and one in the Bajio. To contact the extension service in each state, it is only necessary to write to the SARH representative in the state.

Seed Production Capacity

The organization known as Productora Nacional de Servillas (PRONASE) is in charge of seed production of new cultivars and seed sales at cost to farmers. The quantity produced depends on the demand for local use and for export. A plan is developed for each year. The Instituto Nacional de Investigaciones Agricolas (INIA) develops new cultivars and hands over seed to PRONASE. It produces basic seed which is used to grow registered seed. This is used to produce certified seed, which is done by contract growers. The certified seed is sold to farmers. The Sistena Nacional de Inspeccion y Certificacion de Servillas (SNICS) inspects production fields, the production of new varieties, and works closely with the Comite Nacional Calificador de Variedades y Plantas (CNCVP) which conducts the final tests at the regional level before a cultivar is released. About 3000 tonnes of seed of kabuli and 9000 tonnes of desi are required annually.

Research on Chickpeas

In 1978 a genetic resources unit was established in INIA. Stocks consist of 207 national collections and many from ICRISAT. They are being evaluated in the Bajio at Celaya, Guanajuato, and at Pabellon, Aguascalientes. Lines have been found with high yield, two pods per node, and more than two seeds per pod.

The objectives of the breeding program at Celaya are the development of cultivars resistant to root rot with high yield and medium to large seeds with brown color.

Little is being done on production agronomy of the local types. Insecticide testing is being done in the northwest. No work is in progress in physiology. Yield tests indicate broad adaptation of cultivars, for example Macarena was adapted to all of the northwest and Cal Grande to all of the Bajio. However, tests with Macarena have not been repeated.

Cooking tests and color and size of the seed are standard in the kabulis for export.

In Calera Zacatecas, Pabellon Aguascalientes, and Valle de Guadiana attempts are being made to utilize the green forage at times when other forage is scarce. Production is limited by low temperatures, and different planting dates will be tested.

On the coast of Jalisco rust is a problem, and a source of resistance is not known.

Few uses of chickpea are known in Mexico, and no investigation of uses is in progress. In Sinaloa, "atoles" are sometimes made, and in the Bajio a few people sometimes eat chickpea stewed and "Guazanas", which are cooked green pods. Green pods are abundant in November and December and are sold by the bag in markets.

Conclusion

1. Two centers of chickpea improvement have been established in Mexico, one at Culiacan (CIAPAN-CAEACU, Aptdo. Postal 356, Culiacan, Sinaloa) for kabulis for export, and the other at Celaya (CIAB, Aptdo. Postal 112, Celaya, Guanajuato) for desi chickpeas.
2. Research on both genetic improvement and cultural practices should be initiated for desi production on residual moisture in the Bajio.
3. It is urgent to train specialists to spend more time on chickpea research.
4. Stronger international cooperation should be promoted in order to solve the problems of plant, soil, water, damaging organisms, and cultural practices.
5. Publications on chickpea in Mexico can be obtained from INIA; Unidad de Divulgacion Tecnica; Apdo. Postal 6-882 y 6-883; Mexico 6, D.F.; Mexico.

Chickpea Research and Production in Nepal

R. P. Sah*

Nepal is a small Himalayan Kingdom with an area of 140 thousand sq km and a population of 14.1 million. The length of the country is about 800 km from east to west, and the width on an average is 160 km. Nepal extends from 26° 20′ N to 30° 10′ N latitude and 80° 15′ E to 88° 15′ E longitude. Of the total area, 83% is covered by mountains, hills, and uplands, and some valleys and river basins are enclosed in them. The only lowland is the Terai belt in the south, which represents 17% of the total area of the country. The altitude increases from south to north; it is about 200 m in the Terai and rises over 8800 m in the Himalayan region.

Climate

While the climate of the Terai and the Inner Terai is subtropical, hot and humid, that of the mountain is temperate with cold and severe winters. But the Himalayan part of the same region has an arid type of alpine climate. Accordingly, temperature decreases from south to north. During summer, it goes beyond 40°C in the Terai and is about 25°C in the midlands and around 10°C in the Himalayan region. However, in winter it falls to around 12°C in Terai, 6°C in the midlands, and below 0°C in the Himalayan region.

Rainfall

As in the other parts of southeast Asia, in Nepal the rainfall is caused by the southwest monsoon. There are often critical variations in rainfall within limited geographic areas from 80 to 100 inches in the Terai and Inner Terai to about 60 inches in the mountain region. However, in the Himalayan region, precipitation in the form of snow decreases to 20 inches. Rainfall is not well distributed throughout the year. More than 90% of the total rainfall occurs from June to September. The eastern sector receives more rainfall than the western during the rainy season (Table 1).

Soil

The variations in the elevation and the climate of the country create great soil variations. While alluvial soil crosses the whole length of the Terai, coarse gravels and torrent boulders, generally mixed with ferruginous sand and clay, cover a great portion of the Inner Terai. Scanty soils prevail in the mountain regions of Nepal, where sandstone, clay, and limestone form the fundamental parent material. Lacustrine soils are found mostly in the Kathmandu and Pokhara valleys. Although soils of Terai and the Kathmandu valley are very fertile, the native fertility is decreasing due to intensive cultivation.

Division into Agroecological Zones

The altitudal differences dictate the variations in the climate, ecological conditions, and features of the surface in the country, which, in turn, not only create conditions of great soil variations but also reflect varying types of land use and methods of farming. On the basis of these, the country can be divided into three important agroecological zones: the mountains, the Inner Terai; and the Terai regions.

A single crop of potato, barley, wheat, and buckwheat is grown in the high altitudes (3000–5000 m elevation). Crops such as wheat, barley, corn, potato, beans, and finger millets are grown between 2500 and 3000 m elevations. Cultivation of two crops a year is found, to some extent, in the midhills up to 2500 m. In such areas, crops such as corn, soybean, mustard,

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Table 1. Mean temperature and rainfall record in the Terai, 1975.

	Tarahara Ag. Farm (eastern Terai)			Parwanipur Ag. Sta. (central Terai)			Nepalgunj Ag. Farm (western Terai)		
	Mean temp. °C		Rainfall	Mean temp. °C		Rain fall	Mean temp. °C		Rain fall
Month	Max.	Min.	(mm)	Max.	Min.	(mm)	Max.	Min.	(mm)
Jan	23.0	7.8	17	21.7	10.3	50	21.6	8.4	25
Feb	26.0	8.6	0	24.0	15.4	21	25.5	8.2	12
Mar	30.0	13.3	56	30.6	17.8	11	31.9	12.1	5
Apr	32.1	20.0	44	37.1	22.0	4	38.8	18.2	0
May	32.4	22.1	75	37.5	24.7	48	39.7	23.6	16
June	32.6	23.4	245	35.5	25.7	332	37.4	25.9	226
July	30.7	23.7	779	31.7	25.5	628	31.2	24.3	691
Aug	32.0	24.0	386	33.2	26.1	127	32.2	25.3	310
Sept	31.0	22.9	294	31.9	24.4	475	30.8	23.6	210
Oct	31.3	21.0	94	32.0	22.3	28	31.1	20.3	40
Nov	29.3	13.4	0	27.8	13.3	0	26.6	10.2	0
Dec	23.3	7.8	0	24.2	9.4	0	23.4	4.8	0
Annual	29.6	17.3	1990	30.6	19.7	1724	30.8	17.1	1534

black gram, wheat, barley, potato, and finger millets are grown in the uplands, while rice, wheat, barley, and potato are grown in the bunded fields.

In the Terai and Inner Terai regions, where elevations are usually below 200 m, the temperature is warm enough to enable three crops in sequence including two crops of rice, if water is nonlimiting. Common crops grown in Terai are rice, corn, wheat, pulses, oilseeds, sugarcane, jute, and tobacco.

Area, Production, and Distribution

The total cultivated area in Nepal is estimated to be 2.3 million ha which is nearly 17% of the gross area (Table 2). Nearly 70% of the cultivated area lies in Terai and Inner Terai, and 30% in the mountain region. Of the total cultivated area, nearly 20% is irrigated, and the rest is rainfed.

Total area, production, and per hectare yield of some of the important crops in the country are presented in Table 3. Rice is the main crop and occupies nearly 65% of the total cultivated area.

Table 2. Total area and its classification, 1977.

Classification of the area	Ha (thousands)	Percent
Forest	4 623	34.20
Cultivation	2 326	16.49
Pasture	1 786	12.66
Water	400	2.83
Residential area & road	30	0.21
Waste land	2 629	18.64
Land under snow	2 112	14.97
Total	14 106	

Source: Agricultural Statistics of Nepal (1977).

Statistical data for the area and production of chickpea and other pulses in the country are currently not available. Pulses occupy a prominent position in cropping patterns, and a number of pulses — for instance, chickpea, lentil, pigeonpea, mungbean, blackgram, soybeans, lathyrus, peas, and beans — are grown; in total, the crops are estimated to cover nearly 10% (23 000 ha) of the total cultivated area. The area under chickpea alone is estimated to be 20% (46 000 ha) of the total area under pulses.

Table 3. Production of major crops in Nepal, 1975/76.

Crops	Area (000 ha)	Production (000 kg)	Yield (kg/ha)
Paddy/rice	1256	2605	2070
Maize	449	748	1660
Wheat	329	386	1170
Millet	125	143	1140
Oilseed	113	68	610

Source: Agricultural Statistics of Nepal (1977).

Most of the chickpea grown are small-seeded desi types, and large-seeded kabuli types are not common. Yield of chickpea, in general, is estimated to be 600 kg/ha; however, yields more than 2000 kg/ha have also been reported in the farmers' fields.

Chickpea is an imprtant winter pulse and is distributed to all the regions of the Terai and Inner Terai and to the altitudes of the midland region. In addition, chickpea has been extensively cultivated in the Siraha, Dhanusha, Mahottari, Sarlahi, and Rautahat districts of the eastern Terai, and in the Banke, Bardiya, and Kailali districts of the western Terai.

Major Uses and Marketing

Chickpea is principally consumed as a pulse (in dhal curry) in Terai, Inner Terai, and some important places in the hills. Leaves are lavishly used for vegetables. Grains are also eaten raw, boiled as vegetables, spiced, or cooked. Flour is largely used for *Satoo* (flour mixed with salt or sugar in water) by the common people. It is specially recommended to patients suffering from acidity or gastric problem. Flour is also used for sweets, split-grains for tidbits, and so on. Chickpea husks and seed coats constitute a feed for cattle.

The grain is commonly processed on the locally-made grinding stone in the village for splitting and flour preparations. However, in the areas where flour mills are available, it is efficiently processed there. Recently, a few pulse-processing plants have been set up in the Kingdom using modern processing devices.

During the last 5 years, the increase in the price of pulses has been more rapid than for other crops in Nepal (Table 4). It has nearly doubled within this period. Price of split chickpea was around Rs 2.25/kg in 1975 and is Rs 4.50/kg at present. Pigeonpea dhal icreases more than the other pulses (Rs 7.50/kg at present).

Food corporation and other marketing agencies deal mainly with the important cereals at present. Hence, the market system for pulses and oilseeds is still unorganized and not regulated. Advances are given to the cultivators by the Indian or Nepalese merchants through their agents, at very low prices, before the crop is harvested. Thus a large portion of produce is purchased at very low prices. During the postharvest season, the price goes up, and all the profits are obtained by the traders. Lack of proper transportation, better storage, and an organized market system enable the middlemen to obtain more profits.

The following middlemen between producer and consumer are involved in chickpea marketing:

1. Village merchant
2. Intinerant trader
3. Commission agent
4. Wholesale trader
5. Retailer

Recently, HMF initiated a "Sajha Program" for the rural people to facilitate their marketing and credit needs. This is a joint program between the government and the people. Most of the village panchayats have a Sajha unit where the farmers can get loans, agricultural inputs, and items of day-to-day needs, and they can sell or store their produce as and when they need. It has been found very useful and effective at many places.

Current Status of Production Practices

Chickpea, grown in the winter season, occupies a prominent position in country's cropping systems. It is grown as a pure, mix, or relay crop in various combinations. Common patterns are:

Early rice — chickpea, chickpea + mustard/linseed
Early rice — potato — chickpea (planted in October in standing crop of potato)
Late rice — chickpea relayed

Table 4. Average (national) price of selected crops (Rs./kg), 1977

Year	Coarse paddy	Wheat	Maize	Mustard oil	Pigeonpea	Blackgram
1966/67	1.07	1.48	1.03	6.87	2.00	1.85
1971/72	1.41	1.66	1.32	9.44	2.51	2.47
1972/73	1.65	2.29	1.69	9.70	2.97	3.23
1973/74	1.76	2.47	1.70	12.96	3.41	3.80
1974/75	1.79	3.11	1.95	15.05	4.46	4.20
1975/76	1.74	2.51	2.04	11.89	4.22	4.24

Source: Agricultural Statistics of Nepal (1977).

Corn — chickpea, chickpea + mustard/linseed

Corn — barley + chickpea

The crop is planted from the last week of October to the middle of November and is harvested during April. It takes nearly 130 days in the eastern Terai and increases to about 150 days in the western Terai.

Currently, only the local cultivars are commonly grown, because none of the improved varieties have been released so far. Systematic efforts have been made since 1975–76 for this purpose, and local cultivars like G-0332, G-0226-12 and G-0228 have been identified for high yields and wide adaptation. The Indian cultivars T3 and Pant-110 have been found suitable for the western Terai region.

Land preparation is done by bullock-drawn desi plows or by tractor harrows. A moderate land preparation is preferred for chickpea. A seed rate of 60–70 kg/ha for the pure crop, and 30–40 kg/ha for the mix crop is used. However, the amount of seed is increased for delayed planting. Broadcasting by hand is the most commonly used planting method for chickpea for the different prevailing patterns in the country. Row planting is rather not in vogue.

Farmers usually do not inoculate the seed with the rhizobial culture, probably because they do not get much response. NPK at 20:40:20 kg/ha as a basal application has been recommended for chickpea, but little fertilizer is used by the farmers. Use of the farmyard manure and compost is rather popular in the farmers' fields. Chickpea is rarely irrigated and is mostly grown as a dryland crop. Moreover, it receives some irrigation in the early stage when grown with mustard, if irrigation water is available. All the intercultural operations and harvesting are done manually. Threshing is usually done by bullock.

With the soaring prices of pulses during the last 5 years, cultivation of chickpea and other pulses has become more profitable in the Kingdom, and farmers are paying more attention and investing more for its better management and high yield.

Major Problems of Production, Protection, and Utilization

The major constraints in chickpea production, protection, and utilization could be outlined as follows:

1. Lack of suitable high-yielding varieties and their agronomic requirements for the prevailing chickpea patterns.
2. Practice of chickpea cultivation commonly on the marginal lands with few inputs and little management used.
3. Negligible funds and facilities available for chickpea research and extension.
4. Little efforts made for its utilization on a commercial scale in the food-processing plants and other such places.
5. Problems of chickpea marketing and storage.
6. Problems of chickpea pest and disease control.

Losses due to various pests and diseases in chickpea have not been systematically assessed at present; however, some pests and diseases have been occasionally very serious, causing a tremendous amount of crop losses. Important pests, diseases, and weeds recorded on chickpea and control measures undertaken in the country are mentioned in Table 5.

Table 5. Diseases, pests, and weeds.

Diseases	Control measure
Wilt (*Fusarium* spp)	Seed treatment with Thiram or Captan @ 2 g/kg seed.
Chickpea stunt	
Ascochyta blight	
Rust (*Uromyces* sp)	
Pest	
Termites and ants	Soil treatment with Chloradane or BHO @ 25 kg/ha.
Cutworms (*Agrotis* spp)	
Podborer (*Heliothis armigera*)	Metacid 50 (0.1% solu.) or Folithion 50 (0.05% So) @ 450 liters/ha.
Bruchid bettle (*Callosobruchus* spp)	Seed-treatments with Malathion dust 5% @ 10 g/kg Grain-Fumigation with Phosfume tab. @ 3 tab/tonne grain.
Weed	
Chenopodium album, Lathyrus spp, *Vicia sativa, Anagallis arvensis, Cyperus rotundus, Cynodon dactylon*	One to two hand weedings in the early stage of the crop.

Research and Extension Support Available

At present, the Agricultural Station, Parwanipur, Birgunj, acts as the center of chickpea research in Nepal, under the Division of Agronomy, Khumaltar, Kathmandu. In addition, some adaptation trials are conducted at the Research Farms located in the various zones of Terai, especially those at Kankai, Janakpur, Bhairahwa, and Nepalgunj. Mostly breeders or agronomists take care of the trials at subcenters devoting approximately 20 to 30% of their time in the season.

Currently, most of the chickpea research projects, including the international trials and nurseries, are being conducted at Parwanipur. One pulse agronomist devotes nearly 60% and other scientists around 20 to 30% of their time on chickpea, with the rest of the time spent on other pulses, wheat, barley, and rice research projects.

In addition, some farmers' field trials are being conducted at some places with the cooperation of the agricultural development officer and the cropping system program to evaluate the promising cultivars in the farmers' field conditions. The cropping systems program has initiated projects to study both the response to phosphate application and the suitable cropping patterns for chickpea at its different research sites in the farmers' fields.

In addition, some varietal and management demonstrations on chickpea are being conducted by the Agricultural Division, NZIDP, Birgunj, in both the Bara and Parsa districts.

Seed Production Capabilities

Seeds of high-yielding varieties are being multiplied in a very small quantity at the government research farms and are being distributed to the farmers in small amounts for testing. Once a variety is released, breeders' and foundation seeds would be produced at the research farms and certified seeds in the farmers' fields, as is done for other crops. Finally, seed production in the farmers' fields and its distribution activities are undertaken by the Agricultural Inputs Corporation (AIC) with the cooperation of the Agricultural Development Officer (ADO), the extension agent in the district.

Research Review

Research activities on pulses were initiated in 1973, under the Division of Agronomy, at Parwanipur Agricultural Station. Projects on chickpea, lentil, pigeonpea, and mungbean improvements are in process at present. For the first 2 years, emphasis was given to the collection and maintenance of indigenous and exotic germplasm. We have, at present, 177 lines of chickpea in our germplasm stocks. This includes 27 local varieties, with the rest from India, ICRISAT, Iran, Morocco, Afghanistan, and the United States. Most of the exotic materials have been received through ICRISAT. These are being evaluated for morphoagronomic characters, and promising ones are promoted for yield and adaptation trials at different locations. Research projects on chickpea could be categorized under the following headings:

Varietal Investigation

With the objective to provide the farmers with suitable high-yielding chickpea varieties, maximum effort and available resources have been utilized for the varietal investigation projects. These include:

1. Evaluation of indigenous and exotic germplasm.
2. Preliminary trials for yield and other characters.
3. International yield trials and nurseries.
4. Chickpea coordinated varietal trials — for yield and adaptation.
5. Farmers' field trials.

On the basis of previous results, the lines in Table 6 have been found promising.

G-0332, a local cultivar, has been identified for high yield and wide adaptation over the years. Pant-110 and T_3 are good for western Terai. These are expected to be released in the near future. Some of ICRISAT's kabuli lines have recorded very high yields in 1977–78 at Parwanipur; these will be tested for confirmation over the years and locations. The maturity period for chickpea generally increased from east to west in Terai within a range of 130 to 160 days.

Cultural Investigation

A date-of-seeding × varietal trial was conducted in 1973–74 with four seeding dates and three different cultivars. November 5 and G-0332 were found the best seeding date and cultivar, respectively, among the variety treatments (Table 7).

A new project on planting dates × variety (desi and kabuli types) with certain modification

Table 6. Characteristics of local and introduced chickpea varieties.

Line	Maturity (days)	Pl. ht. (cm)	Pods/plant	Seeds/pod	100-seed weight (g)	Yield (kg/ha)	Remarks
G-0332	147	49	108	1.9	10.9	2430	high yield and wide adaptation
G-0226-12	144	48	101	1.9	12.0	2379	
G-0228	145	48	109	1.7	12.7	2318	
Pant 110	161	59	173	1.9	14.5	2912	Suited for Western Terai
T_3	161	58	162	1.5	23.5	2719	
ICRI. 7358-8-2-B-Bh	145	62	116	1.6	23.5	4525	ICCT-K (1977/78)
ICRI. 7347-6-4-B-BH	143	54	112	1.6	23.5	4187	

Table 7. Effects of sowing dates and cultivars on seed yield (kg/ha) at Parwanipur in 1973–74.

Varieties	Sowing date				
	Oct 26	Nov 5	Nov 15	Nov 25	Mean
G-0331 (large-seeded)	550	950	830	730	770
G-0333 (kabuli-type)	1130	1180	1006	900	1080
G-0332 (desi type)	1750	2300	1450	1530	1760
Mean	1140	1470	1090	1050	

is being initiated for 1978–79 at Parwanipur.

A spacing trial on chickpea was conducted in 1973–74 with the local desi type, and planting at 33 × 15 cm (222 000 plants/ha) was found optimum (Table 8).

A project to determine suitable spacings for desi and kabuli types is now under study at Parwanipur.

Performance of chickpea and lentil under different tillage conditions was studied in 1977–78 at Parwanipur (Table 9). Lentil and chickpea yielded higher with earlier planting (first week of November), and this can be put into practice with relay planting in late paddy fields approximately 2 to 3 weeks before harvest. In case of late planting conditions, minimum tillage planting with mulching could be adopted to maintain higher yield level.

Nutritional Investigation

A fertilizer trial with three N levels and five P-levels was conducted in 1973–74 (Table 10). There was no response to applied N, which might be due to a high native fertility and a higher *Rhizobial* population. But the response due to P_2O_5 application was highly significant. A combination of 40 kg N and 40 kg P_2O_5/ha was found optimum, giving a maximum yield of 1580 kg/ha.

Projects on cultural and nutritional aspects currently are inadequate; however, they are very important, and more effort and resources should be utilized in the coming years.

Pathological and Entomological Investigation

No systematic work was done on the pests in these lines; however, we have initiated one project on each of them from this season (1978–79) to get some preliminary ideas of pests and diseases attacking chickpea

Conclusion

Chickpea has been a neglected crop in Nepal in the past and had no way to compete with wheat but soaring prices of agricultural inputs and decline in the price of wheat, have compelled the farmers to go for a crop such as chickpea and lentil that could give comparable profits as well as could enrich their soil fertility. At present, the prices of pulses on the whole are quite favorable, and the area under pulses has been increasing in recent years.

Table 8. Effects of plant spacing on seed yield of local desi type chickpea at Parwanipur in 1973–74.

Plant spacing (cm)	Grain yield (kg ha)
Broadcast	890
25 × 10	1190
33 × 15	1470
40 × 20	1210
50 × 25	1250

Table 9. Seed yields (kg/ha) of chickpea and lentil under different tillage conditions at Parwanipur 1977–78.

Treatments	Yield
Relay planting of chickpea	1675
Relay planting of lentil	1652
Planting of lentil with no tillage + mulching	1597
Planting of chickpea with no tillage + mulching	1494
Planting of lentil followed land preparation	1448
Planting of chickpea followed land preparation	1049
Planting of chickpea with no tillage	798
Planting of lentil with no tillage	496

Table 10. Effects of nitrogen and phosphorus on seed yields (kg/ha) in 1973–74.

	Applied N (kg/ha)			
Applied P_2O_5	0 N	20 N	40 N	Mean
0	590	726	970	760
20	760	910	1060	910
40	810	1010	1580	1130
60	1280	1140	820	1080
80	1600	800	750	1050
Mean	1010	920	1040	990

Chickpea occupies a prominent position in our cropping patterns. It is grown in the Terai region, but could be extended to the Inner Terai and to some river basins and valleys as a winter crop. It has good scope as a summer crop in the high altitudes, in places such as Jumla and Jomsom, where average annual rainfall is below 20 inches.

The importance of pulses has been realized in the country's cropping system and economy, and the Department of Agriculture has a plan to give it a separate identity as a "coordinated program" in the sixth 5-year plan, and more scientists, funds, and resources would be utilized for its research, extension, and production. The following recommendations should be given due consideration to strengthen the pulse program and its activities in the country.

Short-term Basis

1. A team of scientists (including a breeder, an agronomist, an entomologist, and a pathologist) should be devoted to do research on chickpea.
2. Due consideration should be given to the training of researchers in their respective fields.
3. Sufficient budget and facilities should be provided to run the program effectively.
4. A strong extension program should be launched for the cultivation and utilization of chickpea.
5. Seed production and distribution should be handled by the pulse program and the government farms.

Long-term Basis

1. A separate headquarter for pulse research should be provided at a suitable place.
2. A number of researchers in various faculties at the headquarter should be increased, and a team of scientists to work on pulses should be appointed at the substations.
3. Budget and facilities should be increased accordingly to run the program effectively.
4. Seed production and distribution should be handled by Agricultural Inputs Corporation (AIC).
5. Marketing of pulses together with chickpea should be regularized and be handled by the Food Corporation or other such agency.

References

BHARATI, M. P., and SAH, R. P. 1977–78. Cooperative performance of lentil and chickpea under different tillage conditions.

MAHANDHAR, J. B. 1975. Notes on winter pulse disease.

SAH, R. P. 1973–74. Reports on date of seeding cum varietal and spacing trials on gram.

SAH, R. P. 1974–75. Report on varietal evaluation projects in gram.

SAH, R. P. 1975–76. Report on chickpea varietal trials and nurseries.

SAH, R. P. 1976–77. Report on chickpea varietal trials and nurseries.

SAH, R. P. 1977–78. Report on chickpea varietal trials and nurseries.

Chickpea Pathology in Pakistan

Inam Ullah Khan*

Blight

Blight of chickpea is caused by a highly pathogenic fungus, *Ascochyta rabiei*. It perpetuates in diseased plant debris and in infected seeds. Since large areas are involved, the only feasible control of the disease is making blight-resistant varieties of chickpea available to the cultivators.

Extensive work on blight of chickpea has been done by Sattar (1933), Luthra et al. (1941), Hafiz (1952), and Kausar (1965).

The chickpea varieties F-8, F-9, and F-10, having been tested for resistance to blight, were recommended for sowing in the affected areas in the 1940s. Slowly these varieties got lost, and the disease again appeared in epiphytotic form from time to time. Fresh screening of new chickpea germplasm commenced in 1974 at Faisalabad. Since Faisalabad does not lie in the blight area, screening work required improvement in methodology.

To create a perfect epiphytotic of blight in the field, the method of production of *Ascochyta* inoculum was totally changed. The fungus takes about a fortnight to fill an average sized petri dish on an agar substrate under laboratory conditions. By shifting to natural media we are now able to produce larger quantities of inoculum within shorter periods of time. This has greatly facilitated screening work at Faisalabad.

So far, more than 1000 chickpea varieties have been screened against blight. At present, we have the honor to cooperate with ICARDA (International Center for Agricultural Research in the Dry Areas) in Syria and with ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) in India. The chickpea varieties received from the above international organizations are being screened for both blight and wilt diseases at Faisalabad. We shall be glad to extend our cooperation to all who are interested in getting their chickpea varieties screened for blight.

Wilt

This disease is very common in comparatively drier areas of Pakistan. The following fungi have been isolated from the roots of wilt-affected chickpea plants:

1. *Fusarium* spp (incidence more than 60%)
2. *Rhizoctonia bataticola* (incidence about 12%)
3. *Rhizoctonia solani* (incidence about 5%)
4. *Sclerotinia sclerotiorum* (incidence about 2%)

Often, a nematode, *Tylenchorhynchus* sp, has been found associated with the roots of wilt-affected plants.

Pathogenicity trials have proved that *Fusarium* spp are particularly severe on chickpea roots when nematodes are also introduced into the infested soil. Other fungi require special conditions for causing root rot. Chickpea stunt (virus) has also been recorded here and there, but it is of minor importance.

References

HAFIZ, A. 1952. Basis of resistance in gram to *Mycosphaerella* blight. Phytopathology 42: 422–424.

KAUSAR, A. G. 1965. Epiphytology of recent epiphytotics of gram blight in West Pakistan. Pakistan Journal of Agricultural Science 2(3): 185–195.

LUTHRA, J. C., SATTAR, A., and BEDI, K. S. 1941. Determination of resistance to the blight disease (*Mycosphaerella rabiei*) Kov. by *Ascochyta rabiei* (Pass.) Lab. in gram types. Indian Journal of Agricultural Sciences 11: 249–56.

SATTAR, A. 1933. On the occurrence, perpetuation and control of gram (*Cicer arietinum*) blight caused by *Ascochyta rabiei* (Pass.) Lab. with special reference to Indian conditions. Annals of Applied Biology 20: 612–632.

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Chickpea Report from Pakistan

M. A. Khan*

Geographical Location, Climate, and Soils

Pakistan is demarcated by longitudes 61° and 76° E and latitudes 23° and 37° N. It is bounded on the northwest by Afghanistan and on the west by Iran. In the extreme north there is a very narrow strip of Afghanistan territory separating Pakistan from Tadzhikistan of the USSR. On the north lies China, and on the east lies India. In the south is the Arabian Sea. The main seaport is Karachi.

The total area of Pakistan is 311 406 square miles (196.70 million acres). Of this area, only about 21% is cultivated. There are four provinces and the distribution of the area by province is as follows:

	Million acres
Baluchistan	85.79
Punjab	50.95
Sind	34.82
North Western Frontier Province	25.14

In northern Pakistan there are the high mountain ranges comprising the Hindu Kush and the Karakorum. Nowhere in the world is the concentration of high mountains, peaks, and glaciers as great as in the Karakorum region of Gilgit and Baltistan. Most of the peaks in this region remain snowbound throughout the year. The climate, even in the lower reaches, is temperate and the flora is alpine.

Toward the Safed Koh is a highly eroded and gullied plateau and the geologically complex salt range. The extension of the plateau towards the west is made of the Karachi plain and the Baluchistan plateau. The Baluchistan plateau is an arid part except for the narrow Makran coastal strip and the hot Sibi plain.

The Indus Valley is a great alluvial plain slanting toward the Arabian Sea at a gradient of about 1 foot/mile. It is watered by the rivers Indus, Jhelum, and Chenab. The areas between the rivers are called Doabs and constitute the central flat part of the country. The edges of this central part often form an escarpment. The main Doabs are shallow basins that drain off into each other and finally into the Indus. Last, there are two desert regions in the extreme southeast of the country, which are named Cholistan and Thar.

The soil texture varies a lot. Three different major types of soils have been recorded.

As far the climatic features are concerned the northwestern part has high mountain ranges with an Alpine climate. The plains have low, irregular rainfall and extremes of temperature. The rainfall everywhere occurs in intense rainstorms. The evapotranspiration over most of the plains is higher than the rainfall. Thus, plant life over most of Pakistan must be sustained through irrigation. Table 1 lists the maxima and minima temperatures and rainfall for selected locations.

Production

Table 2 shows the area sown and production from 1971 to 1976.

Major Uses and Marketing

Chickpea is recognized as a major source of vegetative protein. Although it is a common cattle feed, it is chiefly used for human food in Pakistan. Grains are used in almost all forms, starting from the fresh greens to the dried split grains and flour. Pealed-off skin (Suri) and its hay (Bho) is of considerable importance as animal feed. Chickpea and wheat are consi-

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Table 1. Monthly mean maxima and minima temperatures (°F) and rainfall (mm) for selected locations in Pakistan.

Location	Trait[a]	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Karachi	M	75.5	76.9	81.8	85.4	88.6	90.4	88.5	85.0	85.6	78.3	82.2	78.7	84.1
	N	57.4	61.0	68.1	74.2	79.0	82.3	81.1	78.5	76.7	73.7	66.9	60.8	71.6
	R	11.7	11.2	7.4	3.8	1.5	18.3	81.3	39.6	13.2	0.5	2.0	5.1	195.6
Hyderabad	M	75.8	81.2	92.5	101.8	107.0	104.5	99.3	95.8	97.3	97.8	88.8	78.6	93.4
	N	50.6	54.5	63.8	71.9	78.2	82.2	81.4	79.2	76.4	70.2	58.8	52.6	68.0
	R	4.3	6.1	5.1	1.8	4.8	7.6	75.7	51.6	16.0	0.8	1.5	2.5	177.8
Faisalabad	M	67.1	71.3	81.6	92.9	102.4	106.0	101.5	98.0	98.1	93.2	82.2	70.7	88.7
	N	39.9	45.1	53.6	63.9	73.9	81.7	82.7	80.5	75.2	62.4	40.1	42.2	62.1
	R	10.2	14.5	14.2	11.9	10.9	31.0	72.6	90.9	37.9	3.1	2.8	6.4	306.4
Lahore	M	68.0	72.1	82.6	94.5	103.7	105.9	99.6	97.0	97.3	94.0	82.9	72.3	89.2
	N	40.1	44.5	53.2	63.2	72.2	79.0	80.1	78.7	73.1	69.8	47.3	40.6	61.0
	R	26.4	24.6	20.1	14.5	17.5	41.7	138.4	130.8	55.9	6.1	2.5	11.9	490.4
Quetta	M	50.2	53.6	63.6	74.0	83.8	91.6	94.0	92.2	86.2	75.6	65.4	55.5	73.8
	N	27.6	30.8	38.3	45.8	51.9	58.7	65.0	61.6	49.7	38.9	32.1	28.5	44.1
	R	49.3	50.3	44.2	177.3	9.9	4.3	11.7	8.4	153.4	3.1	7.1	25.7	544.7
D. I. Khan	M	68.0	71.6	81.8	92.6	103.5	107.8	103.3	103.5	99.4	93.3	81.9	71.5	89.6
	N	40.3	44.9	55.0	65.2	74.7	81.5	82.7	81.2	75.6	61.7	48.7	41.2	62.7
	R	11.4	17.0	24.4	17.5	9.9	15.5	58.2	48.3	16.0	2.8	3.8	6.1	230.9
Peshawar	M	63.0	66.2	74.8	85.2	97.0	105.0	102.5	98.2	95.0	87.8	76.8	66.7	85.0
	N	40.4	44.0	52.4	60.5	70.4	77.2	80.2	78.9	71.8	60.5	48.9	40.9	60.5
	R	36.6	13.5	62.0	44.7	19.6	7.9	32.0	51.6	20.6	5.8	7.9	17.0	319.2
Islamabad	M	62.3	65.2	75.1	86.2	97.7	103.5	97.8	93.7	93.4	88.6	77.7	66.8	84.0
	N	37.9	41.7	50.4	59.3	68.7	75.9	77.1	75.5	69.3	57.0	44.4	37.8	57.9
	R	63.3	63.0	67.8	48.8	31.8	58.7	205.0	233.0	98.8	15.2	7.1	31.5	924.0

[a] M = Maximum temperature (°F); N = Minimum temperature (°F); R = Rainfall (mm).

Table 2. Area sown to chickpea and production, Pakistan, 1971–72 to 1975–76.

Year	Area (thousand acres)	Production (thousand tons)
1971–72	2383.2	502.2
1972–73	2513.8	544.4
1973–74	2738.1	600.6
1974–75	1462.3	541.5
1975–76	2640.2	591.9

dered to be best utilizable protein components. Chickpea is used to make curry of the fresh green seeds, dried seeds, and split grains (dhal) and is eaten with unleavened bread (chapati) or sometimes baked with flour mixed with salt and peppers. It is also mixed with wheat flour to make chapati (Missi Roti). It is a common belief that when eaten together, wheat and gram synergize, which increases the efficiency of both ingredients. Chickpea flour is a major ingredient in certain sweets and "Pakoras" and is partly used in ground meatball preparations and in coating fried fish and chicken pieces.

Fresh shoots are eaten as a vegetable mixed with spinach and tender shoots of green mustard. Green plants are uprooted and sold in the vegetable markets for fresh green grains. Early crops bring premium prices, but the later crops then come in competition with fresh green peas. Dried seeds are threshed in the field and filled in the bags, which are transported to the grain markets. There is not much fluctuation in the price structure, which in terms of Pakistani rupees is Rs 3/- per kilo.

Current Status of Production Practices

There is a common belief among chickpea growers of Pakistan that this crop does not need much cultivation and inputs. For that reason, it is seldom planted with great care, as is wheat. Mostly it is grown in rainfed areas or areas of marginal productivity, on rather poor soils of various structure and texture. If planted in irrigation areas, the water is utilized only once for land preparation (Rauni). In barani areas, the rotation is chickpea-fallow-chickpea. In the Sind and certain other places, it is grown as a "Dobari" crop on residual moisture after harvesting paddy. Wheat-maize/sorghum/bajra-gram (chickpea) is also a common rotation in areas where irrigation water is available.

The approved varieties are Pb-7, Pb-1, C-612, C-727, Saniasi, and Chola. They all cover not more than 50% of the total area planted under this crop. The seed rate used is from 15 to 20 kg/acre. The planting is commonly done with bullock plows, either through pipes tied behind the plow or by dropping the seed in the opening made by the plow. If dropped in the open furrow, it is followed by planking to cover it; if planted with pipe, then it needs no planking. Although it has been confirmed that fertilizer application does increase the yield, seed inoculations, application of fertilizers, or use of any other inputs are negligible.

Harvesting and threshing are commonly done by manual labor. Dried plants are collected and threshed with sticks. At places where there is a bigger bulk, threshing is done with the help of bullocks or tractors, running them round and round on it, and then the seed is separated by winnowing.

Major Problems of Production, Protection, and Utilization

Among the common diseases of chickpea, the most virulent is *Ascochyta rabiei* (chickpea blight). The gram wilt is another serious disease, the incidence of which depends on the type of causal organism involved. Nematodes are also a problem since parasitic activity of *Fusarium* spp has been linked with nematodes. Preliminary studies at Faisalabad have revealed that species of *Fusarium, Rhizoctonia solani, Sclerotium bataticola*, and *Macrophomina phaseoli* are predominantly associated with the roots of wilted chickpea plants.

Pest problems are also serious and create considerable losses to the chickpea crop. Chickpea caterpillar, *Agrotis vpsilon*, and pod borer *Heliothis armigera*, are the worst enemies of chickpea crops. The major pest of stored grains is *Bruchid.*

Agrotis attack was successfully controlled by BHC dusting, and Thiodan and Diazinon were successful in controlling *Heliothis* attack. Phostoxin tablets were beneficial in controlling stored grain pests.

Problems limiting the productivity and economic viability of chickpea are classified under the following subheads:

Agronomic

Usually the land given to chickpea is of marginal productivity because there is no good water supply for irrigation. Under rainfed conditions, farmers are unable to make use of better agronomic practices because of the following limitations: (1) lack of conducive conditions for seed-bed preparations, sowing, cultural practices, or utilizing better inputs such as fertilizers and insecticides; (2) insufficient supply of better seed; (3) mistaken notion that fertilizer use has no beneficial effect; (4) lack of sowings at optimum time due to uncertainty of rains; and (5) lack of sufficient information regarding best agronomic requirements for getting better yields.

Varietal

Varietal problems include the (1) nonavailability of a resistant variety to chickpea blight and (2) a lack of resources for providing proper tests to various genotypes with respect to varied ecological conditions.

Inputs

Required inputs are lacking due to (1) the low purchasing power of the growers for use of necessary inputs; (2) a lack of incentive through subsidy and credit; and (3) lack of information on fertilizer response on chickpea crops.

Research

Research is not being conducted because of (1) the lack of facilities for accommodating a broad-based gene pool including wild species; (2) insufficient studies on host-pathogen relationships for determining the basis of resistance to chickpea blight and wilt; (3) nonavailability of nodulation-promoting bacterial cultures; (4) erratic pod setting; (5) lack of information regarding appropriate soil management and agricultural practices; and (6) complete lack of work on growth analysis and physiological requirements.

Establishment of disease nurseries is of utmost importance.

Economic

The farmer receives only a low return per unit area, and this directly affects his purchasing power.

Research and Extension Support

Table 3 lists the researchers in Pakistan who are working on chickpea improvement.

Seed Production Capability

The Department of Agriculture in every province has farms and can easily multiply seed and distribute through the extension staff or seed corporation.

Research Review

Enhancement of grain legumes production through efficient operation and coordination of different aspects of yield increase has been the aim of the chickpea experts. In the complex problem of human nutrition, grain legumes, specially chickpea, occupy a strategic place since all efforts to increase production levels via varietal improvement, crop management, crop protection, and other cultural practices cannot yield maximum results unless the crop in question possesses the potential to respond fully to the improved environment. Such efforts have already begun in Pakistan.

The germplasm in hand comprises local collections (over 1000) and selections and introductions from FAO, the United States, Mexico, Australia, Bulgaria, Egypt, Morocco, Iran, and about 1500 from ICRISAT and ICARDA.

In the first half of the present century, the local gram proved to be susceptible to *Ascochyta* blight, and the severe epidemics from 1935 to 1940 resulted in an almost complete failure of the gram crop. Then, out of 392 exotic and local combined collections tested by the then economic botanist, three varieties F-8, F-9, and F-10 out of the material supplied by the United States

Table 3. Current researchers in Pakistan who are working on chickpea improvement.

Organization	Scientist	Specialization	% time on chickpea
1. University of Agr. Faisalabad	Dr. M. Aslam	Plant Investigator	10
	Dr. M. Abdullah Khan	Sr. Breeder of Grain Legumes	80
	Dr. Inamullah Khan	Plant Pathologist	80
2. Punjab Agr. Research Institute, Resalewala, Faisalabad	Dr. M. Iqbal Khan	Pulses Botanist	100
3. Agr. Research Inst., Ternab, Peshawar, NWFP	Mr. Said Badshah	Economics Botanist	10
4. Agr. Res. Institute, Tandojam (Sind)	Dr. Ahmad Mustafa Khan	Agronomist	10
5. Dept. of Agriculture	Secretary Agr., Lahore	Extension	
	Secretary Agr., Hyderabad	"	
	Secretary Agr., Peshawar	"	

Bureau of Plant Industry proved tolerant. F-8 did well in the barani blight-affected area, but because of its low yield and susceptibility to wilt, it failed badly in other parts of the country. This led to an effort to hybridize F-8 with local varieties including Pb-7 and Pb-1, which were otherwise the top varieties of that era except that they were susceptible to blight. As a result, C12/34 was evolved in 1942. The years 1957–58 and 1958–59 were really the blight years and provided a golden opportunity for selection under natural epidemic conditions. One type, C-727, held promise as one of the survivors. From the later studies by way of screening through the disease nurseries, 5/1A and CS-19 proved tolerant to the blight disease, whereas C57/3, C88/11, and C218/1 were tolerant to wilt, and the performance of C-727, C392/1, and C357/1 was promising against both diseases.

In order to determine the extent of bearing of various plant characters on the seed yield, simple, partial, and multiple correlations and heritability, variability, and path coefficients were worked out between them. Studies on the reasons for low seed setting in gram, flower development, and pollen tube growth were also undertaken. Inheritance studies on flower and leaf color; seed shape, surface, and size; food characters; and resistance to blight were also carried out as an aid to breeding.

Most of consumers prefer a white bold-seeded variety of chickpea. Sind province has a lead in growing white chickpea. Recent research has proved the superiority of the varieties Sanyasi and Chola. They grow commercial chickpea as a Dobari crop on residual moisture after harvesting paddy and as there is no serious danger of blight epidemic in that tract, these varieties were doing very well.

Research in North West Frontier Province (NWFP) has indicated the superior performance of varieties 6077, 12-70, 1-06486, and C137/1. They are said to have better yields than C-612 and C-727. Efforts are also being made to use chickpea as an alternate crop for replacing poppy.

Through the establishment of a pulse section at Punjab Agricultural Research Institute, Faisalabad, and since the intensification of research on grain legumes at the University of Agriculture, Faisalabad, many more lines have been received from exotic research as well as through mutation breeding. The latest research has shown a greater tolerance to chickpea blight in varieties 6558, 173, CS-30, 132, C150/4, and AUG-426. Efforts were made to pool the tolerance of these varieties and, therefore, out of the crosses, the varieties 59, 60, 63, and 6212 are doing better than the existing varieties. For the last 3 years, ICRISAT has been sending international yield trials and screening nurseries.

There was quite a difference in behavior of varieties against pod borer (*Heliothis* spp), stored grain pests, and other insect pests of chickpea. The varieties also showed considerable differences in protein percentage which varied from 16 to 29%.

On the agronomic side, the fertilizer response of different chickpea varieties showed that 50 lb N in combination with 50 lb P_2O_5 was the best rate in areas of medium fertility.

Conclusions

The importance of chickpea as a major grain legume crop and a source of cheap protein, food energy, and other nutrients cannot be overlooked any longer.

Not much research work has been done to evolve many more new strains. Even the strains which are available have no regular program for screening through the disease nurseries and testing them under different ecological conditions, working out their appropriate agronomic requirements, and multiplying them in a sizeable quantity. None of the prevalent varieties has full resistance against blight and wilt, and thus the crop continues to suffer.

Priorities for Improvement

1. Pakistan Agricultural Research Council should act as coordinator for research work and, if need be, provide technical assistance and financial support for special projects.
2. There is a need for separate, independent research on chickpea breeding, agronomy, physiology, insect pests and pathology, and biochemistry, instead of the present status where the economic botanists, wheat breeders, and the pulse botanists work with various crops and cannot devote their full time to chickpea.
3. Provincial governments should be requested to set up a system of a main research station and substations in the crop belt for providing necessary information to the researchers.
4. To cut down the breeding period, a second generation of breeding material should be explored for raising in Kaghan/Quetta or elsewhere.

Chickpea Production in Peru

Cesar Apolitano Sanchez*

Chickpea (*Cicer arietinum*) is a legume accepted by Peruvian consumers, and demand for it has increased. Chickpea is in sixth place in area and value of all legumes planted, and in fifth place in total production; its share of the national production is 25%.

Both area planted and yield have suffered marked fluctuations from 1965 to 1975 (Table 1), and therefore production was variable. However, some chickpea areas have achieved high yields (Table 2). Since 1975 the tendency has been for area and yield to diminish.

Climate and Soil

In Peru, the Department of Lambayeque has the largest area planted to chickpea with 1760 ha in 1975, which was 66% of the national total. Geographical and environmental features of Lambayeque are: latitude 6° 44′ S, 79° 48′ W, and 37–50 m elevation above sea level. Annual rainfall varies from 0.75 to 10.65 mm. The soil varies from clay to clayey sand with pH from 7.3 to 8.0. The soils are low in organic matter and in fertility.

Distribution

Peru is divided into the geographic zones of coastal, mountain, and forest or jungle, each of which consists of departments, provinces, and districts. The area planted to chickpea is located in the Departments of Libertad, Lambayeque, Huancavelica, Ica, Lima y Callao, Apurimac, Ayacucho, and Cuzco.

Cultivation in the mountains and coast differs; on the coast, irrigation by gravity is used, while in the mountains the crop is rainfed. The area planted in the mountains is small (Table 3).

Principal Uses and Marketing

The settlers in Peru use chickpea in their diet, both green and dry. Dry chickpeas are eaten both boiled and toasted. In any of these forms, they are always mixed with rice or vegetables.

At present, there is a scarcity of chickpea, and the price is surprisingly high. While production cannot satisfy domestic demand, export markets are increasing their demands.

Commercialization follows a channel from producer to consumer through middlemen who inflate prices. Consumer preferences are related to size, color, and shape of the grain. Large, cream colored, rounded grains are preferred.

Present Systems of Production and Principal Problems

Chickpea is sown in the winter months of June through August after rice or maize, or in monoculture. Where irrigated, planting is done

Table 1. Area, yield, production, and value of chickpea in Peru, 1965–75.

Year	Area (ha)	Yield (kg/ha)	Production (metric tons)	Valve ($1000)
1965	5570	495	2756	15 081
1966	2365	605	1433	6 682
1967	3910	745	2918	17 776
1968	360	750	271	2 114
1969	4900	570	2803	26 219
1970	8275	720	5967	52 027
1971	4555	635	2897	26 941
1972	3995	504	2013	28 271
1973	3940	704	2776	28 844
1974	3055	739	2215	31 109
1975	2660	769	2046	36 235

Source: Ministerio de Agricultura y Alimentacion. Anuario Estadistico Agropecuario, Ahos 1965–1975, Lima.

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Table 2. Area planted and yields of chickpea by zones and departments in Peru, 1965–75.

	North Zone				Central Zone						South Zone					
Year	La Libertad		Lambayeque		Huancavelica		Ica		Lima & Callao		Apurimac		Ayacucho		Cuzco	
	ha	kg/ha	ha	kg/ha	ha	kg/ha	ha	kg/ha	ha	kg/ha	ha	kg/ha	ha	kg/ha	ha	kg/ha
1965	1140	1050	3800	250			400	960	20	950	20	600	120	650	20	3000
1966	750	1000	1420	365			20	720			5	1500	120	635	50	1345
1967	700	1050	2590	665			440	670			10	1000	120	690	50	1460
1968			140	705	50	600	70	990			15	1135	70	560	10	1000
1969			4420	550	55	705	230	850	15	500	165	700	130	660	10	780
1970	220	980	5450	600	75	745	240	950	30	885	85	900	65	590	30	690
1971	300	990	3950	600	10	700	800	170	15	870	25	800	65	635	20	650
1973	300	950	3050	650	65	702	340	950	5	850	45	940	105	681	30	680
1974	350	930	2160	680	65	731	340	920	5	850	25	740	80	733	30	695
1975	200	980	1760	690	45	733	455	1000	40	850	20	725	40	735	100	700

Table 3. Area planted and yields of chickpea under irrigation and rainfed in Peru, 1965–75.

	Coast		Mountains			
Year	Irrigated		Irrigated		Rainfed	
	ha	kg/ha	ha	kg/ha	ha	kg/ha
1965	5400	480			170	975
1966	2190	585	35	885	140	855
1967	3730	735	40	800	140	955
1968	210	800	15	920	130	635
1969	4655	565	30	620	215	700
1970	7890	715	160	890	225	760
1971	4420	635	25	720	110	695
1973	3690	702	50	863	200	705
1974	2850	739	40	851	165	701
1975	2415	772	60	850	185	702

20 days after a preplanting irrigation. Where rainfed, planting is done after the end of the rains.

The planting rate is 60–100 kg/ha. Row spacing is 80 cm with hills 40 cm apart. Four seeds are planted per hill, at a depth of 5 cm. Seeds are not treated with a fungicide. No fertilizer is used.

Varieties planted are of the Mexican and Spanish type and include Giant American and Criollo (local). Their vegetative period is 100 to 150 days.

Pests and diseases are very important, the most serious being *Heliothis* spp and *Fusarium* spp. Insecticides are applied; frequent spraying is the main factor in raising the cost of production. Harvest is by hand. Tricycle-type tractors are used for threshing.

In recent years, salinization of soil in areas planted to chickpea has limited area and yield.

Control and Agricultural Extension

Control measures are suggested by the Department of Plant Protection and the Agencies of Production. Also the experiment station (CRIA II) through the legume project gives guidelines for the best technical management of the crop.

Research

CRIA II at Chiclayo has been investigating the principal problems of chickpea since 1948. Research started with the introduction of five cultivars: Spanish No. 6, Criollo (local), Chilean, Spanish No. 9, and Spanish No. 8. They are listed in order of descending yield in 1948, from 1250 to 533 kg/ha. In 1950 the range of yields was from 3217 to 2337 kg/ha.

Criollo, Spanish, and Giant were tested for 3 years with the following yields, respectively:

Table 4. Yield tests (kg/ha) of chickpea cultivars at Muy Finca, Peru, 1972–75.

Variety	1972	1973	1974	1975	Total	Average	Vegetative period (days)	Seed characters			
								Size	Color	Surface	g/100 seed
USA-G-I-736	2035	4069	5068	5439	16 611	4153	129	Small	Light orange	Smooth	29.0
Turkey G-2-PMI	2237	3015	4964	4121	14 337	3584	133	Medium	"	"	45.1
Turkey 18-2	1997	3568	3732	4933	14 231	3558	133	"	"	Semi-rough	46.9
Turkey G-2-PM3	2543	3361	3551	3694	13 149	3287	133	"	"	Smooth	41.5
Turkey G-1	1706	3424	3652	3954	12 736	3184	134	"	Brown	Semi-rough	47.3
Turkey G-2-PM2	1992	2687	3949	3923	12 551	3138	133	"	Light orange	"	45.5
Syria G-2	2403	4143	2878	3003	12 427	3107	121	Small	Light brown	"	31.5
Spanish	1921	2868	3964	2979	11 732	2983	131	Large	Light orahge	"	64.2
Giant R. F.	2126	3108	3821	3516	11 571	2893	133	"	Light brown	Rough	54.8
American Giant	1638	3934	3486	2420	11 478	2869	138	"	Brown	"	54.9
Criollo (Local)	2058	3166	3344	1499	10 517	2517	121	Small	Light brown	"	32.4
Spain G-I-13	1055	2424	3532	2374	9 385	2346	139	Large	Light orange	Semi-rough	50.4
Spain G-I-20	863	1980	2924	2435	8 202	2050	131	"	Brown	"	56.3
Yearly total	24 574	41 747	48 865	43 291							
Yearly average	1890.31	3211.31	3758.85	3330.08							

582, 289, and 264 in 1957; 1283, 1213, and 1118 in 1958; and 1772, 1406, and 1716 kg/ha in 1959.

In 1960 and 1962, we compared 81 lines and found the following to be the highest yielding: Turkey G-2, Turkey G-3, Syria G-1, Egypt G-1, and Spanish, with yields of 1854, 1511, 1481, 1443, and 1435 kg/ha respectively.

In 1964, to find cultivars with high yield, early maturity, and resistance to pests and diseases, we compared 50 introduced cultivars and found the highest yielding to be Syria G-2 PM-1, Giant, Pakistan G-1 PM-1, and Tukey G-2 PM-2 with yields of 2931, 2503, 2559, and 2518 kg/ha, respectively.

In 1965, seven cultivars were tested and ranked as follows: Syria G-2 PM-3, Pakistan G-1, Egypt G-1 PM-7, Syria G-2, Criollo, Spanish, and Giant with yields of 929, 816, 810, 794, 724, 572, and 510 kg/ha, respectively.

From 1966 to 1969, 24 cultivars were studied; 11 cultivars did not differ significantly, and their yields were over 1000 kg/ha. Only Syria G-2 was stable in yield. It had a vegetative period of 115 days and was tolerant to *Fusarium*.

In 1970, the commercial cultivar Chancay (Syria G-2) was released; its cultivation lasted only about 2 years since it became susceptible to other types of *Fusarium*.

In 1972, cultivar evaluation was continued (Table 4).

In 1974, a hybridization program was started. The objective was to develop new cultivars with resistance to *Fusarium*. The hybrid populations were selected and advanced in bulk.

In 1977, chickpea research was stopped because of the lack of funds and personnel. At present, we are conducting tests in cooperation with ICRISAT: two professionals are available for 10% of their time in the areas of control of insects and diseases, respectively.

Seed Production

Basic and foundation seed are produced by the experiment stations of CRIAN (Centro Regional de Investigaciones del Norte). This seed is made available to farmers through Zones of Production of the Ministry of Agriculture and Food.

Summary and Conclusions

There is an urgent need for a national program of research on chickpea. There is a scarcity of basic foods and consequently a shortage of protein sources. Furthermore, the problems of production are numerous, and most of them have not been solved to date.

In recent years Peru has consumed more chickpea, but lowered production is not meeting the demand. Because of land limitations, diseases and pests, and lack of incentives for production, the area planted has decreased from 5570 ha in 1965 to 2660 ha in 1975.

Grain type is important in commercial movement of the chickpea; large, cream-colored, rounded seed is preferred.

Cultivars planted are highly susceptible to *Heliothis* spp and *Fusarium* spp.

References

Ministerio de Agricultura y Alimentacion. Anuario Estadistico Agropecuario, Ahos 1965–1975. Lima, Peru.

Centro Regional de Investigaciones Agropecuarias del Norte, Informes Anuales anos 1965–1975. Chicklayo, Peru.

Centro Regional de Investigaciones Agropecuarias del Norte. El cultive de Menestras en el Departmento de Lambayeque. Manual No. 1. 1976. Chiclayo, Peru.

16

Research on Chickpea in Spain

Jose I. Cubero*

In January 1975, during the workshop organized by ICRISAT, I described the research carried out in Spain up to that date. In fact, we were the only group working on chickpea at that time. At present, there are three trials (and one national program of trials) going on.

In my report of the first workshop, I commented that the total cultivated area of chickpea was decreasing in Spain but that varieties for human consumption were increasing because of the high market prices for such a product. In the last 5 years, this tendency has been strongly reinforced. The latest current market prices for first-quality seeds are about $1.30 per kg to the farmer; which is about $1.70 at the grocers' (in bulk) and $2.10 in the supermarkets where chickpea is carefully packed in bags of about 500 g.

This increase in price has given rise to two things — first, an increased interest by farmers for the chickpea, and second, new interest in some places in chickpea as a material for study.

I will describe briefly the work that is at present being carried out in Spain.

Plant Pathology Group

The youngest group will start its work during the present year. It is the Department of Plant Pathology of the Escuela Técnica Superior de Ingenieros Agrónomos (ETSIA) of the University of Córdoba. The research is on root diseases of chickpea. The main motivation for selecting such a research line is that with the increasing area of cultivation some soils became (or were) infected, resulting in huge losses. This situation was reported by me at the 1975 workshop, and now the problem is rather general.

The work undertaken by this group can be summarized as follows:

1. To obtain information about distribution of chickpea root diseases in Andalucia (the southernmost Spanish region), evaluation of losses, soils affected, and so on.
2. Identification of the pathogen. Certainly one of them is *Fusarium* spp, but it is not possible to exclude the presence and influence of others.
3. Reproduction of the diseases under controlled conditions, not only to study the pathogenesis but also to provide a useful test for resistance.
4. To look for resistance and for the existence of physiological races. This part of the work will probably be carried out in collaboration with the Department of Genetics of the same Center.

Microbiology Group

A second group has been formed including members of the Department of Microbiology of the ETSIAs of Córdoba and Madrid; the work will be done on the *Rhizobium*/chickpea symbiosis.

The contribution of N_2 fixation to the nitrogen nutrition of commercially grown chickpea, the symbiotic capacities of the native flora of rhizobia nodulating chickpea, and the factors limiting N_2 fixation by this legume crop will be studied. The main lines of research are as follows:

1. Study of symbiotic properties of indigenous chickpea *Rhizobia*.
2. Selection of efficient N_2-fixing strains of *Rhizobium* in symbiosis with chickpea.
3. Evaluation of the response of field-grown chickpea to inoculation of seeds with efficient and selected strains of *Rhizobium*.

Genetic Group

The third group was already working when the 1975 Workshop took place. An account of the

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work was presented, and since then, we have modified some of those ideas. Two papers were published on the systematics and the quantitative genetics of *C. arietinum*, and one on the description of Spanish varieties of chickpea will be submitted this year. These works are being realized by the Department of Genetics of the ETSIA of Córdoba and the "Pulses Group" of the Centro Regional de Andalucia of the Instituto Nacional de Investigaciones Agricolas (INIA).

In principle, our objectives were the systematics and the genetics of *C. arietinum*. In fact, the most time-consuming program is that of the study of the inheritance of seed characters, such as coat color and surface, color of cotyledons, and seed size and protein content. We have found the same difficulties that other workers have described, i.e. a complex genetic system for both color and surface of the seed, with epistasy as a common factor. For size, we have checked our previous result; the small size is at least partially dominant over the larger size.

At the time of the 1975 Workshop, we were asked by farmers and by experts of the Extension Service to work on resistance to root diseases. We tested our collection and we did find some resistant varieties, but not useful for Spanish requirements. Our potential of performing artificial crosses is rather limited, and we asked ICRISAT for help. We received bulk segregating generations, one of the parents being the kabuli type. We multiplied this material during 1977. In 1978 it was sown again, and we expected a heavy infection, but it was not so. Happily, the developments in chickpea research have provoked an increased interest of the provincial services of the Ministry of Agriculture, which has provided us with really heavily infected soils.

Concerning *Phyllosticta rabiei*, the problem has not been important in the last 10 years. Probably, the reduction of the area has a direct connection with this fact, because "rabia" was traditionally a serious pest on Spanish chickpea. (Just as a comment, I will say that my work in plant breeding began looking for resistance to the "rabia" while working with Dr. Puerta-Romero at INIA.) Very probably, the increase in the cultivated area in some zones will lead to a comeback of the disease. In fact, last year we observed some large spots of anthracnose in one of the INIA experimental farms in Andalucia. We, of course, will take advantage of this opportunity to work on the disease.

The problem is not only to find resistance, but to transform high-quality varieties into resistants. And this will not easily be accomplished (at least, not quickly) because of the standard required. We hope that with the collaboration of ICRISAT and ICARDA, this will be solved in the near future.

Acknowledgments

I am grateful to Prof. Rafael Jimenez, Head of the Department of Plant Pathology, and to Mrs. Inés Minguez, at present working in the Department of Microbiology, ETSIA, Córdoba, for providing the information presented here, and to Dr. Jose Puerta, of the Ministry of Agriculture, for his interest in pulses and his encouraging support.

Chickpea in Sudan

Farouk Ahmed Salih*

Geographical Location

The Democratic Republic of the Sudan, a territory of nearly 2.5 million sq km with a population of more than 17 million lies between latitude 3° 53' and 21° 55' N and longitude 21° 54' and 38° 30' E. It is bounded on the north by Egypt, on the northeast by the Red Sea, on the south by Kenya, Uganda, Zaire, and Congo Brazzville, and on the west by the Central African Republic and Chad.

The Sudan is essentially a country of vast plains, interrupted by rolling country and a few widely separated groups of hills or mountains. It is divided from south to north by the Nile River and its tributaries.

Climate

Rainfall varies from zero in the north to 1524 mm (60 inches) in the south, making the country to vary from barren desert to thick forests. In the central Sudan the effective rainfall is concentrated within a period of 4 to 5 months, and during the bulk of the year the plain is covered with dry parched herbage and such drought-resisting trees and shrubs as are able to survive the dry season. The rainfall period lengthens southwards; in the extreme south, rain occurs in varying amounts almost throughout the year. This distribution of rain is reflected in the type of vegetation, which passes from thorny, almost leafless, drought-resistant types in the north to evergreen and deciduous forests in the south.

Temperatures show considerable diurnal variation in the northern desert areas, where some of the highest maxima and lowest minima are recorded. Further south, the variation is less because of increasing rainfall and humidity; temperatures here are in general more equable throughout the year.

Soils

The influence of the soil is reflected in its water-holding capacity and less prominently in its acidity or alkalinity. In northern Sudan we have predominantly sandy types, often with little water-holding capacity. In central Sudan and in parts of southern Sudan vast areas of heavy, almost impermeable alkaline clays occur; in southern Sudan are found the more permeable acidic red ironstone soils. Among the river banks and in the flood plains of the "baraka" and "gash" are found permeable river silts.

Agroecological Zones

The country can be divided for cropping purposes into seven ecological zones (Fig. 1).

1. Desert Zone: Arid with less than 150 mm rainfall. Summer is hot; winter is mild. Includes the desert and arid areas north of the southern strip of the coastal mountain range and north of the southern strip of the western sandy areas.
2. Semi-arid zone of stony soils: Semi-arid belt about 150 km in width, running east and west of Khartoum. The climate is semi-arid tropical and semi-tropical, with rainfall (occurring in summer only) of about 150 to 500 mm.
3. Semi-arid Zone of sandy soils: Includes the sandy area east of the western mountains, south of the gravelly soils, west of En-Nahud, north of Eloobeid, and north of the southwestern hills. The climate is hot semi-tropical, semi-arid, changing to sub-humid in its southwestern part. Mean annual rainfall of 300 to 700 mm, occurring in July and August.
4. Western mountain zone: Covers the area of the eastern mountain (Jabal Marray and Jabal Gurgei) ranging in elevation between 1000 to 2000 m above sea level.The

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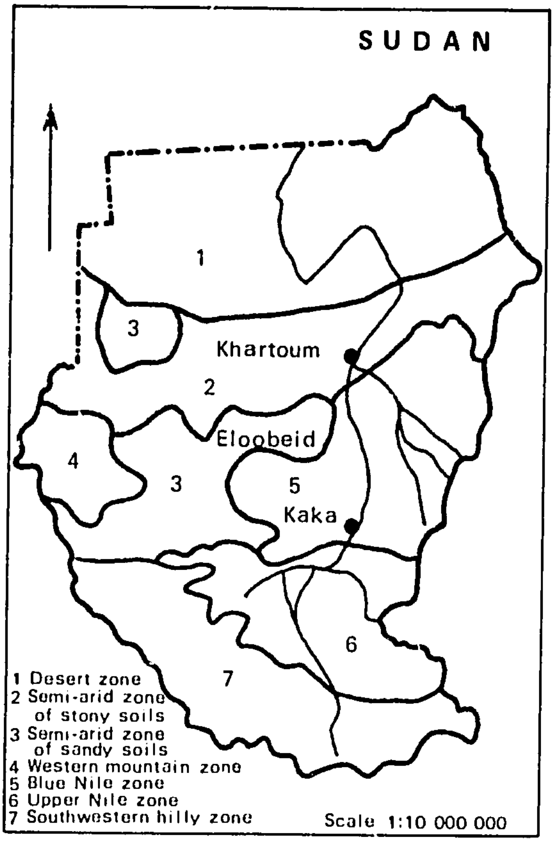

Figure 1. Agroecological zones in Sudan.

climate is of cool-winter, hot tropical type, with winter sufficiently cool for many cryophilous crops.

5. Blue Nile zone: Covers the plains area of swelling clay soils, north of Kaka town. Semi-arid tropical, with summer rainfall. A part of this zone (Gezira area) is irrigated to grow cotton, sorghum, groundnut, coarse rice, and wheat. In the Gedarif area, rainfed sorghum and millets are grown.
6. Upper Nile zone: Covers the southern part of the plain of self-mulching clayed soils (surface soil becomes granular upon drying). Rainfall is 800 to 1000 mm, occurring in summer.
7. Southwestern hilly zone: Covers the area of the low hills in the south and southwest. The surface is rolling to hilly. The climate is hot tropical; winter is too warm for crops like wheat. The rainfall is 1000 to 1500 mm, occurring throughout the year.

Area, Production, and Distribution

Chickpea is grown as a rainfed, flood-plain, and irrigated crop on cracking clays and on sandy soils.

In the northern part of the country between the annual isohyets of less than 25 mm and 200 mm (the major chickpea-producing areas), about 20% of the chickpea is grown as a winter crop (mid-Nov) under full irrigation by pump or water wheel. About 80% of the crop area is planted in September on banks, islands, and basins that have been flooded by the Nile. Most of the soil thus cropped is silty.

The area under chickpea cultivation (Table 1) represents about 10 to 15% of the total area under leguminous crops (broad bean, dry bean, and lentil).

Major Uses and Marketing

In Sudan, chickpea (kabuli type) is boiled in water with salt and sesame oil to produce Balilah, a popular energy-giving food eaten especially during the fasting period of Ramadan. It is mixed with onions, chilies, garlic, and baking powder, all ground together, to form a dough of chickpea. The dough is split into small round shapes and fried in any vegetable oil to make Tammia for breakfast or supper. Sometimes immature pods are picked for use as a green vegetable.

Until now, chickpea has not played a prominent role in the country's economy and has not figured much as a cash crop. Yields and prices are not high enough to make chickpea a profitable irrigated crop. It does not appear to be a very

Table 1. Total area, production, and yield of chickpea grain, 1970–76.

Season	Area (ha)	Grain production (tonnes)	Grain yield (kg/ha)
1970/71	2100	2000	952
1971/72	2100	2000	952
1972/73			1150
1973/74	1260	1000	794
1974/75	1680	1000	592
1975/76	2730	2500	916

popular food in the Sudan except during Ramadan (fasting month). It is very susceptible to store pests. If high-yielding cultivars can be found to replace the local Baladi type, if agronomic practices can be developed to increase the yield, if good storage facilities can be made available, and if good prices become available in the local market, the cultivated area under irrigation may expand in the near future. The crop will then perhaps be capable of bringing higher returns and playing an important role in the economy of Sudan.

All chickpea produced is at present consumed locally. Prices fluctuate from month to month and from one locality to another, depending on distance from the area of production. For example, in El-Damer (the center of production), chickpea prices have fluctuated between 0.46 and 0.71 U.S. dollars/kg between May and November 1978. During November 1978, the per kg price of chickpea in Khartoum and El-Damer were 1.43 and 0.71 U.S. dollars, respectively.

Current Status of Production Practices

It was mentioned that 80% of the crop area is planted in September on banks, islands, and basins flooded by the Nile.

As the water subsides from the flooded area or drains out of the basins, the exposed land is sown with seluka or torea cultivation. Seluka consists of a wooden stick with a slightly curved and flattened point end. This is forced into the ground by means of a projecting footrest and the stick is rotated to produce a hole for sowing. Torea is a simple two-handed digging hoe.

Generally, a man walks ahead making the holes with a torea or seluka and a woman or child follows behind, dropping a few seeds into the hole. Covering the seeds is accomplished by scraping earth over them with the foot.

Under controlled irrigation, the seed may be broadcast before plowing, or dropped behind the plow, or broadcast after plowing and buried with a drag. Sometimes broadcasting is done on land that has been slightly ridged and then reridged to raise and bury the seed; this is a useful sowing method on soils that form a hard crust. The cultivated land is divided into small plots to control irrigation. The crop receives five to seven waterings during the growing season. Seeding rate varies with the prospective soil water supply from 66 to 200 kg/ha. If not accelerated by drought, the maturation is 4 to 5 months.

Chickpea as a leguminous crop is never fertilized and is never inoculated with the *Rhizobium* inoculum. Usually it is rotated with cereal crops like wheat in a simple rotation of cereal-legume-cereal-legume. Weeding is done by hand once or twice per season.

Under Hudeiba conditions, flowering for the Baladi type usually occurs in 7 to 8 weeks after planting, and 8 to 9 weeks later the crop becomes ready for harvesting. Harvesting is done when most of the leaves and pods have turned light yellow or yellow. The crop is uprooted; often it is cut with a sickle so that the roots or the plants left behind may enrich the soil. The crop is dried completely before threshing. Threshing is normally done with a flail or spear shaft, or with a tool which is like a cricket bat, on a specially prepared threshing floor about 7.3 m in diameter. This floor may be nothing more than a cleared area of well-beaten earth, or it may consist of a mixture of mud and cow dung allowed to harden and dry off. After threshing, the grain is cleaned of dirt and chaff by winnowing. After cleaning and sacking, the bulk of the crop is sold to grain buyers as quickly as possible for it is very susceptible to store pests.

Concerning varieties, the only variety or type grown till now in the Sudan is the Baladi. The varietal improvement program was initiated at Hudeiba Research Station in 1973, and an accelerated introduction, selection, and hybridization program has been under way since that year. This breeding program is going on with the hope that within 2 or 3 years one or two varieties will be ready for release.

Major problems of Production, Protection, and Utilization

Common Diseases

The diseases observed were wilt, root rots, and stunt. Both *Rhizoctonia* and *Fusarium* seem to be involved in the root rot. The negligible incidence of root rots and wilt in the trial of the International Chickpea Root Rot/Wilt Nursery (ICRRWN) and other breeding materials in the field could be due to the planting of the materials in plots where chickpea had not been cultivated earlier. A sick plot for both diseases was established by the pathology section in July 1978 by burying debris of the sick plants on this piece of land. The ICRRWN trial for this season, 1978–79, was planted in the prepared sick plot by the pathology section.

At present, stunt is the major problem and the incidence of the disease was about 15%. The higher incidence of stunt could be due to large-scale cultivation of broad bean, lentil, haricot bean, and peas in the research station farm — these species might be serving as the sources of inoculum. *Aphis* spp may be involved in the transmission of the disease (vectors).

Common Insect Pests

Chickpea is attacked by many insect species, in the field and stores, and few of them are considered important pests in the Sudan.

Chickpea podworm (*Heliothis armigera*), the pod borer, is a serious pest. As soon as pods appear the larvae attack and feed upon them. It was noticed that infestation increased and yield decreased proportionally to the delay in sowing.

About 80% damage to chickpea grain is estimated to be caused by the beetles, *Bruchus chinensis* and *Bruchus theobroma*. While feeding, the insects scoop out the contents of grains. Unfortunately, entomological studies were not made in the past, and there is little information on control of chickpea insects. We hope that trials may be conducted at Hudeiba Research Station beginning this season.

Common Weeds and other Pests

Weeds (essentially unwanted plants) occurring among cultivated crops are injurious for a number of reasons. *Cyperus rotundus* Linn. and *Cynodon dactylon* Pers. are the two most troublesome and persistent weeds of all cultivated land in the Sudan. Some success had been achieved for killing the grass by frequent deep plowings or deep disking in the irrigated areas. In the flooded or basin-irrigated areas, attempts have been made to control weeds by preventing flood water from reaching badly affected areas for a period of 6 years or longer.

Cuscuta spp occur in all parts of Sudan. Hand pulling and burning of both the parasite and the host plant are the only methods of control in practice.

Ipomoea spp is an annual weed. No control measures are practiced, except hand-digging the plant from the root or pulling it.

All weeding is done by one of the iron-headed tools. Frequently workers squat or sit while weeding, especially when using one of the very short-shafted implements. It is usual in the north to refer to weeding as hoeing.

Research on using herbicides in killing weeds in chickpea fields has not yet started.

Birds, notably *Passer domesticus orboeus* sp, sometimes take a heavy share of the ripening chickpea crop.

Problems for Productivity and Economic Viability

There are many areas in the Sudan where the environmental conditions suit the production of this crop. However, it must be emphasized that chickpea production may be slightly expensive because of high harvesting costs and, if irrigated, of the water expenses; by increasing the yield up to 1 tonne/acre; however, the crop should be profitable, if seed-bed preparation, seeding, and harvesting can be mechanized.

Exhaustive research on marketing possibilities is an essential prerequisite for chickpea's success as a cash crop in the Sudan.

Research and Extension Support Available

Hudeiba Research Station is a well established center for research on pulse crops in Sudan. It has a qualified team of scientists (Table 2) working on these crops. All are working in a crop-oriented team approach. Chickpea has not yet received much attention and is still in the observational stages in many respects.

The latest results of scientific research, improved varieties, and improved methods in agriculture are provided to the farmers through the Extension Service Department, an integral part of the Ministry of Agriculture, Food, and Natural Resources of Sudan.

The staff available at present within the Nile and northern provinces looking after the agricultural extension service includes one senior extension worker with a B. Sc. degree and a few local extension workers who are graduates of intermediate schools and who have received inservice training.

Seed Production Capacity

As I mentioned, serious breeding improvement work on this crop began in 1973. Until now, the plant breeder had no single variety to initiate for release to the Plant Propagation Technical Sub-Committee. Outstanding varieties are now being tested for yields. We hope that the release of a variety may be possible within 3 years.

Usually the Plant Propagation Technical Sub-Committee advises the Propagation Committee on the release of a variety or selection of a crop initiated for release by the plant breeder; the breeder then turns over to the Plant Propagation an initial quantity of breeders' seed.

The Plant Propagation Administration of the Ministry of Agriculture, Food, and Natural Resources is responsible for seed multiplication and distribution for all crops other than cotton.

The Plant Propagation Technical Sub-Committee consists of the plant breeders, head of the horticultural section, head of the entomological section, and head of the pathological section.

Research Review

Germplasm Collection

Chickpea is probably not indigenous to Sudan but was a very early introduction. There was only one variety or type, the Baladi, which was found under different local names. Seeds of the Baladi are small, white, and of the kabuli types. Early in the 1940s the "fransawi" variety, an introduction from Syria, had larger seed and outyielded the Baladi in preliminary trials.

The research interest in this crop began in 1973 when a program of crop improvement was initiated at Hudeiba Station by the introduction of improved varieties. These varieties were offered to the station through the international cooperation program of ICRISAT and ALAD (now ICARDA). Accordingly, a germplasm collection of over 250 entries of the white seeds of the kabuli types was assembled. A large number of single-plant selections or bulk selections from the crosses-segregating populations were retained for further yield testing and future uses.

Table 2. Scientists working with chickpea in Sudan.

Organization	Scientist	Specialization	Time on chickpea %
Agricultural Research Corporation, Wad Madani, Sudan	Dr. Farouk A. Salih	Plant Breeder	25–30
	Dr. Ibrahim A. Babiker	Soil Chemist	7–10
	Dr. Sami O. Freigoun	Pathologist	15
	Dr. Gaafar El Caraag	Agronomist	25

Breeding Work

The breeding work on this crop started at Hudeiba Research Station in 1973. As an urgent measure, work was concentrated on adaptation and screening of introductions supplied by ICRISAT, ALAD (previously), and ICARDA through their breeding nurseries, disease-resistant nurseries, and international comparative yield trials. The best entries from these screening nurseries were included in pilot trials for yield evaluation and from there to the standard variety trial. Due to this process of yield testing for the last 4 years, the outstanding 10 entries (with Baladi as a standard variety) were all included in a regional variety trial in 1978. This regional variety trial was planted at three locations along the northern part of the country.

The average yields of these selected entries were conistently in the 1900 to 2230 kg/ha range in variety trials. Their yields exceeded the yield of the Baladi by 50 to 80%.

All selections from the Baladi type failed to give yields as high as the best introductions, so work with selection from the local type was stopped.

The long-term policy was built around crosses to combine the best diverse characters from the world collection available at ICRISAT and ICARDA. From the start of the breeding work, the previously mentioned international organizations supplied seeds of different populations of different crosses at different segregating generations. A large number of selections were made from these crosses-segregating populations. Emphasis was concentrated on the best plant type characteristics: erect plants with a large number of fruiting branches, medium to large white or creamy white seed, early maturation, high harvest index, and resistance or tolerance to wilt, root rot, or stunt virus. These selections were planted in a progeny-row test for more screening, yield consideration, and seed multiplication for next season's yield test.

Agronomic Work

There is a big need for flexible genotypes in terms of adaptation to a wider range of sowing dates. If seed is available, the crop can be grown in September on river banks, islands, and basins flooded by the Nile and brought under irrigation in the second week of November. The optimum sowing date was found to be the second and third week of November. The optimum recommended plant and row spacings under irrigation for seed production are 5 cm with a single plant per hold and 60-cm wide rows. Results of the work on the effect of watering intervals showed that watering intervals of 7, 14, and 21 days had either no or only slight effect on yield. Chickpea thus has some tolerance to drought.

Chickpea responds highly to applications of nitrogen, especially at sowing. The application of 85 kg N/ha gave an increase in seed yield of more than 200%. None of the applied potassium or phosphorus rates had an effect on increasing seed yield. The response of chickpea to inoculation with different *Rhizobium* strains with and without nitrogen was investigated recently at Hudeiba Research Station. It was found that inoculation with race IC-53 gave yields similar to that obtained from the application of 85 kg N/ha at sowing. The rates of increase from the treatments over the control were 107, 104, and 146% respectively, for (1) seed inoculation with race IC-53, (2) the application of 85 kg N/ha, and (3) the *Rhizobium* of race IC-53 or CB-1189 with 85 N/ha.

Conclusions

Chickpea research is hindered by a severe shortage of trained personnel at all levels. For example, the main chickpea breeder for the country also handled the breeding of broad bean, dry bean, and lentil. It is hoped that this situation will be eased in coming seasons.

The varieties available at present are limited in number and characters, especially the types with white seeds. Early maturity varieties could be considered. Varieties suited to the various stress environments of waterlogging, moisture lack, and soil salinity should be developed.

Research activities should be carried out in collaboration with the Extension Service in order to transfer the results to practical farming without undue delay.

Practices leading to conservation of soil moisture must be studied. Further, irrigation regimes must be taken into consideration.

Breeding varieties with resistance to various diseases and insect pests is another major objective. However, not much is known about the pathogens that cause diseases of this crop, and screening methods are often not developed. Therefore, the international and national cooperative program should have a strong component of plant pathological and entomological research. How to combat pests and diseases, especially the *Bruchus* spp (the store pests), must proceed hand in hand with other cultural studies, however.

In the development of this crop, cooperation among countries with similar agroecological conditions would be beneficial. Efforts should be made by national authorities as well as international organizations to stimulate cooperation through facilitating seed exchange, development of regional nurseries, and other coordinated programs.

The value of microbial fertilizer as seed treatment in varied environments should be evaluated in different national programs. Selection of suitable microbial strains should help the economy of nitrogen fertilizer.

Hand planting is the general rule now. Trials to plant, weed, and harvest by machines could be started.

Production and marketing possibilities should be explored.

References

Annual Report, 1973–1978, Agronomy, plant breeding, and plant pathology sections, Hudeiba Agricultural Research Station, Ed-Damer, Sudan.

AGEEB, O. A. A., and AYOUB, A. T. 1977. Effect of sowing date and soil type on plant survival and grain yield of chickpeas (*Cicer arietinum* L.). Journal of Agricultural Science 88: 521–528.

Chickpea Improvement in Tunisia

Mohamed Bouslama*

Agriculture is considered the main source of the national economy in Tunisia; most of the cultivated land is restricted to northern Tunisia (Fig. 1) — 37° lat. et 10° long. — and farmed under rainfed condition. The weather is usually mild during the winter season and hot during the summer. Rainfall varies from one area to another (400 to 800 mm) in the northern part of this country; however, it fluctuates widely from year to year in amount, intensity, and distribution. The bulk of rain normally falls in late fall, winter, and early spring. Although some regions are more prone to hail or frost than others, these factors are not predictable.

Soils in northern Tunisia vary tremendously. Black and grey-brown rendzinas are common and are found in the regions of Beja, Mateur, and Le Krib. Good, deep soils of alluvial origin are also found throughout the north.

Area, Production, and Distribution

Grain legumes cover only 6% of the cereal-cultivated land in Tunisia. Broad bean and chickpea are grown as rainfed crops and are the dominant grain legumes grown (86%); the area sown to chickpea varies from year to year (Table 1) depending on the amount and distribution of rainfall during the whole season. Generally, this crop is confined to areas where the average annual rainfall is more than 350 mm.

Tunisian national yield of chickpea is very low, due to "varieties" with low yield potential, late maturity, and susceptibility to diseases (e.g., *Ascochyta* leaf blight).

The winter season of 1977 was dry, and chickpea yield was reduced to 502 kg/ha.

Major Uses and Marketing

Chickpea (Homs) is mainly used for human consumption. It can be boiled in water with salt and pepper to make Lablabi, a famous food eaten for lunch. It can be used to make Mermez and many other dishes in Tunisia. Recently, quite a considerable area of chickpea was substituted for coffee in this country.

Chickpea does not seem to play an important role in the export trade. The export of chickpea varies from one year to another. A few years ago it was estimated to be 4600 metric tons. All chickpea produced is now consumed locally.

The prices paid to farmers are unstable and often low because of low quality yields and irregular production. In addition, there is great variation from season to season because of variation in climate, diseases, insects, and poor "varieties". For instance, the price has increased rapidly over a period of 2 years (fivefold increase) due to lower yields. Even in good years, the farmers cannot store his product and must sell it soon after harvest, consequently at a relatively low price.

Table 1. Chickpea production in Tunisia, 1971–78.

Season	Area (ha)	Production (tonnes)	Yield (kg/ha)
1971	25 000	17 500	700
1972	30 000	21 000	700
1973	ND	19 000	ND
1974	19 940	17 620	880
1975	20 565	18 387	900
1976	19 799	19 148	970
1977	21 700	10 900	502
1978	15 905	18 749	724

ND = No data.

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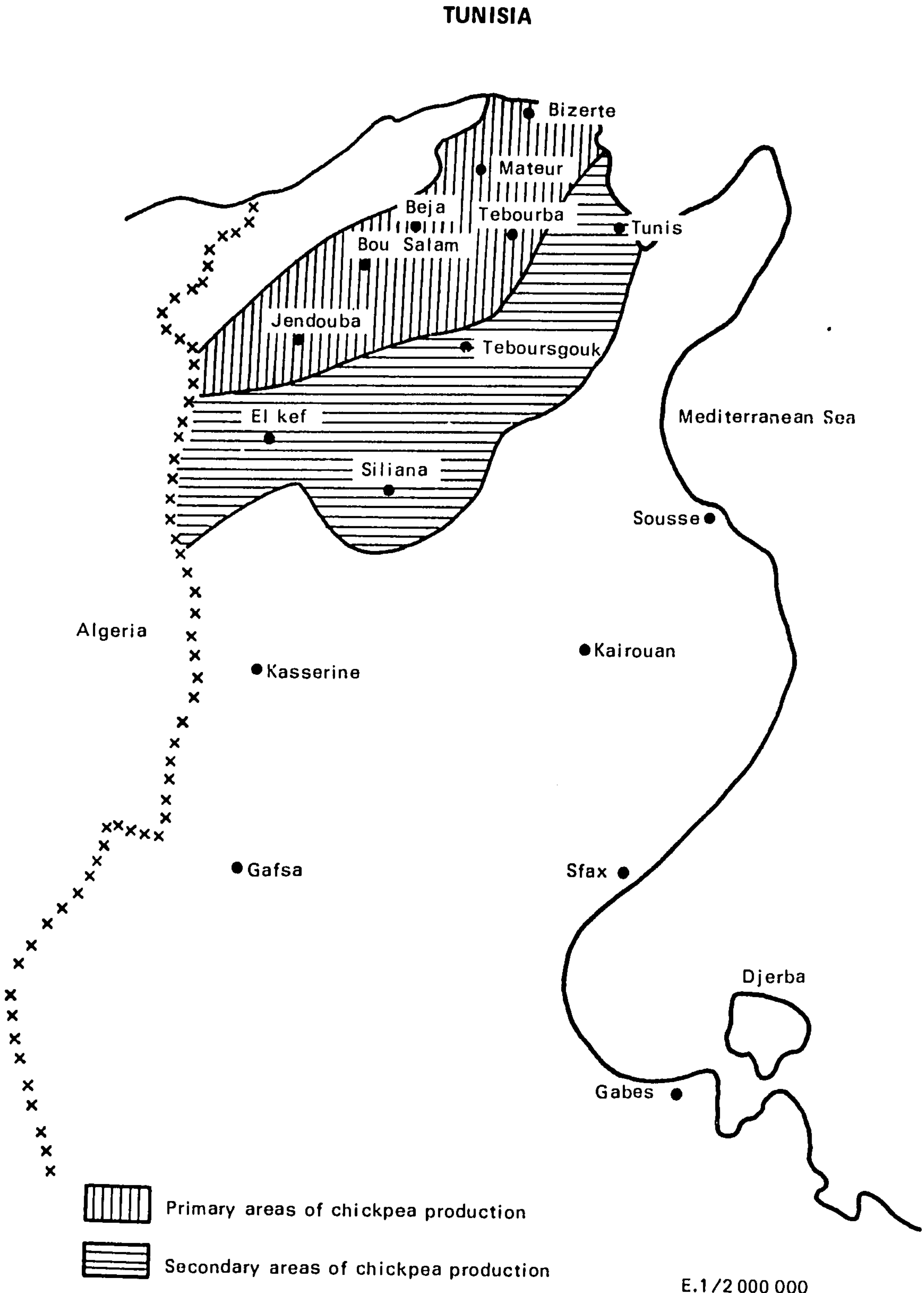


Figure 1. Geographical distribution of chickpea cultivation in Tunisia.

Current Status of Production Practices

Crop cultivation follows a 3- or 4-year rotation — either forage-chickpea-wheat or sugar beat-forage-chickpea. Both systems of rotation are common in Tunisia. The effectiveness of this system has been demonstrated in many areas where weeds in cereal crops have been eliminated.

The Technical Division of the Office of Cereals has carried out some field trials on cultural practices on food legumes.

Seeding-rate studies have indicated that 80 to 100 kg/ha of seeds is the best rate. Date of planting extends from the beginning to the middle of March at Beja and from the beginning to the middle of April at Le Krib. Date of harvest occurs from the end of June to the end of July depending upon the region.

Fertilizer use on legumes has increased over the years. Levels of phosphate ranged from 130 to 180 kg P_2O_5 depending on the area. Nitrogen and potassium are not usually applied for chickpea.

The cultivation is mechanized in some regions; however, in may others seed is broadcast, and the crop is harvested by hand.

Chickpeas grown in this country are generally unimproved local cultivars, such as Amdoun, which is grown by the majority of farmers.

Major Problems of Production, Protection, and Utilization

Common Diseases

The major diseases observed on chickpea are *Ascochyta* spp and *Fusarium* spp. The extent of damage depends on climatic conditions (humid spring), which vary from one season to another, except in 1978 when the damage caused by *Ascochyta* was estimated at 80%.

Seed with colored seed coats have been shown to be tolerant to *Ascochyta rabiei*, but unfortunately they are of no commercial value.

Crop yield losses due to *Fusarium* spp varied from 20 to 40% in Tunisia during 1977.

The ultimate solution for anthracnose is the use of adequate cultural practices (e.g., withholding legume in the area infected for 4 years).

Insects

Bruchus spp and *Liriomyza cicerina* (leaf miner) are very common.

Weeds

Some years, weeds constitute serious problems to our cultivated crops. Herbicides have been used for the last few years, but on a small scale and not exceeding 10% of the total legume area while more than 50% is hand weeded. The most common herbicides used in legume crops to control weeds are Treflan, Gesatop, and Avadex.

Our local cultivars lack satisfactory yield potential and stability, and resistance to diseases. Moreover, moisture is one of the most limiting factors for this crop. It is urgent to identify and grow improved chickpea varieties of high yield potential with wide adaptation and with a desired grain quality.

Yields are also reduced because of lack of adequate mechanization for these crops.

There is also a scarcity of resources for research extension to promote chickpea cultivation.

Research and Extension Support Available

Most of the work carried out is devoted to applied research and extension. The research work is carried out by researchers and organization listed in Table 2.

The Technical Division of the Office of Cereals encouraged adoption of new praactices by:

1. Providing information through the mass media.
2. Holding meetings with farmers, before planting and after harvest. Fied days are organized to show the results of technical practices.
3. Conducting demonstrations on the farmers' fields.
4. Helping to insure that adequate supplies of seeds, fertilizers, and herbicides reach the farmers on time.

Improved cultural practices in agriculture are provided to the farmers, in general, through the extension division, a part of the Ministry of Agriculture of Tunisia.

Table 2. Chickpea research scientists in Tunisia.

Organization	Scientist	Specialization	Time on chickpea %
Technical Division of the Office of Cereals (ex-wheat project)	Mohamed Bouslama	Agronomist	25–30
National Agronomic Institute of Research	Ahmed Mlaiki	Pathologist	15–20
National Agronomic Institute of Tunisia (College of Agriculture)	Salem Laouar	Crop Physiologist	10–15

Seed Production Capacity

The breeding program has only recently started. The Directorate of Agricultural Production, a part of the Ministry of Agriculture, is responsible for seed production and multiplication for cereal grains.

Research Review

General trials on cultural practices, weed control, and variety improvement were carried out in the government stations and on farmers' fields.

Cultural Practices

Agronomic research covers the levels of fertilizer requirement, rate and date of seeding, application of herbicides, and control of insects. Various experiments have shown that chickpea has a high response to phosphorus (Super 45).

The Breeding Program

The breeding program on chickpea started about 1 year ago, with the main objective to create new varieties that are high-yielding with good stability and moderate resistance to the major diseases (e.g., *Ascochyta* leaf blight).

To reach this objective, we have started a collection of a promising germplasm (Table 3) from different programs in the world (ICARDA, USA, Europe). The material received is planted at several stations in the country where different notations are taken, and therefore promising lines are identified and subsequently used as potential parents in our breeding program. After a few testing cycles, the most promising lines are tested for their yield potential throughout the country.

Table 3. Observation lines in Tunisia.

Chickpea Adaptation Trial (CAT-79): 8 entries.
Chickpea International Screening Nursery (CISN-79): 60 entries.
Chickpea International *Ascochyta* Blight Nursery 1979 (CIARN-79): 40 entries.
Varietal yield trials:
Chickpea International Yield Trial (CIYT-79): 24 entries.
Chickpea Fertility and Plant Population Trial (CFPPT-79):

Conclusion

Chickpea in Tunisia is much neglected in terms of practical research related in varietal improvement. New, high-yielding, and stable varieties are needed in this country to replace the low-yielding land varieties and especially those with sensitivity to *Ascochyta* leaf blight. Moreover, there must be an improvement in the cultural practices employed in chickpea cultivation.

Efforts toward these main objectives should be initiated by introduction of germplasm from existing programs at ICARDA and ICRISAT.

Another objective is to develop the linkage between research and extension by the active participation of our research workers and technicians in the extensive testing of varieties and cultural practices in farmers' field.

Reference

Progress Reports on Grain Legume Research, 1972–78. Technical Division of the Office of Cereals, Tunis, Tunisia.

Sessions 7 and 8 — Country Reports

Discussion

Samet Paper

O. P. Rupela

In your paper you mentioned that no attention is given to seed inoculation with *Rhizobium* culture. May I know the nodulation status of this crop in general in your country?

A. Q. Samet

Research work began in 1974. Right now at our research institute for all departments we have only one microscope, so, sorry to say, I don't have a status report here now.

Aeschlimann Paper

O. P. Rupela

May I know the nodulation status of chickpea in your country in general?

J. Aeschlimann

We have no studies on this aspect yet; however, it is possible to say that nodulation of chickpeas in Chile in general is very poor or does not exist. This is my personal impression by means of a lot of visual observations in the field.

J. M. Green

Have you found any of the ICRISAT material with sufficiently large seed to compete in the export market?

J. Aeschlimann

No, but we hope to use the best of the introduced material as parents in our crossing program.

Bejiga Paper

B. M. Sharma

What are the countries to which lentil and horse gram are exported?

G. Bejiga

Lentils and other legumes are mostly exported from Ethiopia to Arabian countries such as South Yemen and Saudi Arabia, and also to Ceylon and others.

Arias Paper

R. M. Shah

What are the reasons for comparatively higher yields of kabuli-type gram than of desi type in your country?

E. A. Arias

The higher kabuli yields result from growing of kabuli under irrigation and desis grown on residual moisture. When desis are irrigated, yields of 2000 to 3000 kg/ha are produced.

O. P. Rupela

May I know the nodulation status of chickpea in your country in general?

E. A. Arias

The use of commercial inoculants has not raised yield. Check plots produce abundant nodules, equal to the treated, and the yields are equal. We have not tested inoculants in new areas where nodulation could be deficient; experimental data would be helpful.

M. C. Saxena

You said the row spacings were more than 1 m for most of the chickpeas. Is this spacing optimum? Does the crop cover the whole ground by the time it reaches flowering and podding stage when planted in such wide row spacings?

E. A. Arias

In irrigated chickpeas spaced more than 1 m apart with double rows the ground is well covered when the plants have fully developed height and lateral branches.

K. B. Singh

1. What is the minimum seed size in kabulis acceptable in Mexico?
2. Is *Ascochyta* blight disease on chickpea a serious problem?

E. A. Arias

1. The minimum size is 30 grams per 60 seeds.
2. No, in some regions with high humidity, a few affected plants are observed.

Sah Paper

J. P. Yadavendra

You stated that chickpea is cultivated as pure, mixed, and relay crops. I would like to request information regarding with which crop chickpea is grown as a relay crop and under what field conditions?

R. P. Sah

Cultivation of chickpea as a relay crop is rather common in terai in rice (transplanted) crop. Relaying is done in mostly the late rice varieties some time during the end of October, 3 to 4 weeks before its maturity.

S. Tuwafe

How yield is obtained generally is due to the method of planting. Since the crop is sown by broadcasting, there is no uniformity of plant stand. Changes of rainfall pattern, short periods of rain, and low or no rainfall during flowering also affect yield. Second priority is generally given to chickpea crops. The yield of kabuli is low due to (1) diseases, (2) nonirrigation, and (3) germination problems.

Melka Werer has been selected for studying irrigation practices on chickpea to improve yields to produce crops that are relatively resistant to *Quelia* pests, and to investigate the potentiality of exotic varieties under irrigation and different climatic conditions.

S. C. Sethi

What is the possibility of taking a summer crop in Nepal, keeping in view rains, maturity, and disease problems. Do you have access to climatic data in the region and could you pass it on to us?

R. P. Sah

We have certain pockets in the high hills, like the Jumala and Jomsom valleys, where temperatures are warm enough to grow chickpea and rainfall is below 20 inches during the summer. This is just my estimation and must be explored. We have the climatological data and it can be supplied upon request.

O. P. Rupela

What is the chickpea nodulation situation in Nepal?

R. P. Sah

We have some preliminary studies on the response of rhizobial inoculation in chickpea. There is not much response to inoculation. Satisfactory nodulation has been noted in chickpea even without inoculation on research farms and in farmers' fields. It may be effective in new areas of cultivation.

Salih Paper

O. P. Rupela

Please change the name of the inoculant from 16-la to IC-53; 16-la was the lab code number that we use while the isolate is being characterized.

F. A. Salih

Concerning the observation of Dr. Rupela, I have requested that the number be changed to the new number in the ICRISAT record. Concerning the effect of *Rhizobium* on increasing the yield, I find that the yield from seed inoculated by race 1189 has been equal to the yield obtained from the application of 85 kg N/ha.

Bouslama Paper

O. P. Rupela

What is the nodulation status of chickpea in your country?

M. Bouslama

It is very important; however, we started this type of research only this year. In fact, we got some fertility trials (of nodulation) from ICARDA, and we are taking notes as we go.

G. C. Hawtin

I would like to point out that ICARDA is also running training courses. We are currently conducting a 6-month course on food-legume improvement, which is being attended by 14 students from 12 countries. As regards chickpea training, the interest is, of course, primarily in kabuli types, and the majority of our trainees are from West Asia and North Africa. However, we do have one trainee from Chile and one from Bangladesh this year. There are plans to hold future short courses on specific topics, such as hybridization, pathology, agronomy, and production technology.

M. C. Saxena

Treflan, Avadex, and Gesagard herbicides are used to control weeds. Would you please indicate the rates of application of each of these chemicals in terms of commercial product and method of their use.

M. Bouslama

The rate of application is about 15 to 20 cc/100 liters for these three types of herbicides. Treflan is applied 1 week before seeding; Gesagard is applied postemergence (some days after planting); Avadex is applied postemergence.

M. C. Saxena

There is a recommendation in your paper for the use of 130 to 150 kg P_2O_5 per hectare. Is it P_2O_5 or the Super-45? If it is P_2O_5, the rate seems to be very high, and I would like to know why such a high rate is needed?

M. Bouslama

It is P_2O_5 with a rate from 130–180 kg. In the type of soil we have, and after wheat and forage, the soil becomes very poor in this element. So that is why we use a high rate of P_2O_5.

Session 9

Meetings of Working Groups

Chairman: J. S. Kanwar

Recommendations of the Working Group on Genetic Resources

Members of the Working Committee
M. H. Mengesha, Convenor

J. Aeschlimann
B. Bejiga
M. Bouslama
V. P. Gupta
L. J. G. van der Maesen
R. P. Sah
A. Q. Samet

Seed samples should be fumigated and treated with Benlate T for international dispatch with phytosanitary certificates in order to increase the percentage of samples allowed entrance through quarantine services.

Short training courses in countries or regions are recommended where needed (ICRISAT, ICARDA, IBPGR). The collection manual by Hawkes could be updated with specific information for the collection of *Cicer* material.

If funds are not available for the collection or dispatch of seeds a special request for funding should be considered by ICRISAT, ICARDA, or IBPGR.

Evaluation efforts at more locations should be increased.

Maintenance of chickpea germplasm is the responsibility of the headquarters of ICRISAT, ICARDA, and the national programs.

Participants from the countries represented at the Workshop made the following comments in respect of their germplasm position:

Algeria — more material is needed; Ethiopia — much more germplasm is needed; Egypt — the position is well covered; Morocco — more material would be useful; Sudan — there is inadequate germplasm, local variation is not great, and some more material is needed; Tunisia — more representative material is needed; Afghanistan — a gene bank has been established and the present collection of cultivated and wild species needs to be enlarged; Burma — more material is required: India — the remaining targets for ICRISAT are Bundelkhand, Himachal Pradesh, Punjab, and pockets in hilly areas. Dr. Gupta will establish high altitude botanical garden(s) for maintenance of wild and perennial *Cicer* spp in the Lahaul Valley, Udaipur near Kyelang, and Palampur; Nepal — Dr. Sah has collected material and in 1979, ICRISAT will be making collections; Iran — wild species are needed in the collection; Iraq — there are only 20 accessions and more are required, especially wild species; Israel — the collection consists of 48 entries, which is an adequate number; Jordan — there are 23 entries in the collection and probably more are needed; Lebanon — the collection is inadequate with only 18 entries and more wild species are needed; Syria — there are only 12 entries and probably there are more with ICARDA; Turkey — although the number is adequate, more diversity is desired from colored seeds and wild annual species; Pakistan — although there is good material in the collection, the total number is inadequate; Bulgaria — the position is inadequate and there are probably few landraces left; Cyprus has an adequate collection; Greece — because wild species are perhaps no longer available, a survey is needed; Hungary — it would be worthwhile to look for species; Italy — there are 18 species in the collection; Portugal possesses only four species, which is an inadequate number; Spain — more species are available from the national collection; USSR — there are 82 items of germplasm which is an inadequate situation; Yugoslavia has only two species which is an inadequate number; Czechoslovakia — a collection has been made recently by Gatersleben; Chile — a collection was made in January-February 1979 by Aeschlimann and colleagues; Mexico — collecting is still being conducted.

Recommendations of the Working Group on Breeding

Members of the Working Group
R. B. Singh, Convenor

P. N. Bahl
J. M. Green
G. C. Hawtin
E. J. Knights
S. Lal
B. P. Pandya
T. S. Sandhu
K. B. Singh
Laxman Singh
A. S. Tiwari
D. L. Van Horn

1. Screening against *Ascochyta* blight should be intensified, with the main collaborators being ICARDA, ICRISAT, and India (Gurdaspur, Delhi, and Himachal Pradesh). Cooperation of other concerned countries will be encouraged in the testing of screening nurseries and selection of resistant material. ICARDA could screen some segregating populations in addition to advanced generation material for cooperators. In addition to information obtained on races from multilocation tests, a center for studying races should be established in a nonchickpea-growing country.
2. Early generation multilocation testing of bulks (F_2 and F_3) should be expanded. F_2s could be tested at a few locations (including hot spots for diseases and insects), and superior F_2s could then be tested in the F_3 at a larger number of locations.
3. Cooperative screening of selected advanced lines should be initiated. Breeders within a zone could share seed of advanced lines when first bulked for single plot observation plantings. In India, such screening nurseries would include the ICSN material from ICRISAT.
4. Kabuli-desi introgression should continue, with various breeding methods being tried. Research on the basic question of genetic and cytogenetic differences should be expanded.
5. Investigation of host – plant × *Rhizobium* interactions on an adequate scale should be undertaken jointly by microbiologists and breeders in order to evaluate the potential for yield increases through improved N fixation.
6. Sound information on the efficiency of various selection and breeding methods should be collected by breeders through use of well-planned simple experiments within the breeding program. Basic studies on breeding methods at universities should be encouraged.
7. ICRISAT and ICARDA will continue to supply early generation and advanced generation breeding material. Both centers will continue to coordinate international trials, and both breeding material and trials will be supplied against specific requests, as long as material is available.
8. All cooperators should report to ICRISAT, the results of each cooperative trial, furnishing data collected or reporting why a test failed.
9. Evaluation of the potential of wild species for the improvement of chickpea and interspecific hybridization methods should receive increased attention.
10. Breeding work should be accelerated through the use of off-season nurseries and techniques for reducing generation time.
11. Training should be expanded at all levels, and both ICRISAT and ICARDA should emphasize training appropriate to the regions and countries.

Recommendations of the Working Group on Plant Protection

Members of the Working Committee
D. C. Erwin-Convenor

A. S. Gill
J. S. Grewal
Y. L. Nene
W. Reed
H. P. Saxena
J. S. Sindhu

It was noted that the ICRISAT program on pulse improvement on a world basis has established a number of important basic programs that have provided the mechanism for the improvement of plant protection from pests and diseases. This program has set up screening methods for the varietal improvement against simple components and against multiple components of the pest and disease complex. The rationale for the vigorous continuance of these programs against *Fusarium* wilt, dry root rot, stunt disease, *Ascochyta* blight, rust, and *Heliothis* has been sound, and a definite trend toward improvement has been evident. The establishment of controls for each of the many important pests and diseases is important to the general goal of breaking the yield barrier on a worldwide basis. This program has not only benefited the improvement of chickpea and the other edible pulse crops directly by its own research, but it has indirectly benefited this crop by the stimulation of research and the provision of guidance in the solution of problems.

In the general approach toward ICRISAT's extending information and in acting as a catalyst for further interaction, the following recommendations seemed to be appropriate:

1. ICRISAT should be encouraged to extend the benefits of worldwide workshops such as this one at Hyderabad to further provide an opportunity for interested scientists to set up regional meetings in which common problems could be aired and discussed. If such meetings in a geographical region could be funded by ICRISAT, many more scientists at the regional level could attend and participate.
2. ICRISAT has set up excellent courses and mechanisms whereby the expertise of scientists can be updated in different areas. The use of the term "Training" by ICRISAT is noted to be objectionable. Training connotes the teaching of methodology and principles to neophytes and not to the interaction between competent scientists at the discipline level. Therefore we suggest that the interaction of discipline-oriented and crop improvement scientists be encouraged and expanded, but that the term "Training" be dropped from this service rendered by ICRISAT and ICARDA.

In relation to plant protection of pulse crops like chickpea, the following specific recommendations are made:

1. That ICRISAT encourage and facilitate a uniform method for determination of races of *Fusarium* wilt and a system of utilization of differential varieties for designating these races, and for disseminating the information about them to scientists at different testing sites.
2. That ICRISAT facilitate publication of a uniform set of methods and procedures for screening varieties against diseases and pests of chickpea at the field and greenhouse level. The rationale for use of each method should be made so that plant breeders who may not be well acquainted with plant protection principles can utilize the methods properly.
3. That research in control of diseases and pests by management or cultural practices, e.g., rotation be continued and encouraged. Genetic resistance may not be available in all cases and under all conditions.
4. That ICRISAT and cooperating scientists

identify disease and pest problems that occur only in specific areas and only under certain conditions and that centers be set up in such areas which are optimum for the testing of varieties against these diseases and pests. In the testing of varieties, both resistant and susceptible control varieties, where known, should be utilized to assist in the proper rating of varieties.

5. That ICRISAT be encouraged to set up an administrative procedure by which key sets of slides depicting symptoms and signs of plant diseases and pests be made available to interested scientists. Slides generally are sharp and portray symptoms well. Sets of slides could be advantageously used for extension and research meetings.
6. From the reports made by delegates from many of the countries it was evident that the delegates did not have the advantage of the expertise of a plant pathologist or an entomologist. This committee wishes to go on record advising administrators in countries lacking such personnel that this level of cooperation is necessary for obtaining the maximum use of a plant breeding or improvement program.
7. We urge that all methods of crop improvement by plant breeders, physiologists, entomologists, or plant pathologists be tested under natural situations under conditions experienced by farmers to further evaluate their practicality.
8. That integrated pest-management practices, which include cultural methods as well as nonpolluting insecticides and biotic methods, be encouraged and carried out at ICRISAT and at national centers for research in cooperating nations.
9. That research on the biotic control of *Heliothis* should be continued and expanded at ICRISAT and at national centers in the cooperating nations.
10. That the study of the role of acidic exudates produced by the chickpea on the pod borer (*Heliothis*) and on other insect pests be continued and expanded.
11. That there is a need to extend the testing of chickpea lines found to be least susceptible to *Heliothis* at ICRISAT to other national centers of research in cooperating nations, such as the AICPIP in India.
12. That the use of insecticides less polluting than DDT for control of *Heliothis* be encouraged.

Recommendations on the Working Group on Plant Growth

Members of the Working Committee
E. H. Roberts, Convenor

D. F. Beach
P. D. Bhargava
S. Chandra
P. J. Dart
E. J. Knights
H. McPherson
R. B. Rewari
M. C. Saxena
N. P. Saxena
A. R. Sheldrake
R. J. Summerfield

The group decided to adopt the following principles to guide its discussions:

1. To concentrate on those aspects of plant growth which were of direct relevance to plant breeding, particularly if they might lead to improvements in methods of selection or screening techniques for plant genotypes, and also for *Rhizobium* strains.
2. To cover the effects of the major environmental components extending to stress conditions, which seem to be particularly important in the chickpea crop, i.e. sub- and supraoptimal temperature, water, inorganic ions, etc.

Seed Quality, Germination, and Field Establishment

There appear to be differences in rates of seed deterioration in storage between the kabuli and desi types. Loss of viability can sometimes be a problem in kabuli types. A factorial investigation is needed on the effects of temperature and moisture content to elucidate these differences. Such work could conveniently be carried out in a university by a postgraduate student.

Poor seed establishment is a common feature of chickpea crops. The problem seems to be largely a result of moisture stress. Two main approaches are possible: agronomic treatments designed to alleviate the stress and the identification of tolerant genotypes. Considerable attention is already being paid to agronomic techniques (depth of planting, etc.), and physiological investigations with a view to developing screening techniques are proposed at ICRISAT. However, again this is a problem which leads itself to postgraduate studies, and further work in universities should be encouraged.

Stress conditions can also affect the survival of *Rhizobium* inocula, particularly high temperature and dry conditions. Work is in hand at ICRISAT but should also be encouraged elsewhere, since there are many ramifications to this problem.

There are some reports in the literature that chickpea can respond to vernalization, but data are scanty. A vernalization response, if present, could have profound effects on all phases of development, but particularly on time-to-flowering; it would operate naturally in environments with low seedbed temperatures, but not in others. It is important to know whether there is a significant vernalization response and, if so, whether there are significant genotypic differences. If there are, then it would be necessary to quantify the effects (e.g., time × temperature interaction) in order to develop suitable screening techniques. Some observational work has started at ICARDA, but laboratory work should be encouraged elsewhere.

Vegetative Growth and Reproductive Yield

The group recognized that there are large differences in rates of vegetative growth and plant morphology. It also recognized that much information on these is already available, but that the advantages and disadvantages of the various characteristics are still a matter for discussion by plant breeders. Work on these aspects continues at many centers, and we do not see the need to make any further proposals so far as shoot investigations are concerned. However, information on environmental and genotypic effects on root development are lacking. Considering the soil moisture regimes typical of the geographical areas and seasons when chickpeas are grown, root studies in chickpeas may be particularly important. But root studies are notoriously difficult. Consequently, it is believed that an appropriate strategy might be to await the outcome of drought-screening techniques which are being investigated at ICRISAT. If drought-tolerant types are identified, then comparative studies should be made on tolerant and intolerant types in order to discover whether root development and morphology are significant factors.

It would be at that stage, too, that other physiological investigations should be carried out on other possible modes of drought tolerance. Such studies might then lead to clearer breeding objectives and criteria for dealing with this problem

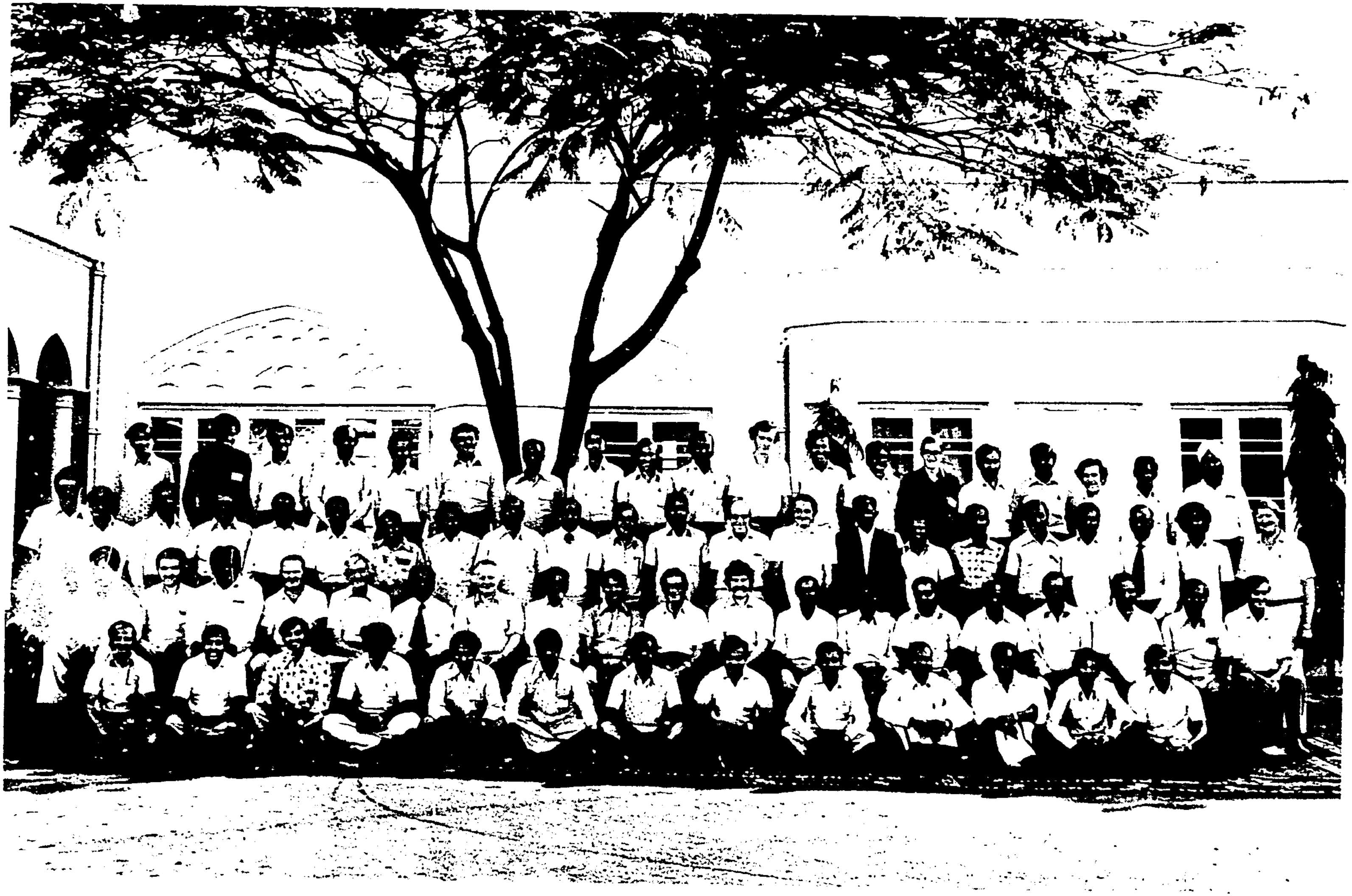
The chickpea is often grown in environments that experience extremes of temperature. At the lower end of the temperature scale, two types of damage have been identified: frost damage at subzero temperatures, and cold intolerance at low temperatures above zero. Some work is already being carried out on frost damage in Queensland, Australia, and attention was drawn to the facts that (1) distinct genotypic differences exist, (2) tolerance changes with stage of growth, and (3) some cultural practices, such as growing crops at high densities, can alleviate the problem. Work is also being carried out at ICARDA on frost damage and low-temperature intolerance. This seems sufficient for the time being since screening trials could easily be arranged by plant breeders at appropriate sites.

There now seems to be evidence that chickpea can suffer direct heat stress at temperatures in the region of 35°C. Work is now starting on this problem. However, more fundamental work might well be encouraged at universities, and attention was drawn to one promising technique which involves the use of leaf disks treated on a temperature-gradient bar.

Salinity is receiving attention both at CSSRI, Karnal, Haryana, and at ICRISAT, and work is almost at the stage where appropriate screening techniques could be used to select tolerant genotypes.

With regard to mineral nutrition, it was felt that more attention should be given to subclinical dificiencies, particularly of zinc and possibly molybdenum — in the case of the latter, especially in areas for which ICARDA has a responsibility.

Appendix: List of Participants



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