Proceedings

Faba Beans, Kabuli Chickpeas, and Lentils in the 1980s

An International Workshop
16 - 20 May 1983

Edited by
M.C. Saxena and S. Varma

The International Center for Agricultural Research in the Dry Areas (ICARDA)
Aleppo, Syria

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Foreword

The International Center for Agricultural Research in the Dry Areas (ICARDA) has the principal responsibility—among the other international agricultural research centers—for research on the improvement of faba beans (*Vicia faba*) and lentils (*Lens culinaris*). Together with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the center also has a regional mandate for the improvement of kabuli-type chickpeas (*Cicer arietinum*).

To be able to perform these responsibilities effectively, ICARDA, at the outset, recognized the need for close collaboration with scientists and institutions within and outside the ICARDA region. With a view to understand the prevailing status of research on these food legumes, ICARDA organized the first international workshop on food legumes improvement and development in April 1978, at Aleppo, Syria, in collaboration with the University of Aleppo. Research in practically every country of the region was reviewed in depth, and recommendations were made on future priorities for increasing the productivity of food legumes in the region. The proceedings were published for ICARDA by the International Development Research Centre (IDRC) in 1979 under the title 'Food Legume Improvement and Development.'

Since that first workshop in 1978, the Food Legume Improvement Program (FLIP) of ICARDA has organized three other more specific international conferences. In 1979, a meeting at Aleppo deliberated on lentils and as a result a volume entitled 'Lentils' was published for ICARDA by the Commonwealth Agricultural Bureau. In 1981, an international faba bean conference, first of its kind, was held in Cairo, Egypt, as a part of the Nile Valley Project, a special ICARDA project funded by the International Fund for Agricultural Development (IFAD). From this conference arose the publication 'Faba Bean Improvement,' published for ICARDA/IFAD by Martinus Nijhoff, The Netherlands. Later in 1981, an international conference on winter sowing and ascochyta blight of chickpeas was held at Aleppo, the proceedings of which were also published for ICARDA by Martinus Nijhoff.

In May 1983, FLIP convened the fifth international conference at Aleppo, covering all three legumes. This conference again brought together a large number of scientists from the region to assess achievements during the preceding five years in the light of the plans and directions developed in 1978, and how collaboration with national programs could be further strengthened to meet the desired objective. The meeting also examined ICARDA's future research and training priorities for food legumes. The timing of this meeting was perfect, as it came immediately after the first external program review (EPR) of ICARDA by the Technical Advisory Committee (TAC) of the Consultative Group on International Agricultural Research (CGIAR). The center had prepared a long-term plan for this EPR and the participants of the workshop were invited to consider these plans in formulating the recommendations.

The present volume reflects the contributions of participants from 24 countries, including those from advanced institutions with which ICARDA collaborates on more basic research. A record of the discussion that occurred following each presentation, and the recommendations of the workshop are also included. It is hoped that this publication will help in further strengthening and expanding the network of food legume researchers, and increasing the general awareness of the constraints on production of faba beans, lentils, and kabuli chickpeas. Finally we hope that this publication will augment the research achievements made so far, and the future research strategies that need to be followed to overcome these constraints.

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M.C. Saxena
S. Varma

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First Session

Food Legume Improvement Program at ICARDA-An Overview

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The Food Legume Improvement Program (FLIP) of ICARDA seeks to improve the productivity of food legumes in the ICARDA region and elsewhere, and thereby increase total food production, improve the supply of good quality protein in the diets of people who largely depend on food legume crops, and encourage the introduction of legumes into new, productive crop systems with attendant benefits to the soil and reduced dependence on nitrogen fertilizer.

The Crops

ICARDA has a worldwide responsibility for research on faba beans (Vicia faba) and lentils (Lens culinaris) and a regional responsibility for work on kabuli-type chickpeas (Cicer arietinum) jointly with ICRISAT, which has the world mandate for chickpeas. Therefore, FLIP addresses itself to these three food legumes.

The area and production of the three mandate crops, in relation to other food legumes, in different parts of ICARDA region and the world as a whole are shown in Tables 1 and 2. Following dry beans and dry peas, chickpeas are the world's third most important pulse crop, faba beans the fourth, and lentils the sixth.

The relative importance of the three crops in West Asia and North Africa components of the ICARDA region, in terms of production statistics, is shown in Table 2. In the North Africa region, which includes the Nile Valley of Egypt and Sudan as well, faba beans are most dominant pulse crop, followed by chickpeas and lentils. In the West Asia region, chickpeas assume the leading importance followed by lentils and faba beans. Taking the ICARDA region as a whole, chickpeas rank first followed by faba beans and lentils in terms of annual production (Table 2).

Table 1. Annual area (x 1000ha) of different food legumes (pulses) in various countries of the ICARDA region and in the world as a whole, averaged over 1979 to 1981.

Country	Pulses	Faba beans	Dry beans	Dry peas	Chick-peas	Lentils	Other
NORTH AFRICA							
Algeria	120	46	2	9	42	17	4
Egypt	146	107	6	3	7	7	16
Libya	8	7					1
Morocco	402	165	10	49	53	33	92
Sudan	74	15	3		3		53
Tunisia	153	75			51	4	23
Total	903	415	21	61	156	61	189
WEST ASIA							
Afghanistan	36						36
Cyprus	8	3	1		2	1	1
Iran	207		94	25	39	38	11
Iraq	53	16	11		14	10	2
Jordan	14				2	8	4
Lebanon	14				1	4	9
Pakistan	1,880		133		1,438	93	216
Syria	219	8	6	1	62	100	42
Turkey	713	30	111	3	227	188	154
Total	3,144	57	356	29	1,785	442	475
Total (ICARDA region)	4,047	472	377	90	1,941	503	664
Total World	63,344	3,721	23,451	7,395	9,958	1,881	16,938

Source: FAO Production Yearbook, 1981

Table 2. Annual production (x 1000 tonne) of different food legumes (pulses) in various countries of the ICARDA region and in the world as a whole, averaged over 1979 to 1981.

Country	Pulses	Faba beans	Dry beans	Dry peas	Chick-peas	Lentils	Other
NORTH AFRICA							
Algeria	53	28	2	3	16	3	1
Egypt	306	240	13	6	11	7	29
Libya	9	7		1			1
Morocco	243	106	7	25	40	13	52
Sudan	83	22	4		3		54
Tunisia	96	52			29	2	13
Total	790	455	26	35	99	25	150
WEST ASIA							
Afghanistan	60						60
Cyprus	8	3			1	1	3
Iran	212		100	31	43	28	10
Iraq	43	17	7		9	9	1
Jordan	7				2	4	1
Lebanon	13	1	1		2	3	6
Pakistan	663		65		461	37	174
Syria	180	14	11	1	46	73	35
Turkey	811	52	167	7	260	199	126
Total	1,997	87	351	39	824	354	416
Total (ICARDA region)	2,787	542	377	74	923	379	566
Total World	40,694	4,198	12,660	8,434	6,153	1,074	8,175

Source: FAO Production Yearbook, 1981.

On the global basis the faba bean and lentil production within ICARDA region accounts for only about 13% and 35%, respectively. This emphasizes the need for greater attention by the Program to the national programs outside the ICARDA region to fulfil ICARDA's world mandate for these two crops.

General Production Constraints

Some of the major constraints to the production of food legumes in the region, and outside, are the inherently low yield potential of the existing landraces, high instability in yield from year to year because of the susceptibility to pests and diseases, poor production techniques, high cost of hand harvesting, and lack of suitable methods for mechanized harvesting. The national programs need support to overcome these constraints since the development of research facilities and trained manpower for food legume research has started receiving due attention only recently. The best support that FLIP can give to national programs is by developing improved genetic material and suitable production techniques which can then be modified or, if needed, improved by national programs, through adaptive research, before making them available to farmers.

Program Objectives

The crop improvement work of FLIP has the following objectives:

1. Collection, maintenance, and evaluation of a diverse set of germplasm from which further genetic improvement can be made.

2. Development and distribution of advanced lines, segregating populations and other genetic material for the development of cultivars having increased seed as well as total biological yield potential and yield stability; appropriate phenology to suit the growing conditions, resistance to common diseases, pests, Orobanche, and temperature and moisture stresses; growth characters that permit mechanized harvest; and acceptable or improved nutritive value and cooking quality of seed.

3. Conducting relevant research on genetics, cytogenetics, physiology, and seed quality in support of the work on cultivar development.

4. Development of appropriate cultural practices for different genotypes and agroecological conditions by conducting research on production agronomy and physiology, pathology, entomology, microbiology, weed management, mechanization, etc.

5. Training scientists from national programs in food legume improvement, developing an international network of food legume scientists, and disseminating technical information through workshops, conferences, information services, research reports, and other publications.

Organization and Strategy

To achieve its objectives, FLIP has organized its activities into specific projects (Fig. 1). The research is applied in nature and is carried out by a multidisciplinary team of scientists. Efforts are made to expeditiously transfer the results to national programs for adaptive research. International nurseries and trials constitute an integral part of this process and training of research personnel is given high priority.

The strategy followed for the development of genetic material and production techniques using the research sites available to FLIP, and the linkages with national programs are shown in Fig. 2. Experience in the past several years with international nurseries has highlighted the need to adopt a less centralized approach to breeding if the benefits are to expeditiously reach the national programs beyond the 'home' zone (Syria, Jordan, Lebanon, etc.). Recognizing this, a start has been made to test a larger proportion of the material in localities where the selections are to be grown. A 'North African Regional Program' has been started, with this consideration, in close collaboration with the Tunisian national program.

There is a need for a regional program site at some high elevation location in West Asia and another, possibly in Pakistan, to serve the region of more southernly latitudes. A special applied research project on faba beans in the Nile Valley is providing an important regional dimension to that part of ICARDA region where the food legumes are grown mainly with irrigation.

As already mentioned, most of FLIP's research is applied in nature, with the adaptive research assuming greater importance in many of the collaborative projects with national programs. As a general policy, the support of advanced institutions is sought for meeting the basic research needs. Links have already been established with institutions in several countries including Canada, France, Italy, Netherlands, U.K., and West Germany.

Achievements and Future Projections

The achievements of various research components of FLIP to date will be discussed by the respective program scientists in their presentations during the course of the workshop. This section will, therefore, deal with the current thinking with respect to future course that FLIP proposes to take. We would greatly welcome suggestions from colleagues from national programs and other workshop participants on this proposal.

The time-trend of the relative emphasis on different activities of FLIP with respect to all three mandate crops for the coming 5 years is shown in Fig. 3. When national programs become stronger to develop cultivars from the breeding materials, the relative emphasis of ICARDA's Food Legume Program will shift from

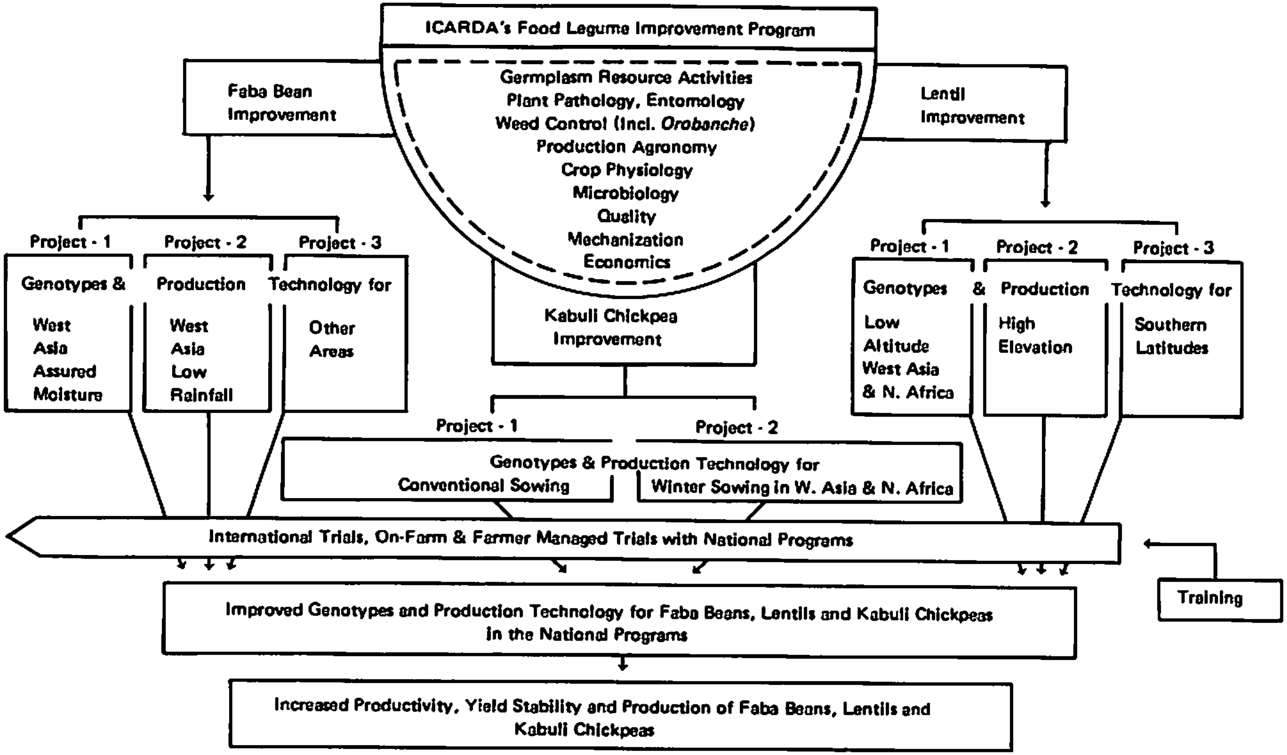

Fig. 1. Organization of research and training strategy in the Food Legume Improvement Program to realize the main objectives of the program.

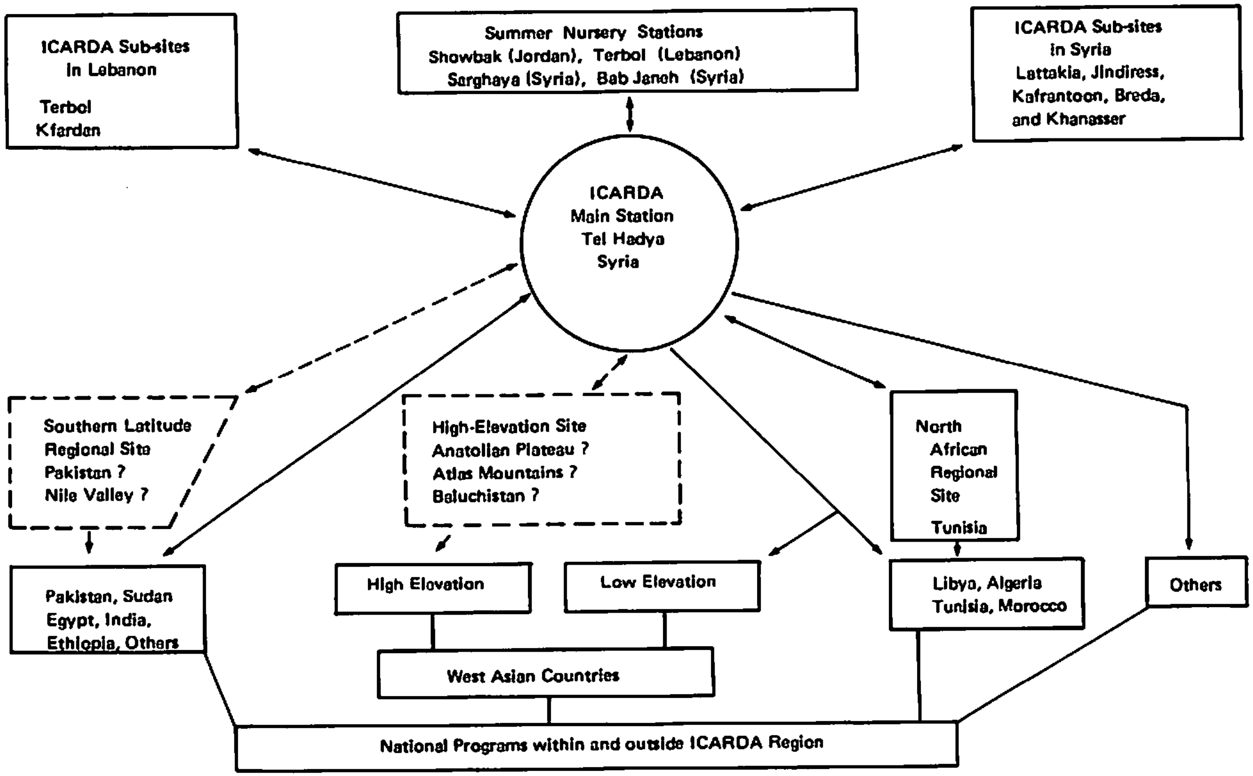

Fig. 2. Development of improved germplasm at ICARDA and its flow to the national programs.

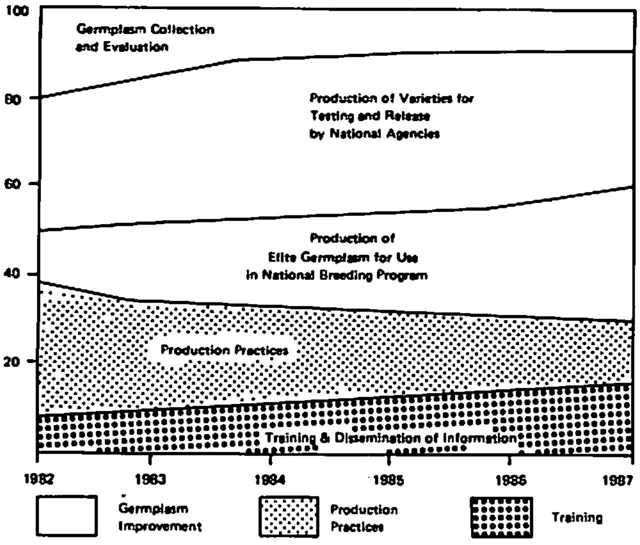

Fig. 3. Time-trend for the relative emphasis on different components of the activity of Food Legume Improvement Program.

developing finished varieties to that of production of superior germplasm for use by national programs. Also, emphasis on the development of production practices will reduce, but emphasis on training will continue to increase.

Faba Beans

Research emphasis in the core program on faba beans is currently divided into about 60% on large-seeded (var. *major*) types and 40% on small-seeded (vars. *minor* and *equina*) types. In addition, the special-funded Nile Valley Project in Egypt and Sudan is mainly devoted to small-seeded types. The core research program will continue to place the main emphasis on *major* types.

There is a wide range of diseases which have been reported on faba beans in the region. These include:

Chocolate spot (*Botrytis fabae*, *B. cinerea*)
Ascochyta blight (*Ascochyta fabae*)
Rust (*Uromyces fabae*)
Leaf spot (*Alternaria* spp. and *Cercospora* spp.)
Powdery mildew (*Erysiphe polygoni*, *Leveillulla taurica*)
Downy mildew (*Peronospora* sp.)
Root rot/wilt (*Fusarium* spp., *Rhizoctonia* spp., *Scelerotinia* spp., *Helminthosporium* spp., etc.)
Bacterial diseases (e.g. *Xanthomonas* sp.)
Viruses (BYMV, CMV, BBMV, PLRV, etc.)

To date, research has concentrated mostly on chocolate spot and ascochyta blight. Promising sources of resistance to these diseases have already been identified and are now being tested widely and incorporated into well-adapted genetic backgrounds. The program will continue its efforts to identify further resistance sources and use them in breeding work. Over the next few years work will also increase on more basic aspects such as mechanism of resistance, pathogen biotype studies, and inheritance of resistance to these two diseases.

Work will be intensified on the next most important diseases: rust, root rot/wilt and virus diseases. Broomrape, a parasitic angiosperm (*Orobanche crenata*, *O. aegyptiaca*) is probably the single most important biotic factor limiting faba bean yields in the region. Research on identifying sources of resistance to broomrape will be intensified in the future as will efforts to find appropriate alternative control measures, including chemical control.

Work has started recently on the stem nematode (*Ditylenchus dipsaci*), a damaging seed-borne nematode which is widespread in West Asia and North Africa. Following the development of suitable screening techniques, the development of resistance to this pest is expected to assume greater importance.

Among the wide range of insect pests of faba beans, special attention will be devoted to aphids and stem borers. Resistance to both these pests is already being sought. There is still a great need, however, for detailed pest surveys in the region to firmly establish the importance and distribution of these and other insect pests.

Throughout the ICARDA region, faba beans are mostly grown as a rainfed crop in areas receiving more than about 400 mm of precipitation per year. In drier areas they are normally given supplementary irrigation or are entirely irrigated, as in the Nile Valley. The major emphasis of the program is for production under these higher moisture conditions, with the nurseries at Tel Hadya being supplied with approximately 100 mm of additional water per year. Although this constitutes the main thrust of the program, approximately 20% of the effort is devoted to developing the crop for drier areas, and as such no irrigation is provided to these materials at Tel Hadya. At about 350 mm of rainfall, or even less, yield levels of the best faba bean lines have been comparable, or even superior to the best chickpea and lentil lines. In view of this, more resources will be devoted in the future to developing drought tolerance in the crop. The specific aim is to develop a crop that would provide farmers in the drier areas (250 - 350 mm) with an alternative to lentils and chickpeas.

Work on alternative growth habits will continue, with determinate materials being tested more widely, especially in the higher rainfall, high-fertility areas.

In respect to quality, protein and cooking quality levels will continue to be monitored to ensure that acceptable standards are maintained. In addition, following the results of current surveys and other research, the objective of breeding cultivars with reduced vicine and convicine levels is expected to be included in the program. These two compounds are strongly implicated as the causal agents of favism.

A special project on wide-crossing in Vicia spp. is being conducted in collaboration with the University of Reading. If successful techniques are developed, the results of interspecific hybridization are expected to make a very major impact on the breeding program a few years hence.

With the research in Syria and Lebanon fairly well established, a small program off-the-ground in North Africa, and the Nile Valley Project under way in Egypt and Sudan, the major faba bean areas of the region are already reasonably well covered. Of course, further strengthening of all areas is needed, but it is intended, additionally, to explore the possibility of establishing collaborative projects in China (where two-thirds of the world's faba beans are grown) and/or Ethiopia. Latin America, although an important faba bean region, will receive attention later.

Lentils

ICARDA region accounts for nearly one-third of the total lentil acreage in the world. The largest producers in the region are Turkey and Syria, and thus ICARDA in Aleppo is well situated for research on this important crop. Of the three food legume species addressed by the program, lentils are grown in the driest areas, and can be found in rainfall zones down to about 250 mm rainfall per year. Both of the two major subgroups of the species are important in the region: the large-seeded (var. macrosperma) and small-seeded (var. microsperma) types. Approximately equal emphasis is placed on the two types.

Improving yield and yield stability are the main objectives of the program. There are comparatively few pest and disease problems. One very important objective is to devise means of reducing the labor requirement for harvesting the crop. Three main approaches to the problem are being followed. First, through breeding, it is aimed to develop cultivars which have substantially reduced pod-drop and dehiscence characteristics, which are taller than conventional types, have pods borne higher off the ground, and which do not lodge. These types would enable harvesting to take place over a longer pèriod and would be more amenable to mechanical cutting, including direct combine-harvesting. The second approach is through agronomy: good seed-bed preparation, rolling, seeding practices, fertilizer use, etc. can all contribute to alleviating the problem. The third approach is the development of appropriate machinery. Some work has been carried out in the past on developing a lentil puller, and on testing a standard bean cutter. Both have shown considerable promise and will be further developed and tested in the future. Work on all three approaches to the harvesting problem will continue, with the agronomy work and machinery increasingly moving to an on-farm trial/demonstration phase.

Another aspect of the research aims at developing cold-tolerant lentil cultivars for high elevations. Some success has already been achieved in this regard in collaborative trials with the Turkish National Program. In view of the substantial yield advances which should be possible by switching from spring to autumn planting, this research will continue to receive a high priority for the higher elevations. Over the next few years screening techniques will be developed and standardized and collaborative projects will be established with organizations working in appropriate environments.

Of the important pests and diseases of lentils, research will continue on Orobanche sp., rust (primarily for the Indian subcontinent, Ethiopia, and Latin America), and root rot/wilt. Sources of resistance are being sought and work in this area will increase over the next few years.

Lentils have a narrow adaptation to environment. Studies on the nature of adaptation have already been initiated both at ICARDA and in collaboration with the University of Reading. As more information becomes available in the next few years, new screening techniques, zoning of the region, etc. will become possible. In view of the narrow adaptation, research in Syria is of comparatively little relevance to the needs of the crop in more southernly locations, particularly in Egypt, Sudan, Ethiopia, and the Indo-Pakistan subcontinent. In Egypt and Sudan, collaborative research on lentils is already under way. In addition, special-project funding is being sought to initiate a subregional project in the Indo-Pakistan subcontinent, where over 50% of the world's lentil crop is grown.

Research on crop quality will continue to place emphasis on maintaining adequate nutritional and cooking quality levels. Additionally, research will be initiated on other quality parameters, especially hulling percent. Straw is a very important by-product of the crop, and can even exceed the value of the grain. Studies on straw quality and utilization are planned for the future.

Agronomy will continue to be an important focus of the program, but resources will increasingly be switched, over the next few years, to more detailed physiological studies on aspects such as drought resistance, cold tolerance, growth habit,and adaptation.

Khabuli Chickpeas

As already mentioned, the chickpea program at ICARDA is a joint program with ICRISAT. The chickpea breeder and chickpea pathologist are both ICRISAT scientists who are seconded to work at ICARDA.

Kabuli types account for about 15% of the total world chickpea production and are widely preferred in southern Europe and Latin America in addition to most countries of the ICARDA region. The ICARDA chickpea program also takes a lead in research on the disease ascochyta blight, caused by *Ascochyta rabiei*.

In the future the chickpea program will continue to place major emphasis on kabuli types, and will devote an increasing proportion of its effort to the large-seeded types.

A notable success of the program has been in demonstrating the feasibility of switching chickpeas in West Asia and North Africa from the normal spring-planted to an autumn-planted crop. Highly promising materials with reasonable cold tolerance and resistance to ascochyta blight have been developed, which are essential to the success of the new system.

Studies have now begun, in collaboration with the University of Reading, on identifying different biotypes of the pathogen. Initial data collected in the region strongly suggest the presence of different physiological races. These studies are expected to provide important information for the design of future screening and breeding strategies.

As research on ascochyta blight becomes well established, greater attention will be paid in the future to other diseases such as root rot/wilt, virus diseases, and possibly certain others such as botrytis grey mold. *Orobanche* sp. and nonparasitic weeds are a major problem on the winter-sown crop compared to the normal spring-sown one. More research efforts will be devoted to this over the next few years. Root-knot and cyst nematodes will also receive attention.

The research on the two major insect pests, pod borers (*Heliothis* spp.) and leaf miners, will continue. Breeding for resistance to both of these pests has started, and resistant materials from ICRISAT will be screened.

There is a strong need to increase the cold tolerance in the breeding materials and considerable efforts will be made to do this over the next few years. A few good sources of cold tolerance have already been identified from a screening of the germplasm at Ankara, Turkey, and at ICARDA sites at Tel Hadya and Terbol.

Winter chickpeas can be grown economically in much drier areas than is possible for the spring crop. Thus, new areas will be opened up for chickpea cultivation. In these areas the soils will mostly be lacking the necessary chickpea rhizobia populations and the crop will greatly benefit from inoculation. Attention will have to be paid to the development of commercial inoculant production facilities in the region to provide the necessary quantities of inoculum.

Agronomy work on chickpeas has concentrated largely on the winter crop. The stage has now been reached for large-scale research/demonstration activities on the components of production of winter chickpeas in West Asia. Major efforts will be devoted to this end over the next few years.

Likewise, in North Africa also, winter chickpeas have shown considerable promise, and a major objective of the North African Regional Program will be to develop and evaluate the practice at the farm level.

The high cost and nonavailability of labor for harvesting chickpeas, although less serious than for lentils, still poses a constraint to production in some areas. The development of tall cultivars suitable for mechanized harvesting is receiving some attention by the program, and will continue to do so in the future.

General

The distribution of materials and trials internationally will continue to assume a very high priority in program activities. The number of different types of nurseries and trials is expected to increase, as more information becomes available about the various needs of the different national programs.

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Faba Bean Germplasm Collection, Maintenance, Evaluation, and Use

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Vicia faba L. is a diploid species, 2n = 12, which does not produce fertile hybrids with any other species. It is partially outcrossing species with outcrossing rates being between 20 and 60% (Bond and Pope 1974; Holden and Bond 1960; Monti and Frusciante 1982; Picard 1953, 1960). This is an important factor in all stages of germplasm management: collection, maintenance, evaluation, and use.

Collection

Faba beans have been the subject of some germplasm collections in the last few years. Ninety-five collections were made in Egypt in 1978 by the International Institute of Tropical Agriculture (Badra 1978). Also, extensive faba bean collections have been made in Egypt by M.M.F. Abdalla (Witcombe 1982). Collections by the Germplasm Laboratory, Bari, Italy, in 1976 included 47 accessions from Algeria, and in 1977 collections of 23 accessions from Greece, 31 from Spain and 18 from Tunisia were made (Witcombe 1982). Germplasm collections have also been conducted in Cyprus (Della 1980) and Ethiopia (Toll 1980).

Holders of major collections of *V.faba* are given in Table 1 (Witcombe 1982). The size of various collections of *V.faba* is small when compared to most cereal collections or other self-pollinated legumes. There are probably many duplications between various collections. The distribution of ICARDA accessions in its ILB (International Legume Bean) collection from various countries is given in Table 2. The most glaring deficiency is lack of accessions from China, though China represents the major proportion of the area under faba bean production. Countries of North Africa and West Asia are also not well represented, though they are the major region for ICARDA work. May 11-12, 1982, a conference was jointly sponsored with the IBPGR at Aleppo by ICARDA on faba bean and lentil descriptors. Areas were also established with priorities for faba

Table 1. Holders of major collections of *Vicia faba* (after Witcombe 1982).

Country	Institute	No. of Accessions
Syria	ICARDA, Aleppo	2791 *V.faba*
USSR	N.I.Vavilov IAPI,Leningrad	2525 *Vicia* spp.*
Italy	LG, CNR, Bari	1469 *V.faba*
GDR	ZGK, Gatersleben	746 *V.faba*
Netherlands	SVP, Wageningen	700 *V.faba*
Czechoslovakia	PBRICL, Tumenice	500 *V.faba*
FRG	IPP, Braunschweig	804 *V.faba*
Spain	ETSIA, Cordoba	800 *V.faba*

* *Vicia faba* numbers unknown.

Table 2. Major faba bean germplasm accessions in the ILB collection at ICARDA, 1983.

Donor country[1]	No. of accessions
Afghanistan	66
Canada	156
Cyprus	103
Egypt	110
Ethiopia	586
France	40
West Germany	257
Holland	43
Iraq	54
Italy	98
Lebanon	28
Morocco	72
Spain	216
Sudan	30
Syria	55
Tunisia	40
Turkey	101
U.K.	186
USA	74

1. Donor countries with less than 28 accessions are not included.

bean germplasm collection. In the first priority were China, Morocco, USSR, and parts of India and Pakistan with areas under indigenous cultivars.

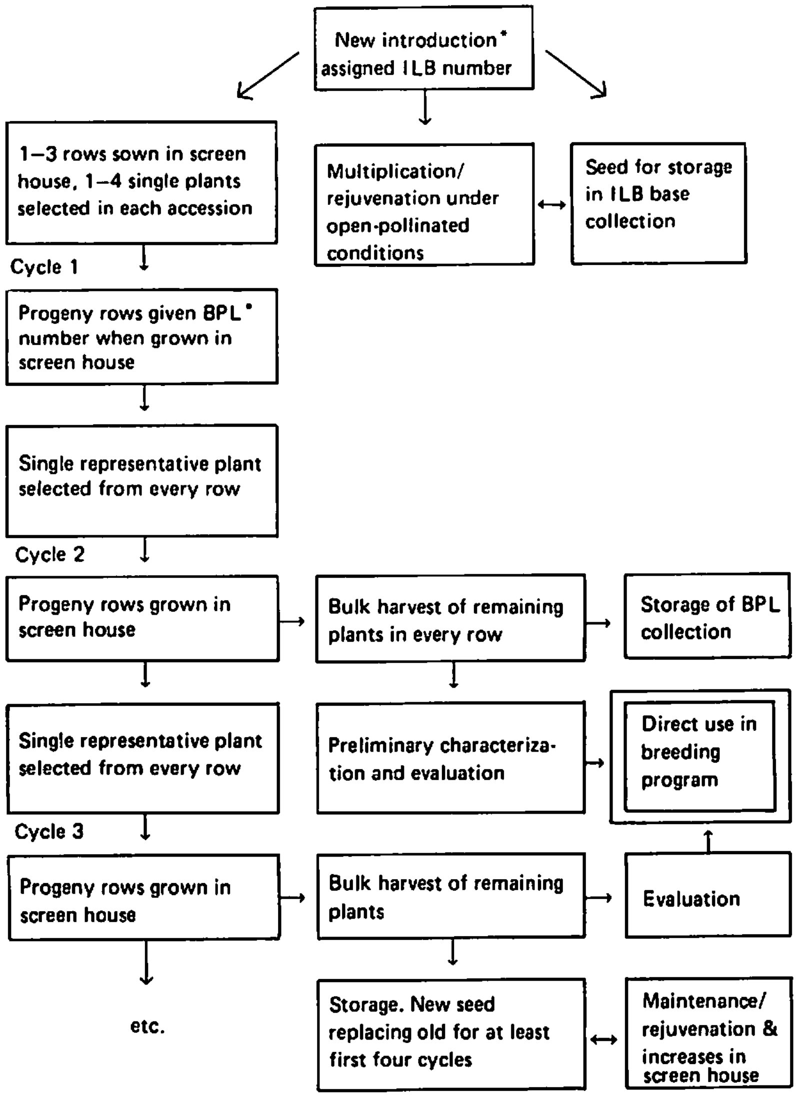
When collections are made, the outcrossing nature of faba beans needs to be considered. Local landraces cannot be represented by seed from one or two plants. Depending on the heterogeneity, larger samples should be taken. Also, separate collections in a small area may not be genetically different accessions, because of outcrossing. Allard (1970) discusses sampling methods for various population structures as does Bennett (1970). Ideally, a large sample, at least one kilogram, should be taken for faba beans to have a good base for long-term storage. Faba bean collections are more likely to be from local landraces grown in farmer fields rather than sampling wild populations except for other species of Vicia which are not of direct use for faba bean breeders. A higher emphasis should be given to collecting primitive local landraces of faba beans before they are replaced by improved cultivars. The variability available to faba bean breeders is under serious threat by improved cultivars because it is almost entirely dependent on man.

Maintenance

To maintain thousands of open-pollinated accessions and keep complete genetic identity is almost impossible. All that can be done is to reduce the intercrossing between lines and the loss of identity. Witcombe (1982) has discussed loss of genetic identity for various ways of rejuvenating faba bean germplasm. The best solution is to reduce generation advance along with growing accessions in a layout to minimize intercrossing. Ways to reduce intercrossing include growing border rows and discarding border plants, growing in an insect-proof cage, or using another species as border that attracts the same pollinating insects (such as Brassica campestris). However, the last two will change the genetic structure if not the gene frequencies of the accessions.

Another approach to maintain cross-pollinated germplasm accessions is as inbred lines (Burton 1979). This simplifies seed maintenance because lines can easily be maintained as inbred lines in screenhouses, though tripping may be required for some. This way, thousands of genetically different lines can be maintained with their identity unimpaired. Another critical factor is that selfing uncovers many recessive genes. After evaluation, seed requests for inbred lines can be easily met while those for open-pollinated lines would seriously erode the original collection.

At ICARDA, because of this difficulty of maintaining and evaluating open-pollinated accessions, a pure-line collection has been derived from the original heterogeneous, heterozygous accessions (Hawtin and Omar 1980). This system is detailed in Fig. 1. The original accession as received at ICARDA is given an ILB accession number. Through a process of selfing, one to four lines



* ILB Base collection identifier (International Legume Bean)
BPL Pure line collection identifier (Bean Pure Line)

Fig. 1. Flow of faba bean germplasm at ICARDA.

(based on variability in the original accession) are developed as pure line BPL accessions (Bean Pure Line) from each ILB line. The process involves growing each ILB line in one to three rows in the screenhouse where one to four plants are selected for growing a progeny row the next year when each progeny row is given a BPL accession number. This whole process is done under screenhouses to insure self pollination. The second year one representative plant is selected for growing in a progeny row the next year. This continues till five cycles of selfing when maintenance is done with roguing. Evaluation will usually start the second cycle of selfing. At this time ICARDA has nearly 2800 ILB lines and has derived 2500 BPL lines from these ILB lines.

Evaluation and Use

The most important stage in germplasm management is evaluation and use. Without this the collection is a useless museum. At ICARDA, sources of resistance for various pathogens such as Botrytis fabae, Ascochyta fabae, Uromyces fabae, and Ditylenchus dipsaci have been found in the BPL collection. Also, lines have been found resistant to Orobanche crenata. Use of BPL accessions allows the identification of any received genes for desired traits.

Other collections have been surveyed for disease resistance. Rollowitz and Schmidt (1982) screened 600 accessions of the German Democratic Republic collection of faba beans for resistance to bean yellow mosaic virus (BYMV) and pea enation virus. Also, many were screened for reactions to broad bean true mosaic virus, alfalfa mosaic virus, and broad bean wilt virus. One line was found very resistant to 14 isolates of BYMV and other lines were found tolerant to the other four viruses. Scarascia - Mugnozza and Pace (1979) evaluated variability for number of pods per plant, seeds per pod, seed weight, and protein content per seed for a sample of 600 accessions from the Bari Vicia faba collection and found wide genetic variability. Boorsma (1980) found several accessions of the Rabat collection tolerant to Orobanche crenata.

Once evaluation is done, lines should be made available for use by breeders. At ICARDA many crosses are now being made for resistance to various pests using lines found as resistant in the germplasm collection. Requests from several countries for lines resistant to various pests, especially to Botrytis fabae have been received. It is important to get information about evaluation of germplasm out to other workers such as done by Hanounik (1982) for Botrytis fabae resistance. Only then can others make use of these lines and the data available. Preferably, a germplasm catalog should be developed for a collection listing information about origin and collection and also evaluation data for various traits. At ICARDA we will put the evaluation and origin data for our accessions in a computer file. This will allow the production of specialized catalogs for various interests. However, the publication of evaluation data, especially pest resistance, frost tolerance, unique plant types, etc., in widely available sources should not be forgotten.

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Discussion

J.I. Cubero

1. Faba bean line F 402 has been found resistant to *Orobanche crenata* under both glass-house and field conditions.
2. *Self-fertile* varieties have produced an increase of two-and-a-half times over standard varieties. I would suggest the selection for self-fertility in many cases; it is easier than selection for synthetics. It is useful in many countries where allogamy is neither high nor constant. I would like also to stress the importance of getting a low ovular abortion.

G.G. Rowland

Fertilization frequency in faba beans declines from the first ovule position (nearest the stigma) to the last. This leads to pods that have one, two, or three seeds per pod, not the desired four. The abortion of fertilized flowers is mainly of those with less than four fertilized ovules. Therefore, it would seem that increasing the fertilization frequency would increase the numbers of seeds per pod and thus the yield of a plant.

Proceedings of the International Workshop on Faba Beans, Kabuli Chickpeas, and Lentils in the 1980s (Saxena, M.C. and Varma, S., eds.), ICARDA, 16-20 May 1983, Aleppo, Syria.

Kabuli Chickpea Germplasm at ICARDA

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A joint contribution from ICRISAT and ICARDA.

Genetic diversity is the key to the crop improvement; the larger the variability the bigger the gain. The need for conservation of the naturally occurring variability in crop plants has been strongly emphasized by scientists the world over. In fact a large number of international and national organizations have started putting together their hands in conservation of the existing resources before they are lost for ever. Some of the success achieved in conservation of genetic resources of chickpea (Cicer arietinum L.) during the past 20 years is reported here.

Chickpea (C.arietinum L.) is believed to have originated in the regions adjoining Turkey, Iran, Afghanistan, and USSR (van der Maesen 1972; Ladizinski and Adler 1976). Chickpeas can be classified into two main types: desi - with small, angular, and colored seed and kabuli - with large, ram-shaped, and beige colored seed. ICRISAT (International Crops Research Institute for the Semi-Arid Tropics), located in India, has the sole responsibility for desi types, and a joint responsibility with ICARDA for kabuli types. ICARDA serves as the world center for the collection, maintenance, and distribution of kabuli chickpea germplasm.

Collection

So far, in chickpeas, no such major breakthroughs have occurred as in certain other crops like wheat and rice, so the landraces and the wild flora are still prevalent in almost all the traditional chickpea areas. Thus, there seems to be tremendous scope for collection and conservation of landraces and other wild types before they are lost for ever.

In the past 20 years a large number of collections have been made by various national and international organizations. ICARDA, in 1977, the year of its inception, inherited 1798 kabuli germplasm accessions from the Arid Land Agriculture Development (ALAD) Program of Ford Foundation, Beirut, Lebanon. Since then, 2627 accessions have been added, raising the total to 4425 accessions and representing 34 countries (Table 1). The list of donors to ICARDA

Table 1. Representation of countries in ICARDA's kabuli chickpea germplasm, 1983.

Country	Number of accessions	Country	Number of accessions
Afghanistan	868	Pakistan	24
Chile	337	Palestine	33
Egypt	50	Spain	213
Ethiopia	29	Syria	83
India	243	Tunisia	245
Iran	1232	Turkey	386
Iraq	30	USA	44
Jordan	127	USSR	56
Lebanon	26	Others	255[a]
Mexico	55		
Morocco	89	TOTAL	4425

a. Countries with less than 20 accessions have not been mentioned separately but pooled together and listed as others.

collections is given in Table 2. Most of these collections have been the landraces from different countries and only a few are recent cultivars. In addition to the cultivated chickpea (*C.arietinum*), ICARDA also inherited 30 samples of seven *Cicer* species from ALAD: *C.pinnatifidum*, *C.montbretii*, *C.judaicum*, *C.yamashitae*, *C.bijugum*, *C.cuneatum*, and *C.reticulatum*. But ICRISAT in India holds 16 *Cicer* species including 8 annual and 8 perennial (van der Maesen *et al.* 1980). The national programs may be in a position to determine whether the collection from their countries is well represented. Additional collection of *Cicer* species and other landraces may be useful. We will encourage the national programs to undertake the responsibility for future collections in collaboration with the newly created Genetic Resources Unit (GRU) at ICARDA and with the IBPGR.

Table 2. Organizations which supplied kabuli chickpea germplasm to ICARDA.

AGRICOL	Agricultural College, University of Tehran, Karaj, Iran
ARCG	Agricultural Research Center, Giza, Egypt
CC	Centro de Cerealicultura, Madrid, Spain
CCGC	Cooperative Centre des Grandes Cultures, Tunisia
DAS	Dept. of Agri. and Soils, Pullman, Washington,USA.
IARI	Indian Agricultural Research Institute, New Delhi,India
ICARDA	International Center for Agricultural Research in the Dry Areas, Aleppo, Syria
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics, Hyderabad, A.P., India
IFC	Institute for Fodder Crops, Larissa, Greece
INIA	Institut Nacional de Investigaciones Agronomicas, La Caneleja, Spain
INRA	L'Institut National de la Recherche Agronomique, Rabat, Morocco
INRAT	L'Institut National de la Recherche Agronomique de Tunisia, Tunis, Tunisia.
IPI	N.I. Vavilov All-Union Institute of Plant Industry, Leningrad, USSR
PIC	PIC, Menemen, Izmir, Turkey
WRPIS	Western Regional Plant Introduction Station, USDA, Pullman, Washington, USA

Maintenance and Distribution

The kabuli germplasm at ICARDA is accessed as ILC (International Legume Chickpea). All information concerning the origin, pedigree, place of collection, time of collection, the donor organization, collecting or breeding organization is entered in the accession book. At present the germplasm is maintained at ICARDA's main center, Tel Hadya, under normal storage, but short-term storage facilities will soon become available. For the sake of safety, it will be desirable if the entire collection is duplicated and kept elsewhere. ICARDA has made this arrangement with ICRISAT.

One of the most important objectives of the Food Legume Improvement Program at ICARDA has been the distribution of the genetic resources to scientists. We have distributed thousands of accessions to our cooperators in national programs (Table 3) and we intend to continue this activity.

Table 3. Distribution of kabuli chickpea germplasm accessions by ICARDA to different national programs since 1977.

Country	Number of accessions	Country	Number of accessions
Pakistan	780	Lebanon	60
Morocco	600	Jordan	26
Turkey	753	Chile	200
ICRISAT (India)	1833	Egypt	500
France	60	Ethiopia	150
USSR	60	Others	250
USA	661		
Canada	180	TOTAL	6238
Mexico	125		

Evaluation

About 3300 kabuli accessions have already been evaluated for morphological, seed, and quality characters during spring and for certain stress factors like ascochyta blight, cold tolerance, iron deficiency, etc. during different seasons in the past. Wide genetic variation has been observed for almost all the characters. The range for different continuously varying characters is presented in Table 4. In addition, a large number of lines with resistance to ascochyta blight, tolerance to cold, tolerance to iron deficiency, and with other desirable traits have been identified (Singh et al. 1983). The country means for various characters have revealed that desirable materials for ascochyta blight resistance were from USSR and Afghanistan; tall and erect habit from USSR; tolerance to cold from India and Pakistan; more biological yield from Spain and Mexico; large seed from Tunisia and Spain; high protein content from Chile and Algeria (Singh et al. 1983).

The evaluation details along with passport information about the accessions have been compiled and presented in the form of a "Kabuli Chickpea Germplasm Catalog," which is available from ICARDA. It is proposed to evaluate the entire collection during winter. The first 1000 accessions have already been evaluated for 10 characters. The collection is also being evaluated for resistance to leaf miner. In view of the increasing importance of photoperiod-insensitivity, it is suggested that the entire germplasm lines be systematically evaluated for this trait. The value of evaluation will greatly increase if it is done at more than one location. Periodic updating of the catalog will be required for incorporating new evaluation details.

Table 4. Minimum and maximum values for different descriptors in kabuli chickpea germplasm at ICARDA, 1983.

Descriptor	Minimum value	Maximum value
Days to flowering (No.)	58.0	94.0
Flowering duration (No.)	11.0	36.0
Days to maturity (No.)	114.0	124.0
Plant height (cm)	15.0	50.0
Canopy width (cm)	15.0	60.0
Primary branches/plant (No.)	1.3	18.0
Secondary branches/plant (No.)	0.3	22.7
Pods per plant (No.)	5.0	100.0
Seeds per pod (No.)	0.1	3.1
Biological yield (g/plot)	110.0	1680.0
Seed yield (g/plot)	23.0	921.0
Harvest index (%)	7.0	84.0
100-seed weight (g)	8.7	59.1
Protein content in seed (%)	16.0	24.8

Utilization

At ICARDA, several high-yielding lines from the germplasm collection have been identified and are being evaluated for their wide adaptation. These have been listed in various ICARDA publications (ICARDA Annual Report 1981, 1982). The lines with such characters as resistance to ascochyta blight, tolerance to cold, large seed size, tall plants, etc. are being utilized for the improvement of existing landraces and other materials. For effective utilization of the germplasm by national programs, the evaluation data have been stored in the computer using VAX-11/780 system.

In future, the responsibility for collection and maintenance will rest with the GRU and for evaluation and distribution with the Food Legume Improvement Program. Scientists in national programs could use the catalog for requesting desirable material for their program.

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Discussion

J.B. Smithson

How are data from several evaluations on a single accession handled?

The slide of frequency distribution of seed protein content in chickpeas showed a mean of about 50% - this seems high. What are your comments?

R.S. Malhotra

In case of chickpeas, for all descriptors except some stress conditions like ascochyta blight, cold tolerance, and iron chlorosis, the data were recorded during only one season in spring. However, for other stress conditions the observations were recorded during different years. In case of protein content frequency distribution shown in the slide, the range was 16.0 to 24.8% and not 50%.

K.B. Singh

In evaluating chickpea germplasm accessions for stress conditions, such as ascochyta blight and cold, we evaluate material for at least two years and possibly at more than one location.

A. Slinkard

Screening initial selections for protein content is a waste of time, money, and effort, since most of this variation is due to environmental effects. Thus, protein screening efforts should be limited to the final stages of testing of new lines.

Proceedings of the International Workshop on Faba Beans, Kabuli Chickpeas, and Lentils in the 1980s (Saxena, M.C. and Varma, S., eds.), ICARDA, 16-20 May 1983, Aleppo, Syria.

Lentil Genetic Resources

Willie Erskine
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Lentil genetic resources are wild lentils and landraces of the cultigen (Solh and Erskine 1981). There are a total of five species in the genus Lens, three of these, namely Lens culinaris, L.orientalis, and L.nigricans are interfertile, forming the primary gene pool of the lentil (see Cubero 1981 for a recent review). Despite recent collections (Muehlbauer 1981), the wild species are underrepresented in collections. They should be collected across their geographic range.

The geographic distribution of variation within the cultigen was admirably described by Barulina (1930). Much of this variability has been reassembled in collections, but some areas are represented by too few accessions. The ICARDA (ILL) collection comprises 5424 accessions from 53 countries (Table 1). High priority areas for collection are Algeria and Morocco. Collections are also needed from Bihar and Madya Pradesh in India, from Bangladesh, from Pakistan, and from S.E. Anatolia in Turkey.

Lentils are orthodox seeds, so their maintenance in storage follows standard procedures (IBPGR 1979). The level of outcrossing is less than 1% (Wilson and Law 1972) and consequently the regeneration of stored germplasm can be in adjacent plots. The ILL collection is stored under ambient conditions. A duplicate collection has been made, and it will be stored at -18 to -20°C after drying to 5-6% moisture.

Since 1979, 4500 accessions have been evaluated in plots for a range of morphological and agronomic characters (Table 2). Other characters associated with the current direction of the breeding program have also been considered: protein content, cold tolerance, and tolerance to Orobanche crenata. These data together with the passport information for the accessions have been entered into the computer, and a catalog is in preparation.

Table 1. Lentil area in various countries of the world and the number of accessions in the ILL collection of ICARDA from these countries, 1983.

Country	Area in 1981[a] (x 1000 ha)	Number of accessions
AFRICA	119	509
1. Algeria	16	14
2. Egypt	6	85
3. Ethiopia	59	375
4. Libya		1
5. Morocco	34	22
6. Somalia		2
7. Sudan		1
8. Tunisia	4	9
N. & C. AMERICA	79	49
1. Canada		2
2. Costa Rica		1
3. Guatemala		2
4. Mexico	10	24
5. USA	69	20
S. AMERICA	89	353
1. Argentina	22	6
2. Chile	48	335
3. Colombia	17	8
4. Ecuador	1	
5. Peru	2	3
6. Uruguay		1
ASIA	1562	3969
1. Afghanistan		124
2. Bangladesh	84	36
3. Burma	3	
4. Cyprus		9
5. India	1000	1905
6. Iran	38	902
7. Iraq	10	22
8. Japan		1
9. Jordan	9	293
10. Lebanon	4	70
11. Nepal		12
12. Pakistan	87	37
13. Palestine		1
14. Syria	127	208

Table 1. Contd.

15. Turkey	200	313
16. Yemen		37
EUROPE	95	278
1. Albania		2
2. Austria		1
3. Belgium		2
4. Bulgaria	1	23
5. Czechoslovakia	2	17
6. France	12	7
7. Germany (DDR)		22
8. Germany (DFR)		3
9. Greece	4	2
10. Hungary	1	3
11. Italy	2	8
12. Netherlands		1
13. Norway		1
14. Poland		4
15. Portugal		4
16. Romania		1
17. Spain	73	151
18. U.K.		1
19. Yugoslavia	1	25
USSR	19	103
Unknown		52
World	1953	5424

a. Source: FAO Food Production Yearbook 1981.

The utilization of the germplasm collection in breeding at ICARDA has been described (ICARDA 1982). Specific subsets of the germplasm have been distributed on request to many countries, with more than 100 accessions going to Bangladesh, Chile, Egypt, Morocco, Pakistan, Sudan, Turkey, and U.K. over the past 3 years.

Table 2. Range and means of entries in the lentil germplasm collection together with the number of accessions measured and the coefficient of variation (cv) of systematically repeated controls, ICARDA.

Character	Season	Range	Mean	No. of accessions	CV (%)
Grain yield (kg/ha)	1979/80	10-3257	1287	3586	13.7
Biological yield (kg/ha)	"	78-10382	4218	3586	12.5
Straw yield (kg/ha)	"	63-7983	2931	3586	15.5
100-seed weight (g)	1978/79	1.07-8.55	3.20	3974	-
Seed numbers per pod	1979/80	1.0-2.0	1.52	3590	9.2
Time to 50% flowering (d)	"	118-162	139.8	3590	4.8
Time to maturity (d)	1978/79	154-197	170.3	2958	1.6
Plant height (cm)	"	10-45	25.5	2895	8.0
Height of lowest pod (cm)	"	6-30	14.1	1772	-
Pod numbers per peduncle	"	1.0-1.7	1.1	403	2.1

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Discussion

J.B. Smithson

What form of environmental control is used when comparing germplasm between years?

W. Erskine

The evaluation for morphoagronomic characters in lentils is undertaken in an augmented experimental design. The data between years are not directly comparable. However, it may be possible to compare the distribution of the different years to develop comparable scoring systems.

Proceedings of the International Workshop on Faba Beans, Kabuli Chickpeas, and Lentils in the 1980s (Saxena, M.C. and Varma, S., eds.), ICARDA, 16-20 May 1983, Aleppo, Syria.

Genetic Improvement of Faba Beans for Increased Yield and Yield Stability

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Vicia faba L. is a partially outcrossing species with cross-pollination the result of insect pollinators. The reproductive system of faba beans influences improvement for yield and yield stability through both autosterility problems of cultivars and also its effects on efficiency of various breeding strategies. Pollination control is a major problem for faba bean breeding programs whether they follow pedigree selection, mass selection within crosses, or develop synthetics. The major constraint to most breeding programs is in overcoming problems of pollination control.

Biological restraints to yield include such factors as pollination and seed set (autosterility) and flower and pod drop. In some areas susceptibility to frost damage is a major problem. Some researchers suggest that changing *V.faba* to a determinate plant type will lead to higher yield levels. Many pests limit yield in various regions. These include *Botrytis fabae*, *Ascochyta fabae*, *Uromyces fabae*, *Orobanche crenata*, *Ditylenchus dipsaci*, and *Aphis fabae* among others.

Limiting Factors

Pollination and Flower and Pod Drop

Studies on yield components in faba beans have been conducted to determine where efforts on breeding can be directed to increase yield and also with the objective of indirect selection and selection indices. Most researchers find yield closely related to number of pods per plant (Cubero and Martin 1981; Ishag 1972; Kambal 1969b; Rowlands 1955; Thompson 1977). Other traits found important include seeds/plant and pods/node. These factors are directly related to problems of flower and pod drop in faba beans. Flower and young pod loss in faba beans can be substantial. Up to 87% and

97% of the buds produced by the varieties Baladi and Giza 1 have been reported lost by flower and young pod drop (Saxena 1979).

Faba bean is a partially outcrossing species with outcrossing the result of pollinating insects. About 20 to 60% outcrossing has been reported (Bond and Pope 1974; Holden and Bond 1960; Monti and Frusciante 1982; Picard 1953, 1960). Pollinating insects have long been recognized as important for high yields. This is due to a requirement for tripping for maximum seed set. Also, the effect of lack of pollinating insects is seen the next year from a crop grown from the previous year seed because of the loss of heterozygosity and the resultant heterosis. The requirement for tripping is not universal and lines have been reported with high levels of autofertility (Hanna and Lawes 1967; Holden and Bond 1960; Poulsen 1975, 1979). At the ICARDA's research farm at Tel Hadya, near Aleppo in northern Syria, several lines have been found with high autofertility by two autofertility indices (Hawtin 1982). Several cultivars (Dacre, Danas, and Deinial) have been released as cultivars with high levels of autofertility by the Welsh Plant Breeding Station (Bond 1979).

Pollination is not the only reason for low pod set. Other factors are cultivar, climatic factors such as temperature and light, agronomic practices such as plant density, unfavorable conditions such as drought, salinity, excessive soil moisture, inadequate supply of nutrients, distribution of assimilates and hormonal balance (El-Fouly 1982; Keller 1974). The distribution of assimilates and hormonal balance are major metabolic factors that affect flower and pod drop.

Many pods set are later lost and Kambal (1969a) and Chapman et al. (1979) have demonstrated that many abscised flowers are fertilized. Gates el al. (1981) found from 16.1 to 65.7% of abscised flowers with pollen tubes in the ovary. Jacquiery and Keller (1978 a,b) found that the earliest opening basal flowers most frequently form pods, unlike those of the raceme apex which are usually shed. Gates et al. (1981) suggested that flower drop of axillary racemes is from physiological changes that stimulate pod set and cause structural alterations of the cell wall. These changes occur in the fertilized flower and young unpollinated bud higher up the racemes. There is a premature lysis of the cell wall middle lamella in the buds that destines them to abscise, even though they may be fertilized before this occurs. Others have shown that pollination triggers abscission of floral structures (Stead and Moore 1979).

Competition for assimilates is a factor that controls flower and pod drop. Duc and Picard (1981) and El-Fouly (1982) list several types of competition for assimilates. These include (1) pods and young pod competition with vegetative parts, (2) competition between pods within the same inflorescence, and (3) competition between pods in their relation to leaf area as a source of nutrients. Others have reported strong competition between reproductive and vegetative growth for assimilates (Jacquiery and Keller 1978 a,b; Chapman and Peat 1978).

Plant Type

Modifications to the plant have been suggested to increase yield through increased pod set. Gates et al. (1981) observed that lines with four to five flowers per node opening over one to two days showed little flower shedding in contrast to northern European lines with eight to nine flowers per node opening over a period of five to six days which gave a 50-60% flower shed. They found synchrony of anthesis within axillary nodes to vary between genotypes and that selecting for this trait could reduce flower shedding and improve yield stability. Duc and Picard (1981) found variability in the young pods/flower ratio and suggested selection. Also, they suggested types with a short flowering period, few flowering nodes distributed on several stems and with few flowers per node to reduce intra-plant competition in young pod nutrition. Ranges for the young pod/flower ratio of 0.24 to 0.94 and for pod/young pod ratios of 0.29 to 0.78 have been reported (Duc and Picard 1982). Poulsen (1977), on the other hand, has suggested selection for increased seeds per pod and pods per inflorescence which may lead to a model with more concentrated (and therefore more efficient) seed production and hence earlier ripening.

A more radical approach to plant type is to change to a determinate type (Sjodin 1971). This type of plant has been discussed by Chapman (1981, 1982). One benefit expected from a determinate type would be to reduce the effect of earlier fertilized flowers on drop of later buds. Austin et al. (1981) found the determinate type not inherently inferior to the indeterminate type and suggested future breeding work should concentrate on increased production of tillers which develop synchronously with the main shoot and against production of infertile branches.

Pest Resistance

Attacks by various weeds, diseases, and insect pests are the major factor in determining yield levels and yield stability in faba beans. Diseases important to faba bean production include ascochyta blight (*Ascochyta fabae*), chocolate spot (*B.fabae*), rust (*U.fabae*), and several viruses such as broad bean mosaic virus (BBMV), broad bean yellow mosaic virus (BYMV), and bean wilt virus (BWV). Stem nematodes (*D. dipsaci*) have also been reported (Hanounik and Sikora 1980). Broomrape (*O. crenata*) is a parasitic weed which can severely attack faba beans and is a major factor in reducing faba bean yields. Insect pests of faba beans include *Aphis fabae*, *Sitona lineatus*, and *Bruchus rufimanus*.

Pest resistance has not received sufficient attention in the past. Chocolate spot is a major cause of yield loss in many environments but few sources of resistance have been found (Enriquez 1977). At ICARDA massive screening of inbred lines produced from the germplasm collection has revealed lines with resistance to chocolate spot (Hanounik 1982) and other diseases and pests. Table 1 lists resistant lines scored for various pests at several ICARDA

Table 1. Sources of resistance identified for some major faba bean pests and diseases.[1]

Disease/pest	Sources of resistance
Chocolate spot (Botrytis fabae)	BPL 266*, 274, 710*, 1179*, 1196, 1278, 1390, 1821.
Ascochyta blight (Ascochyta fabae)	BPL 2485**
Rust (Uromyces fabae)	Sel. 80 Latk. 15563-1, -3, -4.
Stem nematode (Ditylenchus dipsaci)	BPL 1, 7, 10, 11, 12, 21, 23, 27, 40, 48, 57, 63, 75, 76, 88, 110, 121, 127, 183, 185, 210, 211.
Broomrape (Orobanche crenata)	BPL 210, 543, 1933, 2009, 2018, 2027, 2053, 2138, 2147, 2210, 2234, 2257, 2270, 2275.

1. Table based on S.B.Hanounik and S.Kukula, personal communication.
* Resistance reconfirmed in Egypt and U.K.
** Resistance reconfirmed in Canada.

stations. Standardized procedures for creating artificial epiphytotics have been developed at ICARDA for B. fabae (Hanounik and Hawtin 1982). Several lines found resistant to chocolate spot in Syria have been found resistant in U.K. (Jellis et al. 1982).

Broomrape is a major pest of faba beans grown in the Mediterranean region. It is an obligate parasite of many legumes and also many other plants. Resistance has been found in a line, Family 402, in the Egyptian breeding program (Nassib et al. 1978), and in some lines in Spain (Cubero and Moreno 1979) and Italy (Elia 1964) as well as in the ICARDA germplasm collection (Table 1). In diallels, the genetic system showed a low partial dominance with resistance being recessive (Cubero and Martinez 1980; Suso 1980).

Breeding for Aphis fabae resistance has led to the identification of several resistant lines (Bond and Lowe 1979; Holt 1979; Tahhan and Hariri 1981; Tambs-Lyche and Kennedy 1958). Bond and Lowe (1979) reported resistance to be expressed as a reduced spread of infestation.

Due to the importance of resistance to various pests ICARDA has been involved in making crosses for disease, Orobanche, and insect resistance (Table 2). These include resistant x high yield lines and also resistant x resistant crosses. Local material from North Africa, the Nile Valley, as well as West Asia are being crossed with resistant lines. Diallels have been set up to study resistance to O. crenata, Ascochyta fabae, and B. fabae.

Table 2. Crosses made at ICARDA for various pests in 1982 and 1983.

	Crosses made at ICARDA for resistance	
Pest	1982	1983
Ascochyta fabae	34	66
Botrytis fabae	38	42
Uromyces fabae	10	35
Orobanche crenata	36	56

Rhizobium

El-Sherbeeny et al. (1977) found differences in dry-matter production between V.faba varieties in association with a single Rhizobium strain. Mytton et al. (1977) further found that differences between lines of faba bean for efficiency of nitrogen fixation with six strains of Rhizobium were specific and highly interactive. To select for improvement in this will be difficult because of the need for simultaneous selection for host and bacterium.

Breeding Strategies

Cultivar Type

Of paramount influence on a breeding program is the type of cultivar desired. Types of possible use with faba beans include (1) open-pollinated populations and synthetics, (2) fully autogamous lines, (3) hybrids, and (4) near-pure lines developed mostly by pedigree selection. All cultivars are open pollinated whether they are heterogenous populations from mass selection or synthetics, or near-homozygous lines from pedigree programs. Use of heterogeneous, heterozygous open-pollinated cultivars, whether synthetics or products from mass selection, offers the exploitation of heterosis. However, F_1 hybrids offer the maximum benefit from heterosis, especially with faba bean without complete outcrossing.

Faba bean synthetics are influenced by the nature of the pollinating system. Bee activity is a variable that influences heterozygosity and there is a mixture of selfing and crossing. Also, hybrids will set more seed than inbreds, and this will be even more pronounced with less bee activity. The proportion of selfed seed may be higher with hybrid than inbred plants. Wright (1977) found that the F (inbreeding coefficient) of a synthetic variety of faba beans approached an equilibrium value which depended largely on the amount of cross fertilization and little on higher seed total or selfing on less inbred parents. He suggested bee hive placement in seed production fields could reduce this value and hence increase heterosis. This was also suggested by Toynbee - Clarke (1971).

Bond (1982) reviewed the use of synthetics in faba beans. He proposed that a synthetic cultivar of faba beans is "any population which has been constituted from a limited number of distinct and well evaluated components." This was because synthetic faba bean cultivars (1) have not all combinations between components because of some selfing as a result of bee pollinating and (2) there usually is no testing for general combining ability of components. Synthetics are being developed at PBI and also Hohenheim GFR (Poulsen 1980b), and Gotha, GDR (Poulsen 1980a), and at Copenhagen, Denmark (Poulsen 1980b). Bond (1982) reported that synthetics outyielded the mean of their components but not always outyielded the best component.

Hybrid vigor should be expressed most with F_1 hybrids, especially for faba beans where synthetics would have a degree of self-pollination. For commercial production, a stable cytoplasmic - genetic male sterility is needed for seed production with V.faba. Bond et al. (1964 a,b) reported a cytoplasmic - genetic male-sterile named 447. Berthelem and Le Guen (1975) have reported another cytoplasmic - genetic male-sterile named 350. Both these systems are unstable and are sensitive to the environment. Environmental effects have been found to be linked to a modification in the cytoplasmic-genetic information transmitted to the progeny (Duc 1980). Researchers have searched for a more stable form of cytoplasmic - genetic male sterility through use of selection within sterile lines and mutagenesis with no success to date (Duc 1981; Thiellement 1979). Both sterile cytoplasm 447 and normal cytoplasm have been used for this work.

Although no system for commercial production is available, researchers have demonstrated hybrid vigor in faba beans. Picard (1960) found most F_1's superior to the populations the inbreds were derived from. Bond et al. (1964a, 1966) found significant yield advantage of hybrids over synthetics and inbred lines. One known effect of heterozygosity is increased autofertility because of greater pollen production (Kambal et al. 1976; Drayner 1956).

Many faba bean workers feel that the partially outcrossing of faba beans with it being between autogamy and allogamy is a detriment to genetic improvement and changing it to an obligate autogamous plant would make for easier improvement (Kambal et al. 1976; Lawes 1980; Poulsen 1976). However, autofertility is only part of the answer, also involved are closed flowers (Poulsen 1976; Knudsen and Poulsen 1981) and other factors of cleistogamy which would insure selfing in the presence of pollinators. These factors are not linked with autofertility and will need to be combined to produce a truly autogamous plant. To make faba beans an obligate autogamous plant would preempt use of synthetic varieties and make use of recurrent selection very difficult. If the flower structure is changed to discourage bee visits this will make production of hybrid seed difficult if a stable cytoplasmic - genetic male sterility is found.

Selection and Testing

Selection and breeding procedures vary with the objectives and type of cultivar desired. Fig. 1 shows a generalized scheme of the breeding program at ICARDA. The program has produced relatively homogeneous lines with inbreeding during the selection process (Hawtin 1982). The use of Brassica campestris to control pollination has resulted in the reduction of intercrossing between lines grown for seed increase.

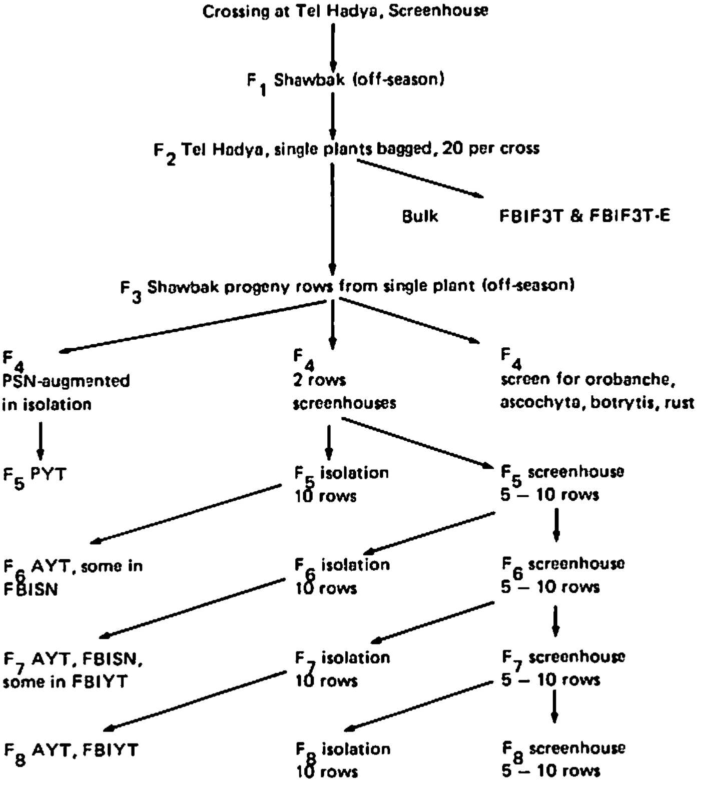

Fig. 1. Flow of breeding material in the ICARDA program.

The procedure is to make the crosses and produce F_2 populations in the off-season at Shawbak, Jordan (Fig. 1). These F_2 populations are then grown in the main season with 20 - 25 plants bagged with frost tolerance and vigor selection (starting next year we plan to grow F_2 populations in B. campestris isolation plots). Seed from each F_2-derived line is increased in the off-season in Shawbak, Jordan to produce an F_2-derived line in the F_4. A bulk of the F_3 from some crosses (with enough F_3 seed) is entered in the $FBIF_3T$ or $FBIF_3T$-E ($FBIF_3T$ = Faba Bean International F_3 Trial). Important modifications would be the initial screening of F_2 populations for disease resistance in nurseries with artificial inoculation and for broomrape in fields with uniformly high infestations of O. crenata. Also, mass selection with and without progeny testing with recombination in the off-season would be an effective way to handle varietal crosses to produce a cultivar with heterotic potential.

F_4 seed of lines would normally be planted in a two-to-three row preliminary screening nursery in an augmented design. One modification would be to now do this with B. campestris surrounding blocks of plots. This would allow pollination control and provide uncontaminated seed for the first yield trial. Also, seed is planted in the screenhouse for each line to produce seed for isolation and the screenhouse the next year. With crosses for disease and broomrape resistance a row is grown for evaluation of resistance or tolerance. At the F_4 stage additional single-plant selections can be made if unique types show up, with the effect of delaying testing procedures one year and two generations. The F_5 is tested in preliminary yield trials, usually at two environments, and lines advanced go to the advanced yield trials in the F_6 with two to three locations. For F_6 and later generations, seed for yield trials comes from isolation plots. In the F_7 lines are tested in the FBISN (Faba Bean International Screening Nursery) and in the F_8 in the FBIYT (Faba Bean International Yield Trial). These are internationally distributed nurseries and are used for testing material for use in national programs. Additionally, lines would continue in the advanced yield trials one to two years.

Recurrent Selection and Combining Ability Tests

Recurrent selection is a procedure to increase the frequencies of desirable alleles and gene combinations by providing recombination among lines derived from different foundation plants while maintaining genetic variability. It is important not to have such high selection intensities so as to maintain variability for future progress. Recurrent selection involves deriving progenies from a population, testing these and then recombining selected progenies to start the process again. Different types of recurrent selection are identified by the type of progenies tested and the type of seed recombined (Hallauer and Miranda 1981).

Rachie and Gardner (1975) proposed several schemes for partially outcrossing grain legumes. These involve both genetic male sterility and insect pollination as used with cowpeas at IITA. Khan (1973) proposed a method of developing random mating composites of pigeonpea with bee hives for recombination and a polycross nursery to develop progenies for testing. Nassib et al. (1979) described populations set up for recurrent selection in faba beans. They found these populations gave few lines with good performance (Nassib and Khalil 1982). Reasons suggested were (1) choice of population components, (2) small size of the population, and (3) low percentage of cross-pollination. These results emphasize the need to begin with the proper components and to maintain enough variability so gene frequencies are not fixed. Also, steps need to be taken to ensure recombination so unfavorable linkages are broken.

Three major factors have to be considered for recurrent selection with faba beans: (1) obtaining any type of testcross progeny for testing will be difficult, (2) recombination will be less than complete because of less than 100% outcrossing, and (3) seed from a single plant will not be sufficient for effective replicated testing. One proposed type of recurrent selection is a modified S_1 recurrent selection (Fig. 2). Obtaining S_1 progenies solves the problem of producing testcross progeny. The modification is to grow the S_1 seed from a plant in a row and bulk seed from a row to form a S_1 line bulked in the S_2 to obtain sufficient seed for replicated testing. This system would require four seasons per cycle and two years per cycle if recombination can be done in the off-season with bees.

Testing for combining ability is difficult, if not impossible, in faba beans. Because of the pollinating system, to produce any but polycross-type progenies would require hand crossing, an impossible task for replicated testing of many lines. A polycross might be produced by planting many replicates of single plants of test lines and bulking seed from each line. This will still show the effect of selfed seed from the lines even with bees in screenhouses. If an effective male gametocide was found the testcrosses could be made with many lines with testers by spraying test entries so seed produced would be from crosses with testers. Bond (1967) has found though, that there was a significant regression of F_1 yields on mid-parent values.

Adaptability

Stability of performance of lines is very important to an institute such as ICARDA. The performance of lines over a series of environments will affect breeding strategies as to when to start multilocational testing and whether lines need to be selected for different regions separately. Faba bean adaptation trials have been conducted by ICARDA four years with data for three years received till now. Table 3 gives the mean yields of entries for two years at different locations. Violetta di Policoro showed a high rank at all locations while Hudeiba 72 ranked low at most locations. Otherwise, lines showed a narrower range of adaptation related to their origin. Examples would be Syrian Local Large in Syria and Lebanese Local

Table 3. Mean seed yield (Y = kg/ha) and rank (R) of entries in the FBAT at different locations, 1979/80 and 1980/81.

ILB No.	Genotype	LEBANON Terbol		SYRIA-Tel Hadya Irrigated		SYRIA-Tel Hadya Rainfed		ETHIOPIA Debre Zeit		ITALY Bari		LIBYA[1]		EGYPT[2]		SPAIN[3]		MEAN	
		Y	R	Y	R	Y	R	Y	R	Y	R	Y	R	Y	R	Y	R	Y	R
1818	Jordan Local	3215	4	3397	8	2305	7	1443	4	2511	9	1353	9	2627	5	1291	9	2268	9
1819	Giza 3	2586	8	3239	9	2164	9	1739	2	2846	7	1818	3	2905	4	1644	7	2368	6
1820	Giza 4	2532	9	3564	7	2318	6	1500	3	2958	6	1722	5	2983	2	1665	6	2405	5
1817	Lebanese L.L.	3493	1	4434	3	2411	5	529	9	3375	5	1856	2	2540	6	2680	1	2665	2
1816	Lebanese L.S.	3056	5	3846	6	2290	8	576	8	2725	8	1399	8	1877	10	1193	11	2120	10
1821	Turkish Local	3415	3	4229	5	2479	3	239	10	3783	2	1454	7	1452	11	1549	8	2325	7
1266	Aquadulce	2852	6	4419	4	2456	4	787	7	3769	3	1986	1	2045	9	2341	3	2582	3
460	Hudeiba 72	1315	11	1521	11	1260	11	1422	5	1212	11	1121	11	2490	7	1196	10	1442	11
1811	Syrian L.S.	2329	10	3042	10	1662	10	2404	1	2225	10	1519	6	3191	1	1871	5	2280	8
1814	Syrian L.L.	2843	7	4631	1	2707	1	162	11	3640	4	1235	10	2065	8	2311	4	2449	4
1822	Violetta di Policoro	3459	2	4464	2	2702	2	1272	6	3804	1	1748	4	2938	3	2411	2	2850	1

1. Mean of Zawia and Tripoli.
2. Mean of Giza and Sids.
3. Mean of Sevilla and Cordoba.

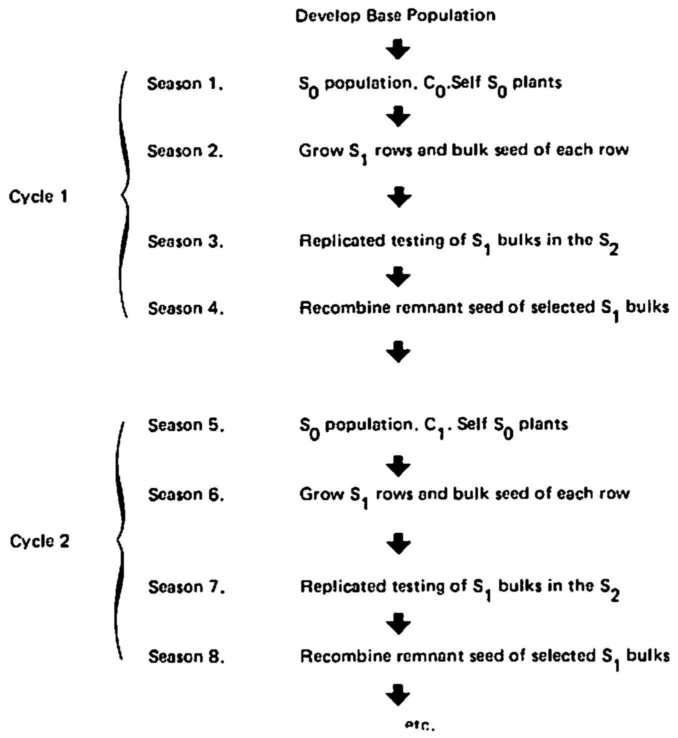

Fig. 2. S_1 recurrent selection in faba beans at ICARDA. Progeny tests are of S_1 bulks in the S_2 rather than of single S_1 plants.

Large in Lebanon. Elegant 5 MCI (ILB 1805) a selection at Douma, Syria, by the Syrian Agricultural Research Directorate has shown high rankings (of 1 or 2) for 7 of 10 and exceeded the local check in 8 of 10 environments for the FBIYT-L 1979 to 1981 (Fig. 3). Lines like Violetta de Policoro and 5 MCI may be worthwhile to investigate to try to determine if there are any traits such as yield components or their compensation which set apart lines with wide adaptability.

Correlations are another measure of adaptability of a set of lines over locations. Table 4 gives correlations between entries at different locations for the FBAT, FBIYT-L, and FBIYT-S for the two years (1979-81). One obvious relationship is among the two Syrian environments and Lebanon, all three have very high correlations. The correlations of the three previous environments with Egypt and Ethiopia are negative and nonsignificant except for the FBIYT-L.

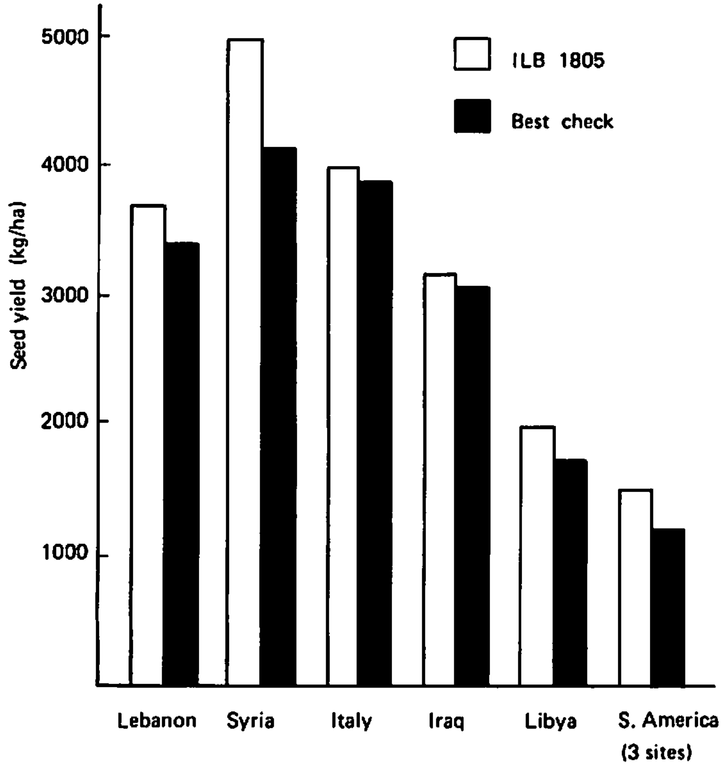

Fig. 3. Seed yield of 5MCI Elegante (ILB 1805) and the best check in the international large-seeded yield trial, (1979/80 and 1980/81), except for S. America (1980/81).

The relationships between entry yields in locations of subregions are not high although there are some exceptions with stable and high yields over environments. von Kittlitz (1982) proposed a "worldwide system of recurrent selection" with evaluation at regional centers and a central center with recombination between the best strains at different centers. One proposal would be to test material from ICARDA in North Africa and the Nile Valley much sooner, such as at the preliminary yield or even preliminary screening stage. This may give a better chance to find widely adaptable lines, and also to find segregants with better adaptation to each subregion.

Table 4. Correlation between the seed yield of entries at different locations during 1979-81.

Locations	Syria - Tel Hadya Irrigated	Syria - Tel Hadya Rainfed	Ethiopia Debre Zeit	Italy Bari	Libya	Egypt	Spain
A. FBAT							
Lebanon-Terbol	0.86**	0.85**	-0.50	0.80**	0.40	-0.29	0.43
Syria-TH-Irrigated		0.94**	-0.62*	0.96**	0.47	-0.35	0.68*
Syria-TH-Rainfed			-0.60*	0.39**	0.40	-0.32	0.53
Ethiopia-Debre Zeit				-0.59	0.09	0.85**	-0.26
Italy-Bari					0.54	-0.36	0.67*
Libya						0.26	0.59
Egypt							0.12
B. FBIYT-L							
Lebanon-Terbol	0.49	0.31	0.40	0.61	0.52	0.40	-0.12
Syria-TH-Irrigated		0.85**	0.84**	0.17	0.66**	0.45	0.15
Syria-TH-Rainfed			0.77**	0.01	0.70**	0.55*	0.22
Italy-Bari				0.02	0.83**	0.64*	0.35
Iraq + Oman					0.01	-0.18	-0.43
Argentina+Chile+Peru						0.66**	0.42
Libya							0.42

	Lebanon Terbol	Syria - Tel Hadya Irrigated	Syria - Tel Hadya Rainfed	Egypt	Cyprus+Spain+Turkey+Lattakia
C. FBIYT-S					
Ethiopia-Debre Zeit	-0.79**	-0.71**	-0.67**	0.36	-0.69**
Lebanon-Terbol		0.91**	0.83**	-0.14	0.72**
Syria-TH-Irrigated			0.89**	-0.17	0.76**
Syria-TH-Rainfed				-0.16	0.66
Egypt					-0.08

*, ** Significant at 5% and 1% levels, respectively.

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Discussant's Remarks on Faba Bean Breeding

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During the last five years excellent progress has been made in breeding for resistance to diseases and *Orobanche* and transferring the resistance genes to adapted varieties of faba beans. In Egypt, F_5 lines in a cross between ILB 938 (resistant to *Botrytis*) and Giza-3 (commercial variety) showed both resistance and adaptation. Some F_2 material from crosses comprising three diverse cultivars (Giza-3 from Egypt, a local landrace from Syria, and Marris Bead from U.K.) and ILB 938 from Columbia had even higher level of resistance. This indicates the importance of compound crosses including landraces that had been under selection pressure for *Botrytis* resistance in their environments for long. For *Orobanche* resistance, F_{402} has proved stable in Egypt, Syria, Lebanon, and Spain and is planned to be grown on about 60,000 ha in Egypt by 1986. Work is under way to combine genes for *Orobanche* and *Botrytis* resistance in one variety. Also studies have been initiated in collaboration between the national and regional programs of Egypt and ICARDA to investigate the mode of gene action for resistance to *Botrytis*. Diallel crossing comprising resistant material identified in both programs is under way.

On the other hand, breeding for yield and stability ascribed to inherent factors in faba bean (other than reaction to diseases and pests) has achieved little success. Although different breeding strategies and methods have been tried and reported, the crop is still very sensitive to environmental changes. The available variability in germplasm does not seem to be enough to tackle the problem of low yield and instability. Crosses between entries belonging to the four botanical types, i.e., *major*, *equina*, *minor*, and *paucijuga* did not increase seed yield. Mutation breeding has received little consideration due to limited resources of breeders. The only one induced mutation available to breeders at present is the determinate type. Spontaneous mutants are being searched in our breeding material in Egypt, though not much can be expected from this source. A well planned long-term mutation breeding program sponsored by ICARDA in collaboration with national programs for screening and testing could provide useful material for autofertility and/or less internode competition or nonsensitivity to environments. Sources of resistance not yet identified for diseases, e.g., root rots and powdery mildew and for stem nematodes may also be obtained. Mutation breeding will not replace other methods but will function side by side with them.

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Problems and Prospects of Wide Crossing in the Genus *Vicia* for the Improvement of Faba Bean

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The Leguminosae are a difficult group for achieving wide crosses. McComb (1975) and Smartt (1979) concluded that many of the successes reported in the literature either involved parents whose status as distinct species or distinct genera is doubtful, or are not true hybrids but result from patrocliny, apomixis, or faulty emasculation. However, some new, well-authenticated interspecific hybrids have recently been produced by conventional sexual means, in both grain and pasture legumes, for example, *Trifolium* (Williams 1978), *Ornithopus* (Williams and de Lautour 1980), *Arachis* (Sastri and Moss 1982), and *Glycine* (Newell and Hymowitz 1982). Success was due to careful manipulation of conditions under which fertilization, embryo development, and "germination" took place, assisted in some cases by the large scale on which interspecific crosses were made.

Cubero (1982) reviewed the work on producing pro-interspecific hybrids involving *Vicia faba*. His review suggests that pollen tubes are capable of reaching and fertilizing the ovules in at least some of the interspecific combinations, but postzygotic barriers prevent development of hybrid embryos beyond the few-celled stage.

The number of species included in *Vicia* section *Faba* has varied, because of different opinions about both the circumscription of the section and the delimitation of some of its species. A species name may therefore be used by some authors in a broad sense, to include taxa which others recognize as species in their own right. The latter may not all behave in the same way in a crossing program. It is therefore necessary to know the taxonomic background of section *Faba* in order to interpret differing results from crosses made within the section.

As defined by Kupicha (1976), section Faba contains three rather different groups of species:

1. V.faba: erect, robust, annual with broad leaflets, lacking tendrils. Chromosome number 2n = 12, with 2 long metacentric and 10 shorter acrocentric chromosomes.

2. The V.narbonensis group: erect annuals with broad leaflets and poorly developed tendrils. Chromosome number 2n = 14, all chromosomes submetacentric to subacrocentric and smaller than those of V.faba.

3. V.bithynica: annual with narrow leaflets, climbing by well developed tendrils. Chromosome number 2n = 14, chromosomes shorter and more acrocentric than those of the V.narbonensis group.

Vicia faba is known only in cultivation. The domesticated forms are divided into four partially distinct but overlapping entities: major, equina, minor, and paucijuga. The small-seeded taxa minor and paucijuga are generally considered closest to the missing wild ancestor of V.faba and hence to other species of Vicia.

The boundaries of taxa in the V.narbonensis group are also poorly defined. V.narbonensis itself is widespread and variable throughout the Mediterranean area, where it occurs as a cultivated plant, as a weed, and in primary habitats. Distinctive variants include those in which either the juvenile or the adult leaflets are crenate or serrate: the former are treated as var. salmonea but the latter considered a distinct species, V.serratifolia, by Schafer (1973). Plitmann (1970) earlier queried the specific status of both V.serratifolia and the Middle Eastern V.galilaea, since intermediates between these taxa and V.narbonensis are common in Turkey. V.hyaeniscyamus, also described from the Levant, may not be specifically distinct from V.galilaea (Schafer 1973). On the other hand, V.johannis, a taxon ignored by most workers except those at Gatersleben and Southampton, is distinct from V.narbonensis on the basis of multivariate morphological analyses (Birch, N., Tithecott, M. and Bisby, F.A. 1983, unpublished) and easily recognizable in living material by its pubescent leaves and yellowish-cream flowers with wing spots which eventually turn dark brown (reminiscent of the wing spots of V.faba). V.johannis occurs wild and possibly also in cultivation in the Middle East, the USSR, and southern Europe (Schafer 1973; Birch, N., Tithecott, M. and Bisby, F.A. 1983, unpublished).

Vicia bithynica is wild throughout Europe and the Middle East. The species itself is clearly defined morphologically, though its inclusion in section Faba is more controversial.

In April 1982, at the request of ICARDA, we started a project to synthesize hybrids between Vicia faba and other species of Vicia, in order to expand the gene pool available to faba bean breeders. We concentrated initially on paucijuga, minor, and equina types of V.faba, since it seemed that these might cross with other species more readily than would the highly evolved major types. We included as much diversity as possible of the other species in section Faba, but have no accessions which conform to the descriptions of V.serratifolia or V.hyaeniscyamus. We will therefore discuss our results in the general context of barriers to wide crossing and techniques for overcoming these barriers.

Barriers to Interspecific Hybridization and Gene Exchange

Pollen Germination

Interspecific crosses often fail because pollen fails to germinate on the alien stigma. This problem seems to be absent in many of the crosses we have made within Vicia section Faba. However, at least in V.faba, there is a barrier to pollen germination on stigmas of unmanipulated flowers. Kambal et al. (1976) found that the stigma of this outcrossing species is covered, to a greater or lesser extent, by papillae and enclosed in a membrane which has to be ruptured to achieve the close contact between pollen grains and stigma necessary for germination. In the field this is brought about by bees tripping the flower. There are no comparable studies on the stigmas of the other species of section Faba which, unlike V.faba, are mostly self-pollinated. When hand-pollinating, we find that if pollen is applied with a pressure judged sufficient to rupture both membrane and papillae, the pollen germinates and pollen tubes penetrate the stigma successfully.

Pollen Tube Growth

Another common reason for failure of interspecific crosses is that pollen tubes either grow slowly or cease growth altogether in the alien style. van Cruchten (1974) crossed V.faba with V.narbonensis and found that pollen tubes of both species grew more slowly in interspecific combinations. He also found that with some lines of V.narbonensis pollen tube growth ceased very early, whereas with other lines of V.narbonensis, pollen tubes reached the alien ovules. The results were similar whichever the direction of the cross. Table 1 gives a brief summary of our data on pollen tube growth.

V.bithynica and the V.narbonensis group clearly differ in other behavior when crossed with V.faba. With V.bithynica, more pollen tubes are found around the alien ovules when V.bithynica is the female parent than in the reciprocal cross, whereas the V.narbonensis group is more successful as male than as female parent. There also seem to be some differences within the V.narbonensis group. Pollen tubes of V.faba never reached the ovules of V.galilaea or V.johannis (though rather few pollinated pistils were studied for these two combinations), whereas they reached the ovules of V.narbonensis in nearly a third of the crosses made. As well as these differences in crossability between species, we suspect that there are comparable differences within at least some of the species in our study.

Table 1. Results of interspecific pollinations in *Vicia* section *Faba*.

		V.n.	V.g.	V.j.	V.b.
V.faba as seed parent	Percent pistils with pollen tubes around ovules	52	67	41	13
	Percent pistils containing fertilized ovules	10	53	38	7
V.faba as pollen parent	Percent pistils with pollen tubes around ovules	29	0	0	53
	Percent pistils containing fertilized ovules	6	0	0	62

V.n. = *V.narbonensis*; V.g.= *V.galilaea*; V.j.= *V.johannis*; V.b.= *V.bithynica*.

These results show that slow pollen tube growth may be a barrier to interspecific hybridization in *Vicia* section *Faba* but, provided crosses are made in the appropriate direction, this barrier may be circumvented.

Fertilization

There are relatively few reports of fertilization failing once pollen tubes have succeeded in reaching the ovules. This is, however, the basis of the self-incompatibility system in *Theobroma* (Cope 1962) and has also been reported in a few interspecific crosses, e.g. *Rhododendron* (Kho and Baer 1970).

Table 1 summarizes our data on fertilization following interspecific pollinations between *V.faba* and the other species. These results will be published in greater detail elsewhere. In most combinations, the percentage of pistils containing fertilized ovules correlates very well with the percentage of pistils in which pollen tubes had reached the ovules. The exception is *V.narbonensis* x *V.faba*. Regardless of the direction in which this cross is made, the percentage of fertilizations is much less than would be expected from the frequency with which pollen tubes reach the ovules. Pollen tubes were observed growing past the alien ovules, without turning to enter their micropyles, suggesting that, whatever the attraction is that causes pollen tubes to enter micropyles, it functioned less efficiently than usual in this cross.

Fertilization therefore succeeds in most of the interspecific crosses involving V.faba in which the pollen tubes reach the ovules, but in V.faba x V.narbonensis the low frequency of fertilization constitutes a further barrier to hybridization.

Embryo and Endosperm Development

The endosperm is another major site at which interspecific hybridization may be blocked. Hanelt et al. (1972) and workers at Dijon (van Cruchten 1974) found that although some pods developed for about 6 weeks after interspecific crosses involving V.faba, at the end of this time all the seeds were dead. The only detailed embryological studies of wide hybrids involving V.faba seem to be those of Gritton and Wierzbicka (1975) on Pisum sativum x V.faba. Here the putatively hybrid embryos developed slowly, but apparently normally, until they rapidly collapsed 6-7 days after fertilization. The endosperm, on the other hand, was abnormal from the time of its first nuclear division, and this was considered to be the primary reason for collapse of the hybrid embryos.

Our studies on pistils sectioned 7 days after interspecific pollination showed that at this stage those ovules which had been fertilized contained embryos with several cells and also several endosperm nuclei. We have not yet seen nuclear divisions in either embryos or endosperms, so we cannot comment on whether any abnormalities are present. Pods harvested 4 weeks after interspecific pollination contained very few embryos, which were all necrotic and had not developed beyond the globular stage. The first serious barrier to production of interspecific hybrids involving V.faba thus concerns development of embryo and endosperm during the period from 1 to 4 weeks after pollination.

Postgermination Developmental Abnormalities

Interspecific and sometimes even intervarietal hybrids in the Leguminosae may be chlorotic. Cubero (1982) lists additional examples from the V.sativa complex. Early embryo development may therefore not be the only critical stage to surmount in producing hybrids involving V.faba.

Hybrid Sterility

Many interspecific hybrids are sterile because chromosomes from the parental species do not pair and disjoin regularly at meiosis in the hybrid. Until interspecific hybrids involving V.faba are actually produced, we can only guess at the sterility and restrictions on recombination that might be present. However, the chromosomes of V.faba differ very considerably from those of both V.bithynica and the V.narbonensis group in DNA content (Chooi 1971) as well as in size and symmetry. Moreover, Giemsa banding patterns of V.faba (Dobel et al. 1973), V.narbonensis (Singh and Lelley 1982), and V.bithynica (Ramsay, G. 1983, unpublished) show no apparent homologies between chromosome arms of these three species. It is therefore likely that any interspecific hybrids will be sterile, and that recombination in between the chromosomes of V.faba and the other species will be restricted.

Prospects for Overcoming Barriers to Hybridization and Gene Exchange in Crosses Involving *Vicia faba*

Mutilations of the Pistil

Artificially shortening the style in Lathyrus produced interspecific hybrids from a cross in which pollen tubes normally grew too slowly to effect fertilization (Davies 1957). van Cruchten (1974) found that pollen applied to decapitated V.faba styles germinated and reached the ovules. Our experiments with pollination of decapitated styles, pollination directly into the locule of the carpel, and pollination of excised pistils or ovules in vitro have not been successful, but have been limited since we do not consider prefertilization barriers to be a serious obstacle to the production of hybrids involving V.faba.

Mentor Pollen

Pollination with mixtures of killed or subviable self pollen (mentor pollen) and fully viable pollen of a second species may overcome barriers to interspecific hybridization associated with failure of style or stigma to recognize foreign pollen. Mentor pollen has been used to produce hybrids which were otherwise unobtainable in Populus, where pollen failed to germinate on the alien stigma (Knox et al. 1972). Mentor pollen combined with chemical treatment and followed by embryo culture yielded hybrids in Cucumis from interspecific crosses in which pollen tube gowth was arrested in the alien style (Nijs and Oost 1980; Nijs et al. 1980). van Cruchten (1974) concluded that mentor pollen did not facilitate production of hybrids between V.faba and V.narbonensis. However, he apparently used fully viable mentor pollen, and radiation or other treatment which reduces the competitive ability of the self as compared to the alien pollen may be essential to the success of this technique, especially when ovaries contain few ovules, as in Vicia section Faba.

Mentor pollen might thus increase the numbers of hybrid embryos produced in interspecific crosses involving V.faba. It would be particularly interesting to investigate whether mentor pollen would enhance fertilization in crosses between V.faba and V.narbonensis.

Chemical Manipulations *in vivo*

Much of the information on the use of chemicals to remove or reduce barriers to hybridization consists of scattered, sometimes serendipitous, observations. Plant growth regulators are the most commonly used, but ethylene inhibitors and immunosuppressants have also been tested. They have been applied before, at the time of, or after pollination, singly or in combination. They may affect pollen tube growth, abscission of interspecifically pollinated flowers or young fruits, development of hybrid tissues in the fertilized ovules, or several of these processes jointly.

Plant growth regulators, particularly gibberellic acid, are commonly used after pollination when making wide crosses in cereals. They affect pollen tube growth (Larter and Chaubey 1965) and possibly also hybrid embryo development (Fedak 1978). Their effect on hybrid embryos is more apparent in an interspecific cross in Zinnia in which hybrid embryo and hybrid endosperm both degenerate after about a week of normal development. Indole acetic acid (IAA) applied immediately after pollination had no effect, but IAA applied 24 hours after pollination retarded embryo abortion for at least a week, so that some embryos reached a size at which they could be cultured successfully (Shahin et al. 1971). In the Leguminosae, Sastri and Moss (1982) found that when hormones were applied after intersectional cross-pollination in Arachis, the fertilized ovary survived longer, again allowing some embryos to reach a size at which they could be cultured successfully. Different hormones (auxins or cytokinins) appeared to have different effects on gynophore extension or pod production. Ackerman and Williams (1982), working on intergeneric crosses in the Theaceae, also found that the chemicals used, their concentration, and their time of application, produced different effects on seed set or fruit set, and that these effects depended also on the seed parent involved.

Ethylene inhibitors and their analogs might be expected to improve fruit set rather than numbers of hybrid embryos produced, but Nijs et al. (1980) found the opposite effect in an interspecific cross in Cucumis. Amino ethoxy vinyl glycine, an analog of a known ethylene inhibitor, applied after pollination, increased the number of hybrid embryos per fruit although relatively few fruits developed.

Immunosuppressants, particularly e-amino caproic acid (EACA), have been used sporadically to enhance production of wide hybrids ever since Bates et al. (1974) claimed that they were effective when applied to the seed parent in intergeneric crosses in cereals. Results in both cereals and other groups (e.g. Ackerman and Williams 1982) are somewhat ambiguous, though Chen et al. (1978) suggested that EACA applied before pollination increased production of hybrid seeds from the cross Vigna radiata x V.umbellata.

Much more experimental work is needed on the chemical manipulation of crossability. Results published so far suggest that each genus, species, and possibly even genotype, as well as each combination of parental species, may require different concentrations or combinations of chemicals, applied at different stages of development. Virtually nothing is known about Vicia in this regard.

Alterations of Ploidy Level or DNA Content

Crosses which are difficult or impossible at the diploid level will sometimes succeed when one or both parents are tetraploid, for example, Beta (Savitsky 1975) and Delphinium (Legro 1961). Tetraploids have been produced in V.faba and V.narbonensis by treating zygotes with nitrous oxide (results cited by van Cruchten 1974) and in V.faba by X-irradiation and colchicine treatment (cited by Poulsen and Martin 1977). The "fragility" of the V.narbonensis tetraploids prevented their use in interspecific crosses (van Cruchten 1974), and many V.faba tetraploids seem to have been sterile, short-lived, or both. A striking exception is the tetraploid line discovered after X-irradiation of 'Svalof Primus,' which has been maintained for over 15 years, has a pollen stainability around 70% and is reasonably seed-fertile (Poulsen and Martin 1977). The deleterious effects of induced tetraploidy in Vicia section Faba may therefore depend on genotype.

If the early death of hybrid embryos in interspecific crosses involving V.faba results from nuclei in embryo or endosperm not dividing and functioning normally, then crosses using induced tetraploids might be more successful. Viable hybrids are obtained from some interspecific crosses only when the correct balance of parental genomes is present in the embryo, e.g. Hordeum (Kasha and Sadasivaiah 1971), or endosperm, e.g. Solanum (Johnston and Hanneman 1982).

Cubero (1982) suggested that the collapse of hybrid embryos involving V.faba could be related to the considerable differences in DNA content between V.faba and the other species of section Faba. This could lead to difficulties in synchronizing replication and division of the very different sets of chromosomes in the hybrid nuclei. Problems of this sort are not inevitable: for example, in the hybrid Pennisetum americanum x Cenchrus ciliaris chromosomes of very different sizes co-exist and apparently function normally (Read and Bashaw 1974). Nevertheless, we intend to try crossing V.faba with species which are outside section Faba but which have DNA contents more similar to V.faba, to see if hybrid embryos can develop further in these combinations.

In vitro Culture of Hybrid Embryos

a. On artificial media. Techniques for in vitro culture of young embryos are steadily improving, but much patient experimentation is required to determine optimal conditions for each species. Important variables are legion, and include basic composition of the medium, whether solid or liquid, type and concentration of any additives, size and/or age of embryos, quantity and quality of illumination, and constant or alternating temperature. That success may eventually be achieved is shown by the work of Newell and Hymowitz (1982) on a wide cross in Glycine. After several years of work to develop suitable cultural conditions, they finally raised hybrids from ovules excised only 19 days after pollination and cultured successively on media of at least three different compositions, matched to the amount of development apparent in the hybrid tissues.

Most work on *in vitro* culture of *V.faba* has concerned long-term maintenance of callus cultures, without regeneration of plants, for cytological studies (Venketeswaran 1962; Cionini *et al.* 1978). However, Galzy and Hamoui (1981) did regenerate plants from meristems of *V.faba*. Explants of immature embryos (Pevalek *et al.* 1980) and of embryos from mature seeds (Mitchell and Gildow 1975) formed callus in culture. Working with embryos of *V.faba* excised 3 weeks after self pollination, we have produced shoots, both directly and via callus, with a frequency of 30-40% on suitable media, though roots differentiate less frequently. We are now attempting to regenerate plants from younger embryos, both by providing conditions *in vitro* which permit these embryos to develop normally through to germination, and by inducing the embryos to form callus, from which hybrid plants might be regenerated.

b. On nurse endosperm. Wide hybrids have been produced in some pasture legumes by the use of nurse endosperm. The hybrid embryo is inserted into the nurse tissue and the whole cultured on an appropriate medium (Williams and de Lautour 1980). In the Leguminosae as a whole, the endosperm is initially free nuclear, but eventually becomes cellular in most genera (Davis 1966). However, *Vicia faba* seems to be one of the species in which the endosperm remains free nuclear throughout (Kapoor and Tandon 1964). This may apply also to other species of *Vicia* as well as to other genera in the tribe Vicieae. All the successes reported with nurse endosperm involved cellular endosperm, so a suitable nurse endosperm for *Vicia* hybrids may have to be sought from a different genus. Williams and de Lautour (1980) found that *Ulex* (tribe Genisteae) provided an effective nurse endosperm for *Trifolium* (tribe Trifolieae), *Lotus* (tribe Loteae), and *Orinthopus* (tribe Coronilleae) although *Cytisus* (also in the Genisteae) did not. Evidently much remains to be learned about intergeneric interactions at this level.

Interspecific Grafting

van Cruchten (1974) has shown that *V.narbonensis* and *V.faba* can be successfully intergrafted, though interspecific hybrid embryos were not produced any more readily on the grafted scions. However, grafting onto parental stocks could be a useful means of rescuing rootless shoots which might regenerate in culture and also of overcoming problems of chlorosis which may occur in interspecific hybrids in *Vicia*. Smith (1954) successfully maintained chlorotic interspecific hybrids in *Melilotus* by grafting them onto green parental stocks.

Problems of Hybrid Sterility and Lack of Recombination

Cubero (1982) has outlined the problems that would still have to be overcome in using interspecific hybrids to improve V.faba, should such hybrids actually be produced. Addition lines, which would contain an entire chromosome from another species in a V.faba nucleus, are unstable in most crops but can be a useful tool for the isolation and identification of chromosomes carrying desirable genes. If recombination between chromosomes of V.faba and the other species does not occur, then desirable chromosome segments from the other species would have to be incorporated in the V.faba karyotype by induced translocations.

Summary and Conclusions

Prefertilization barriers are not usually an insuperable obstacle to production of interspecific hybrids involving V.faba. There do seem to be unilateral barriers among the species in section Faba, so that V.bithynica and the V.narbonensis group behave differently in reciprocal crosses with V.faba. There are also differences among the various taxa of the V.narbonensis group, with V.galilaea being the most effective and V.narbonensis the least effective in fertilizing V.faba ovules. Provided parental accessions are selected carefully, and the cross is made in the appropriate direction, hybrid embryos can probably be produced from most interspecific crosses involving V.faba. It may be possible to increase the numbers of these embryos by applying mentor pollen and/or treating with chemicals such as plant growth regulators.

A major barrier to hybridization occurs after fertilization, during the first few weeks of seed development. Scattered reports suggest that the problem may be malfunctioning of the hybrid endosperm rather than inviability of the hybrid embryo. This problem might be overcome by working at the tetraploid level, or by culturing hybrid embryos on a nurse endosperm, but success seems most likely if the hybrid endosperm can be bypassed altogether and appropriate conditions developed for in vitro culture of ovules or very young embryos. Reports of such work with undifferentiated embryos, of both legumes and other crop plants, suggest that this may be difficult, and is more likely to succeed via production of hybrid callus and regeneration of plants from such callus.

If sexual hybrids cannot be produced, then the possibility of achieving interspecific transfer of genes by the parasexual means of protoplast fusion should be explored. This requires the development of distinctive cultural techniques for each crop species, so it is generally accepted that the feasibility of sexual hybridization should be investigated first. Since there is reasonable evidence that fertilization does occur in vivo in crosses involving V.faba, we are currently concentrating on production of sexual hybrids.

Further problems in transferring desirable genes to V.faba are likely to arise as a consequence of the differences between the chromosomes of V.faba and the other species. However, rapid developments of in vitro techniques for maintenance and multiplication of hybrid tissue and induction of nonhomologous recombination mean that even a single viable hybrid callus could make possible the transfer of genes between species hitherto isolated genetically.

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Second Session

Breeding Kabuli Chickpeas for High Yield, Stability, and Adaptation

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Joint contribution from ICARDA and ICRISAT.

Chickpea (Cicer arietinum L.) is the third most important pulse crop in the world and first in the ICARDA region. The biological value of chickpea protein is considered to be the best among the food legumes.

Chickpea is grown during winter in the Indian subcontinent, Ethiopia, and Latin America and during spring in the Mediterranean region. It is mainly cultivated as a rainfed crop but approximately 10% of the area is irrigated. Most of the cultivation takes place in areas between 15 and 40°N of equator. Thus the thermo- and photoperiodic regimes differ greatly. The crop is comparatively drought tolerant and matures in about 80 to 200 days; therefore it fits well in many cropping systems. Ascochyta blight and leaf miner are major problems in the Mediterranean climate, and root rot, wilt, and Heliothis in tropical and subtropical climates. Thus, growing conditions are so variable that a range of cultivars will have to be developed to suit the different agroecological situations.

The causes for low yield have been discussed in detail earlier (Singh and Auckland 1975). However, a few deserve mention here. First, high-yielding cultivars have not been developed in most countries, so farmers still use landraces. Second, cultivation practice has not changed, except that farmers have begun to use fertilizer. Third, diseases continue to devastate the crop periodically. Fourth, lack of mechanization of operations has also contributed to low priority assignment to this crop by farmers.

In spite of several production problems, chickpea has good prospects for increased production. First, it has been demonstrated that yield could be increased up to 100% by adopting winter sowing in the Mediterranean region where the crop is currently spring sown (Hawtin and Singh 1983). Syria has already taken a lead by releasing ILC 482 for winter sowing. Second, the fallow land in cereal-fallow rotation in West Asia and North Africa could be utilized for sowing winter chickpeas and thereby production can be increased. Turkey has already shown the way and has increased its annual average chickpea production from 81,000 tonnes during 1948-52 to 280,000 tonnes in 1981. Third, wherever possible, growing chickpeas with irrigation will increase the productivity. The per hectare productivity (about 1700 kg/ha) in Egypt is the highest in the world. The crop is solely grown with irrigation. Fourth, the research input, though still grossly inadequate, has increased manyfold at national and international levels in recent years and is bound to have an impact on chickpea production.

Area and Production of Chickpea

Area, production, and productivity of chickpeas (both desi and kabuli) in the world, in the ICARDA region, and in some major chickpea-growing countries for 1948-80 are shown in Table 1. The world production of chickpeas increased by 25% in 30 years and almost all of it came through increased productivity. In the ICARDA region the production increased by 11% in the same period and all of it came from increased area; in fact, the per hectare yield has been reduced by 1.6%. The population increase has outpaced the increased chickpea production, therefore per caput availability of chickpeas has been reduced.

Area and Production Under Kabuli Chickpea in the World

No precise estimate is available on the proportion of area and production of kabuli-type chickpeas in the world. Based on a few literature reports available, personal discussions, and our own experience, it appears that in 1981 the area was approximately 1.143 million hectares and production, 0.870 million tonnes (Table 2). Thus kabuli chickpea occupied abut 12.5% of the world area and contributed 14.2% to the world production of chickpeas in 1981.

Breeding Objectives

The overall objective of ICARDA's breeding program is to increase kabuli chickpea production in the world. This we endeavor to achieve through the supply of early and advanced segregating populations and elite lines to the national and regional programs. In view of the varied conditions under which kabuli chickpeas are grown, the breeding objectives have been categorized as under:

Table 1. Average area, average production, and average yield of chickpea in world, ICARDA region, and major producing countries(4 years averages for 1948-80).

Country	1948-52			1961-65			1966-70			1971-75			1976-80		
	A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y
World	10187	5385	5.3	11839	7029	5.9	10247	6210	6.1	10140	6267	6.2	10263	6745	6.6
Algeria	24	11	4.5	21	10	4.7	30	15	4.8	28	12	4.5	39	21	5.6
Egypt							4	6	1.9	3	6	17.4	5	9	16.9
Libya										1		5.4			11.8
Morocco	81	39	4.8	136	65	4.8	116	77	6.8	116	83	6.9	67	42	6.1
Sudan	3	3	9.8	2	2	7.1	2	2	8.8	2	2	10.1		3	9.3
Tunisia	16	6	3.6	21	8	3.8	25	10	3.9	27	17	6.2	38	23	5.7
Cyprus										1	0	4.0	1	1	6.2
Iran	60	43	7.2	90	45	5.0	98	49	5.0	54	37	6.8	37	41	11.2
Iraq	3	2	6.0	5	3	6.2	5	4	7.1	8	4	5.7	14	9	5.8
Jordan	4	2	5.4	6	4	6.7	3	2	5.4	7	3	5.9	2	1	3.6
Lebanon	2	2	9.6	1	1	8.8	3	2	7.1	3	2	6.5	1	2	18.4
Pakistan	1073	658	6.1	1225	675	5.5	1073	572	5.4	998	543	5.4	1123	550	4.9
Syria	29	16	5.5	41	26	6.4	42	36	8.1	55	33	6.4	57	35	6.6
Turkey	80	81	10.2	86	89	10.3	88	102	11.6	153	175	11.7	174	211	12.0
ICARDA Region	1375	863	6.2	1634	928	5.7	1489	877	5.9	1456	917	6.3	1558	948	6.1
Ethiopia	261	154	5.9	272	165	6.0	280	173	6.2	301	218	7.2	157	95	6.1
Mexico	125	92	7.3	134	118	8.8	182	144	8.0	230	202	9.5	83	226	11.7
Burma	87	31	3.5	117	56	4.8	109	62	5.6	154	71	4.6	141	182	5.8
India	7763	3989	5.1	9257	5537	6.0	7822	4731	6.1	7549	4599	6.1	7835	5172	6.6
Spain	354	141	4.0	237	124	5.2	200	126	6.3	144	77	5.4	105	62	5.9

A = Average area (x 1000 ha); P = Average production (x 1000 tonne); Y = Average yield (x 100 kg/ha).
Source: FAO Production Year Book.

Table 2. Approximate area and production of kabuli-type chickpea in the world during 1981 as derived from the actual estimates of area and production of total chickpea.

Country	Kabuli as % of total	Area (x1000 ha)		Production (x1000 t)	
		Total*	Kabuli	Total*	Kabuli
Africa					
Algeria	100	43	43	16	16
Egypt	100	8	8	13	13
Ethiopia	1	145	2	1	1
Morocco	100	32	32	6	6
Tanzania	0	27	0	8	0
Tunisia	100	52	52	32	32
Americas					
Mexico	30	238	71	258	77
Argentina	100	5	5	4	4
Chile	100	16	16	6	6
Peru	100	3	3	2	2
Others	100	23	23	12	12
Asia					
Bangladesh	5	58	3	38	2
Burma	5	177	9	98	5
India	5	6720	336	4652	233
Iran	30	39	12	43	13
Iraq	100	15	15	9	9
Jordan	100	2	2	2	2
Lebanon	100	1	1	3	3
Pakistan	5	961	48	387	19
Syria	100	78	78	53	53
Turkey	100	240	240	280	280
Europe					
Bulgaria	100	1	1	1	1
Greece	100	13	13	15	15
Italy	100	13	13	16	16
Portugal	100	29	29	7	7
Spain	100	83	83	33	33
USSR	100	1	1	1	1
World		9132	1143	6141	870

*Estimates are based on FAO Production Yearbook 1981.

Common Objectives

High yield, ascochyta blight resistance, less photoperiod sensitivity, tolerance to iron deficiency, and maintenance of existing level of protein content.

Specific Objectives

(i) For spring sowing in the Mediterranean region: suitability for earlier sowing and heat tolerance.

(ii) For winter sowing in the Mediterranean region: cold tolerance, early flowering, and monitoring Orobanche susceptibility.

(iii) Large seeded (>40 g/100 seed), avoidance of susceptibility to root rots and wilt.

(iv) For winter in the Indian subcontinent and the Nile Valley: responsive to irrigation, early maturity, and tolerance to wilt and root rots.

Future Objectives

(i) Breeding for new plant type.

(ii) Breeding for leaf miner resistance.

(iii) Breeding for high inputs.

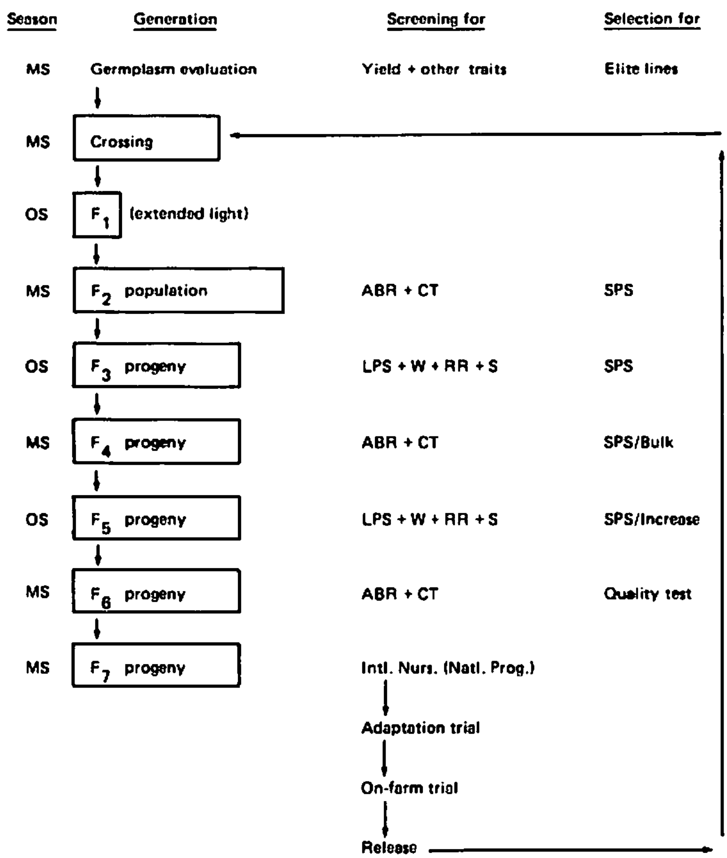
(iv) Breeding for better symbiotic nitrogen fixation.

Breeding Methods

Chickpea is a self-pollinated species. We make 300 to 400 crosses each year, of which 75% are two-way and the remaining three-way crosses in which the third parent is either a large-seeded or tall type. The F_1s are grown in the off-season with extended day length. The plants found susceptible to Orobanche parasite or showing iron chlorosis are eliminated in the main season and likewise plants found susceptible to wilt, root rots, or stunt are eliminated in the off-season. While selecting plants in segregating generations, seed size and seed type are given consideration. The quality test for protein and cooking time is introduced in F_6 generation. We have adopted three methods, namely, pedigree, modified bulk, and backcross-pedigree.

Pedigree Method

The flow chart for the pedigree method of breeding is shown in Fig. 1. This method has been adopted for the development of material for winter and spring sowing, with the main aim to incorporate genes for resistance to disease, cold, and iron deficiency, and day length insensitivity in high yield background. We have found pedigree method effective in fulfilling these goals. Common program for varietal development for winter and spring sowing is carried up to F_5 generation. Thereafter, the F_6 seeds produced from single plants in F_5 generation are divided into four parts and grown at Tel Hadya (Syria) and Terbol (Lebanon) during both winter and spring seasons. Selection is practiced at each of the four environments.

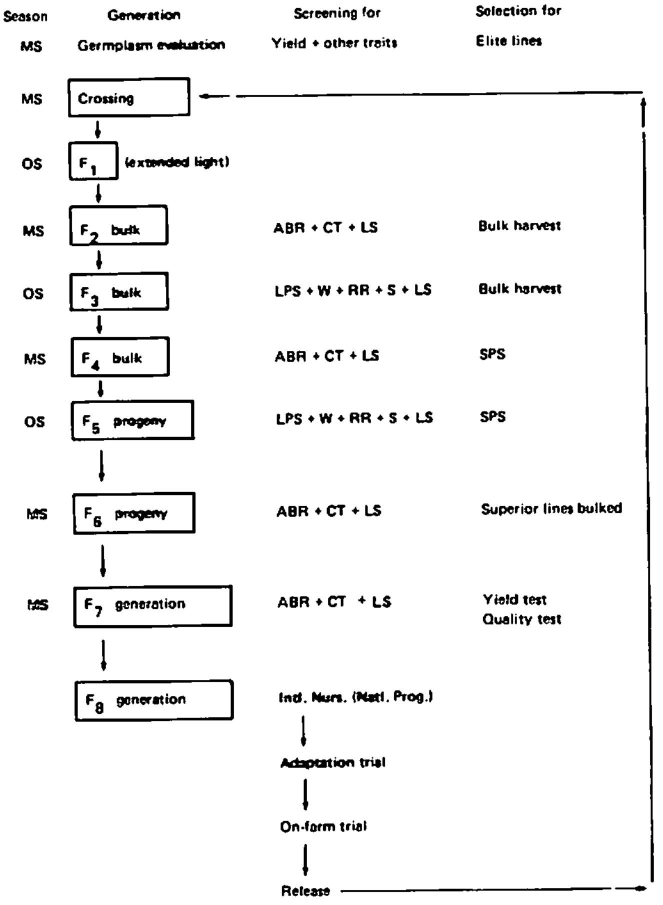


MS= Main season; OS= Off season; ABR= Ascochyta blight resistance; W= Wilt; RR= Root rots; S= Stunt; CT= Cold tolerance; LPS= Less photoperiod-sensitivity; SPS= Single plant selection; Intl. Nurs.= International nurseries; Natl. Prog.= National programs.

Fig. 1. Flow chart of pedigree method of breeding chickpea for winter and spring sowing.

Modified Bulk Method

This method (Fig. 2) has been adopted for development of large-seeded chickpeas. The major difference between pedigree and



MS= Main season; OS= Off season; ARB= Ascochyta blight resistance; W= Wilt; RR= Root rot; S= Stunt; CT= Cold tolerance; LPS= Less photoperiod-sensitivity; SPS= Single-plant selection; LS= Large seeded; Intl. Nurs.=International nurseries; Nat. Prog.= Nat. Prog.= National programs.

Fig. 2. Flow chart of modified bulk method of breeding for large-seeded chickpea.

bulk method is that the desirable plants from F_2 through F_4 generations are bulk harvested. The harvested seeds are passed through a seive and only those found larger than 40 g/100-seed weight are retained. The suitability of this method is not yet fully ascertained but the indications are that it is producing desirable results.

Backcross-Pedigree Method

This method is mainly employed to improve the local landraces that are well adapted to a given set of agroecological conditions, and seed characteristics desired by the consumer. The improvement is made for yield, ascochyta blight resistance, and cold tolerance. Two backcrosses are made and thereafter pedigree method is followed. The procedure is explained in Fig. 3.

Breeding and Selection Procedure for Different Characters

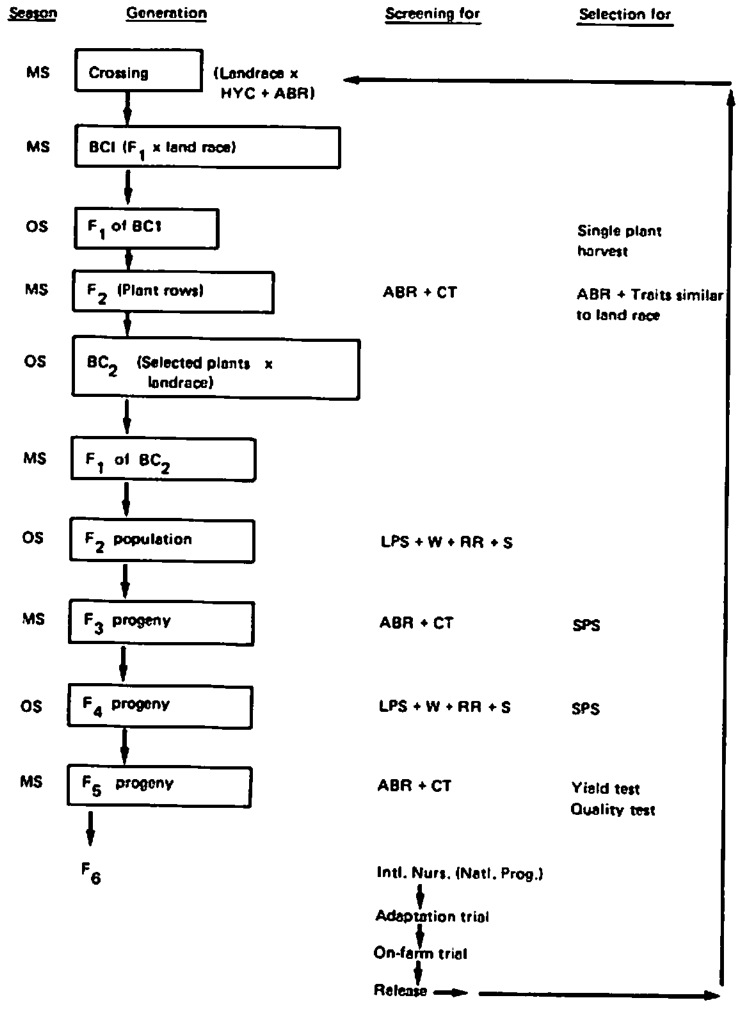
Breeding for Ascochyta Blight Resistance

A reliable screening technique for scoring germplasm and breeding lines has been developed and a number of sources of resistance identified (Singh *et al.* 1981). In addition to a single dominant gene controlling the resistance to ascochyta blight, a single recessive gene has also been found (Singh and Reddy 1983). Utilizing these sources of resistance, a breeding program was initiated in 1978 and has been going on since then. A large number of lines have been produced which are in various stages of testing in preliminary, advanced, and international yield trials.

Four races of *Ascochyta rabiei* have been identified during 1982 and 1983, and material resistant to these races is being developed.

Breeding for Cold Tolerance

Besides ascochyta blight resistance, another major requirement for the success of winter sowing is adequate level of cold tolerance in chickpeas. Therefore, over 300 germplasm accessions were screened for cold tolerance at Tel Hadya and Terbol during 1978/79 and at Hymana (near Ankara in Turkey) during 1979/80 (Singh *et al.* 1983) . But the conditions for screening were excellent at Tel Hadya during 1981/82 when 10,800 lines were screened (Table 3). There were 31 nights with subzero temperatures, which killed susceptible plants, whereas in previous years only partial damage was recorded. A large number of germplasm accessions and breeding lines showed high degree of tolerance. During the 1982/83 season the kabuli tolerant sources were sown in late October for confirmation of cold tolerance. This season turned out to be colder than 1981/82, as subzero temperatures were recorded for 43 nights. Many lines found tolerant in 1981/82 turned out to be susceptible but 10 lines were found to be tolerant. These lines are now being utilized in the crossing program.



MS = Main season; OS = Off season; ABR = Ascochyta blight resistance; W = Wilt; RR = Root rots; S = Stunt; CT = Cold tolerance; LPS = Less photoperiod-sensitivity; SPS = Single-plant selection; HYC = High yielding cultivar; Intl. Nurs. = International nurseries; Natl. Prog. = National programs.

Fig. 3. Flow chart of backcross-pedigree method for improvement of local landraces of chickpeas in yield and resistance to ascochyta blight.

Table 3. Screening of chickpea germplasm accessions, cultivars in yield nursery, and advanced breeding lines for cold tolerance at Tel Hadya, 1981/82.

Scale[1]	Germplasm accessions[2]		Cultivars		Breeding lines	
	Number	% of total	Number	% of total	Number	% of total
1	1808	26.7	0	0.0	0	0.0
2	769	11.3	1	0.3	4	0.1
3	1024	15.1	12	3.1	110	3.0
4	709	10.5	91	23.5	1126	30.9
5	774	11.4	76	19.6	1348	37.0
6	603	8.9	53	13.7	614	16.9
7	500	7.4	58	15.0	274	7.5
8	322	4.8	63	16.3	136	3.7
9	261	3.9	33	8.5	31	0.9
	6770	100.0	387	100.0	3643	100.0

1. Scale : 1= Highly Tolerant; 3= Tolerant; 5= Intermediate; 7= Susceptible; 9= Highly susceptible.
2. Accessions include both desi and kabuli.

Breeding for Less Photoperiod-Sensitivity

Most of the sources of resistance to ascochyta blight are highly photoperiod-sensitive and when sown during the off-season, from June to October, do not mature. Often the plants of F_1 generation involving photoperiod-sensitive lines as a parent fail to reach maturity. Further, these photoperiod-sensitive lines are unadapted to southernly latitudes due to late maturity. On the other hand, most of genotypes originating in West Asia or North Africa or the Indian subcontinent do mature when sown in the main as well as in the off-season indicating that they are less photoperiod sensitive and are thus better adapted. The major difference between the main and off-season is that the crop is grown with increasing day length during the main season and with decreasing day length during the off-season.

The F_3 and advanced generations are grown and screened for less photoperiod sensitivity in the off-season. Forty-five percent F_3 progenies did not mature and hence were rejected (Table 4) but rejection due to non-maturity was reduced to 24% in the F_5 generation. The material will be screened for one more time to retain only those progenies that are less photoperiod sensitive.

Table 4. Screening segregating generations of chickpeas for less photoperiod-sensitivity during the off-seasons of 1981 and 1982 at Terbol (Lebanon).

Screening	Generation	1981		1982		Total	
		PS	% PM	PS	% PM	PS	% PM
First time	F_4	1595	54	1007	56	2602	55
Second time	F_5	1765	75	56	89	1821	76

PS = progeny sown; PM = progeny matured.

Score: Physiological maturity was the criterion for selecting material for less photoperiod-sensitivity.

Breeding for Resistance to Root Rot and Wilt, and Pea Leaf Roll Virus Diseases

Root rot, and virus diseases are of minor importance in the ICARDA region, but they are important, especially Fusarium wilt, in Spain, North America, and Mexico. Since facilities for resistance breeding to these diseases are still under development, we are exercising negative selection to these diseases so that while breeding for resistance to ascochyta blight and other stresses we may not be developing supersusceptible lines to wilt complex.

Breeding for Wide Adaptation

The program endeavors to develop genetic stocks that may be suited to a wide range of environments. After screening the segregating populations at least once but more often twice for resistance to ascochyta blight, cold tolerance, and less photoperiod sensitivity, the advanced breeding lines are divided and grown at Tel Hadya and Terbol during both winter and spring seasons. The material suitable for both seasons is selected independently and then furnished to national programs in the form of international screening nursery and yield trials for spring and winter sowing. The material showing good performance across environments is considered to be widely adapted. Such material is used in the crossing program.

Breeding for Tall Type

Tall type chickpeas are better suited for mechanical harvesting. We have over 20 tall lines in our collection. Many of them have high level of resistance to ascochyta blight and cold. But all of them are late in maturity, moderate in yield and have intermediate type of seed. Past five years' breeding effort has resulted in development of tall types with true kabuli seeds. Efforts are under way to improve the yield and earliness.

Breeding for Quality Characters

Three quality parameters, namely, protein content, cooking time, and seed size, are important considerations in chickpeas. These are discussed in another paper in this volume. However, the protein content of new lines is routinely determined to ensure that it is not lower than that of local cultivars. Cooking tests are also conducted with the same objective.

Progress to Date

1. Kabuli Chickpea Germplasm Catalog

   About 4500 germplasm accessions have been assembled from 34 countries. Most of these accessions have been evaluated for 27 descriptors and a 'Kabuli Chickpea Germplasm Catalog' published. Sufficient genetic diversity was found for each of the descriptors. This gene bank is an excellent reservoir for exploitation of any new variability in the future.

2. Winter Sowing

   Advancing sowing date from spring to winter in the Mediterranean region with ascochyta blight resistant and cold-tolerant cultivars gives substantial increase in seed yield. With winter sowing, it should be possible to introduce chickpea cultivation in areas too dry for conventional spring-sown chickpeas. Adoption of winter sowing will have the following advantages:

   (i) The production of chickpeas has remained static over the past three decades, but winter sowing can change the situation and substantial increases can be achieved.

   (ii) At least part of the fallow land in the two-course rotation of cereal-fallow could be replaced by chickpeas in West Asia and North Africa.

3. Release of ILC 482 for Winter Sowing in Syria

   To demonstrate the advantages of winter sowing over spring, ICARDA/ICRISAT program collaborated with many national programs in organizing on-farm trials. In Syria, winter sowing has been compared with spring sowing in on-farm trials. The results showed that the yield of ILC 482, when winter sown, exceeded by 100% that of Syrian local landrace from Syria (Syrian Local) sown in spring. Further, ILC 482 maintained its yield superiority over Syrian local in three consecutive seasons, whether spring or winter sown (Table 5). The Syrian Ministry of

Table 5. Mean results of the on-farm chickpea trials conducted in Syria from 1979/80 to 1981/82.[a]

Year	Seed yield (kg/ha)				Percent increase of ILC 482 over Syr. Loc. in	
	ILC 482		Syrian Local			
	Winter	Spring	Winter	Spring	Winter	Spring
1979/80	1839		988	973	89	
1980/81	1685	962	500	646	161	49
1981/82	1255	875		626	100	40
Mean	1593	919	744	748	114	23

a. There were 18, 24, and 20 locations in 1979/80, 1980/81, and 1981/82, respectively.

Agriculture therefore approved ILC 482 for general cultivation in Zones B and C (<350 mm rainfall) in 1982. ILC 482 is the first chickpea cultivar to be released for winter sowing in the Mediterranean region.

4. Development of New Genetic Stock

We have extensively used the ascochyta blight resistance sources for the transfer of resistance gene into high-yielding, large-seeded kabuli lines. Through off-season advancement, we have rapidly developed new genetic stocks with desirable attributes.

(i) The original sources of resistance to ascochyta blight were late maturing, highly photoperiod sensitive, and with intermediate-type seed of small size. Now a range of ascochyta blight resistant kabuli genetic stocks have been developed with variable plant habit (conventional and tall types) with less photoperiod sensitivity and seeds of variable size (from 25 to 45 g/100-seed weight). Such sources of resistance will be more useful in the breeding program.

(ii) High yield. During the winter season of 1981/82, 63 newly developed lines were evaluated in three advanced yield trials with three checks at Tel Hadya, Lattakia, and Terbol. The five best yielding entries and ratings for ascochyta blight and cold are shown in Table 6. Very high yields (exceeding 3000 kg/ha) have been obtained. One line produced 5882 kg/ha yield at Lattakia which is perhaps the highest yield ever reported in the world. This suggests the high yield potential of chickpeas.

Table 6. Five highest yielding entries of chickpea in Advanced Yield Trails-Winter (AYT-W) at Tel Hadya (TH), Lattakia (L) and Terbol (T), 1981/82.

Trial/ Entries	Yield (kg/ha)				Evaluation at TH		
	TH	L	T	Mean	AB[1]		Cold Tol.[2]
					Veg.	Pod	
AYT-W1							
FLIP 81-10 W	2267	3648	2431	2782	3.3	5.3	4.3
FLIP 81-3 W	2298	3311	2704	2771	3.8	6.0	4.3
FLIP 81-11 W	1709	3494	2852	2685	4.5	6.8	5.0
FLIP 81-12 W	1239	3819	2796	2618	4.3	7.3	5.5
FLIP 71-15 W	1628	3976	2188	2597	4.0	6.0	6.0
Checks ILC 482	620	3110	2660	2130	4.8	7.5	5.5
ILC 3279	2230	2860	2690	2610	2.0	2.0	4.8
ILC 1929	0	0	2140		9.0		8.5
Trial mean	1000	2860	2450	2100			
SE ±	161	408	189				
CV (%)	29	29	15				
AYT-W2							
FLIP 81-41 W	2184	4519	2788	3164	3.0	3.3	4.8
FLIP 81-37 W	1723	4907	2158	2929	3.5	5.8	5.3
FLIP 81-27 W	1687	4233	2625	2848	3.3	4.0	6.3
FLIP 81-35 W	1553	4448	2481	2827	4.0	6.3	5.8
FLIP 81-24 W	1311	4611	2494	2805	5.3	7.0	6.3
Checks ILC 482	480	4580	2390	2480	5.7	8.0	6.7
ILC 3279	1840	2890	2310	2350	2.0	2.0	4.8
ILC 1929	0	0	2410		9.0		8.0
Trial mean	1430	400	2370				
SE ±	129	424	126				
CV (%)	18	21	11				
AYT-W3							
FLIP 81-60 W	1358	5882	2819	3353	4.5	7.0	4.8
ILC 3279	2427	4539	2671	3212	2.0	2.0	4.5
FLIP 81-56 W	2691	4129	2810	3210	3.0	4.3	4.5
FLIP 81-43 W	1489	5179	2546	3071	4.0	7.0	6.3
FLIP 81-57 W	1897	4954	2278	3043	4.0	4.8	5.5
Checks ILC 482	490	4680	2170		4.8	7.7	6.2
ILC 3279	2430	4540	2670		2.0	2.0	4.5
ILC 1929	0	0	2260		9.0		8.0
Trial mean	1245	4483	2252				
SE ±	158	369	207				
CV (%)	25	16	18		3.0	5.0	5.0

Underlined figures were in the top significant group.

1 AB= Ascochyta blight rating on 1-9 scale, where 1 is free and 9 dead.

2 Cold tolerance evaluated on 1-9 scale, where 1 is free and 9 dead.

5. Identificaiton of Promising Lines

Lines identified for a few key characters are listed below:

(i) Ascochyta blight resistant lines : ILC 72, 196, 201, 202, 2506, 2956, 3274, 3279, 3346, Pch 128.

(ii) Cold-tolerant lines : ILC 666, 668, 1071, 2487, 2505, 3081, 3287, 3470, 3598, 3789.

(iii) Less photoperiod-sensitive lines: ILC 215, 236, 249, 260, 482, 604, 1255, 1276, 1305, 1345, 1376, 1397, 1407, 1427, 1649, 1669, 1694, 1695, 1703, 1709, 1714, 1757, 1919, 2396, 2582, 2585, 2608, 2712, 2843, 2858, 2906, 2912, 2915, 2916, 2919, 3133, 3257.

6. Components of Seed Yield

Correlation and path coefficient studies were conducted using 150 diverse genotypes during winter and spring season of 1981/82 at Tel Hadya. The correlation of seed yield with other characters is shown in Table 7. The path coefficient study based on these characters revealed that biological yield and harvest index had direct effect on seed yield during winter season but in addition to these characters 100-seed weight also had direct effect during spring season. It is therefore concluded that biological yield, harvest index, and 100-seed weight are important yield contributing characters in kabuli chickpeas.

7. Resistance to <u>Orobanche</u>

Chickpea is highly resistant to <u>Orobanche</u> when sown during spring. In winter sowing, however, some infestation has been found. A total of 405 kabuli accessions were screened at ICARDA subsite at Kafr Antoon (Syria) during 1981/82. Most of the accessions were resistant, including 72 which were totally free of the parasite in all three replications.

8. International Trials/Nurseries

Detailed discussion on this topic has been covered in a companion paper in this workshop. Our biggest effort has been in the area of strengthening the national programs. During 1982/83, 410 sets of trials/nurseries were furnished to 35 countries on specific requests indicating the interest of cooperators in our material. A large number of genetic stocks have been included in the multilocation trials and in the on-farm trials with a view to release them as cultivars, if found suitable.

Table 7. Genotypic correlation between different characters during the 1981/82 winter and spring (in parentheses) seasons in kabuli chickpeas at Tel Hadya.

Character	Secondary branches/ plant	Tertiary branches/ plant	Plant height	Pods/ plant	100-seed weight	Biological yield	Harvest index	Seed yield
Primary branches/plant	0.468* (0.624*)	0.106 (0.172*)	-0.163* (-0.517*)	0.465* (0.644*)	-0.056 (-0.330*)	0.502* (0.469*)	0.449* (0.231*)	0.592* (0.439*)
Secondary branches/plant		0.460* (-0.468*)	-0.104 (-0.115)	0.335* (0.267*)	0.070 (-0.297*)	0.526* (0.289*)	0.343* (-0.310*)	0.557* (0.289*)
Tertiary branches/plant			-0.848 (-0.876*)	0.554* (0.471*)	-0.219* (-0.434*)	0.199* (-0.395*)	0.432* (0.714*)	0.314* (0.157*)
Plant height				-0.225 (-0.726*)	0.012 (0.650*)	0.138 (0.107)	-0.757 (-0.395*)	-0.217 (-0.092)
Pods/plant					-0.688* (-0.734*)	0.368* (0.299*)	0.546* (0.340*)	0.513* (0.337*)
100-seed weight						0.291* (0.273*)	-0.042 (0.201*)	0.699* (0.311*)
Biological yield							0.406 (0.447*)	0.936 (0.910)
Harvest index								0.683* (0.784*)

* $P<0.05$.

Looking Ahead

Some of the problems which may require attention are discussed here.

Interspecific Hybridization

Although we have found the desired level of genetic variability in the cultivated species for several characters, there may be certain opportunity where interspecific hybridization may prove useful. For example, Cicer montbretti, C.pinnatifidum, and C.judaicum have been found to be immune to ascochyta blight. Since interspecific hybridization in Cicer species has been limited between C.arietinum x C.reticulatum, the highly resistant gene for resistance to blight cannot be transferred. With the latest technique of tissue culture, it should be possible to achieve this kind of transfer.

Synthesis of New Plant Type

Past efforts to develop an ideotype for chickpea have led to no success. Here we look to plant physiologists for assistance and guidance.

Horizontal Resistance to Ascochyta Blight

With the identification of at least four races of Ascochyta rabiei in Syria, no line has been found to be resistant to all of them. This suggests that we intensify our effort towards pyramiding of resistant genes and looking for horizontal resistance.

Breeding Cultivars Responsive to Inputs

The present-day chickpea cultivars do not respond to application of production inputs. We believe that unless cultivars reponsive to inputs are developed, very high yields cannot be realized. These aspects deserve attention of breeders.

Breeding for Leaf Miner Resistance

Precise estimate of yield loss due to leaf miner (Lyriomyza cicerina L.) is lacking but indications are that it may be in the range of 15-20%. Preliminary evaluation of 1556 germplasm accessions during the 1981/82 season revealed variation in susceptibility (Table 8). Nineteen lines, identified as resistant, have been sown for reconfirmation this season. Our entomologist is trying to develop a reliable screening technique. It is also planned to score another 3000 accessions this season. The results of different studies will be examined at the end of the season to decide the future course of insect resistance breeding.

Table 8. Preliminary screening of kabuli chickpea germplasm accessions for leaf miner at Tel Hadya, 1981/82.[a]

Scale [b]	Germplasm accessions	
	Numbers	% of total
1	0	0.0
3	19	1.2
5	148	9.5
7	356	22.8
9	1033	66.5
Total	1556	100.0

a. Source: Entomology program, FLIP, ICARDA.
b. Scale : 1=Highly resistant; 3= Resistant; 5= Tolerant; 7= Susceptible; 9= Highly susceptible.

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Discussion

Claude Bernier
Dr. Singh, you talked about the cross between the ascochyta resistant and other lines of chickpeas, but did not mention about the inheritance of the resistance.

K.B. Singh
As far as inheritance is concerned, it was reported earlier to be controlled by a single dominant gene. We now have lines with a single recessive gene controlling the resistance to ascochyta blight. In fact most of the lines we have possess a recessive gene for resistance.

Shaaban Khalil
You mentioned about the need for evaluation of different crosses for their nodulation behavior. Could you elaborate the procedure that should be adopted for evaluation of segregating populations for nodulation?

K.B. Singh
We are not doing much in this area. Some work is going on in ICRISAT on this aspect. The area is very fascinating and we would benefit from the observations that will be made there to follow under our conditions.

J.B. Smithson
Would Dr. Thompson like to comment on the work going on at ICRISAT?

J.A. Thompson
Lot of our work is done with individual plants. We therefore have some confounding of the effects. For example we can select plants which are nodulating well, which also happen to be the plants that are growing well with lot of photosynthetic activity. We have still to develop a reliable methodology.

Howard Gridley
You referred to a fair measure of wide adaptability in the genotypes being developed in your breeding program because of the selection pressure that you apply and stresses that you give at different sites in Syria and Lebanon. I think this is possibly true from some of the results I have seen in North Africa so far. However, would you agree that it would help in increasing selection efficiency or faster improvement in yield under the North African condition if we could introduce material from your preliminary yield trials or segregating populations?

K.B. Singh
We have been supplying early generation segregating material to the national programs who demand such material. We have also been making crosses based on the special requests of the national programs and in future we will be supplying more and more early generation material with the objective that you have rightly indicated.

Habib Halila

Would you please comment a bit further about the race situation in case of ascochyta blight in the region and the possibility of using horizontal resistance to tackle the problem of variability in the pathogen?

K.B. Singh

You would hear more about race situation from the presentations to be made later. The work at ICARDA by Dr. M.V. Reddy has revealed that there are perhaps four races and four biotypes present in Syria and Lebanon. We do not have any line of chickpea resistant to all the four races. We have started a crossing program with a view to pyramid the genes for resistance against all the four races.

Habib Halila

You mentioned about unconscious selection against the susceptibility to insect pests. How seriously an entomologist will take that kind of resistance?

K.B. Singh

We are so far making unconscious selection because we do not protect our breeding material against any insect pest. However, the leaf miner is perhaps the most serious pest of chickpeas in the Mediterranean region and we are going to start a conscious breeding program against this pest with involvement of both breeder and entomologist. A beginning has already been made.

Proceedings of the International Workshop on Faba Beans, Kabuli Chickpeas, and Lentils in the 1980s (Saxena, M.C. and Varma, S., eds.), ICARDA, 16-20 May 1983, Aleppo, Syria.

Perspectives in Lentil Breeding

W. Erskine
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Lentils (Lens culinaris) were cultivated on 1.95 million hectares around the world in 1981 (FAO 1982). Despite this sizeable area, the lentil remains genetically unexploited. Landraces still occupy most of the cultivated land in the major lentil-producing countries like Bangladesh, Ethiopia, India, Pakistan, Syria, and Turkey. New cultivars have made an impact on production only in Algeria, Egypt, Greece, and USA; of these production only in USA is in excess of 20,000 tonnes/year (Solh and Erskine 1981). Thus plant breeding has so far had a negligible overall effect on lentil production globally. Nevertheless, with the increased effort on lentil breeding in both national and international programs over the past 5 years, new and improved cultivars are expected to become available in many areas within this decade.

Genetic Variation

The basic resource of the plant breeder is the genetic variation of his crop. The primary gene pool of lentil consists of the cultivated species, Lens culinaris, and the two wild species, L.orientalis and L.nigricans (Cubero 1981). The variation within the wild Lens species is currently both underrepresented in collections and unevaluated. Of more immediate value to plant breeders is the variation within landraces of the crop. The largest assembly of germplasm is at ICARDA, where the ILL collection now stands at 5424 accessions from 53 countries. A major effort has been under way since 1979 to evaluate and document this material, as a prerequisite for its full exploitation. A catalog of germplasm is now in preparation.

Mutation breeding offers scope for widening the genetic base of the crop when the necessary variability is not found in germplasm. For example, lentils in Bangladesh have a short season of only 115-125 days. Germplasm introduced into Bangladesh is too late in maturity. Mutation breeding with local genotypes offers a way of increasing the available variation in an early-maturing background. Hybridization with later-maturing genotypes could also be used. Mutation breeding was undertaken at ICARDA to increase the height of the local landrace for mechanical harvesting. Exposure to irradiation did not increase the variability for plant height within the landrace, and the tallest selection was found within the unirradiated landrace (ICARDA 1982). The experiment emphasized the wealth of variation within landraces, so the mutation breeding work has been discontinued.

Goals of Lentil Breeding

The major limitations of the crop that may be addressed through plant breeding are now discussed to focus future breeding efforts. The breeding techniques appropriate to lifting such limitations have been fully discussed by Muehlbauer and Slinkard (1981).

Seed Yield Potential

The crop yields poorly. During the period 1975-80 the average world yield was 633 kg/ha (FAO 1982), which was only 13% more than the average for the period 1948-52. By contrast, bread wheat yields increased 59% (from 1110 to 1760 kg/ha) over the same period. This striking increase in wheat yield was partly due to improved management practices and partly to better cultivars. In lentils, both aspects are not adequately explored.

With conventional crop management, there exists considerable scope for a genetic advance in seed yield. Pure-line selection of landraces is the first step, and it has resulted in such cultivars as the Kislik series from Ankara, Laird from Canada, Giza 9 of Egypt, and Tekoa from USA. At ICARDA a genetic advance in seed yield has resulted from the single-plant selection of landraces (Table 1), and the best of these selections are now included in on-farm trials in Jordan, Lebanon, and Syria.

With unconventional crop management, the possible increase in seed yield is greater. For example, in the Middle East at altitudes below 1000 m elevation the crop is traditionally planted in December, despite the rains starting one month earlier. Farmers delay their sowing because of weeds (volunteers, broad-leaved weeds, and Orobanche), which are reduced by sowing in December, and because of the risk of spring frost. Agronomic experimentation indicates that there is an economic benefit from the longer growing season afforded by earlier planting in November. Breeding directed at increasing the seed yield from an early sowing could result in higher yields.

At altitudes above 1000 m in the Middle East, the manipulation of planting date can also result in yield gains. For

Table 1. Mean seed yield (kg/ha) of 78S 26004, a promising lentil genotype, and its percent advantage (parentheses) over the local check in 1980/81 and 1981/82 seasons at different locations in Syria.

Selection	ILL	Origin	1980/81[a]	1981/82[b]
78S 26004	9	Jordan	1771 (33%)	1382 (32%)
Syrian local	4401	Syria	1330	1050
SE±			54.6	42.4

a. Mean of two locations.
b. Mean of four locations.

example, on the Turkish High Plateau, lentil is planted in spring because of the severe winter conditions. However, earlier (prewinter) planting can be considered if the necessary cold tolerance is available. Screening of germplasm under severe winter conditions (temperatures down to -26°C) has revealed cold tolerance in 238 of 3592 accessions tested (Erskine et al. 1981). Pure-line selection and mass selection of landraces would be useful in selecting cold tolerance, and, thereafter, systems like simple recurrent selection may play a role.

In brief, using unconventional crop management, such as manipulating the date of sowing, opportunities exist to increase seed yields through an exploitation of the genotype x environment interaction.

Harvest Methods

The increasingly high cost of harvest labor is preventing some farmers in the Middle East from growing lentils. In Jordan the area of lentils decreased from 25,000 ha in 1969-71 to 9000 ha in 1981 (FAO 1982).

The crop is, however, harvested mechanically in North America. In addition to mechanical problems of mechanization of harvest in the Middle East, there are three biological problems to be addressed: the lodging susceptibility of landraces; their short, semi-prostrate growth habit; and their pod dehiscence and pod drop.

Lentils lodge as they senesce. If the crop is harvested when 60% of pods are golden-brown, there is less lodging than if it remains to the full maturity needed for a combine-harvester (100% pods golden-brown). Heritable differences in susceptibility to lodging have been found, and 78S 26002 (ILL 8), for example, shows lodging resistance, and is also a high-yielding selection. Lentil plants carrying no pods will tend to lodge less than those bearing heavily. Consequently, resistance to lodging must be sought in adapted material. It is still unclear which factors confer lodging resistance: possibly, stem thickness or stem lignification may be important. The use of wind-tunnels could help select lodging resistance. Possibly the very tendrilous habit of ILL 2357 and ILL 3463 could knit the canopy sufficiently to avoid lodging. In the field, lodging can only be assessed in populations.

The landraces in the Middle East are usually insufficiently tall and erect to permit mechanical harvesting. Mechanical harvesting by cutting or pulling requires a clearance of about 15 cm between the soil surface and the lowest pods. Taller material with a higher first pod height is not required and is, in fact, more prone to lodging. The upper extreme for plant height and the height of the lowest pod above the ground is represented by the cultivar, Laird (ILL 4349). Many of the macrosperma accessions in the germplasm collection are of sufficient stature to permit mechanical harvesting. Many of these tall accessions are late to mature, but germplasm from Egypt is generally both tall and early. Selection from germplasm accompanied by hybridization will alleviate the problem of growth habit.

Lentils are harvested by hand when around 60% of pods are golden-brown. A delay in harvest causes crop loss from pod drop and pod dehiscence, which may be up to 870 kg/ha with a delay of 5-6 weeks. Combine harvesting is most successful when all pods are ripe. However, the indeterminate flowering habit of the crop gives a spread in the maturity between the first-formed and the last-formed pods. High temperatures and low humidity promote the dehiscence of the early maturing pods. Genetic differences in the seed loss from a delayed harvest have been found, but this requires confirmation before initiating hybridization. Selection for pod retention and pod indehiscence can be practised by delaying the harvest of bulk segregating populations, although care must be taken to avoid selecting for late maturity.

Photoperiod-Sensitivity

Lentil is a long-day plant. The length of day in some parts of the world, notably the Indian subcontinent, decreases to about 11 hours by the time of flowering. These short days have limited the introduction into India of long-day lentils from the Mediterranean region (Erskine and Hawtin 1983). The genetic base of the crop in India is, thus, relatively narrow. It is composed of the botanical variety pilosae (Barulina 1930) which is relatively insensitive to photoperiod. Breeders in India wishing to cross Indian cultivars with the Mediterranean introductions can only synchronize the flowering of the two groups by extra day length in the greenhouse or in a summer Himalayan nursery (Tyagi and Sharma 1981). The inheritance of the variation in sensitivity to shorter days must be studied.

Attempts at ICARDA are being made to break the day length bottleneck, in order to widen the genetic base of the crop in the Indian subcontinent. Direct introduction from other 'short day' growing environments may be considered. Thus a germplasm accession Precoz (ILL 4605), originating from northern Argentina where the growth conditions are also short days (about 11 hr), flowered synchronously with local Indian cultivars in New Delhi. Precoz has a seed weight of 5.2 g/100 seeds and is thus the first macrosperma lentil found with a phenology suited to Indian conditions. It will be useful in broadening the genetic base in the region.

Another approach to breaking the bottleneck is with hybridization. Since the 1980 season about 90 single cross combinations have been made annually between high-yielding cultivars from the Indian subcontinent and genotypes originating from either Ethiopia or around the Mediterranean Sea (many of which are macrosperma). The bulk populations of these crosses are now being sent to breeders in the Indian subcontinent in an attempt to broaden the genetic base of the crop in this region.

Diseases

The diseases of lentil are proportionally less damaging than the diseases of most other major pulses. However, there are some economically important diseases of lentil (Khare 1980). The wilt/root rot complex is both widespread and injurious. There are known sources of resistance to the various races of Fusarium oxysporum f.sp. lentis (Kannaiyan et al. 1978; Khare 1980), and these may be used in breeding programs. A wilt-sick plot must be developed for screening for resistance. Rust (Uromyces fabae) is locally important, particularly in Madhya Pradesh and Punjab in India, Chile, Ethiopia, and Pakistan. Again, sources of resistance have been identified for use in breeding programs (Pandya et al. 1980). Hot spots for rust like Debre Zeit in Ethiopia and Pantnagar in India are useful locations in screening for rust resistance. Resistance for both wilt and rust can now be incorporated by hybridization into adapted, high-yielding genetic backgrounds.

Orobanche

Orobanche crenata is a parasite of lentils around the Mediterranean, being of particular importance in Egypt, Italy, Morocco, Spain, and Syria. The quantity of its wind-blown seeds can increase dramatically in the soil over two cycles of lentil production (Basler 1981). The seed may lie dormant for more than 10 years. Surveys of Orobanche infestation in lentil crops tend to underestimate the extent of the problem because of the justifiable reluctance of farmers to sow lentils in infected fields. Following the identification of lentil genotypes (ex-India) tolerant to Orobanche crenata at ICARDA, an international nursery of this material has been initiated (ICARDA 1982). In Syria, the low temperatures severely affect the tolerant genotypes from India. This underlines their poor adaptation to the Mediterranean environment, and also the need to recombine them with locally adapted material.

Drought

In Syria and parts of West Asia, lentil is cultivated in the rainfall isohyets of 275-400 mm/year. Although such areas are characterized by variable rainfall, the most commonly encountered drought and heat stress is during the reproductive period of growth. Drought tolerance is required to stabilize production in these areas, and possibly to enable production in lower rainfall zones.

A problem hampering the work has been the inability to estimate drought tolerance. Initially, late spring planting was undertaken at ICARDA to ensure temperature and moisture stress during screening. However, in a particularly wet season, when there was no moisture stress, the spring-planted lentils were radically different in growth habit and phenology from the normal winter-sown crop. This showed that other important environmental factors are confounded with water stress in spring sowing. Furthermore, these other factors may not be important to winter-sown lentils. Spring-sowing to measure drought tolerance has been abandoned.

Drought tolerance is now being measured by manipulating the total seasonal moisture supply at one site with a normal date of sowing. Three moisture regimes are being used, viz., assured moisture (irrigation), rainfed, and rainfed excluding the precipitation in October and November with plastic sheeting.

Another approach is to select for drought avoidance through early maturity. There is considerable variation among early flowering lentil accessions and this is being capitalized at ICARDA. Additional variability for response to drought stress may be found within *Lens orientalis*.

Straw Yield

In West Asia lentil straw is an important feed for livestock, entering into both national and international trade (Nordblom and Halimeh 1982). Consequently, it must be considered in regional breeding programs. At ICARDA, the emphasis has been on increasing seed yield, but the relationship between the yield of seed and straw is also being studied.

In a world germplasm collection of 3586 accessions grown at ICARDA's principal station at Tel Hadya, Syria, the mean yields of seed and straw were 1287 and 2932 kg/ha, respectively. The phenotypic correlations between seed and straw yields were positive and significant at $r = 0.526$ and $r = 0.239$ for *microsperma* and *macrosperma* accessions, respectively. In another trial of 24 cultivars grown at three locations, the mean seed and straw yields were 1222 and 3166 kg/ha. The genetic correlation between seed and straw yields was $r = 0.755$. It can be concluded that further selection for higher seed yield in breeding programs will not adversely affect straw production (Erskine 1983).

Insects

Among the insects which damage lentils, the weevils of the genus Sitona are the most important economically (Hariri 1981; Tahhan and Hariri 1982). Sitona adults attack the leaflets of seedlings, and then their larvae feed on the nodules. A reliable estimate of the crop loss due to Sitona is not yet available. A screening method for Sitona larval damage to lentil nodules needs to be developed to establish genetic differences in susceptibility.

Other insects are of considerable local importance and these may also justify breeding for host-plant resistance.

Quality

There are no quality standards for lentil seed or straw in most developing countries. Some standards based on the local landraces must be set for comparison purposes.

The important characters for seed include size, color, protein and methionine concentration, ease of decortication, and cooking quality. The time for cooking was well predicted by seed size with a genetic correlation of $r = 0.92$. For lentil straw, digestibility and protein concentration are important traits. There is genetic variability for all the above characters within the germplasm of the cultivated lentil. The aim of breeding with regard to quality will usually be to monitor all these traits so that unacceptable levels in relation to the established standards are not found in new cultivars.

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Discussion

M.A. Rizk

1. What is the correlation between plant height and lodging in lentils?
2. How do we select for both characters for mechanical harvest?

W. Erskine

Tall plants lodge more than short ones. But there are plants with an intermediate height, sufficient to permit a mechanical harvest, which have a low tendency to lodge. Screening is done in the field.

Shaaban Khalil

What are the main objectives of mutation breeding in lentils besides plant height?

W. Erskine

Mutation breeding can be useful in upgrading a genotype for any one character. Mutation breeding to increase the breadth of genetic variation available in lentil is not yet necessary because of the variation existing in the species is still underexplored.

M.C. Saxena

1. The mutation program was also aimed at developing genotypes in macrosperma background suitable for southern latitudes. However, no success was obtained.
2. The lines found in central India are decidedly larger seeded than Syrian Local Small and almost of the same size as Syrian Local Large, or even larger.

S. Sithanantham

You are exploring the scope for identifying Orobanche-resistant types of lentil. Do you encounter problems in such selection on account of differences in species of Orobanche occurring in the crop growing regions?

W. Erskine

Orobanche crenata and O. aegyptiaca are both found on lentil in Syria. O. crenata is the more important species here and outside Syria. We are screening now in areas with a high O. crenata seed load and no O. aegyptiaca in order to separate the effects.

F.J. Muehlbauer

When referring to the root rot-wilt complex of lentil, has there been an attempt to separate the two diseases and, if so, is there resistance to the separate components of the complex?

W. Erskine

There is resistance to several races of Fusarium oxysporum reported from both Jabalpur and Pantnagar in India. (See Khare 1981, in "Lentils", published by CAB).

Y.L. Nene

To add to the information you gave on screening for wilt resistance in India, I would like to say that at Pantnagar the most dominant fungus in our wilt nursery was Fusarium oxysporum f. sp. lentis, but we also had some incidence of Sclerotium rolfsii, and Rhizoctonia solani. Our wilt-resistant material showed no mortality or least mortality in such a nursery.

S. Salem

What is the correlation between plant height and seed yield of lentils?

W. Erskine

The correlation is under investigation, and we do not yet know its value. However, field observations suggest that it is high.

R. Summerfield

In seeking taller plants, or those which bear lowermost fruits>15 cm above the ground, presumably there will be consideration given concurrently to stem strength (e.g. specific stem weight, population density (taller plants often have more acute branch angles than shorter, prostrate ones, and an 'agronomic package' suitable for the'unconventional' types.

Y.L. Nene

I would like to share some information on lentil rust. At Pantnagar in north India (28°N latitude) where rust occurs severely, only small-seeded types showed resistance. The large-seeded types which I had obtained from central India (22°N) were invariably susceptible to rust. I have often wondered if there is a relationship between large seed size and susceptibility to rust.

W. Erskine

Cultivar Laird has very large seeds and I believe it is resistant.

A. Slinkard

Large-seeded cultivar Laird has been reported as resistant to rust in Chile. But one should not ignore the fact that there are races and any generalization may be hazardous.

R.S. Malhotra

What should be the ideotype in case of lentils?

W. Erskine

We do not know enough about the plant to blinker ourselves with an ideotype at present.

M.S. El-Mott

Do you have any genotypes which are large seeded, early maturing, and tall?

W. Erskine

Yes, there are some good segregants from the cross Laird x Precoz which are early, tall, and bold seeded.

J.B. Smithson

A comment on lentils in the Indian subcontinent. It seems that because of importance there and the differences, physiologically, disease and insect wise, there is a justification in expansion of efforts there and perhaps ICRISAT's position there might make it suitable to help in this regard.

Proceedings of the International Workshop on Faba Beans, Kabuli Chickpeas, and Lentils in the 1980s (Saxena, M.C. and Varma, S., eds.), ICARDA, 16-20 May 1983, Aleppo, Syria.

Discussant's Remarks on Lentil Breeding-I

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Lentil breeding programs need to focus on developing cultivars that are able to make more productive use of the environemnts they are intended for (Summerfield 1981). Though grown as a spring crop in the high plateau regions of Algeria, Turkey, and Iran, lentil is a short-season winter crop with better cold and drought tolerance than all other pulses. Breeders should take advantage of these unique characteristics which, in spite of the declining trend in lentil area, have kept lentils among the important crops in many parts of the world.

Breeding Problems

Several interrelated breeding problems seem to be contributing to the declining trend in lentil production. These include low yield potential; low yield stability; labor-demanding harvest and threshing; pod shattering; low plasticity; susceptibility to *Sitona* weevil which, besides lowering yield, reduces the value of lentils as a legume crop in rotation; susceptibility to *Orobanche*; and susceptibility to other disease and insect pests. Lentil breeders are aware of these problems and their breeding programs aim to eliminate or minimize the problems relevant to their regions. But, to date, progress has been limited.

Most of the relatively few cultivars released or identified as being superior to local checks are introduced landraces or are derived from selection within heterogeneous populations. Such genotypes are good genetic stocks for high yield potential, but they may or may not be accepted as improved cultivars to replace the local ones. As for yield, progress has also to be made in identifying good genetic stock for other characters. To make an impact on lentil production, the good attributes of the genetic stocks identified need to be incorporated in cultivars well adapted to a particular environment.

The possibilities of improvement in lentils should be viewed in conjunction with the reasons that have limited the progress. The reasons may be grouped into three categories: technical, institutional, and economic.

On the technical side, emphasis on lentil germplasm collection and evaluation, genetics and breeding, and methodology started only about 10 years back. Germplasm collections available in Syria, India, and USA have considerable genetic variability that needs to be exploited by breeders. More efforts are needed to evaluate these collections for characters contributing to high and stable yield. Generally, lentils evolved under poor fertility conditions of marginal lands and some alleles responsive to higher levels of input were probably lost. However, genes for higher productivity may be scattered in different genotypes of these large collections. Intensive hybridization program will increase the chances for recombination of these genes. Research on genetics of lentils began as early as 1928, however, genetics of only one qualitative character was reported up till 1975 (Muehlbauer and Slinkard 1981), but in the past 7 years genetics of eight other qualitative traits has been resolved. Of these, two traits, namely, number of flowers per inflorescence and growth habit, may have an impact on yield potential.

As indicated earlier, breeding work is mainly based on introduced material selected for adaptation to a particular area (Muehlbauer and Slinkard 1981). Emphasis on hybridization as means of genetic improvement started only recently. Similarly, work on breeding methodology is also recent, but has provided helpful leads to handle segregating populations more efficiently.

On the institutional side, the infrastructure of national lentil improvement programs is generally weak or is not existing. Most of the lentil-producing countries are the developing nations where there is not enough emphasis on research as a whole due to financial, technical, and other reasons. With the establishment of ICARDA, national programs may receive more technical help in terms of availability of genetic material and training. Unfortunately, even when such an opportunity is available many national improvement programs are still not ready to make use of such a help because of their local system. ICARDA can never and should not replace national improvement programs but it should help the producing countries in obtaining bilateral assistance to finance and direct the development of these programs. Support of International Fund for Agricultural Development (IFAD) for research on faba beans in the Nile Valley of Egypt and Sudan is a good example of such bilateral assistance.

Economically, the elasticity of demand for lentils needs to be investigated further. One cannot claim that lentils constitute a major portion in the diets of the people in producing countries (Nygaard and Hawtin 1981). In Syria, where per caput consumption of lentil is highest in the world, consumption of lentils in 1977 was 6 kg per person. In certain years both Syria and Jordan were not able to export their surplus production. This might be due to reasons unrelated to elasticity of demand. However, many of the important producers, such as India, consume all of their production at home and thus only about 16% of total production enters into international trade (Nygaard and Hawtin 1981). With poor elasticity of demand, the incentive to increase production will be weak.

Possibilities for Improvement

Technically, the possibilities in lentil improvement are there, in spite of the slow progress due to certain constraints. This statement is justified considering the following points:

1. The germplasm already available has enough variability for most desirable traits. However, more collection of germplasm has to be done in agroclimatic zones that are poorly or not represented in the world collection (Solh and Erskine 1981).

2. ICARDA among others has already identified genetic stocks for higher yield potential, wide adaptation, tallness, tolerance to *Orobanche*, tolerance to cold and drought, and resistance to *Fusarium* wilt and rust diseases. However, there is a need for more effective screening of germplasm for characters related to the problems mentioned earlier. Work on tolerance to *Sitona* weevil and pod shattering should be given priority. Attributes of genetic stocks should express well in the environment of ultimate use.

3. The components of genetic variance have been studied in some quantitative characters. More work is needed on this subject. The genetics of desirable traits or their components should be resolved. Such information will help in the choice of effective breeding methodology.

4. Some leads in breeding methodology have been identified. Such work should continue with emphasis on reducing the nongenetic plant-to-plant variation.

5. Intensive hybridization programs, already under way, have provided selections from segregating populations for inclusion in yield trials. To incorporate the attributes of genetic stocks in cultivars adapted to specific environments, multiple crosses should be emphasized more than two-way crosses. This will increase the probability of achieving more desirable gene combinations. The crosses should include at least one local cultivar. Selections in segregating generations may need to be backcrossed to the local cultivar.

6. Because of insufficient infrastructure, both crossing and selection, particularly in early generations, are usually done in an environment which is different from the one for which the selection is intended. This is hindering the progress in lentil improvement. Selection in segregating populations needs to be

carried out in agroclimatic zones where selections are intended to be used. To speed up the progress, means should be found to establish or strengthen national lentil improvement programs. Without that the impact of improvement efforts on lentil production will remain weak.

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Discussant's Remarks on Lentil Breeding-II

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There are clear-cut areas growing microsperma lentil in the Indian subcontinent and some other areas, and macrosperma lentil in the Middle East. Due to the limitation of day length, the Indian subcontinent presently cannot use the good attributes of macrosperma lentils, so ICARDA's lentil breeding program should accord top priority to generate material in the macrosperma group fit for testing and selection in countries such as India, Pakistan, Bangladesh, and Nepal. ICARDA may supply lentil germplasm and segregating material to national programs for screening and identifying lines which grow well under short-day conditions.

Orobanche

Orobanche has been mentioned as a serious parasite on lentils. Every effort should be made to make sure that the seed supplied to countries where this parasite does not exist is free of Orobanche.

Diseases and Pests

It has been said that sources of resistance have been identified and the resistant genes can be incorporated by hybridization into adapted, high-yielding lines. I hope that identification of resistance genes for ascochyta blight is also on the priority list. In Pakistan the pathologists have reported that 30-40% of lentil crop on farmers' fields has been damaged in 1982/83 by blight. Moreover, there will sooner or later be the problem of physiological races of various lentil diseases. So there is a need to maintain a set of internationally identified differential lines with which the new races may be identified.

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Third Session

Screening for Resistance to, and Chemical Control of Major Diseases in Faba Beans

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Faba bean (Vicia faba L.) is a part of daily diet of people in many parts of Southwest Asia and North Africa. Its production, however, is not stable due to a number of diseases that cause huge losses to the farmer every year. Although severity of these diseases may vary from one location to another, it is widely held that chocolate spot (Deverall and Wood 1961; Hanounik 1979, 1981; Kaiser et al. 1967; Sundheim 1973), ascochyta blight (Hewett 1973; Sundheim 1973) and rust (Conner and Bernier 1982; Hanounik 1979; Kaiser et al. 1967; Williams 1978) are the most important ones. Reports concerning disease severity-yield relationships showed that chocolate spot, ascochyta blight, and rust can reduce faba bean yield by 67%, 52% and 40%, respectively (Hanounik 1979, 1981; Williams 1978).

In most crops, disease-resistant cultivars have been the most practical method of combating disease problems; this is particularly important in crops such as faba beans where the present economic returns in no way justify the use of expensive fungicides. But very little work seems to have been done on identifying resistance sources for faba bean diseases. Therefore, our program at ICARDA focuses on identification of newer and better sources of resistance for major diseases of faba beans. Faba bean genotypes with moderate to high level of resistance to chocolate spot, ascochyta blight, and rust have been identified. Since utilization of such genetic materials is still under way, short-term chemical control measures have also been developed.

Recently, certain resistant faba bean genotypes developed susceptible-type chocolate spot lesions (Hanounik 1983); this was immediately investigated and data indicating pathogenic variabilities in Botrytis fabae are presented here.

Screening for Disease Resistance

Screening and identification of sources for resistance to major faba bean diseases is conducted at ICARDA's subsite at Lattakia, Syria on the Mediterranean coast where environmental conditions are suitable for natural disease development.

Chocolate Spot (*Botrytis fabae* Sard.)

A two-cycle screening technique (Hanounik 1983) was adopted to identify chocolate spot resistant sources in ICARDA's germplasm collection. During the first cycle, a mixed inoculum of B.fabae, obtained from a wide range of naturally infected beans in Syria was propagated on faba bean dextrose agar (FDA) and used to inoculate 8-week-old plants of 1730 lines under polyethylene sheet tents in the field. Resistant selections made from the first cycle developed few lesions which were believed to have induced by physiologically different propagules. B. fabae isolated from such lesions was then inoculated back in a second screening cycle to the progenies of resistant selections made from the first cycle.

Sowing was done in October using 20 seeds per entry, in single rows, 2 m long and 50 cm apart. A Lattakia local landrace (ILB 1815) was planted as a standard local check after every 10 test entries. Disease readings were made using the following 1-9 rating scale:

1. No disease symptoms, or very small specks (Highly resistant)
3. Few small discrete lesions (Resistant)
5. Some coalesced lesions with some defoliation (Moderately resistant)
7. Large coalesced sporulating lesions, 50% defoliation, some plants dead (Susceptible).
9. Extensive lesions on leaves, stems, and pods, severe defoliation, heavy sporulation, stem girdling, blackening and death of more than 80% of the plants (Highly susceptible).

Of the 1730 lines tested, 11 rated 1 and 104 rated 3. Average scoring for local check entries was 7.4. In this study 385 single-plant selections were made. Representative chocolate spot resistant lines are listed in Table 1.

Highly resistant selections from this study (BPL 710 and BPL 1179), provided for testing in Egypt and the U.K., were rated highly resistant compared to local susceptible cultivars at both locations (Table 2). The confirmation of resistance in BPL 710 and BPL 1179 in Egypt and the U.K. besides Syria, is of considerable importance, because such multilocation chocolate spot resistance was lacking in the past.

Ascochyta Blight (*Ascochyta fabae* Speg.)

A mixed inoculum of A.fabae collected from a wide range of naturally infected faba bean seeds was propagated for 2 weeks on FDA culture and used to inoculate 10-week old plants of 620 lines. An inoculum

Table 1. Chocolate spot resistant faba bean lines identified at Lattakia, 1981/82.

Line		Disease rating[1]	Line		Disease rating	Line		Disease rating
BPL	Sel 82 LAT		BPL	Sel 82 LAT		BPL	Sel 82 LAT	
18	3013	3	1278	3151	1	1689	3271	3
110	3021	1	1390	3152	1	1749	3299	3
112	3022	1	1390	3153	1	1752	3307	3
261	3032	3	1544	3186	3	1758	3313	3
266	3038	1	1546	3191	3	1764	3322	3
266	3039	1	1547	3193	3	1803	3368	3
658	3094	3	1548	3196	3	1821	3377	1
710	3099	1	1550	3198	3	1831	3383	3
1179	3137	1	1556	3204	3	1832	3387	3
1196	3139	1	1648	3243	3	1876	3407	3

1. Readings are on a 1-9 rating scale (see text for details of scale).

Table 2. Chocolate spot reaction of certain faba bean resistant genotypes in Syria, Egypt, and England.

	Disease rating[1]		
Genotype	Syria	Egypt[2]	England
BPL 710 (ILB 438)	1	3	1
1179 (ILB 938)	1	3	3
261	3	3	NA
266	1	3	NA
678	3	3	NA
43	5	NA	5
470	3	4	NA
Lattakia Local (ILB 1815)	9	7	7

1. Readings are on a 1-9 rating scale (see text for details of scale).
2. B. fabae isolate from Alexandria region in Egypt.

density of 500,000 spores/ml was used, employing 20 ml of spore suspension per plant. Sowing was done in October using 20 seeds per entry, in single rows, 2 m long and 50 cm apart. A susceptible cultivar, Giza-4, was planted after every two test entries. Disease readings were made on the following 1-9 rating scale:

1 - No disease (Highly resistant)
3 - Few scattered lesions (Resistant)
5 - Lesions common with some defoliation (Moderately resistant)
7 - Lesions very common and damaging (Susceptible)
9 - Lesions extensive, many plants killed (Highly susceptible)

Of the 620 lines tested, 14 rated 1 or 3 and the remaining 606 entries rated between 5 and 9. The susceptible cultivar (Giza-4), however, was rated 9 (Table 3). Resistant selections from this study provided for testing at the University of Manitoba in Canada gave resistant or susceptible reactions depending on the isolate used for testing (Table 3). The resistant selections

Table 3. Ascochyta blight reaction on certain faba bean selections in Syria and Canada.

	Disease reaction				
	Syria		Canadian isolates[1]		
Entry	1980[a]	1981[b]	A	Y	X
Sel. 80-LAT (14435-3)	3	2	S	NT	NT
(14422-2)	3	3	R	NT	NT
(14434-1)	3	3.5	S	R	R
(14986-3)	3	3	S	R	R
(14998-1)	3	3	S	R	NT
(15035-3)	3	3.5	R	NT	NT
(15563-3)	3	3	NT	NT	NT
(70015)	3	4	NT	NT	NT
(14200)	1	3	NT	NT	NT
(14336)	3	5	NT	NT	NT
(14339)	3	5	NT	NT	NT
(14398)	3	5	NT	NT	NT
(14399)	3	5	NT	NT	NT
(14427)	3	3	NT	NT	NT
(15025)	3	3	R	NT	NT
BPL 2485	3	3	R	R	R
Giza-4	9	9	NT	NT	NT

a. Mixed inoculum
b. Inoculum from Sel. 80 LAT (14200 and 70015).
1. S = Susceptible, R = Resistant, NT = Not tested.

14434-1 and 14986-3 made in Syria also looked resistant to isolates Y and X in Canada. More important is the resistance in BPL 2485 to all three Canadian isolates A, Y, and X. Confirmation of resistance in these selections at Manitoba provides our program with a slightly more broad-based resistant sources which were lacking in the past.

Rust [*Uromyces Vicia-fabae* Pers. (Schroet.)]

In general, rust reaches epiphytotic levels in faba beans almost every year in Lattakia area. Therefore, no artificial inoculations are normally needed in the rust screening nurseries.

The 80 faba bean entries received from the University of Manitoba, Canada, were tested in the 1978 season, in rows 2 m long and 50 cm apart. A Lattakia local cultivar (ILB 1815) was planted after every eight test entries. Rating was done on a 1-9 scoring scale where:

1. No pustules visible (Highly resistant)
3. Necrotic flecks with few pustules (Resistant)
5. Pustules common on leaves, no damage (Moderately resistant)
7. Pustules common on leaves and stems with defoliation (Susceptable)
9. Pustules very extensive on all plant parts with death of some leaves (Highly susceptible).

In this nursery, 65 single-plant selections were made. These selections were retested in 1979, 1980, and 1981 seasons following the same procedures. In this study, the Sel. 80 LAT. 15563-3 derived from a line originally identified as being rust-resistant at Manitoba, Canada, was the only one that looked also resistant in Syria.

Seeds of promising resistant lines identified for chocolate spot, ascochyta blight, and rust were increased and distributed for disease evaluation during the 1983 season in Egypt, Tunisia, Algeria, Canada, and the U.K. This multilocation testing should provide important information concerning the performance of these lines under different environmental conditions. Several crosses have been made using the resistant lines, and F_2 progenies are being tested during the 1983 season at Lattakia.

Pathogenic and Cultural Variations in *B. fabae*

Knowledge concerning pathogenic variations in B.fabae is essential to set up sound strategies for breeding cultivars resistant to chocolate spot. Heterokaryosis as a source of genetic variability in B.cinerea was demonstrated by obtaining strains of the fungus, differing in their cultural characteristics, from single spore cultures (Hansen and Smith 1932; Lauber 1971; Manzinger 1964). Although different isolates of B.fabae may vary widely in their virulence on faba bean (Hosni et al. 1981; Hutson and Mansfield 1980), no attempts had been made in the past to study such variabilities in relation to cultural characteristics or geographical origin of different isolates. This study was initiated to determine pathogenic variabilities and cultural characteristics of certain isolates of B.fabae obtained from different geographical regions in Syria and Lebanon where chocolate spot is a serious problem.

Seven faba bean pure lines, selected previously (Hanounik 1983) for their diversity of disease reaction, were cross-inoculated separately in moist chambers in the field, with three different isolates of B.fabae obtained from Syria and Lebanon. These isolates had been selected for diversity of their cultural characteristics, propagated on FDA, and then used to inoculate 4-month old plants. The same isolates were also used to cross-inoculate the same faba bean pure lines in a detached leaf test (Mansfield and Deverall 1974) in the laboratory. Treatments in both tests were replicated three times in a split-plot design with isolates in the main plot and genotypes in the subplots. The detached leaf test was repeated three times.

Data in Table 4 indicate a disease differential potentiality pattern among faba bean pure lines in both tests. Lines BPL 710, 261, 266, 274, and 1179 were significantly (P<0.01) more resistant to the three isolates, than BPL 470 and ILB 1815. Differences in

Table 4. Reaction of certain pure lines of *Vicia fabae* to three different isolates of *Botrytis fabae* at Lattakia.

Isolates of *B. fabae* and origin	Pure lines[1]						
	710	261	266	274	1179	470	ILB 1815
A. Field test							
Syria-Tel Kalakh (T)	NT	4.3^{a}	4.3^{a}	5.7^{a}	6.3^{a}	7.0^{a}	8.3^{a}
Lebanon-Doha (D)	NT	3.0^{b}	3.7^{b}	3.7^{b}	3.0^{b}	5.0^{b}	7.0^{b}
Syria-Lattakia (L)	NT	2.3^{c}	3.0^{c}	3.7^{c}	3.0^{b}	4.3^{c}	7.0^{b}
Control (water only)	NT	1.0^{d}	1.0^{d}	1.0^{c}	1.0^{c}	1.0^{d}	1.0^{c}
B. Detached leaf test							
Syria-Tel Kalakh (T)	1.8^{a}	3.5^{a}	3.8^{a}	6.1^{a}	5.8^{a}	7.5^{a}	8.7^{a}
Lebanon-Doha (D)	1.0^{b}	2.1^{b}	2.4^{b}	2.7^{b}	2.4^{b}	5.5^{b}	7.2^{b}
Syria-Lattakia (L)	1.0^{b}	1.8^{b}	2.1^{b}	2.4^{b}	1.8^{b}	5.0^{b}	7.0^{b}
Control (water only)	1.0^{b}	1.0^{c}	1.0^{c}	1.0^{c}	1.0^{c}	1.0^{c}	1.0^{c}

1. See text for disease ratings for each column, ratings with different letters are significantly different (P<0.01) according to Duncan's Multiple Range Test.

the reaction between BPL 470 and ILB 1815 were also significant (P<0.01) across all isolates. Meanwhile, isolates T, D, and L varied considerably in their virulence on faba bean. Field and detached leaf tests showed that isolate T was significantly (P<0.01) more virulent than both isolates D and L across all entries, indicating a distinct pathogenicity pattern. Although isolate D was significantly (P<0.01) more virulent that isolate L on BPL 261, 266, and 470 in the field, no such differences were detected in detached leaf tests.

Differences in virulence among isolates T, D, and L should indicate distinct pathogenic variabilities in B.fabae, and must be considered in breeding cultivars resistant to chocolate spot. Although the pathogenicity pattern induced by isolate T is discrete, it would not be wise at this stage to designate a race status for it, because isolate T was obtained from a single lesion, at one location, and hence it may not represent a population (Vanderplank 1975). A wide scale survey is, therefore, needed to determine whether or not such virulence is prevalent in the region. If isolate T is encountered in some locations, then this might explain why certain genotypes resistant to B.fabae in Syria may display a susceptible reaction to certain isolates from other locations (Hosni et al. 1981).

Pathogenic variabilities in B.fabae were found to be associated with distinct cultural characteristics. The more virulent isolate T produced significantly (P<0.01) less conidia and formed larger sclerotia compared to the less virulent isolates D and L (Table 5).

Table 5. Sporulation and sclerotial size of three isolates of *Botrytis fabae*.

Isolates	Sporulation[1] (Conidia x 1000/ml)	Dimensions of sclerotia (mm)[2] Length Average	Length Range	Width Average	Width Range
Syria-Tel Kalakh (T)	1800[a]	3.4	1.5-5.7	2.8	1.5-4.0
Syria-Lattakia (L)	3240[b]	1.3	0.7-2.0	1.2	0.7-1.9
Lebanon-Doha (D)	3420[b]	2.3	1.0-4.0	2.0	1.0-3.0

1. Different letters indicate significant differences (P<0.01), Duncan's Multiple Range Test for both sporulation and number of sclerotia.
2. Average of 30 readings.

Based on growth rates, the three isolates of B.fabae can be separated into a slow-growing category represented by isolate L, and a fast-growing category represented by isolates D and T (Fig. 1). Meanwhile, the fast-growing isolates can further be separated into isolate D, with abundant sporulation, as compared to isolate T with sparse sporulation (Table 5).

Chemical Control

Preliminary Screening of Certain Fungicides

The efficacy of nine different fungicides for the control of chocolate spot, ascochyta blight and rust has been determined in the field. Seeds of the local faba bean cultivar ILB 1815 were planted in rows, 2 m long and 50 cm apart in 2 x 1 m plots. Fungicides were applied once every 15 days employing 400-500 liters of solution per hectare. Chemical treatments started when plants were 8-week old, and terminated when nine sprays were completed. Artificial inoculations were made after the first chemical treatment, according to previously mentioned procedures. Rust was prevalent and hence no artificial inoculations were needed. Disease ratings were made on a

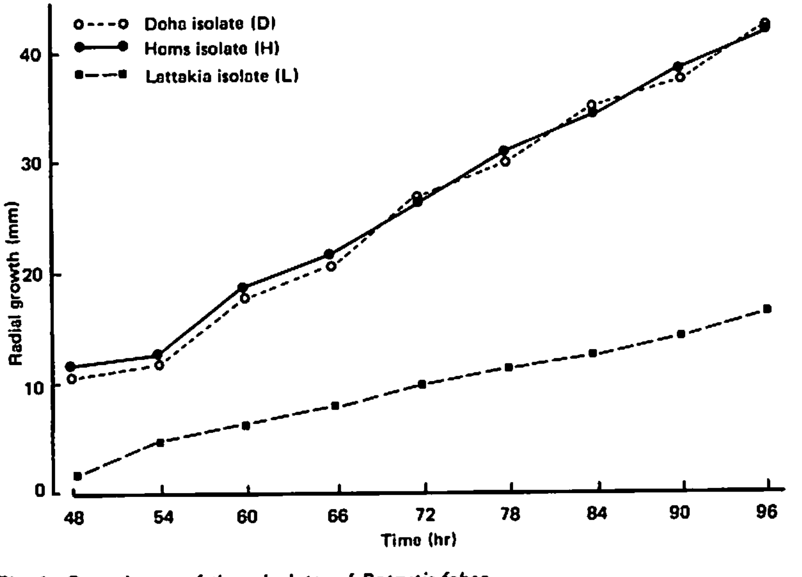

Fig. 1. Growth rate of three isolates of *Botrytis fabae*.

1-9 scale described previously. Results from these tests indicated that Dithane-M45 (a coordination product of zinc, iron, and manganese ethylene bisdithiocarbamate), Bravo-6F (cholorothalonil), and Ronilan (vinclozolin) were the most effective fungicides for the control of rust, ascochyta blight, and chocolate spot, respectively (Table 6).

Table 6. Efficacy of different fungicides in the control of certain faba bean diseases at Lattakia.

Fungicide and rate (cc or g/l)	Efficacy[1]		
	Chocolate	Ascochyta blight	Rust
Dithane-M45 (2.5 g)	**	***	****
Difolatan-80WP (2.5 g)	**	**	***
Trimilox (5.0 g)	*	*	***
Bravo-6F (2.5 cc)	**	****	**
Topsin- -70WP (1.0 g)	**	**	**
Calixin (0.5 cc)	*	*	**
Bavisin 50WP (0.7 g)	*	*	**
Ronilan 50WP (2.0 g)	****	*	*
Allisan-DP 50% (2.0 g)	***	*	*

1. * = Very low efficacy, **** = Very high efficacy.

Influence of Chemical Treatment and Host Genotype on Severity of Ascochyta Blight and Yield in Faba Bean

This test was conducted to study the influence of Bravo-6F, Dithane-M45, and Benlate-50% (benomyl) treatments on disease severity-yield relationships of A.fabae in faba beans. In order to establish a differential host reaction to A.fabae, the moderately resistant Syrian Local and susceptible Giza-4 faba bean cultivars were planted in 4 x 4 m plots in the field. Chemical treatments and artificial inoculations were made according to procedures mentioned under preliminary screening of certain fungicides.

All chemical treatments (Table 7) reduced disease severity and increased yield in faba beans. Decreases in disease severity in Bravo -6F and Dithane M-45 treated plots were associated with significant increases in yield of both Giza-4 and Syrian local faba bean cultivars. Maximum yield increases, however, were obtained with Bravo as compared to other chemical treatments.

Table 7. Influence of chemical treatments and host genotypes on severity of ascochyta blight and yield in faba beans at Lattakia.

Treatments	Giza-4 (ILB 1820)[1]			Syrian Local (ILB 1815)		
	Disease[2] severity	Yield[3] (kg/ha)	Increase in yield over control (%)	Disease severity	Yield (kg/ha)	Increase in yield over control (%)
Bravo-6F (1.5 cc/l)	3.0[a]	6250[l]	294.8	2.3[j]	6708[l]	76.9
Dithane-M45 (1.5 g/l)	4.3[b]	4766[f]	201.0	2.3[j]	6316[l]	66.6
Benlate-50% (0.5 g/l)	7.0[c]	1958[g]	23.6	5.0[k]	4458[m]	1.75
Untreated control	8.3[d]	1583[g]	0.0	5.6[k]	3791[n]	0.0

1. Within a column, means followed by different letters are statistically different (P=0.05) according to Duncan's Multiple Range Test.
2. Rating done on a 1-9 scoring scale described previously.
3. Yield expressed in kg green pod weight per hectare.

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Discussion

Howard Gridley

My particular concern is about variability in Botrytis fabae which devastated the crop of faba bean last year in Tunisia. In your presentation you did refer to this. What strategy do you suggest for future for programs elsewhere such as in North Africa.

Salim Hanounik

We adopted the two-cycle screening technique so that we screen for the widest possible variations that may be existing in our local population of Botrytis fabae. We identified several lines that looked promising and these have been sent out for evaluation under different environmental conditions. In future it will be worthwhile to combine genes from these different lines so that a wider range of variations existing in the region could be covered.

Bashir Malik

How do you ensure that there are no escapes in your disease screening work?

S.B. Hanounik

Screening for disease resistance is all done at ICARDA's Lattakia site where standardized techniques are used every year to make sure that faba bean disease screening nurseries are subjected to high disease pressure. Therefore, no disease escape would be expected under those conditions.

Proceedings of the International Workshop on Faba Beans, Kabuli Chickpeas, and Lentils in the 1980s (Saxena, M.C. and Varma, S., eds.), ICARDA, 16-20 May 1983, Aleppo, Syria.

Root Rot/Wilt Complex, Powdery Mildew, and Mosaic Disease of Faba Beans and Their Control

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Faba bean (Vicia faba) is the most popular food legume in the Sudan. The stewed dry bean is the main breakfast dish in most parts of the country. Faba bean is grown as a winter crop under irrigation, almost exclusively in the northern region, where suitable climatic conditions prevail. The average total area under the crop is about 20,000 hectares. The consumption is steadily increasing and there is always a need to import. This year shortage of faba beans led to an unprecedented price level of US$ 3/kg, so considerable amounts had to be imported from Spain, Turkey, and Egypt. Unlike in some other countries, faba bean is not popular as green vegetable in the Sudan (Watson 1981).

Root rot/wilt, powdery mildew, and mosaic are the three major diseases that attack faba beans in the Sudan and cause considerable losses. This paper describes the progress on identifying the factors affecting the incidence and control of these diseases. The information has been drawn mainly from the phase I report of the Nile Valley Project on Faba Beans (Hussein 1983).

Root Rot/Wilt

This is economically the most important of the three diseases. Losses could be tremendous especially in seasons when hot spells prevail just after germination. Affected plants are either killed or, if survived, show greatly reduced growth. The pathogens (Fusarium oxysporum causing wilt and F. solani f. sp. fabae causing root rot) are soilborne and are present all over the growing area but only attack whenever suitable conditions (mainly high temperature) prevail.

Powdery Mildew

It is caused by *Leveillula taurica* and *Erysiphe polygoni*. Both pathogens are equally common but the former has a wider host range. *L. taurica* is endoparasitic and usually infects the crop at an earlier stage than *E. polygoni* which is ectoparasitic. The disease usually spreads late in the season and is therefore especially severe on late-sown crops.

Mosaic

Mosaic is caused by two viruses: Pea Mosaic Virus and Broad Bean Mottle Virus which can be present separately or in combination. They are both mechanically- and seed-transmitted. The former, being aphid-transmitted and having a wider host range, is more important and usually inflicts most of the damage. The disease spreads late in the season (around January) when favorable temperatures for virus multiplication and maximum aphid infestation occur. Thus, like powdery mildew mosaic is most serious on late-sown crops.

Work Conducted Since 1978

The work was mainly carried out under the auspices of the Nile Valley Project. It entailed monitoring diseases in the on-farm and certain back-up research trials conducted at various research stations, as well as production areas, and assessing their prevalence in relation to certain agronomic practices such as sowing date, irrigation, plant population, etc.

Disease assessment was done by frequent counts conducted regularly throughout the growing season. The number of infected plants was recorded in each count for each treatment and expressed as percentage of the total population of that treatment. The accumulated data were then analyzed after appropriate transformations.

Sowing date affected the incidence of the three diseases highly significantly at all sites for three successive seasons. Table 1 shows the disease incidence in relation to sowing date at Zeidab site which is taken as a representative of other sites. Early sowings were severely affected by root rot/wilt disease and late sowings by mosaic and powdery mildew. The decrease in the incidence of root rot/wilt disease with late sowings correlates well with decrease in temperature. Varieties or interaction between varieties and sowing dates did not significantly affect the incidences of any of the three diseases.

The effect of sowing date and plant population on yield and yield components of faba beans was studied at several sites. Five sowing dates (10 Oct, 20 Oct, 30 Oct, 10 Nov, and 20 Nov) and three plant populations (16.6, 33.3, and 49.9 plants/m^2) were tested in all possible combinations in a factorial experiment in the 1981/82

Table 1. Effect of sowing date on the incidence of three major diseases of faba beans over three seasons at Zeidab (Mean % infected plants).*

Sowing date	Root rot/ wilt	Powdery mildews	Mosaic
1979/80			
10 Oct	48.3	2.4	2.4
20 Oct	33.6	4.9	2.2
30 Oct	10.4	1.2	2.6
10 Nov	0.2	1.3	2.4
20 Nov	1.0	0.4	11.4
30 Nov	1.0	0.0	39.1
1980/81			
10 Oct	12.4	0.9	0.8
20 Oct	1.9	0.5	0.9
30 Oct	0.2	0.3	1.0
10 Nov	0.1	0.3	1.1
20 Nov	0.1	17.7	8.8
30 Nov	0.0	20.0	34.2
1981/82			
10 Oct	9.0	3.2	0.3
20 Oct	3.0	2.7	0.3
30 Oct	0.8	1.5	0.6
10 Nov	0.4	0.3	0.5
20 Nov	0.2	0.02	0.2

* Hussein _et al_. 1912.

season. The most important factor leading to reduced seed yield in the early-sown crop was the reduced number of plants per unit area. Plant mortality was due mainly to root rot/wilt disease. Incidence of dead plants was significantly higher in the 16.6 and 33.3 than in the 49.9 plants/m^2 at Zeidab, but at Selaim the incidence of dead plants was not affected by plant population (Tables 2 and 3). Incidence of mosaic and powdery mildew was significantly higher in the sparse than denser population both at Zeidab and Selaim (Tables 2 and 3).

Seed yield was also significantly affected by plant orientation. At Hudeiba the highest seed yield on average (2721 kg/ha) was obtained by sowing on the west and north sides of ridges,

Table 2. Incidence of three major diseases of faba beans in relation to sowing date and plant population at Zeidab site (mean % dead plants transformed into $\sqrt{x + 1}$).

Population	Sowing date 10 Oct	20 Oct	30 Oct	10 Nov	20 Nov	Mean
a) Root rot/wilt						(± 0.2)
16.6 p/m^2	3.5	2.3	1.4	1.3	1.2	1.9
33.3 p/m^2	4.2	1.8	1.3	1.1	1.1	1.9
49.9 p/m^2	2.8	1.8	1.2	1.1	1.0	1.6
Mean (± 0.26)	3.5	2.0	1.3	1.2	1.1	
b) Powdery mildew						(± 0.09)
16.6 p/m^2	2.2	2.4	1.7	1.2	1.0	1.7
33.3 p/m^2	1.8	1.7	1.5	1.2	1.0	1.4
49.9 p/m^2	2.0	1.4	1.5	1.0	1.0	1.4
Mean (± 0.12)	2.0	1.8	1.6	1.1	1.0	
c) Mosaic						(± 0.05)
16.6 p/m^2	1.2	1.3	1.4	1.3	1.2	1.3
33.3 p/m^2	1.0	1.1	1.2	1.2	1.1	1.1
49.9 p/m^2	1.1	1.0	1.1	1.1	1.1	1.1
Mean (± 0.07)	1.1	1.1	1.2	1.2	1.1	

while the poorest (2231 kg/ha) was by sowing on the east and south sides. This difference is believed to be due mostly to loss in stand caused by root rot/wilt disease. Detailed measurement of soil temperature is, however, required to support this finding.

Root rot/wilt disease is the main obstacle to extension of faba bean cultivation to new nontraditional areas where plenty of land is available and irrigation is cheap. Several experiments were conducted at Shambat and Gezira Research Stations, south of Khartoum, on various methods of shading, intercropping, mulching, frequent watering, etc. to reduce the soil temperature and hence decrease the incidence of the root rot/wilt disease.

Three sowing dates (11, 21, and 31 Oct), two watering intervals (7 and 14 days), together with and without mulching, were tested in a factorial complete block design with four replicates at Shambat and Gezira Research Stations. Sowing date at Gezira Research Station significantly affected the incidence of the

Table 3. Incidence of three major diseases of faba beans in relation to sowing date and plant population at Selaim site (Taha *et al*. 1981).

Population	Sowing date					Mean
	10 Oct	20 Oct	30 Oct	10 Nov	20 Nov	
a) Root rot/wilt*						(± 0.02)
16.6 p/m^2	1.3	1.0	1.0	1.0	1.0	1.1
33.3 p/m^2	1.2	1.1	1.0	1.0	1.0	1.1
49.9 p/m^2	1.3	1.0	1.0	1.0	1.0	1.1
Mean (± 0.03)	1.3	1.0	1.0	1.0	1.0	
b) Powdery mildew**						(± 1.5)
16.6 p/m^2	38.4	35.0	30.2	36.0	37.7	35.5
33.3 p/m^2	29.0	28.1	24.4	26.4	25.0	26.6
49.9 p/m^2	24.7	22.3	21.9	21.5	23.6	22.8
Mean (± 1.9)	30.7	28.5	25.5	28.0	28.8	
c) Mosaic**						(± 1.1)
16.6 p/m^2	24.6	28.7	25.4	25.5	24.1	25.7
33.3 p/m^2	19.6	26.3	18.9	19.9	18.6	20.7
49.9 p/m^2	19.8	20.3	16.4	17.4	15.9	18.0
Mean (± 1.4)	21.3	25.1	20.3	20.9	19.5	

* Mean % dead plants transformed into $\sqrt{(x + 1)}$

** Mean % infected plants transformed into degrees.

disease, which decreased with late sowing (Table 4). Mulching also significantly affected the incidence by decreasing the number of dead and infected plants (Table 4). Short watering intervals (7 days) reduced the number of infected plants, and significantly so, of the dead plants (Table 4). There was also a highly significant interaction between sowing dates and watering interval and between sowing date and mulching (Table 5), but not between watering interval and mulching. Such effects were not apparent or consistent at Shambat.

Extensive screening for resistance to root rot/wilt disease in local as well as introduced material was carried out under natural conditions in the field. But no firm results have yet been achieved, largely because the disease pressure was not high enough at the required time to make proper assessment. This could be either because the pathogens (inoculum potential) were not

Table 4. Effect of certain agronomic factors on incidence of root rot/wilt disease of faba beans at Gezira Station (percentages transformed into degrees).

Factor	Treatment	Infected plants	Dead plants
Sowing date	11 Oct	15.6***	22.2***
	21 Oct	12.7	14.6
	31 Oct	9.5	11.1
	SE ±	0.89	1.03
Mulching	Mulch	9.1***	12.5***
	No mulch	16.0	19.5
	SE ±	0.73	0.85
Irrigation interval	7 days	12.3	28.1***
	14 days	12.9	37.6
	SE ±	0.73	0.73

*** Significant at P<0.001.

Table 5. Effect of interaction of certain agronomic practices on incidence of root rot/wilt disease of faba bean at Gezira Research Station (mean % dead plants transformed into degrees).

Treatment	Sowing date			
	11 Oct	21 Oct	31 Oct	Mean
Irrigation interval				
7 days	33.6	29.3	21.5	28.1
14 days	48.6	35.3	28.6	37.5
Mean (±1.27)	41.1	32.3	25.1	
Mulching				
Mulch	33.7	30.9	22.8	29.2
No mulch	48.5	33.6	27.3	36.5
Mean (±1.27)	41.1	32.3	25.1	

sufficient at that particular spot of the field, or the temperature was not high enough to induce infection (as is the case in cooler seasons). The solution for this would be to screen under artificial conditions, or establish sick plots in the field and sow fairly early in the season when temperatures are likely to be high enough to induce infection.

The effect of root rot/wilt disease on yield of faba bean was measured by tagging naturally infected plants in the field and comparing their yield and yield components with adjacent healthy plants. Generally, the infected plants either died (complete loss) or tolerated the infection and survived to produce an unsatisfactory crop (partial loss). Even when the plants survived, the effect of the disease was drastic on yields (Table 6). The data further showed that varietal difference in reaction to the disease was negligible, especially when judged by the effect on seed weight.

Other potentially important diseases observed in faba bean in the Sudan include leaf roll and phyllody (Hussein 1982).

Table 6. Effect of root rot/wilt disease on per plant yield and some yield components of faba beans at Hudeiba.

Genotype	Height (cm)	No. of pods	No. of seeds	Seed yield (g)
H.72				
Healthy	84	29	72	279
Infected	53	10	23	79
Loss (%)	37	65	68	82
Selaim				
Healthy	96	28	67	272
Infected	73	17	29	67
Loss (%)	24	39	57	75
Beladi				
Healthy	101	24	53	223
Infected	84	18	37	28
Loss (%)	17	25	30	87

Leaf Roll Disease

Incidence of this disease was recently observed by Bos (1980). The disease is caused by persistent aphid-transmitted Bean (or Pea) Leaf Roll Virus and is claimed to be widespread in many food and fodder legumes which act as sources of infection. Symptoms consist of interveinal leaf chlorosis and characteristically thick leathery leaves. The disease causes poor pod and seed setting, and up to 80% reduction in yield has been reported in some countries.

Incidence at Wad Medani was more than 50% in 1980/81 season, but steadily decreased northwards to about 1% at Selaim. Most of these infections were early infections from which plants recovered completely. In 1981/82 the incidence was almost nil. This season the disease was widespread and incidences ranging from 77% to 98% were recorded in the adaptation trial at Hudeiba Research Farm in which 14 genotypes were tested. This was generally a moderate infection from which most plants recovered.

Phyllody

This disease is caused by a leafhopper-borne mycoplasma. At present its incidence is low and does not exceed 2%. No secondary spread is known to occur but the disease is potentially serious since infected plants are rendered completely sterile.

Control

Previous work has not provided any effective measure of control for the three diseases of faba beans. Seed-dressing fungicides had no effect on control or reduction of incidence of root rot/wilt disease, and local and introduced material tested then were all susceptible. For powdery mildew, efficient control has been achieved through the use of certain fungicides but that was hardly accompanied by any increase in yield, suggesting that the disease does not cause economic yield loss perhaps because it appears late in the season. Chemical control of the vector had no effect on the incidence of mosaic disease and no source of resistance was found in the local or introduced material tested.

The present work, however, showed that sowing date (temperature) consistently affected the incidence and development of the three diseases. For faba beans Nov 1 was the optimum date for sowing in most of the growing areas. So adoption of this date by growers will help in escaping or greatly minimizing these diseases.

Frequent irrigation and mulching during early stages of development help decrease the incidence of root rot/wilt disease and improve plant stand. Plant population, ridge direction, and plant orientation most likely affect the incidence of root rot/wilt disease but more basic work is still required along these lines for confirmation.

However, the most promising and lasting control of these diseases lies in breeding and selection for resistant varieties.

Priorities for the 1980s

1. To improve ways and means of breeding and selection for root rot/wilt resistance through adoption of sick-plot techniques, artificial inoculation, and efficient exchange of breeding material with ICARDA and other relevant research organizations.

2. To identify heat and root rot/wilt tolerant genotypes for use in the nontraditional areas for faba beans south of Khartoum.

3. To investigate and confirm the exact effect of certain agronomic factors, like plant population, ridge orientation, mulching, etc., in controlling or minimizing faba bean diseases.

4. To carry out proper studies on leaf roll disease, virus etiology, and possible variability in the existing strains, identification and control of vector, and screening for host resistance.

5. Since optimum sowing date proved to be an important factor in controlling or minimizing the main faba bean diseases, more work needs to be done to establish the optimum sowing dates, in relation to temperature, for each locality.

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Discussion

Y.L. Nene

You mentioned pea leaf roll virus affecting faba bean in the Sudan. I may mention that the same virus causes chickpea stunt, which is also prevalent in the Sudan.

Proceedings of the International Workshop on Faba Beans, Kabuli Chickpeas, and Lentils in the 1980s (Saxena, M.C. and Varma, S., eds.), ICARDA, 16-20 May 1983, Aleppo, Syria.

Strategies for Disease Control in Faba Bean

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Breeding for resistant cultivars is the most widely used method of controlling diseases in annual crops of low cash value. However, the usefulness of cultivars with resistance based on a single gene has often been short-lived, giving rise to serious disease epidemics until those cultivars were replaced by other resistant ones. This is particularly true of biotrophic, highly mobile pathogens such as rusts and powdery mildews which have a great ability to generate more virulent pathotypes. The breakdown or transient nature of specific resistance has received so much attention that there is a tendency to forget that not all single gene resistances have been short-lived. Resistance of flax and cabbage to fusarium wilt and of oats to *Helminthosporium victoriae* has lasted for many years. In Europe, several spring wheat cultivars have shown long-lasting (durable) resistance to yellow rust (Johnson and Taylor 1976). Why specific resistance is stable in some host-pathogen systems and not in others remains unknown.

Research efforts of the past 20 years have revealed the dynamic nature of the host-pathogen relationship, and brought about a better understanding of the genetic and epidemiologic aspects of resistance and of the importance of genetic uniformity of crops in the development of epidemics. Attention has also been focused on the usefulness of moderate, or field, resistance that operates by reducing the rate of pathogen development, and on possibilities of managing the use of specific resistance genes to provide greater stability against changes in the population of a pathogen. Thus, the techniques and approaches available to pathologists and plant breeders to maximize the effectiveness and duration of resistance have increased considerably in recent years.

Before proceeding with development of strategies we need to consider briefly the concepts of resistance, the terminology used in this field, and the methods of testing for resistance.

Concepts of Resistance and Terminology

The meaning of the terms used in this area have not been consistent. Fortunately, a consensus appears to have been reached (Nelson 1973; Parlevliet and Zadoks 1977; Parlevliet 1979). The problem is due to the fact that resistance was defined and named in terms of genetics, epidemiology, differential interaction between host and pathogen, and on magnitude of effect by many authors working on different host-pathogen systems. Parlevliet (1979) has expressed the clearest views on this subject in my opinion, and his terminology has been followed.

Host resistance is defined as "the ability of the host to hinder the growth and/or development of the pathogen". The term "complete resistance" is used when the multiplication of the pathogen has been completely prevented, i.e., spore production (SP) is zero. "Incomplete resistance" refers to the resistance that allows some SP. "Partial resistance" is used when the SP is reduced even though the host plants are susceptible to infection (susceptible infection type).

Horizontal resistance (HR) is used in the sense of race-nonspecific resistance, characterized by the absence of genetic interactions between host and pathogen genotypes. Vertical resistance (VR) is characterized by the presence of genetic interactions between host and pathogen genotypes.

The cultivar-isolate test suggested by van der Plank (1963) to distinguish between VR and HR on the basis of differential interaction is laborious, and many researchers have turned to measuring disease reduction as an indicator of HR, and terms such as "partial resistance" (Parlevliet 1979), "rate-reducing resistance" (Nelson 1973), and "slow rusting" (Wilcoxson et al. 1975) are now widely used.

According to the proposed terminology, complete resistance can be governed by a single gene, i.e., infection type (IT) of 0 (no sign of infection or necrotic flecks) in rusts, or by several "minor genes" with additive effects (Sharp and Volin 1970). Partial resistance can also be due to a single gene, i.e., IT of 2 or X (small uredia) in rusts, or to polygenes.

Methods of Testing for Resistance

The failure to identify resistance in the evaluation of germplasm is often wrongly attributed to an absence of resistance because the methods used often allow the detection of complete resistance only. To ensure success, the plant material must be adequately challenged using a single race or pathotype, whether selection is for complete resistance or partial resistance. To illustrate, three cultivars each having a single gene for resistance to a given race of a pathogen would be identified only when inoculated singly with each isolate and not if the isolates were used in a mixture.

The ability to recognize HR in the presence of VR in plants exposed to a mixture of pathogen races was recently discussed by Parlevliet (1983). He concluded that using a single race provides the best conditions for the selection of HR in the presence of VR, and that the race should have the broadest possible virulence spectrum to suppress the expression of as many VR genes as possible.

Exposure of the plant material to the pathogen should be as uniform as possible so as to prevent any escape from infection. This is seldom achieved when material is evaluated in plots under conditions of natural infection. Adequate exposures can be achieved readily in the field if small plots are sprayed with inoculum and then covered with a polyethylene sheet to maintain leaf wetness overnight. This also means that all the plants become infected at the same growth stage, which facilitates comparisons.

Partial resistance (slow rusting) is best evaluated in adjacent or isolated field plots (Conner and Bernier 1982b; Parlevliet and van Ommeren 1975; Wilcoxson et al. 1975). Inoculum is applied to spreader rows sown at right angles to the plots, or at a point source in larger plots. Disease severity is assessed several times from the beginning to the end of the epidemic. The data are used to calculate the apparent infection rate or the area under the disease progress curve.

Formulation of Strategies

The first task in formulating strategies for the control of faba bean diseases involves identifying the kind of resistance most appropriate for each pathogen. This task is never easy and is certainly much more difficult in the case of faba bean where the data base on most host-pathogen systems is still not complete. Parlevliet (1979) summarized these difficulties very well. He wrote "There is no simple characteristic by which one can always discern polygenic from monogenic resistance without fail. Only a sound knowledge of host-pathogen systems in general and of the host-pathogen system implicated in particular, is a good guarantee that one uses the resistance that is most appropriate for the situation concerned".

Several attributes of a pathogen can provide some indication of the stability of vertical resistance and whether rate-reducing resistance would be more appropriate. These include the type of reproduction (sexual or asexual), whether spore dispersal is widespread or restricted, the extent of pathogen variation and virulence patterns, and the epidemiological competence of the pathogen.

An inventory of the resistance available for each of the major faba bean diseases is presented in Table 1, along with what is thought to be the most appropriate resistance, on the basis of the existence of pathotypes and the type of dispersal of each pathogen. Resistance is available for six of the eight diseases listed, but

Table 1. Inventory of the availability and type of resistance for major faba bean diseases.

	Resistance			Pathogen		
Pathogen	Availabiltiy	Type	Most appropriate	Pathotypes	Dispersal	References
Rust	Yes	VR r-red	 r-red	Yes	Wide	Conner and Bernier 1982a Conner and Bernier 1982b Rashid and Bernier 1983
Ascochyta fabae	Yes	VR	VR	Yes	Restr.	Kharbanda and Bernier 1980 Bernier, unpublished
Botrytis fabae	Yes	VR	r-red?	Yes?	Wide	Hanounik 1983 Elliot and Whitington 1979
Powdery mildew	No		r-red	Yes	Wide	
Aphanomyces euteiches	Yes		VR?	Yes	Restr.	Lamari 1982
Fusarium root rot and wilt	No		VR?		Restr.	
BYMV	Yes	VR Tol	VR	Yes	Wide	Frowd and Bernier 1977 Gadh 1982
Orobanche	Yes		VR?		Restr.	Nassib *et al*. 1982

VR = Vertical Resistance; r-red = rate-reducing resistance; tol = tolerance.

the type of resistance is known only for four diseases. It sould be pointed out that most resistances have only been recently identified and have not been widely tested in other regions.

The most appropriate resistance for rust would seem to be rate-reducing resistance because rust spreads widely and many races have been readily identified in Manitoba. We can assume that races also exist elsewhere. There is also the possibility of accumulating several vertical genes in one cultivar, or of using single vertical resistance genes in several multiline components or in the development of synthetic cultivars. However, either approach would require the constant monitoring of races and heavy inputs of time and labor that would exceed the capabilities of most programs. These comments also apply to powdery milew and Botrytis fabae.

Vertical resistance would appear appropriate for ascochyta blight and root rots caused by Aphanomyces euteiches or Fusarium spp., which all have restricted distribution, even though pathotypes have been identified.

Resistance and tolerance to Bean Yellow Mosaic Virus (BYMV) are each controlled by two recessive genes. However, resistance is preferred because it is effective against both mosaic and necrotic strains of the virus, whereas tolerance is only effective against the mosaic strain.

Breeding for Resistance to Multiple Diseases

Breeding programs need to improve agronomic traits, adaptation, yield, and resistance to several diseases and pests concurrently. New cultivars with resistance to one or two pathogens but susceptibility to a third, or with resistance but poor adaptation or yield, will not be accepted by farmers. To breed for resistance to all the major pathogens listed in Table 1 would certainly be a formidable task. Fortunately, the pathogens do not appear to be epidemiologically competent in every region of the Middle East and North Africa. For example, rust, chocolate spot, and Orobanche are major problems in Egypt whereas in Sudan, faba beans are more vulnerable to powdery mildew, fusarium root rot and BYMV. Thus, resistance to all major pathogens could be achieved if necessary, once cultivars with multiple resistance on a regional basis are available.

Transferring resistance genes into adapted, high-yielding cultivars can be accomplished in several ways. However, in view of the partially outcrossing nature of faba bean, the most logical approach would appear to be through the development of synthetic cultivars (Bond 1982). Resistant populations or lines for use as components in the synthetics can be developed by recurrent selection or by backcrossing. As stated by Bond, "synthetics, unlike multiline cultivars, are not an end in themselves, but are potential sources of further variation". The synthetics then become valuable pools of germplasm from which selections can be made. However, the use of such a program to improve disease resistance has so far not been examined.

Diseases Management

Partial resistance is, by definition, incomplete resistance. If the magnitude of partial resistance is not sufficient, it may need to be reinforced by other control measures, such as crop rotation or plowing of crop debris to reduce the amount of initial inoculum, or one or two applications of fungicide to the foliage to reduce the rate of pathogen development.

Conclusions

The strategies formulated for the control of faba bean diseases in the Middle East must be viewed as tentative and subject to periodic revision, for they are based on an inadequate data base for individual host-pathogen systems. Nevertheless, the techniques and approaches on which the strategies were developed were effective in other host-pathogen systems and should also be effective in controlling faba bean diseases. The task of developing adapted high-yielding cultivars with multiple disease resistance may appear formidable, if not utopian, but it is attainable, as shown by the success achieved in rice (Khush 1977) and in cotton (Bird 1982). Success, however, will require a team approach and the close cooperation of plant breeders, pathologists, and entomologists.

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Discussion

K.B. Singh

In literature, often only two classes, viz. resistant and susceptible, are mentioned, but there is invariably a class of intermediate type. Could you please comment on this?

Claude Bernier

I am sorry, I did not refer always to two classes. One should be able to score the plants on infection types and then on disease intensity-pustuler frequency, etc. That should give you a lot of scope to make several classes. But it is important to make these classes on the basis of any of the criterion being used independently so that you could distinguish. There is scope for intermediate ratings reflecting partial resistance.

K.B. Singh

In view of the existence of different races, the task of breeding resistant cultivars has become difficult. We have identified lines which have been consistently resistant in six to eight countries. Do you believe that by using such lines we would be breeding lines resistant to different races which might be present in various countries?

Claude Bernier

An answer to your question would be possible if we know what kind of resistance you have in the material-whether it is a partial or an absolute resistance; without really identifying the pathotypes that may be difficult.

S.B. Hanounik

I think we are at a stage now where we ought to take an in-depth look into the structure of the population of *Botrytis fabae*, *Ascochyta fabae*, and *Ascochyta rabiei*. A wide-scale survey is urgently needed to determine the distribution pattern of virulence within each pathogen. If highly virulent isolates are detected at one or more locations, then our breeding strategies should be laid down accordingly. Meanwhile, we must start immediately an active screening program particularly in chickpeas in order to identify genes for resistance to those highly virulent isolates. Such genes can be combined with other genes for resistance into well adapted cultivars that could be released and be much more effective and longer lasting. On the other hand, we should be very careful not to go ahead with cultivars that are already susceptible to certain existing pathotypes. Such cultivars will not only break down soon, but might also disturb the natural distribution pattern by increasing the frequency of highly virulent pathotypes for which genes for resistance would perhaps be difficult to find.

K.B. Singh

In view of the race situation in most of the diseases, the task of breeding resistant cultivars becomes rather difficult, particularly at an international center. With respect to ascochyta blight of chickpeas, we have identified some lines, which have been found to be resistant in six to eight countries. Without knowing the race situation do you think those lines could be used in the breeding program, and could one expect that material so generated will be resistant in those areas?

Salim Hanounik

I would like to make a small comment here. It is time now to take an indepth look on the frequency of virulence that we have in pathogen by surveys using differential set.

Proceedings of the International Workshop on Faba Beans, Kabuli Chickpeas, and Lentils in the 1980s (Saxena, M.C. and Varma, S., eds.), ICARDA, 16-20 May 1983, Aleppo, Syria.

Exploitation of Host-Plant Resistance in the Management of Ascochyta Blight and other Diseases of Chickpeas

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Joint contribution from ICARDA and ICRISAT

Diseases are the most important constraint to chickpea production (Nene 1980, 1982). In the past three years ascochyta blight (Ascochyta rabiei (Pass.) Lab.) and other foliar diseases have caused serious losses to chickpea production in the Indo-Pakistan region and the countries in the Mediterranean region (FLIP 1982; PARC 1981). The necessity for the control of ascochyta blight in winter-sown chickpeas was emphasized at the workshop on Ascochyta Blight and Winter Sowing of Chickpeas held at ICARDA in 1981, (Saxena and Singh 1984). In this paper the progress to date on the management of ascochyta blight in the joint ICARDA-ICRISAT Cooperative Progam at ICARDA, the on-going efforts, and the future strategies in the 1980s are presented. The approach to other diseases in kabuli chickpeas, such as root rots, wilt, and viruses is also discussed. These diseases are not of major concern at the present but are potentially dangerous.

Ascochyta Blight

Host-Plant Resistance

Since kabuli chickpea improvement work started at ICARDA in 1977/78 season, a major emphasis has been on the exploitation of host-plant resistance in the control of ascochyta blight. Reliable field, greenhouse, and laboratory inoculation techniques for screening germplasm and breeding materials for resistance have been developed, rating scales standarized, and systematic screening of the world collection of germplasm, comprising both desi and kabuli types, undertaken (Nene et al. 1980; Nene et al. 1981; Reddy and Nene 1978; 1979; Reddy et al. 1980; Reddy et al. 1984; Singh et al. 1981; Singh and Reddy 1981). During the past four seasons (1977/78 to 1980/81), over 13,000 germplasm accessions have been screened. Seventeen resistant to moderately resistant and 47 tolerant lines have been identified (Table 1). These lines showed resistance/tolerance both in the vegetative and podding stages of crop growth against the isolates of A.rabiei predominant at Tel Hadya, ICARDA's main research station. Kabuli and desi lines with a rating of 4 or less (moderately resistant to resistant) are listed below.

Resistant (3 rating):

Kabuli - ILC 202
Desi - ILC 6262

Moderately resistant (4 rating):

Kabuli - ILC 72, 196, 201, 2506, 2956, 3274, 3279, 3346, Pch 128.
Desi - ILC 3634, 4200, 4248, 4368, 5124, 6981.

Table 1. The frequency distribution of chickpea germplasm accessions on a 1-9 scale (1=highly resistant, 9=highly susceptible) for ascochyta blight resistance at Tel Hadya, 1979-82.

Blight rating	No. of accessions		Per cent of accessions	
	Kabuli	Desi	Kabuli	Desi
1	0	0	0.00	0.00
2	0	0	0.00	0.00
3	1	1	0.03	0.01
4	9	6	0.24	0.06
5	7	40	0.18	0.42
6	78	1198	2.03	12.51
7	876	311	22.84	3.26
8	17	80	0.44	0.83
9	2847	7939	74.24	82.91

The lines that were found promising at Tel Hadya have been tested at other locations in the region in the Chickpea International Ascochyta Blight Nursery (CIABN) for the past four seasons. The major objectives of this nursery are to study the performance of promising lines, to share the resistant sources with the national programs, and to collect information on the variability present in the blight fungus. A total of 190 lines were tested at 41 locations in 10 countries. Several resistant lines were found in each of the 10 countries (Table 2). Lines found resistant in different countries are:

Syria : ILC 72, 196, 201, 202, 2506, 2956, 3274, 3346, and Pch 128.
Lebanon : ILC 72, 182, 183, 187, 191, 194, 195, -196, 200, 201, 202, 215, 3342, 3346, 3400, and Pch 128.
Jordan : ILC 72, 182, 183, 191, 195, 200, 201, 202, 482, 484, 1695, 1757, 2380, 2548, 2555, 2956, 3257, 3279, 77MS 73022-2, and Pch 128.
Turkey : ILC 72, 182, 183, 187, 191, 194, 195, 196, 200, 201, 202, 2380, 2506, 2548, 2956, 3279, 3346, and Pch 128.
Algeria : ILC 182, 183, 190, 191, 192, 194, 195, 200, 201, 202, 205, 210, 248, 482, 1757, 2380, 2459, 2582, 2919, 3000, 3279, 77MS 73022, and 77MS 73131-12.
Tunisia : ILC 182, 183, 187, 201, and Pch 128.
Morocco : ILC 72, 182, 183, 187, 191, 194, 196, 200, 201, 202, 2380, 2506, 2548, 2956, 3346, and Pch 128.
India : ILC 191, 2380, ICC 76, 641, 1467, 1468, 1591, 1903, 2160, 4107, 7520, and NEC 138-2.
Pakistan: ILC 72, 3279, 3346, and Pch 128.
Greece : ILC 72, 183, 191, 194, 195, 484, 2380, 2548, 2956, 3257, 3279, 77MS 730022-2, and Pch 128.

Eight lines, ILC 72, 191, 194, 201, 202, 2956, 3279, and Pch 128, showed resistance in 6 to 8 out of the 10 countries where the testing was done. These have been provided to the national programs

Table 2. Number of kabuli and desi chickpea lines found resistant to ascochyta blight in different countries 1978-1982.

Country	Resistant[1] lines	
	Kabuli	Desi
Syria	10	7
Lebanon	28	28
Algeria	24	12
Tunisia	7	4
Morocco	18	12
Turkey	18	22
Pakistan	4	-
India	2	10
Jordan	21	16
Greece	13	3

1. Lines with 1-4 rating; with up to 15% of broken branches and pod infection. A few pycnidia observed in the stem lesions.

and are being used in the blight resistance breeding programs at ICARDA and ICRISAT. All these resistant lines have small and pea-shaped seed and are photoperiod sensitive. The genes for resistance have now been incorporated into typical kabuli lines, which are large seeded, tall and less photoperiod sensitive and have been made available to the national programs.

Variability in *Ascochyta rabiei*

The results from the CIABN indicate the existence of large variability in the blight fungus in the region (Nene et al. 1980; Singh and Reddy 1983). During the 1981/82 season, 50 blight samples were collected from spring-sown farmers' fields in Syria, winter-sown chickpeas at ICARDA's experimental sites (Tel Hadya, Kfar Antoon, Jindiress, Breda, and Lattakia in Syria, and Terbol in Lebanon), on-farm trial sites in Syria, and the experimental stations of the Syrian government. Based on the reaction of a differential set of 18 chickpea lines, the isolates were classified into four distinct races and four biotypes (Table 3). The differential sporulation rates of these races and biotypes further supported the distinction between them (Table 4). The more virulent isolates were mostly obtained from the experimental stations and

Table 3. Reaction of a differential set of 18 lines of chickpeas to 4 races and 4 biotypes of *Ascochyta rabiei* from Syria and Lebanon.

Chickpea line	Blight reaction Race							
	1	1A	2	3	3A	3B	3C	4
ILC 72	T	R	T	R	T	T	S	R
182	S	T	T	T	S	S	S	R
191	S	T	S	S	S	S	S	T
194	R	R	T	T	T	S	S	T
200	T	R	T	T	T	S	S	T
215	R	R	R	S	S	S	S	S
249	R	R	R	S	S	S	S	S
482	R	R	R	T	S	S	S	S
484	T	R	S	S	S	S	S	T
1929	S	S	S	S	S	S	S	S
3279	R	R	R	R	S	T	S	T
ICC 1591	T	R	S	T	T	S	S	S
1903	R	R	S	S	S	S	S	S
2232	S	T	S	S	S	S	S	S
3996	R	R	R	R	R	S	S	R
4107	R	R	R	T	T	T	S	T
C 235	T	R	R	S	S	S	S	S
F 8	S	R	S	S	S	S	S	S

R = Resistant; T = Tolerant; S = Susceptible.

other sites where research materials were tested. The less virulent isolates came from farmers'fields. Many resistant lines when infected by more virulent isolates showed considerable residual effect of the 'defeated genes' (Nass et al. 1981). These isolates while accumulating genes for virulence showed a significant decrease in their aggressiveness as measured by their sporulation rates on the susceptible cultivar (van der Plank 1978).

Vir and Grewel (1974) found two races and one biotype in north-western India. A collaborative project between ICARDA and the University of Reading, UK, is in progress to determine the extent of variability present in *Ascochyta rabiei* in the Near East and North Africa region. A preliminary report on the project is given elsewhere in this volume.

Screening of breeding material in the field at ICARDA is done against a mixture of races 1,2 and 3, which are predominant in farmers' fields. The germplasm is screened against the most virulent isolate (race 3C) in plastic house. Most of the earlier resistant lines showed susceptibility to type 3C. Over 3,500 germplasm lines have been screened and three lines, ILC 187, 202, and Pch 128 have shown resistance in repeated tests. The more virulent isolates will be incorporated in field screening when resistance sources are identified and crosses made with them.

Table 4. Sporulation capacity of 4 races and 4 biotypes of *A. rabiei* on 18 differential lines of chickpea.

Chickpea line	Spores x 10^6/g of inoculated tissue — Race							
	1	1A	2	3	3A	3B	3C	4
ILC 72	0.0	0.0	0.6	0.0	0.2	0.6	9.8	0.9
182	0.0	0.0	1.7	1.7	0.1	2.1	6.2	0.0
191	1.2	0.0	3.3	1.0	0.3	2.4	2.2	0.7
194	0.7	0.0	1.7	1.0	1.3	0.0	10.8	0.6
200	0.0	0.0	0.0	1.7	0.3	0.0	8.3	0.0
215	3.2	3.2	0.0	23.2	13.2	6.4	87.5	5.8
249	1.6	1.8	0.0	1.5	10.7	1.4	361.9	4.7
482	0.0	0.5	0.0	1.5	6.1	5.8	4.4	1.0
484	4.4	1.5	2.7	7.5	1.6	4.4	58.3	0.0
1929	345.0	115.0	30.7	31.1	10.4	92.4	36.5	2.5
3279	1.4	2.1	0.0	0.0	0.4	2.0	3.1	0.0
ICC 1591	3.8	1.0	14.6	0.0	1.0	1.5	10.0	0.9
1903	2.9	2.2	10.0	1.8	1.1	2.2	17.9	0.6
2232	5.8	2.2	14.5	9.0	6.6	1.6	73.3	1.7
3996	0.9	0.0	0.0	0.9	0.2	0.7	1.3	0.0
4107	2.4	4.0	0.0	1.4	1.7	0.0	5.4	1.0
C 235	0.0	0.0	1.1	1.6	3.7	2.1	21.3	1.2
F 8	36.7	0.0	0.0	2.3	1.0	6.0	3.6	0.7

Integrated Control

The studies so far indicate that chickpea has sufficient genetic resistance in the vegetative stage for the control of blight. However, the seed-borne nature of the disease and the large variability in the fungus make it advisable to find fungicides for seed dressing, and foliar application in the event the resistance "breaks down". Lack of high levels of resistance during the reproductive phase, especially in desi types, may necessitate the use of supplementary control measures.

Screening of some new fungicides, singly and in combinations, for the control of seed-borne inoculum showed Calixin M (11% tridemorph + 36% maneb), a mixture of Calixin M and Benomyl (1:1) and Tecto 60 (thiabendazole MSD) to be very effective (Reddy 1980; Reddy et al. 1982). A single foliar application of Bravo 500 (chlorothalonil) at early podding stage significantly increased the yield of a tolerant cultivar (Hanounik and Reddy 1984).

Sowing infected seed at 15 cm or deeper in pots was found to prevent the seed-borne inoculum being expressed in the plant above ground despite infection on the underground parts (Table 5). Similarly, burial of the diseased debris at 10 cm or deeper made the inoculum ineffective. In a study of the duration of survival of A.rabiei in buried diseased debris, the fungus could not be recovered even from the surface debris after eight months. Application of N, P, K, and Rhizobium inoculum did not influence blight development.

Durable Resistance

In an attempt to identify lines with durable resistance to Ascochyta rabiei, germplasm is screened against a range of races and biotypes at Tel Hadya, and resistant lines are tested in multilocation trials throughout the region. In addition, experiments are conducted in the plastic house and laboratory for resistance characters, such as low sporulation rate and low leaf-wettability.

The reactions of some promising genotypes to four isolates of A.rabiei and the sporulation rates are presented in Table 6. In many lines there was no relationship between the disease severity and sporulation rate. However, some lines, such as ILC 191, 194, 200, 202, 2548, 2956, 3279, 3340, 3342, 3346, 3400, ICC 3996, 4107, and 4475 showed lower sporulation rates and may possess durable resistance.

The leaf-wettability of these lines was also measured at different stages of crop growth, from the seedling to maturity stage. In general, leaf-wettability increased with the age of the plants. Again there was no relationship between blight reaction and leaf-wettability but some of the lines such as ILC 182, 187, 236, 484, 2548, 2956, and 3400 showed comparatively lower leaf-wettability. Of these, ILC 2548 and 2956 also showed lower sporulation rates.

Table 5. Effect of depth of sowing on transmission of ascochyta blight through infected chickpea seed.

Depth of sowing	1980/81[a]			1981/82[b]			1982/83[c]		
	A	B	C	A	B	C	A	B	C
3 cm	Not tested	Not tested	Not tested	65.6	14.0	5.9	56.7	19.1	14.7
3 cm	75.0	20.0	3.8	76.3	7.8	8.5	66.7	6.3	23.7
10 cm	65.0	12.0	5.5	66.3	0.0	12.5	50.0	6.7	23.4
15 cm	76.3	0	7.5	61.9	0.0	10.7	50.0	0.0	11.7
20 cm	71.3	0	5.0	63.8	0.0	11.3	34.2	0.0	36.6
CV (%)	-	-	-	14.57	37.97	51.22	22.6	132.7	31.91
LSD (5%)	-	-	-	14.98	9.25	7.69	21.8	17.34	14.39

A= % germination; B= % above ground infection; C= % Below ground infection.

a. 80 seeds tested for each treatment of susceptible cultivar ILC 1929.

b. Average of 3 replications, 40 seeds tested per replication. Cultivar ILC 1929.

c. Average of 3 replications, 40 seeds tested per replication. Cultivar ILC 482.

Table 6. Ascochyta blight disease severity and sporulation rates by four isolates (TH1,TH3,Lattakia and Terbol) of A. rabiei on some promising chickpea genotypes in relation to susceptible check ILC 1929.

	Blight rating					Spores x 10^6/g tissue				
Line	TH1	TH3	L	T	Mean	TH1	TH3	L	T	Mean
ILC 72	4	8	4	3	4.8	1.0	14.0	9.5	3.5	7.0
191	5	8	5	7	6.2	2.0	4.0	1.0	4.0	2.8
194	3	7	8	8	6.5	0.0	1.5	11.0	5.0	4.4
200	4	8	6	7	6.3	1.0	4.0	6.0	3.0	3.5
202	5	8	4	5	5.5	0.5	4.0	6.0	4.0	3.6
482	2	7	7	3	4.8	0.0	7.0	19.5	3.0	7.4
2548	5	7	7	6	6.3	3.0	1.0	4.5	4.5	3.3
2956	4	8	5	6	5.8	1.5	2.5	1.5	4.5	2.5
3279	4	8	5	6	5.8	1.5	7.5	0.5	4.0	3.4
3340	6	8	5	8	5.5	1.0	5.0	5.0	1.0	3.0
3342	5	8	6	8	5.5	2.0	3.0	1.5	1.0	2.0
3346	6	8	5	6	6.3	5.0	2.5	2.0	3.0	3.1
3400	5	8	5	6	6.0	1.5	8.5	2.5	4.5	4.3
ICC 76	5	7	5	3	5.0	5.5	18.5	5.5	6.5	9.0
607	5	7	5	3	5.0	15.0	24.5	7.5	4.5	12.9
641	4	7	5	3	4.8	4.0	18.5	23.5	2.0	12.0
1467	3	7	3	3	4.0	11.5	18.0	8.5	2.5	10.1
1468	3	7	5	3	4.5	7.5	16.5	11.5	3.5	9.5
2160	4	8	3	5	5.0	9.5	63.0	11.0	4.5	22.0
3921	5	8	3	3	4.8	20.5	20.0	5.0	1.5	11.8
3932	5	8	4	3	5.0	31.0	16.5	7.0	2.0	14.1
3940	3	8	3	5	4.8	10.0	28.0	4.5	0.0	10.6
3996	5	3	5	3	4.0	3.5	3.5	1.5	1.0	2.4
4107	4	4	4	3	3.8	6.0	6.0	6.5	1.0	4.9
4192	3	7	3	3	4.0	0.0	16.0	1.5	2.0	4.9
4472	5	6	5	4	5.0	2.0	32.5	10.5	1.0	11.5
4475	3	6	5	5	4.8	1.5	14.0	2.5	1.0	4.8
ILC 1929	7	9	9	7	8.0	36.2	131.5	148.0	17.0	82.6
CV (%)						53.8	29.9	45.0	56.3	
LSD (<0.05)						8.2	11.5	12.3	10.5	

L = Lattakia

T = Terbol

Wilt and Root Rots

The work at ICARDA concentrates mainly on ascochyta blight and that at ICRISAT on wilt and root rots. In the ICARDA region, as a whole, no serious problem of wilt and root rots has been observed. However, a considerable incidence of wilt (Fusarium oxysporum) has been noticed in spring-sown chickpeas at the experimental stations and in some farmers' fields in Tunisia since the 1979/80 season. Pathogens isolated from plants suffering from root and collar rots were Rhizoctonia solani, F. solani, R.bataticola, and Sclerotinia sp. The incidence of these pathogens was, however, very low. Seed, seedling and root rots, and wilt are known to occur in the Americas.

In the ICARDA region wilt and root rots were mostly observed in the spring-sown crop, whereas Sclerotinia sp. was observed mostly in the winter crop. The comparatively low temperatures that prevail during seedling stage of the winter-sown crop seem to minimize the problem of seed, seedling and root rots and wilt as compared to the spring crop. Once satisfactory levels of resistance to ascochyta blight are achieved, selection for resistance to the wilt and root rot pathogens will be made in collaboration with ICRISAT. Already crosses are being made between the blight, wilt, and root rot resistant lines at ICRISAT.

During the 1981/82 season, two field trials, one at Tel Hadya and the other at Terbol (Lebanon), were conducted to study the effect of seed dressing with different fungicides and combinations on the stand and yield in both winter- and spring-sown chickpeas. There was no significant improvement due to seed dressing either in stand or yield at Tel Hadya, indicating that the seed rots and seedling blights are not a problem at this site. The results of the spring-sown trial at Terbol are presented in Table 7. The results of the winter-sown trial were affected due to non-uniform soil moisture. There were significant increases both in the stand and yield due to seed dressing and ridge planting in the spring-sown crop.

Table 7. Effect of method of planting and fungicidal seed dressing (3g/kg seed) on the stand and yield of Lebanese local and ILC 482 chickpeas at Terbol, Lebanon, spring 1981/82 season.

Cultivar	Seed treatment[1]	STAND Flat	STAND Ridge	STAND Mean	YIELD (kg/ha) Flat	YIELD (kg/ha) Ridge	YIELD (kg/ha) Mean
Lebanese Local	B+Cal M	214	182	198.1	625	998	812
Lebanese Local	Captan	209	251	230.0	807	1150	978
Lebanese Local	Cal M	192	220	206.0	790	892	841
Lebanese Local	Control	49	131	90.3	212	807	509
ILC 482	B+Cal M	245	245	244.8	1097	1220	1158
ILC 482	Captan	270	297	283.5	1203	1223	1213
ILC 482	Cal M	269	276	272.7	1190	1007	1098
ILC 482	Control	149	203	176.0	8281	1020	924
Mean		199.7	225.7		844	1040	
		LSD (P<0.05)			LSD (P<0.05)		
Method of planting (m)		38.9*			369.5*		
Seed treatments (S)		25.0**			232.1**		
M X S		NS			NS		

1. B, Benlate; Cal-M, Calixin M; B + Cal M mixture 1:1.
*Significant at P < 0.05 level; **Significant at P < 0.01 level;
NS, Nonsignificant.

Virus Diseases

Pea leaf-roll virus, causing stunting, is the most widespread viral disease affecting chickpeas. Serious incidence of an unidentified virus was observed in the winter-sown chickpeas at the Beja Experimental Station in Tunisia during the 1981/82 season. Symptoms were similar to those of alfalfa and bean yellow mosaic viruses. Isolated plants with symptoms similar to bean yellow mosaic virus were also observed in winter-sown chickpeas in experimental plots in Syria during the 1982/83 season. More observations on the incidence of virus problems in winter-sown chickpeas is needed before giving any serious consideration to these problems.

Multiple Disease Resistance

Although the major emphasis at present is on the use of host-plant resistance to control ascochyta blight, lines highly susceptible to other potentially dangerous diseases, such as wilt , rust, and viruses are not selected. Off-season generation advancement during the summer at Terbol, Lebanon, provides an opportunity to eliminate material highly susceptible to these diseases. Up to 10% incidence of virus diseases, with a predominance of stunt, and 5% of wilt and root rots has been observed in some seasons. The incidence of rust is also serious, especially in late maturing lines.

Lines identified as resistant to wilt, root rots, and stunt at ICRISAT are tested against blight at Tel Hadya to identify lines with multiple disease resistance. So far 72 wilt and root rot, and 96 stunt resistant lines have been screened. Of these, one wilt (GG 688) and one stunt (ICC 8930) resistant line have shown vegetative resistance to blight in repeated screenings.

Seven lines identified as resistant to wilt and root rots at ICRISAT were screened against Fusarium solani in pots. These were ICC 554, 8446, 8454, 8622, 10466, ICC L 80002 and 80004. ICC 554 has shown resistance to F.solani. Thirty-one lines including both desi and kabuli types which were found resistant to blight at ICARDA were screened against Rhizoctonia solani in the plastic house. None showed resistance to this disease. The desi types showed comparatively higher susceptibility than the kabuli types.

Conclusions and Future Outlook

As a result of extensive screening of chickpeas for resistance to ascochyta blight in the past four seasons, resistant lines are now available. The international testing of the lines, and work carried out in Syria and Lebanon indicate the existence of enormous variability in the virulence structure of the fungus. With this information and results from the ICARDA - University of Reading collaborative study on the variability in the fungus on a wider geographic scale, the resistance screening work can be placed on a firm footing. The work on the use of fungicides in blight control has revealed their potential for seed dressing and as foliar application in combination with tolerant cultivars especially with the lines with low pod resistance. Although blight is the major disease problem at present, other potentially dangerous diseases, such as wilt, rots and viruses, cannot be ignored.

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Discussion

Y.L Nene

1. I commend ICARDA pathologist for following a uniform disease rating scale because that is of help for all.
2. Strategies being used: In a situation when resistance is virtually unknown, the priority will be to identify quickly sources of resistance and utilize them as quickly as possibly and make them available to the farmers. As a second line of defence, we should always work for durable resistance: identify the components involved in resistance, utilize them to the best, and make durable resistance available to the farmers.

3. Variations in *A. rabiei* are tremendous even within small geographical areas. But I am confident that solutions will be found.

Claude Bernier

Dr. M.V. Reddy puts durable resistance right at the end of the list. I think it is because of the problem of terminology. Describing a durable resistance as Johnson used it-the one that will last for ever, may be a wishful thinking. What one should be aiming at is something that is less subject to the boom and bust cycles that have been seen in rusts in North America. where a resistant cultivar is not affected for 2 years in the field and the third year it falls completely to the disease.

M.V. Reddy

The durable resistance is not the last priority in our strategy. In fact, we are now giving it the highest priority and our interpretation of durable resistance is more like what you have indicated. We are not aiming at a material which would remain resistant for ever, as we know. we may not be ever able to achieve that.

Proceedings of the International Workshop on Faba Beans, Kabuli Chickpeas, and Lentils in the 1980s (Saxena, M.C. and Varma, S., eds.), ICARDA, 16-20 May 1983, Aleppo, Syria.

Preliminary Studies of Variability in *Ascochyta rabiei*

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A number of chickpea cultivars were identified as resistant to *Ascochyta rabiei* in the Chickpea International Ascochyta Blight Nursery (CIABN) at ICARDA. Of these, six cultivars have been found to be resistant over 3 years of testing in CIABNs in Syria, Lebanon, Algeria, Turkey, and Pakistan (Singh *et al.* 1984). Evidence for differential interactions of *A.rabiei* with some chickpea cultivars has been reported in these nurseries (Singh *et al.* 1984). The higher yield potential of winter-sown chickpeas (Hawtin and Singh 1984) can only be realized with cultivars that are resistant to *A.rabiei*.

Breeding for ascochyta resistance requires some knowledge of the variability of *A.rabiei*. Studies on the pathogenicity of isolates from different locations should be done in a country where chickpeas are not grown commercially. Such work is now under way, therefore, at Reading.

This paper reports some preliminary experiments in which seedlings of a number of chickpea cultivars supplied by the Food Legume Improvement Program, ICARDA, were inoculated with isolates of *A.rabiei* taken from diseased material sent to Reading by ICARDA collaborators from throughout the region.

Methods

The facilities at Reading University permit inoculations with spore suspensions of *A. rabiei* either at the seedling stages in a controlled temperature room maintained at 20°C, or with mature plants in a plastic tunnel with temperature and humidity control.

Cultures of *A. rabiei*

Isolates taken from diseased material were maintained on chickpea meal agar. High spore concentrations for inoculations were obtained by preparing inoculum on 3-5g autoclaved chickpea seed in 25 ml flasks.

Chickpea Seedlings

Seeds were surface-sterilized in 25% w/v sodium hypochlorite for 2 minutes and sown in compost (John Innes No. 2) or in a 2:1 loam-sand mixture. Plants were grown in plastic propagation trays (60.4 x 32.4 x 8.3 cm), each tray containing 50 plants, or individually in 7 cm square pots.

Conditions of Inoculation and Disease Development

Inoculations were done 7-10 days after emergence when seedlings were 7-12 cm tall. Spore suspensions of 40,000 spores/ml were sprayed on the foliage until run-off, using a hand-operated pressure sprayer. During the four days following inoculation air temperature was maintained at 20°C with high humidity obtained by covering the trays with perspex lids or by enclosing the pots in perspex cabinets. Plants were subsequently uncovered and transferred to ambient temperatures. The daily mean air temperature in July, August, September, and October was 16.5, 16.3, 14.2, and 10.8°C, respectively. The mean maximum temperature was 21.3, 21.2, 18.8, and 14.9°C, respectively. The mean minimum temperature was 11.6, 11.4, 9.6, and 6.7°C, respectively.

Disease Assessment

Disease was assessed on an individual plant basis using a 1-9 scale based on the quantitative scale developed by Reddy *et al*. (1984). It was found that plants which reached a rating of 7 never recovered.

Six experiments were conducted (Table 1):

Experiment 1: Inoculated 2/8/82, grown in propagation trays, 10 replicates. Assessed 21 days after inoculation.

Experiment 2: As for 1 but grown in small pots, six replicates.

Experiment 3: Inoculated 12/8/82. Grown in small pots, six replicates. Assessed after 26 days.

Experiment 4: Inoculated 26/8/82. Grown in small pots, five replicates. Assessed after 20 days.

Experiment 5: Inoculated 1/9/82. Grown in propagation trays (60 plants/tray), six replicates. Assessed after 20 days.

Experiment 6: Inoculated 23/9/82. Grown in propagation trays, 10 replicates. Assessed after 19 days.

Table 1 Disease assessments based on mean score on 1-9 scale in six experiments with seedlings.

Cultivar	Isolate		
	SY 4(3)	SY 2(6)	SY1 (3)
Experiment 1			
ILC 202	4.1	6.4	2.5
ICC 2232	7.5	6.9	3.7
ICC 4935	9	8.9	3.5
ILC 482	9	7.9	4.1
ILC 1929	9	8.9	6.8
Experiemt 2			
	Sy 4(3)		Sy 1(3)
ILC 202	2.5		2.0
ICC 2232	4.2		3.4
ICC 4935	4.9		3.6
ILC 482	4.1		3.6
ILC 1929	7.7		4.7
Experiment 3			
	Sy 4(3)	Sy 2(8)	Sy 1(2)
ILC 202	3.5	7.1	3.4
ICC 2232	4.7	7.6	5.0
ICC 4935	7.1	8.0	5.0
ILC 482	7.0	7.6	6.1
ILC 1929	8.5	8.3	7.3
Experiment 4			
	Tu 3(4)	Sy 1(6)	Sy 2(8)
ILC 72	3.2	3.8	5.8
ILC 182	2.6	4.0	4.4
ILC 202	3.8	3.6	5.4
ILC 194	4.0	4.4	5.6
ILC 215	6.0	8.2	9

Table 1. Contd.

ILC 249	4.8	7.6	7.0
ILC 482	4.8	6.2	7.6
ILC 484	5.6	6.6	8.0
ICC 2232	4.2	4.6	6.4
ICC 4935	4.4	6.0	6.2
ICC 5127	4.4	6.0	7.2
ILC 1929	9	8.0	8.8

Experiment 5

	Mo 4(4)	Tu 3(4)	Lb 1(5)	Sy 4(4)	Sy 2(6)
ILC 72	5.4	6.2	5.3	7.4	9
ILC 191	5.5	6.2	6.5	6.1	8.7
ILC 202	5.7	5.7	4.8	7.0	8.8
ILC 194	6.5	4.5	6.0	8.7	8.0
ILC 3279	4.7	5.7	4.5	6.0	8.5
ILC 215	8.5	7.0	6.8	9	9
ILC 482	6.0	5.8	6.3	8.7	9
ICC 2232	7.3	8.3	7.3	8.1	9
ICC 5127	7.7	8.0	5.0	7.7	7.5
ILC 1929	9	9	8.5	8.7	8.7

Experiment 6

	Sn 1(4)	Mo 4(4)	Lb 1(3)	Sy 2(4)	Pk 5i(3)	Id 1 (4)
ILC 202	3.3	3.2	3.6	6.8	5.8	3.6
ILC 482	4.5	3.3	5.2	7.6	6.7	5.0
ICC 5127	4.8	4.3	4.9	8.5	6.7	4.6
ICC 2232	5.0	3.9	4.6	7.3	6.8	4.1
ILC 1929	6.9	6.3	6.5	8.5	8.2	6.0
ILC 3279	3.4	4.9	3.3	6.6	3.8	4.9
ILC 182	3.6	6.3	3.9	6.2	3.5	5.7
ILC 482	4.5	4.9	4.8	6.4	5.5	7.1
ILC 215	5.1	5.9	5.1	6.6	5.8	7.4
ILC 1929	7.4	8.5	9	7.0	6.3	8.3

Isolate country codes: Id=India; Lb=Lebanon; Mo=Morocco; Pk=Pakistan; Sn=Sudan; Sy=Syria; Tu=Turkey.

Results and Discussion

Isolate Sy2, which was collected by Dr.M.V. Reddy from a patch of infected resistant chickpea at ICARDA experimental station in 1980/81 was more pathogenic than the other isolates. Isolate Sy4 was collected from a patch of infected ILC 482 on an ICARDA on-farm trial site at Mareat Debse, and may be similar to Sy2. Isolate Syl was collected from the ICARDA station in 1980/81, and appeared to be the least pathogenic of the Syrian isolates so far tested.

In these experiements no differential responses to isolates among the kabuli cultivars ILC 72, 182, 191, 194, 202, and 3279 were observed.

Several inconsistencies appear in the results from different experiments. It is difficult to reconcile the susceptibility of ICC 2232 to Sy4 in Experiment 1, but with moderate resistance to the same isolate in Experiments 2 and 3, and, similarly, the differing responses of this cultivar to isolate Mo4 in Experiments 5 and 6.

Experiment 6 was divided into two parts to allow a greater number of cultivars to be tested. ILC 1929 and ILC 482 were common to each part and experiments were identical in that both trays were sprayed simultaneously with the same sprayer containing the same inoculum. However, the difference in the disease reaction of ILC 482 between trays inoculated with isolate Tdl was greater than 2 points. Similarly, with other isolates, infection on ILC 1929 varied considerably between trays.

Some experiments were assessed over longer periods. In such cases the final assessments were usually higher than those presented.

Conclusions

It would be premature to draw firm conclusions on the basis of the results presented. There do appear to be some variations between isolates from different sources, and these isolates will be tested again in next season. It is encouraging that five cultivars (ILC 72, 191, 194, 202, and 3279) were resistant or moderately resistant in all tests against all but the Sy2 and Sy4 isolates, as these cultivars were among those recorded as resistant at CIABN sites in Syria, Lebanon, Algeria, Turkey and Pakistan (Singh et al. 1984).

It is probable that the experiments would have been more precise if greater numbers of replicates or multiple plants per plot were used. Future experiments will not be on a single-plant plot basis. Similarly, attention will be given to provide uniform environmental conditions in the post-infective stage and it will be necessary to investigate the variability that might occur within the samples that have been sent to Reading by ICARDA collaborators.

Acknowledgement

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Fourth Session

Insect Pests of Faba Beans, Lentils, and Chickpeas in North Africa and West Asia: a Review of Their Economic Importance

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A large number of insect pests attack faba beans, lentils, and chickpeas in North Africa and the Middle East. Over 50 species have been recorded but, as is the case with other crops, only a few pose an economic threat to the farmer. In general, there is little effort for widespread control in the region. Insecticides are too expensive for the small farmer, and mechanization is limited, so there is little room for cultural control practices. No attention seems to have been paid to applied biological control. Thus, pest management in faba beans, lentils, and chickpeas in the ICARDA region is usually left to nature, though some farmers occasionally may use insecticides. Although several reports are available on insecticidal recommendations, very little information is available on their benefits and costs. Such information is essential for developing a suitable strategy for a pest management program. This paper reviews the state of knowledge on the economic importance of insect pests of food legumes and attempts to suggest areas requiring further attention for developing rational control strategies.

Faba Beans

The literature on economic losses due to insects in faba beans is scanty. Most studies on faba bean insects do not clearly define the economic status of individual species. Recent surveys conducted in Syria (ICARDA, unpublished results) and in North Africa (Diekmann 1982) revealed that the most important insects affecting faba beans are the *Sitona* complex, several aphid species, leaf miners, *Apion* spp., thrips, and different species of bruchids. Of local importance are *Spodoptera exigua* Hb. in the Sudan (Siddig 1981), and the stem borer, *Lixus algirus* L. in Morocco, Tunisia, and the coastal areas of West Asia (Diekmann 1982).

Useful studies to quantify losses due to insects in faba beans were recently carried out by Tahhan and Hariri (1981a). In a series of trials, effects of soil and foliar application of insecticides on insect populations and yields were studied. Yield increases of up to 28.6% were obtained (Table 1). However, since these trials had different objectives it is not yet possible to separate the relative importance of *Sitona* spp., the most common soil insect, from that of foliar insects (mainly aphids, *Apion* spp., and thrips). Carbofuran has been found to stimulate plant growth in other crops (IRRI 1980). Also, in at least one trial, the residual effect of carbofuran was sufficient to control *Apion* and thrips later in the season. These effects have masked the effect of *Sitona* spp. larval and adult damage. Current research at ICARDA is attempting to clarify these points.

Table 1. Percentage yield increases obtained in faba beans through chemical control of insects in Syria.

Kind of protection	Yield increase (%)		
	1979/80	1980/81	1981/82
Soil	15.6	16.2	7.1
Foliar	3.5	28.6	-1.8
Complete	19.8	-	2.2

Trials aimed at measuring total yield losses provide only partial information and usually result in extremely expensive, unrealistic recommendations. A possibility is to combine the yield loss assessment *per se* with a series of treatments aimed at quantifying yield losses partitioned among crop growth stages, determining the key pest or pests responsible for yield losses and, most importantly, evaluating the costs and returns of the technology. This line of research is being pursued at ICARDA.

One interesting case is that of *Sitona* spp. Since the larvae attack faba bean nodules and adults consume the foliage at early growth stages it has been suggested that the foliar and nodule damage have a severe effect on the N-fixing process of the plant. The economic importance of *Sitona lineatus* L. is a matter of controversy in England (Bardner *et al.* 1982). In Syria, infestations by adult *Sitona limossus* (Rossi) are high (Tahhan and Hariri 1981b). Carbofuran, applied at the high rate of 1.5kg a.i./ha increased the yield by 16%. In another trial (Tahhan and Hariri 1981a) a nonsignificant increase of 15.7% was obtained. The objectives of the current research at ICARDA are the separation of yield losses due to larvae and adults, and the comparison of carbofuran with a supposedly plant-neutral granular insecticide.

The literature on the economic importance of other faba bean insect pests is scanty. For example, the only reference to the leaf miner, *Liriomyza* sp., is that of work carried out by Maher Ali *et al.* (cited by Diekmann 1982). According to this research, even an 80% infestation did not significantly affect yields.

Surprisingly, there does not seem to be any report on yield losses in faba beans due to aphids in Egypt, even though aphids are regarded as the most important pest in that country (Kamel 1982). Economic losses caused by *Spodoptera exigua* Hb. in Sudan need further evaluation. Siddig (1982) found that the combined effect of *Spodoptera* spp. and aphid damage reduced yields by 19%. In other trials when *Spodoptera* spp. and thrips were controlled, yields increased by 17.2% in 1974 and 21.1% in 1975 (Siddig 1982). Since *Spodoptera* spp. attacks occur early and can be selectively controlled, it should be possible to quantify its economic importance more precisely.

Bruchids attack faba beans throughout the region. *Bruchus dentipes* Baudi affects up to 77% of faba bean seeds in Syria (Tahhan and Hariri 1981c). In the Sudan, Siddig (1982) reports up to 30% damage by *B.elnairensis* Pic, but Bushara (1983) indicates that the average infestation amounts to 9.5%. This low level of damage is attributed to the fact that storage periods in Sudan are short. Fam (personal communication) dismisses the importance of *B.rufimanus* Boheman in Egypt on the basis that it is easily controlled by routine, government-sponsored, fumigations. This species is regarded as a serious pest in Lebanon, Syria, and Iran (Hariri, 1980).

No referances to the economic importance of *Lixus algirus* L. could be found. The insect is extremely common in coastal areas and according to our studies may infest up to 90% of faba bean stems with no apparent effect on yields. An attempt to quantify the losses due to this species is in progress.

Lentils

Descriptive reviews of insects affecting lentils in the Middle East have been published by Kawar (1979) and Hariri (1979). These have been superceded by a more comprehensive account by Hariri (1981a). Subsequently, Tahhan and Hariri (1982b) conducted a survey in Syria. According to these workers the *Sitona* spp. complex, several species of aphids, *Apion arrogans* Wenck, thrips, and bruchids are the most important pests. Other insects, such as cut worms, pea moth, and pod borer, are regarded as less injurious.

The *Sitona* spp. complex, of which the major species are *S.lineatus* L., *S.macularius* Marsham, and *S.limossus* (Rossi), has received most attention but with conflicting results. Islam (1981) initially reported that carbofuran treatment could increase grain production by 97.2%. Subsequently, Islam and Afandi (1982) calculated an average yield increase of 28% when *Sitona* spp. were controlled. Thahhan and Hariri (1982a) found that the maximum yield increase due to carbofuran was 16.2% (Table 2). In the 1981/82 season there was no response to carbofuran applications even though infestions in these trials were consistently high. It is unfortunate that a consistent pattern of evaluation was not kept across the seasons. Nevertheless, the data tend to support the conclusion reached by Tahhan and Hariri (1982a) that insects attacking foliage (mainly aphids, Apion spp., and thrips) are more important in terms of yield losses. The status of Sitona as pest of lentils is now under review. Trials in which larval and adult damage are partitioned, and in which the possible stimulatory effects of carborfuran are being assessed should further clarify the importance of soil and foliar insects. Current research also attempts to assess yield losses in an economic context.

Literature on the importance of bruchids is rather scarce. According to Hariri (1980), attacks by Bruchus ervi Fröll, B.lentis Fröll, and B. signaticornis affect up to 80% of lentil seed in Syria, Turkey, and Iran. Of the Callosobruchus species, C.maculatus (F.) and C.chinensis L. are most important, and up to 70% infestation has been recorded in Cyprus (Hariri 1980). Weight losses in lentils affected by C.chinensis L. range from 8% to 46% and seed containing four or more beetles may fail to germinate. Smaller seeds are more affected (Hariri 1981a)

Table 2. Percentage yield increases obtained in lentils through chemical control of insects in Syria.

Kind of protection	Yield increases (%)			
	1979/80	1980/81	1980/81	1981/82
Soil	7.6	16.2	-	0
Foliar	-	28.6	-	5.7
Complete	14.5	-	18.7	9.2

Chickpea

Chickpea has few problems, with the exception of the leaf miner, Liriomyza cicerina Rond. and the Heliothis spp. complex. These are the most important field pests in North Africa and West Asia. In storage, Callosobruchus chinensis L. is the predominant species.

The economic impact of leaf miner and Heliothis spp. attack has been studied. A recent report (Sithanantham et al. 1983a) summarizes the information gathered in West Asia. The crop losses due to insects in chickpea on a wider geographical basis have been reviewed by Sithanantham et al. (1983b).

Results from a series of trials in Syria indicate that average yield increase due to insect control in winter- and spring-planted chickpeas are 20% and 25%, respectively (Table 3). The data also suggest that *Heliothis* spp. are more important in winter plantings and support the findings of Sithanantham *et al*. (1984). If winter planting becomes widespread in West Asia, there is the possibility of *Heliothis* spp. becoming a serious threat, especially in years when, as recorded by Hariri (1981b), a mild winter or an early spring may allow the moths to emerge from diapause in February or early March.

It has been impossible to separate yield losses due to leaf miner from those due to pod borers in chickpea (Sithanantham *et al.* 1983b). Current research attempts to do this. However, given the low levels of pod borer damage in spring plantings (Table 3), one can assume that leaf miner accounts for most of the observed damage. This is true in northern Syria and Turkey. The situation may be different in Jordan and southern Syria, where *Heliothis* spp. populations are higher (Sithanatham *et al*. 1983a).

There is no information on the economic importance of the leaf miner in North Africa, although the insect is said to be common in Tunisia, Algeria, and Morocco. Likewise, quantitative estimates on losses due to the *C.chinensis* L. are not available.

Table 3. Percentage yield increases due to chemical control of insects in winter- and spring-sown chickpeas and mean levels of pod borer damage detected in untreated plots, Tel Hadya, Syria.

	Winter sowing		Spring sowing	
	% yield increase	% pods damaged by *Heliothis* spp.	% yield increase	% pods damaged by *Heliothis* spp.
1979/80	17.5	4.0	20.8	2.7
1979/80	27.6	6.5		
1980/81	19.1	10.9	23.2	1.1
1980/81	15.5	9.1	21.1	1.2
1981/82			45.0	2.4
1981/82			18.0	6.3

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Discussion

J.A. Thompson

Although the data presented did not show a reduction in yield due to *Sitona*. there is quite possibly an effect on the proportion of the N fixed. The ^{15}N technology already in use at ICARDA can provide a measure of this loss in N fixed.

R. Summerfield

1. Your trial designs lack three treatments which would make them factorial and, presumably, may improve the efficiency of data analysis (exposing interactions, etc). Are there any reasons why the design is not a factorial one?
2. How do you sample? Do you consider sweeping to be appropriate? What about vacuum sampling? Do you correlate infestation estimates based on different sampling methods?

C. Cardona

1. Size is the main reason. Since fairly large plots have to be utilized the trial would become too big.
2. Samples depend on the insect species. Sweep net is appropriate for some insects such as leaf miner adults, *Heliothis* larvae, to cite a few examples. This is not suitable for other insects, such as *Sitona*, for example. The vacuum sampler is better and more efficient and we are in the process of purchasing one. Yes, we try to correlate different infestation estimates.

S.B. Hanounik

Do you have plans to study the role of some of these insects as virus vectors?

C. Cardona

Yes, we intend to move in that direction when aspects of higher priority have been completely investigated.

Shaaban Khalil

In Egypt we found that some faba bean genotypes were clearly sensitive to chemical control against aphids. What are your recommendations in this case?

C. Cardona

There are several efficient systemic insecticides which can be used against aphids, such as dimethoate, pirimicarb, phosphamidon, and ometoate. These, if used at the proper rate, should not be phytotoxic.

M.V. Reddy

1. What will be the future strategy for insect control when the yield levels are doubled such as winter chickpeas?
2. It is difficult to understand that in spite of huge damage due to insects there is no loss in yield.

C. Cardona

1. There will be a need to keep a thorough monitoring system for insect pests in winter chickpea, particularly for the pod borer.
2. The reason is that at different or particular growth stages a plant can stand a heavy population without a significant effect on yield because of growth compensation.

R.S. Malhotra

Artificial infestation or spread of insect pests for screening against insect pests seems difficult as compared to artificial spread of diseases. In this connection, I would like to know whether you are trying to investigate some indirect parameters which are related to resistance mechanisms which could be of help for screening of materials, e.g. certain chemical constituents of the different genotypes which may be responsible for resistance. These will be easy to be scored for, if some relations are established.

C. Cardona

We have not yet started this aspect in our studies. But when reliable sources of resistance have been identified, these could be used for getting an indication of the basis of their resistance and could thus permit us to develop an indirect method for resistance screening.

Proceedings of the International Workshop on Faba Beans, Kabuli Chickpeas, and Lentils in the 1980s (Saxena, M.C. and Varma, S., eds.), ICARDA, 16-20 May 1983, Aleppo, Syria.

Weed Control in Lentils, Faba Beans, and Chickpeas

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Legumes are more sensitive to weed competition than cereals through the entire cropping season. In contrast to many other crops, where early season weed-free conditions are sufficient, legumes (especially lentils and chickpeas) do not achieve ground cover sufficient to prevent the late establishment of weeds. Lentils, particularly small-seeded cultivars, have shown relatively poor tolerance to weed competition compared with other food legumes.

Weed control in legumes is a major constraint, especially to early winter planting. Early plowing and other preplanting soil tillage operations are of limited use, because weed seeds usually germinate at the same time as the legume crop, thereby competing for moisture and nutrients. Narrower row spacing or higher seeding rates have not shown any benefit. Mechanical weeding removes some weeds, but large numbers survive and quickly overgrow the crop. Crop injury may also be a negative effect of mechanical weeding. Chemical weed control is possible but there are problems of phytotoxicity. The parasitic weed Orobanche spp., causes significant losses to food legumes, especially faba beans, lentils, and winter chickpeas. Breeding for resistance to Orobanche has not yet been completely successful but has shown promise. There are no effective cultural practices or chemicals to control this weed on a commercial level.

Weed Control in Lentils

Yield losses in lentils due to weeds depend upon weed infestation level, weed species involved, soil fertility, and soil moisture. Basler (1980) found an 87% yield loss in an unweeded, fertilized crop, as compared to the weed-free control.

Soil moisture has a direct effect on weed pressure on lentils, as increased available moisture tends to be utilized better by weed species and volunteer crops. Particularly, early emerging species grow rapidly and offer increased competition to lentils.

Cultural and Agronomic Practices of Weed Control in Lentils

Tillage is recognized as a major factor in weed control. Basler (1980) reported up to 40% reduction in weed dry-matter production from cultivations, as opposed to a zero tillage system. Tillage does reduce the initial population of weeds, but cannot control those that germinate later.

The timing of cultivation is important in weed control. Final seedbed preparation after the first rain, which allows weeds to germinate, will reduce the population of early germinating weed species (Table 1).

Table 1. Total dry matter of weeds (TDM) as influenced by timing of cultivation in a fertilized and unfertilized crop of lentil (Basler 1980).

Time of Cultivation		Weed TDM (kg/ha)	
Plowing	Harrowing	Fertilized	Unfertilized
Before first rain	Before first rain	5550	1950
Before first rain	After first rain	4233	2950
After first rain	After second rain	1750	1200

However, this practice cannot be widely adopted since the delay in planting may result in yield reductions, particularly in areas with low rainfall. Manual weeding, the traditional method of weed control, is no longer economical due to high labor cost. For the adoption of mechanical weed control two basic requirements have to be met: (i) the crop must be planted in wider row spacing to permit interrow cultivation, and (ii) low soil moisture, permitting the use of machines. However, Basler (1980) found no yield benefits from interrow cultivations, as compared to an unweeded control. Two interrow cultivations actually reduced the yield by 38%.

Chemical Weed Control

Lentils are relatively more sensitive to preemergence herbicides than other, mainly larger seeded, legumes. This is because the small-seeded lentils start to take up nutrients from the soil, along with herbicides, earlier than the large-seeded species. None of the existing foliar-acting, postemergence herbicides, excepting a few grass-killers, has proven sufficiently selective in lentils, particularly in low rainfall areas. Therefore, special care must be taken with postemergence herbicides with respect to the rate, method, and time of application.

Amongst broadleaved preemergence weed killers the most promising are prometryne (Gesagard) at 1.0 or 1.5 kg a.i./ha (in higher rainfall zones) , cyanazine (Bladax) at 0.5 kg a.i./ha, and chlorbromuron (Maloran) at 1.0 kg a.i./ha. Each of these herbicides applied with pronamide (Kerb) at the rate 0.5 kg a.i./ha provides satisfactory control of both broadleaf and grass weeds.

Metolachlor (Dual) is selective and effective against many grasses, when applied before emergence at the rate of 1.0 kg a.i./ha, but has little effect on volunteer cereals. Diclofop-methyl (Illoxan) is the most effective, and selective, grass killer when applied postemergence at 1.0 kg a.i./ha at the two to three leaf stage of growth of the grass. It controls a wide range of grasses, but does not control volunteer cereals. PP009 (Fusilade) is an excellent selective postemergence herbicide for control of a wide spectrum of grasses, including volunteer cereals. It is best applied when grasses and volunteer cereals are 10-15 cm tall.

Depending upon the situation, different treatments are recommended (Table 2).

Table 2. Herbicide recommendations for weed control in lentils.

Application	Weed situation	Herbicide	Rate (kg a.i./ha)
Preemergence	Annual broadleaved weeds	cyanazine	0.75
	Annual broadleaved and grass weeds	cyanazine +pronamide or chlorbromuron + pronamide	0.5 0.5 1.0 0.5
Postemergence	Annual broadleaved weeds	dinoseb acetate	1.0
	Annual broadleaved, grasses and volunteer cereals	dinoseb acetate + PP009	1.0 1.0

Orobanche Control

Orobanche species, commonly known as broomrapes, are an important parasitic weed of lentils. A single Orobanche plant infecting a lentil plant causes such a drain on nutrients that the host plant will die before producing seed.

The most effective control of Orobanche spp. would be through developing resistant lentil cultivars. Existing cultivars show differential susceptibility to the various Orobanche spp. and screening for resistant lines is in progress. Chemical control of Orobanche spp. has been attempted, and several products appear promising. Ethyl dibromide (EDB) has shown good control of Orobanche crenata at 3.0 ml a.i./meter row length. The treated soil must be immediately covered to prevent volatilization. Glyphosate (Lancer) at 0.08 kg a.i./ha in three applications, starting when lentils are 10 cm tall, seems to be very promising (Table 3).

Weed Control in Faba Bean

Faba bean is more tolerant to weed competition than most legumes but without weed control measures, crop losses of up to 54% have been recorded. The tillage and cultural practices, such as higher seed rate, and narrow row spacing, failed to increase crop competitivity. The critical period for weed/crop competition in faba bean begins six weeks after sowing. In cases with low infestation, interrow cultivation may reduce weed competition. However, it cannot entirely eliminate the weeds, particularly those growing within the row of the crop. Additional hand weeding or other means of control are required.

Chemical Control

Faba beans are tolerant to many herbicides, the best of which are preemergence herbicides for broadleaved weeds. Methabenzthiazuron (Tribunil) at 3.0 kg a.i./ha or terbutryne (Igran) at 2.0 kg a.i./ha appear effective (Table 4). The combination of terbutryne with pronamide (Kerb) at 0.5 kg a.i./ha provides good control of broadleaved weeds and some grasses.

Postemergence herbicides may cause crop phytotoxicity. However, bentazon (Basagran) applied at 1.0 kg a.i./ha gives sufficient broadleaf weed control and significantly increases the yield of faba bean in comparison to the weedy check. The postemergence application of PP009 (Fusilade), at 1.0 kg a.i./ha, provides excellent control of grasses, including cereal volunteers.

Orobanche Control

Of the legume crops, faba bean is the most sensitive to Orobanche crenata. Total crop loss may occur when infestation is severe. Cultural practices for controlling this parasite are limited and ineffective. Delaying planting can significantly decrease Orobanche spp. infestation, but can also reduce the yield of faba bean (Table 5).

Table 3. Chemical control of *Orobanche crenata* in lentil (ILL 4401).

Treatment	Lentil dry wt		*Orobanche* spikes		*Orobanche* dry wt	
	kg/ha	%[1]	No/m^2	%[1]	g/m^2	%[1]
Glyphosate at 0.04 kg a.i./ha 3 times at 10 day intervals starting when lentils were 10 cm high	1699	81	68.5	68	22.4	61
Glyphosate at 0.08 kg a.i./ha 3 times with 10 day intervals starting when lentils were 10 cm high	2212	106	18.8	19	9.4	26
Pronomide at 2.0 kg a.i./ha when lentils were 10 cm high	1881	90	54.9	54	20.6	56
Pronomide at 4.0 kg a.i./ha when lentils were 10 cm high	2094	100	41.7	41	17.4	48
Trifluralin at 0.5 kg a.i./ha preplanting incorporation	853	41	23.3	23	13.5	37
Pronomide at 2.0 kg a.i./ha + Glyphosate 0.08 kg a.i./ha twice with 10 day intervals starting when lentils were 10 cm high	1473	71	22.6	22	10.6	29
Orobanche removal by hand	1720	82	83.2	82		
Control (no removal of *Orobanche*)	2087	100	101.4	100	36.5	100
LSD 5%	506		33.9		8.9	
CV (%)	19		44.4		36.2	

1. Relative to control. Control = 100%.

Table 4. Results of the International Faba Bean Weed Control Trial at Tel Hadya (with rainfed ILB 1814) and Hama (with irrigated Cyprus local faba bean) in 1981/82. Crop phytotoxicity (Ph) recorded on 1-9 scale; 1=no toxicity, 9=complete kill. SY=Seed Yield (kg/ha). Herbicides applied as preemergence spray.

	Tel Hadya		Hama *	
Treatment	SY (kg/ha)	Ph	SY (kg/ha)	Ph
Weedy check	1290		3196	
Weed-free check	1754		5163	
Weeding 2 times	1628		4450	
Chlorbromuron 1.0 kg a.i./ha	1628	2	4597	1
Chlorbromuron 1.5 kg a.i./ha	1510	2	4898	1
Chlorbromuron 2.5 kg a.i./ha	1489	4	4574	1
Methabenzthiazuron 2.5 kg a.i./ha	1419	1	4821	1
Methabenzthiazuron 3.0 kg a.i./ha	1610	1	4391	1
Methabenzthiazuron 3.5 kg a.i./ha	1510	2	5127	1
Terbutryne 2.0 kg a.i./ha	1374	2	5074	2
Terbutryne 2.5 kg a.i./ha	1406	5	4608	2
Terbutryne 3.0 kg a.i./ha	1469	5	4657	4
CV (%)	12.9		10.2	
LSD 5%	348.4		669.7	

* Data from Farouk Yassin and M.C.Saxena (Personal communication).

Table 5. Orobanche infestation and faba bean yield as affected by three dates of planting.

Date of planting	No. of Orobanche shoots/4 m^2	Orobanche dry matter g/4 m^2	Faba bean yield g/4 m^2
December 28	14.80	23.4	328.8
December 19	6.40	12.5	334.4
January 10	0.56	1.7	193.1

Breeding for resistance to Orobanche: Screening of germplasm has identified a number of faba bean lines tolerant to Orobanche crenata. These lines will be used to develop Orobanche resistant lines.

Chemical control: Investigations on chemical control of Orobanche crenata have been undertaken. Glyphosate, pronamide, and trifluralin show some promise. There are large variations in the effect of glyphosate between different environments; phytotoxicity and reduction in yield at the high rainfall site, Lattakia, and yield increase under low rainfall conditions at Tel Hadya (Table 6). In the time of application trials at Lattakia it was found that glyphosate is best applied at 50% flowering. Both pronamide, as a postemergence herbicide, and trifluralin, a presowing incorporated chemical, were used successfully under high rainfall conditions, but were ineffective at Tel Hadya.

Table 6. Control of Orobanche crenata in faba bean (ILB 1814) with herbicides at low (Tel Hadya) and high (Lattakia) rainfall sites during 1981/82.

Treatment	Tel Hadya				Lattakia			
	Faba bean yield		Orobanche dry wt.		Faba bean yield		Orobanche dry wt.	
	kg/ha	%	g/m^2	%	kg/ha	%	g/m^2	%
1	703	858	4.3	4.2	527	126	2.5	2
2	70	86	57.7	60	1393	429	15.5	10
3	95	116	72.3	75	1370	414	0.7	0.5
4	53	64	31.3	33	538	129	61.0	38
Control	82	100	96.3	100	417	100	160.2	100
LSD (5%)	289		18.9		565		28.9	
CV (%)	108		28.3		42		39.20	

1 = Glyphosate at 0.08 kg a.i./ha 3 times starting early flowering.
2 = Pronamide at 4.0 kg a.i./ha, early postemergence.
3 = Trifluralin at 0.5 kg a.i./ha preplanting incorporation.
4 = Pronamide at 2.0 kg a.i./ha + Glyphosate at 0.12 kg a.i./ha at flowering.

Weed Control in Chickpea

Yield losses in chickpea due to weeds have been estimated to range from 30 to 50% (Saxena 1980). Winter-planted chickpeas require more control than the spring-planted crop. At Terbol, a high rainfall site, a yield reduction of 75% due to weed infestation was recorded in winter-planted ILC 482 (Table 7). Postemergence herbicides are not recommended for use on chickpea due to the possibility of their phytotoxic effect on the crop. However, PP009 (Fusilade) provides selective control of grassy weeds when applied at the rate of 1.0 kg a.i./ha when grasses are 10-15 cm tall.

Table 7. Effect of weed control treatments on yield of winter planted chickpea at low (Tel Hadya) and high (Terbol) rainfall sites.

Treatments	Application rate (kg a.i./ha)	Tel Hadya Yield kg/ha*	Tel Hadya No. of weeds /m^2	Terbol** Yield kg/ha
Weedy check		289	135	399
Weed-free check		389		1575
Weeded 2 times		338		1296
Terbutryne + Pronamide	2.0+ 0.5	310	26	1340
Terbutryne	4.0	119	16	1136
Cyanazine + Pronamide	1.0+ 0.5	345	34	863

* Very low yield at Tel Hadya was due to ascochyta blight infestation
**Data from M.C.Saxena (Personal communication).

Studies in India (Dhingra et al. 1982) indicated that the preemergence application of terbutryne (Igran) at 0.75 kg a.i./ha or methabenzthiazuron (Tribunil) at 1.05 kg a.i./ha were most effective in controlling weeds in chickpea. These treatments reduced weed infestation to a level similar to that obtained with hand weeding twice, which is the traditional practice, and gave slightly higher yields.

Orobanche Control

Spring-sown chickpea is highly resistant to Orobanche crenata. When sown in winter, resistance is lower. A total of 504 kabuli chickpea accessions were screened in a winter-sown nursery at ICARDA in 1981/82. Most were found to be resistant, including 72 that were totally free from infestation in all replications.

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Discussion

S. Salem

1. Have you carried out economic evaluation of your herbicide treatments vs. hand weeding?
2. What was the residual effect of the herbicides you mentioned in the faba bean trial, especially in the rainfed area?

S. Kukula

1. Obviously, if there is heavy weed infestation, any kind of weed control is economic, including hand weeding. If the weed infestation is low, neither chemical nor hand weeding is of economic importance.
2. We have not observed any residual effect of herbicides used in faba bean on following crops. However, we have not done bioassay. The herbicides and their rates we apply in legumes are safe for the following crops growing in the region.

K.G. Cassman

Would not the weed control method selected depend on the yield potential? For example, in Table 7 you show data which indicate hand weeding would be an economic control method at Terbol since yield increased four-fold to about 1600 kg/ha from 400 kg/ha in the weedy check. In contrast, at Tel Hadya where there was little yield response to chemical or hand weeding control methods and poor yields, no weed control method would appear economic. In high yield potentil areas, is not hand weeding still an economically viable weed control method?

S. Kukula

You are right, and depending upon the local cost of hand labor , the economics of hand weeding vs. chemical control could change. Within ICARDA region there is a large variation in the rates.

Proceedings of the International Workshop on Faba Beans, Kabuli Chickpeas, and Lentils in the 1980s (Saxena, M.C. and Varma, S., eds.), ICARDA, 16-20 May 1983, Aleppo, Syria.

Nematodes of Faba Beans, Chickpeas, and Lentils in the Mediterranean Region and their Control

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Plant parasitic nematodes are worldwide in distribution, and of economic importance in many crops. Lamberti (1981) reviewed their occurrence in the Mediterranean region and reported that most of the important species are uniformly distributed. However, information for some countries is scanty.

Faba bean (Vicia faba L.), lentil (Lens culinaris Moench.) and chickpea (Cicer arietinum L.) are important crops in the Mediterranean area. Their yields are very often reduced by nematode attack; the most damaging of them are briefly discussed here.

Ditylenchus dipsaci

The bulb and stem nematode, Ditylenchus dipsaci (Kuhn) Filipjev, is the major nematode problem of faba beans in many areas. It is both soil- and seed-borne, as the preadult stage can survive for many years even in dry or freezing conditions as a quiescent stage in soil, seeds, or plant remains. However, prolonged temperatures above 40°C are lethal. Marinari et al. (1971) demonstrated that the nematode could also survive in the animal intestine.

Infested seeds are an important means of distributing the nematode. However, sowing infested seeds does not usually result in much injury to the crop, although large populations in the soil at harvest may result in noticeable yield losses in the following crop (Hooper 1971). D. dipsaci can feed and reproduce on several hundred plant species, including weeds, which maintain pathogenic population densities of the nematode in the soil even in the absence of the host crops. More than 15 races of the nematode have been identified, the most important for faba bean being the giant race.

When seeds germinate the nematodes become active, and when plantlets are wetted by dew, fog, or rain, they move towards the above-ground parts, penetrating stems or leaves. On their migratory pathway the nematodes feed on the surrounding cells causing them to become necrotic. Each female lays up to 500 eggs, from which second-stage juveniles emerge. These in turn migrate within the plant tissues and destroy cells. Whenever the surface of the plant is wet the nematode may also emerge from the plant and move towards an uninfested site. The life cycle of the stem nematode can be completed in 19-23 days at 21°C (Yuksel 1960) and several generations may occur in a growing season. Therefore, even in the case of low soil infestation, under suitable conditions, nematode populations may build up rapidly to a level at which crops may be destroyed.

Leaves of infested faba bean plants become dark and necrotic. According to Hooper (1971), the stems develop a reddish brown discoloration which eventually turns black, a symptom which can be confused with plant senescence, or certain diseases. The infestation on stems and leaves may eventually reach the pod-bearing region when pods and seeds may also be infested. When the plant becomes senescent, thousands of fourth-stage specimens may also aggregate at the base of the stem (Lamberti and Greco 1974).

Infested seeds may be identified by brown spots on the cotyledons, which are more clearly seen when the testa is removed. A heavily infested seed may contain 10,000 nematodes. Green and Sime (1979) found that 38% of the samples of stock seed examined were infested by _D. dipsaci_, but even in the case of a heavy infestation only 25% of the seeds of a given sample were infested (Green 1979).

Because of the longevity, polyphagy, prolificity, and pathogenicity of the stem nematode, control measures need to be used. Good control can be achieved by treating the soil with nematicides, but this is expensive and usually uneconomical for faba bean. The use of clean seed should be encouraged. Plant quarantine regulations of many countries prohibit importation of seed stocks infested by _D. dipsaci_.

Powell (1974) demonstrated that a CTP (concentration time product) of 3000 mg hr/l of methyl bromide eradicated the nematode even from heavily infested seeds. Unfortunately, such a concentration reduces germination and normal seedling development, but phytotoxicity is negligible if a CTP of 1000 mg hr/l is used, which is sufficient to kill all nematodes in lightly infested seeds. Winfield (1970, 1971, 1973) showed that _D. dipsaci_ infesting narcissus bulbs can be controlled satisfactorily by soaking in hot water at 44-45°C for 3-4 hours. Chitwood (1941) eradicated infestations in narcissus bulbs by treatment with 0.5% hot formalin solution. Therefore, the hot water treatment should also be investigated for faba bean seeds, since it is safe for the operator and could provide the farmer with an easy and effective routine method to clean seed stocks just before sowing. It is also suggested that seed stocks should be produced only in fields pronounced free from the nematode following inspection by experienced personnel.

Unfortunately, improved faba bean cultivars resistant to D. dipsaci are not available, but Sturhan (1980) found that a local Moroccan variety showed a satisfactory degree of resistance.

Heterodera goettingiana

The pea cyst nematode, Heterodera goettingiana Liebscher, occurs in Italy and Algeria (Lamberti et al. 1975), where it reproduces on many leguminous plants. Di Vito et al. (1980) found that this endoparasitic sedentary nematode reproduced well on garden pea (Pisum sativum L.), field pea (Pisum arvense L.), faba bean, vetch (Vicia sativa L.), and Lathyrus cicera L. Some reproduction was observed on lentil and none on chickpea. The cyst, which is a very resistant stage of the nematode, can persist in the soil for several years. When seeds of host plants germinate, the eggs contained within the cyst are stimulated to hatch by root diffusates if soil temperature and moisture are suitable. Second-stage juveniles emerging from the eggs enter the root tips, and after three moults, develop into adults and rupture the cortex. Females remain sedentary but males are active and mobile.

Fertilized females produce an egg sac in which a variable number of eggs are laid. Most of the eggs are retained in the female body, whose cuticle becomes brown and thick to form the cyst. Apparently only the eggs in the egg sacs hatch soon, while those within the cyst may take about 2 months before a substantial hatch occurs. Depending upon soil temperature the life cycle is completed in 1-2 months. In Italy, Di Vito et al. (1974) showed that two generations are completed per growing season on early pea crops but only one on late crops. No nematode activity occurs at soil temperatures of about 25°C or above. Root tissues surrounding the anterior region of the nematode react by forming a syncytia of several cells, which become necrotic when exhausted by the feeding of the nematode. Therefore, many necrotic areas can be observed in infested roots. Large populations of Heterodera spp. may cause reduction of nodulation by Rhizobium sp. (Barker et al. 1976), and H. goettingiana favors the pathogenicity of Fusarium oxysporum f.sp. pisi (Garofalo 1964). Symptoms of nematode attack are stunting and yellowing of plants, with few flowers, and few and small pods; such plants are usually seen in patches in the affected field. Although heavily infested fields of faba bean may yield very little, information on the relationship between population density of the nematode and yield is lacking.

Field trials by Di Vito and Lamberti (1976) and Whitehead et al. (1979) indicated that good control of the pea cyst nematode on pea can be achieved by treating the soil with fumigant nematicides, such as D-D, Di-Trapex and Telone (300-500 l/ha), or with non-volatile nematicides such as Fenamiphos (10 kg a.i./ha), Furadan

(12 kg a.i./ha), Aldicarb and Oxamyl (2.8-11.2 kg a.i./ha). Generally, the best results with non-volatile nematicides are obtained by incorporating them into the top 10-15 cm of soil at sowing. However, these treatments are expensive, and therefore the control of this nematode should be investigated under local field conditions before advice is given to the farmer. Crop rotation may be effective for the control of H.goettingiana, but a 4- to 5-year rotation is usually necessary. While cultivars of faba bean resistant to this nematode are not available, Di Vito and Perrino (1978) found that accessions of Pisum abyssinicum, P.arvense, and P.elatius were moderately resistant. They may be of interest in a breeding program for resistance to this pathogen.

Heterodera trifolii

The clover cyst nematode, H. trifolii Goffart, is also widespread in France, Italy, and Tunisia. It attacks many species of clover, and can reproduce on and cause damage to several other leguminous plants. However, investigations on the host range of H.trifolii have led to conflicting conclusions, probably because of the occurrence of different pathotypes. The life cycle of the clover cyst nematode is similar to that of the pea cyst nematode, but males have only rarely been observed and the species can reproduce parthenogenetically. Unlike H.goettingiana, females of H.trifolii have a transitional yellow stage before becoming cysts and many eggs are laid in the egg sacs.

Where this nematode is likely to cause yield losses, the control measures suggested for H.goettingiana can be used.

Meloidogyne Species

Root-knot nematodes, Meloidogyne spp., have been reported to greatly damage hundreds of crops all over the world, although they seem more noxious in subtropical and tropical countries. In the Mediterranean basin, root-knot nematodes are distributed throughout all countries (Lamberti 1981) and generally the health of infested crops suffers. M.arenaria (Neal) Chitwood, M.artiellia Franklin, M.hapla Chitwood, M.incognita (Kofoid et White) Chitwood, and M.javanica (Treub) Chitwood have been reported as parasites of faba bean, lentil, and chickpea, but information on the yield losses caused by a range of population densities of the root-knot nematodes is lacking.

Infestation of root-knot nematodes is readily recongnized by galls appearing on infested roots. The nematodes survive as the egg stage, free or in a gelatinous matrix.

When a host plant is planted, the eggs hatch and the second-stage juveniles move through the soil until they come into contact with the rootlets. They then penetrate the root tips and moult three times. Females swell as they moult, rupture the cortex and extrude a gelatinous matrix in which up to 1000 eggs are laid.

The eggs may soon hatch and a second generation starts. Males are worm-like and free living.

Root tissues react to the nematode by forming giant cells, which are essential for nematode feeding and which may cause interruption of the xylem and phloem. Next to giant cells there is a proliferation of small cells and thus the nematode becomes enclosed in a gall. The size of a gall varies according to host reaction. Galls may join together and more than one nematode may be found in the same gall. For most species the optimum temperature is in the range 25-27°C and several generations may be completed in a growing season, each one taking about 1 month. The buildup of populations with subsequent generations may result in considerable damage to a host. If a similar host is planted following the crop, damage may be extensive from the outset. Interaction with fungi (McClellan and Christiei 1949; Ross 1965) and antagonism with Rhizobium leguminosarum (Ali et al. 1981) have also been demonstrated. Symptoms of nematode infestation are poor growth of the host plant, yellowing of the leaves, early senescence and yield reduction. In the field, affected plants are generally in patches, but when heavy infestations occur the entrie field can be destroyed.

Root-knot nematodes can be controlled by using the same chemicals as for H.goettingiana, but these are expensive and are therefore not recommended. Although root-knot nematodes have a very wide host range, crop rotation and weed control can provide an effective means for their control. Farm practices such as plowing the soil soon after harvest, by reducing soil moisture, and increasing the temperature in the upper layer would reduce the nematode population. Moreover, late-sown chickpea (Gaur et al. 1979) may escape nematode infestation in the early growth of the crop. Although many investigations have indicated that some cultivars or lines of Vicia species have resistance to root-knot nematodes, no resistance has been reported for cultivars of faba bean, lentil, and chickpea.

Other nematodes

Lesion nematodes, Pratylenchus vulnus Allen et Jensen (Jensen 1953) and P.penetrans (Cobb) Chitwood et Oteifa (Inserra et al. 1979), attack faba bean and are widespread in the Mediterranean basin. Lesion nematodes are endoparasitic migratory nematodes which cause necrosis of root tissues, resulting in formation of cavities especially in the cortical parenchyma. Externally, brown spots are evident on the surface of the roots. Infested plants have yellow leaves and grow poorly. The nematodes may also interact with some soil fungi.

Rotylenchulus reniformis Linford et Oliveira, a semi-endoparasitic nematode reported on chickpea and faba bean (Timm 1956), frequently occurs in the Mediterranean countries and may injure these crops. Many more nematode species belonging to the genera Paratylenchus, Pratylenchus, Rotylenchulus, Rotylenchus, Helicotylenchus, Tylenchorhynchus and others are of wide distribution in the perimediterranean area (Lamberti 1981). These may occasionally cause problems to leguminous crops and control measures for them may be required.

Conclusions

In areas where faba bean, chickpea, and lentil are important crops, surveys are needed to provide information on the most destructive nematodes, their population densities, biology, and host range. The relationship between population densities of the various nematodes and yield of the host crops should be investigated to estimate the tolerance limit and predict yield losses. If it is expected that the crop will be injured, control methods must be chosen. Volatile and non-volatile nematicides have shown promise in controlling plant parasitic nematodes but their effectiveness may be affected by soil and climatic conditions. Thus, time, mode, and rate of application should be investigated under local field conditions. Nematicides are expensive and in many instances may not be economically viable. Moreover, soil treatments require well trained personnel and appropriate farm machinery, and ancillary problems such as environmental pollution have to be considered. Therefore, much more attention should be paid to investigations on cultural methods of control. Nematodes may also reproduce on a number of weeds, the control of which may prevent the buildup of nematode populations in the absence of host crops. The effect of agronomic practices and crops on the dynamics of nematode populations should be investigated to provide information from which the most profitable crop rotation for a given area and/or field can be determined.

Resistant cultivars offer promise for the control of many diseases and pests, including nematodes. Therefore, cultivars and breeding lines of faba bean, lentil, and chickpea should be screened for the most important nematodes to identify sources of resistance which can be used in breeding programs.

A single control measure may not lead to satisfactory results, but a combination of several in an integrated pest management program could provide an effective and economic means of control for most of these nematodes.

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Discussion

Simon Gowen

The root infecting nematodes are generally most important in intensive agriculture. Until actual yields begin to approach potential yields root nematodes must surely be a secondary research priority. In the mean time, nematologists involved with legumes might find the investigations into the effects of nematodes on root nodulation an important area of strategic research.

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Fifth Session

Environmental Regulation of Flowering in Faba Beans, Chickpeas, and Lentils

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Perspective

Before attempting to review the environmental regulation of flowering in faba beans, chickpeas, and lentils, we would like to pose a few questions and to make a number of generalizations which have been discussed in greater detail elsewhere (Summerfield and Roberts 1983).

The timing of reproductive events in all grain legume crops is modulated strongly by two environmental factors, photoperiod and temperature, and genotypes differ markedly in their relative sensitivity to either or both of these factors. However, has the research done on soyabeans, one of the classical species used by scientists interested in the environmental regulation of flowering, inclined us to a too absolute view of the need for a specific photoperiodic stimulus for flower evocation (Evans 1969)? Have researchers concentrated too much on photoperiodic effects when, it seems, photoperiod x temperature interactions largely dictate the rate of reproductive ontogeny in legumes (Summerfield and Wien 1980)? They probably have. Failure to recognize the importance of interactions between temperature and other environmental factors means that much of the previous research on these aspects, e.g. in Phaseolus vulgaris, has now to be reevaluated carefully and/or repeated (Wallace 1980). Then again, the significance of photoperiod-vernalization adaptation in crop evolution has never been well explored and we are largely ignorant of the genetic control of variation in this respect (Simmonds 1979). Clearly, the generalizations which follow and which attempt to synthesize the findings of almost 500 publications over the last 60 years can only be tentative.

In a few cases where studies on grain legumes have been sufficiently extensive, photoperiodic effects on reproductive ontogeny have been readily modified and sometimes overridden by temperature. In contrast to many non-leguminous species, where the initiation of flowers seems to be the reproductive stage most sensitive to environmental regulation, in legumes the expansion of flower initials seems equally, if not more, sensitive to external control (Vince-Prue and Cockshull 1981). Unfortunately, terms such as 'sensitivity,' 'neutrality,' 'optimum,' and 'critical' are often used in a vague manner to describe the responses of many legumes to photoperiod. To some extent this is inevitable because basic data are not yet available for most species.

It is very difficult to generalize from published data because only few experiments on the effects of these environmental factors have been designed factorially or have continued through successive periods of reproductive development. Even when experiments have been designed to investigate the effects of temperature and photoperiod concurrently, some confounding between the heat sum and light integral is usually inevitable and, in any event, conclusions may be biased because of the narrow range of germplasm and/or environments under evaluation (Lawn 1980). Moreover, in most cases it is impossible to ascribe differences in time to the appearance of the first flower to the rates and/or durations of floral initiation and/or bud development. However, there can be little doubt that there are important differences between species and cultivars among the legumes with respect to:

a. the optimum photoperiod (that at which the rate of development during a particular stage of reproductive ontogeny is most rapid),
b. photoperiod sensitivity (the delay or hastening of a particular developmental sequence per unit change of photoperiod),
c. the critical photoperiod (that above or below which a given developmental sequence is delayed or arrested),
d. separate effects of day and night temperature,
e. temperature effects on a and/or b and/or c above,
f. temperature effects at successive stages of development.

The possible combinations of responses are evidently very numerous (Evans and King 1975; Major and Johnson 1977), and we have summarized published data in Table 1. However, it should be remembered that sometimes the responses reported could be artifacts of experimentation. Nevertheless, with this reservation, we offer the following generalizations:

a. the effects of photoperiod and cold temperature vernalization are closely associated with taxonomic grouping and climate of the geographical origin of the taxon,
b. warm conditions, particularly at night, can compensate for shorter nights in short-day species,
c. cool conditions, particularly at night, can compensate for longer nights in long-day species,

Table 1. Responses to air temperature and to photoperiod in grain legumes of economic importance (based on a literature survey of data published between 1920 and 1978; see Summerfield and Wein 1980).

Tribe/Species	Juvenile period	Vernalization requirement	Optimum[1] photoperiod for flowering			Flowering sooner in response to warmer air temperature[2] by				
			SD	IND.	LD	DAY	NIGHT	MEAN	CONSTANT	IND.
Vicieae/Cicereae										
Cicer arietinum		±		+	+	+	+	±	±	
Lens culinaris	+	±		+	+				+	
Pisum sativum		±		+	+		+	±	±	+
Vicia faba	-	±		+	+				-	
Phaseoleae										
Cajanus cajan	±		+	+						
Glycine max	-	-	+	+		+	+	+	+	+
Phaseolus lunatus			+	+		+	+	+	+	+
P. vulgaris			-	+		+	+	+	+	+
Psophocarpus tetragonolobus			+					±		
Vigna mungo			+	+				+		
V. radiata			+	+				+		
V. unguiculata	-		+	+				+	+	+
Genisteae										
Lupinus albus		±		+	+					
L. angustifolius		±		+	+			+		
L. cosentinii		±			+			+		
L. luteus		±			+			+		
Aeschynomeneae										
Arachis hypogaea		-		+				+	+	

1. SD usually 12 hr duration, or less; LD usually 14-16 hr duration or longer; indifference (IND) based on responses in photoperiods from 14-24 hr duration.
2. Where day-night temperatures have not been combined factorially, it is possible only to describe flowering response in terms of a range of weighted mean temperatures of the diurnal fluctuations investigated. Constant temperatures refer to studies without a diurnally-changing thermal regime. Indifference (IND) rating based on widely differing temperature ranges between species and/or experiments. Data based on the findings reported in 487 publications from 1920 to 1978.

d. the effects of temperature on the shapes of daylength response curves have hardly received any attention,
e. indifference (neutrality) to daylength with respect to the onset of flowering has been reported for many legumes but only in one species (Arachis hypogaea) does this seem to apply to all genotypes (but see Summerfield and Roberts 1983),
f. the requirement for shorter or longer photoperiods (depending on the nature of the effect) becomes progressively more stringent after the first flowers have been initiated, and
g. successive stages of reproductive ontogeny may have narrower temperature limits.

Such marked effects of day, night, and mean temperatures on reproductive ontogeny (Table 1) raise serious doubts about the wide latitudinal adaptation of supposedly 'photoperiod-insensitive' cultivars (Bythe 1968; Jones and Laing 1978; Shanmugasundaram 1975; Tanner and Hume 1976).

In common with many non-legumes, those species of grain legume which originate from more or less temperate climates (e.g. in Asia, the Mediterranean, or in southern Europe) are responsive to cold temperature vernalization and, where they remain responsive to daylength, flower sooner in longer than in shorter days (Table 2). On the other hand, and maintaining the strong correlation with taxonomic grouping, members of the Phaseolae of tropical origin have no vernalization requirement and, for the most part, are quantitative short-day plants. In both cases, however, it has been possible to breed daylength indifferent cultivars, and with long-day plants not all cultivars respond to vernalization.

The productivity of many legume crops depends critically upon the induction of flowering, and photoperiod is a major regulatory factor. It has been reported that night temperature (mean minimum) is often the main interacting factor, and is easier to determine from standard meteorological data than day temperature (Evans 1963). However, attempts to describe the temperature relations of legumes have almost invariably been related to day temperature only or to the weighted means of diurnal temperature fluctuations (Summerfield and Wien 1980). Nevertheless, more detailed work on cowpeas and soyabeans grown in a wide range of photothermal regimes is revealing that, when confounding effects with day and night lengths are discounted, the major regulating attribute of temperature on development is the mean value (Hadley et al. 1983). Too often, air temperatures, especially at night, have not been precisely regulated in controlled environment studies (e.g. Byth 1976; Polson 1972) and traditional 'time-of-planting' experiments in the field have seldom been designed even to attempt to take into account the effects of altitude (and thus temperature) on legume growth and development. Hitherto, research has concentrated on dry-matter production, but neglected morphology and phenology, on carbon metabolism, but neglected nitrogen nutrition, and on environmental regimes that bear little relevance to the seasonal changes and complex interactions between factors which are so characteristic of natural situations. Unless the critical

Table 2. Summary of flowering responses of grain legume crops to photoperiod and cold temperature vernalization (compiled from numerous sources).

Species	Tribe	Center of origin	Photoperiodic response[1] Short day O	Short day Q	DN	Long day O	Long day Q	Vernalization response[1] O	Q
Arachis hypogaea	Aeschynomeneae	S. America/Africa			*				
Lupinus spp.	Genisteae	Africa/Mediterranean			*		*		*
Cicer arietinum	Cicereae	Asia			*		*		*
Lens culinaris	Vicieae	Asia/Mediterranean			*		*		*
Vicia faba	Vicieae	Asia/Mediterranean			*		*		*
Pisum sativum/arvense	Vicieae	Asia/Mediterranean			*		*	*	*
Cajanus cajan	Phaseoleae	Africa/India	*	*	*				
Glycine max	Phaseoleae	Manchuria/China	*	*	*				
Phaseolus lunatus	Phaseoleae	Mexico/Guatemala		*	*				
Phaseolus vulgaris	Phaseoleae	Asia		*	*				
Psophocarpus tetragonolobus	Phaseoleae	Papua New Guinea (?)		*					
Vigna mungo/radiata	Phaseoleae	Asia/India	*	*	*				
Vigna unguiculata	Phaseoleae	Africa/India	*	*	*				

1. O and Q denote obligate and quantitative responses, respectively.

environmental features and how and when they influence development and yield are known, breeders will not have the information they need to improve adaptation and so increase yields. Instead, the only outcome of the increased availability of germplasm and of support for research on legumes will be an explosion in the number of 'traditional' investigations on 'environmental adaptation.' We should, instead, seek to explain how environmental variations in time and place affect physiological and morphological processes, and hence growth, development, and yield, rather than merely to describe the outcome by increasingly complex and unwieldy statistical procedures (Bunting 1975; Murfet 1977).

Faba Beans (*Vicia faba* L.)

Vicia faba has a wide range of adaptability (Lawes 1980). Many cultivars (populations) are precisely adapted to local conditions in which they produce mature seeds anywhere between 90 and 220 days from sowing (Kay 1979). However, little is known about the principal environmental factors which regulate phenological development, or whether genotypes are appreciably different in their responsiveness to these factors.

Except for the earliest flowering genotypes, many cultivars respond to cool temperature vernalization by flowering earlier, particularly if grown subsequently in short days and warm temperatures (Evans 1959). Vernalization is more rapid at 10°C than at cooler temperatures, and can take place during embryo development on the mother plant, during germination, or, most effectively, during seedling growth. Late flowering, European winter genotypes and those commonly grown in Mediterranean climates seem more responsive to vernalization than genotypes sown in the spring, the response is most often quantitative although in some winter genotypes it may be qualitative (obligate) (Saxena 1981). However, genotypic differences, duration and temperature of vernalization treatment, persistent effects of maternal environment, photothermal conditions subsequent to vernalization, and criteria used to evaluate responses have undoubtedly contributed to the diverse (and perhaps even artifactual) responses ascribed to this species (Saxena 1981).

Although flowering in some spring beans is said to be independent of temperature, photoperiod, and irradiance (Blondon 1975), such invariance is certainly not typical of the species (Evans 1959; Saxena et al. 1981). In a survey of the photoperiodic responses of a wide range of cultivars, all were found to be quantitative long-day plants except for the earliest flowering genotypes, which were indifferent to daylength (Evans 1959). Late-maturing, European winter genotypes seem to be the most sensitive to daylength (Saxena et al. 1981). No cultivars responded as qualitative (obligate) long-day plants, but responses to long days were accentuated by warmer temperatures, and long days were clearly beneficial not only for flower initiation but also for the complete development of initiated inflorescences (Evans 1959; Tamaki et al. 1974).

Plants of var. Minica came into flower in the field in Wageningen, the Netherlands, 55 days after sowing, and in controlled environments set at 26°C day (14 h) and 16°C night (10 hr) after 45 days. In both cases the accumulated average daily temperatures (> 0°C?) were said to be almost identical and close to 600°C (Dekhuijzen et al. 1981). Whilst the authors suggest that this approach may be valuable in the evaluation of phenological development of the same variety grown in field trials in different locations in Europe, their data for plants grown in the growth chamber do not substantiate the relationship stated. The usefulness of predictive relationships involving heat sums and flower initiation in *V. faba* remains unresolved.

Constant temperatures above 23°C can inhibit flowering (Evans 1959), as can diurnally-fluctuating regimes warmer or cooler than 20°C day - 10° and/or 15°C night (Abdalla and Fischbeck 1978; Said et al. 1967). However, there are complex interactions between current and subsequent photoperiods and temperatures, and with previous vernalization treatments, which preclude reliable generalizations (Saxena 1981).

Variations in the duration of the pre-flowering period are probably not affected by the presence of (or marked variability in) a juvenile period. In several cultivars the lowermost node at which flowers first appeared was about the same as the number of nodes present when seedlings emerged (Evans 1959), implying that there was no marked juvenile period during which plants were not responsive to otherwise inductive environments.

So, it is clear that flower initiation in *V. faba* can occur over a wide range of photoperiods and temperatures, albeit after different durations and, depending on concurrent effects of these factors on growth, at different locations on plants which may differ appreciably in morphology. However, we still have to rely largely on the work of Evans (1959), for the most pertinent study of these responses. Subsequent research has failed to capitalize on his findings and, we believe, many data are artifacts of experimental design and are limited by the small range of germplasm which has been tested. Since the relative durations of pre- and post-flowering growth are likely to be major determinants of adaptability (Evans and King 1975), it is fortunate that in current internationally-orientated breeding programs there is an appreciation of the limitations of our current understanding not only of floral biology but also of reproductive ontogeny in this species (Hawtin 1979; Lawes 1980; Saxena 1981).

Chickpeas (*Cicer arietinum* L.)

Chickpea crops experience markedly different ranges of temperature and light regime, and rates of change of these environmental factors, during crop duration, depending on where and when they are grown (Duke 1981; El-Baradi 1977; Hawtin et al. 1980; Kay 1979; Summerfield et al. 1980). Genotypic differences in relative sensitivity to vernalization, to post-vernalization temperatures and to photoperiod are major determinants of the timing of reproductive events in the crop (Summerfield *et al.* 1980). A pronounced juvenile phase, during which plants are insensitive to normally inductive conditions, has not been reported.

Some genotypes, and perhaps the kabuli types especially (Saxena and Siddique 1980), 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 (Chakravorti 1953), and flower earlier, and at lower nodes, than plants produced from non-vernalized seeds (Chakravorti 1964; Pillay 1944). Vernalization can also influence chickpea morphology by hastening stem elongation and suppressing branch formation, although there are complex interactions between vernalization treatment and the temperature and photoperiodic regimes to which plants are subsequently exposed (Angus and Moncur 1980; Nanda and Chinoy 1960a and b). Then again, 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." A modest vernalization requirement may be advantageous in Mediterranean climates in order to prevent the appearance of flowers before winter. Likewise, for crops grown through the Indian winter, requirement for vernalization may enhance yields by delaying flower initiation until plants are well established. In southern Australia such a cold requirement may permit early autumn sowings without the risk of late winter flowering (Corbin 1975).

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).

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 (Summerfield and Wien 1980). With chickpeas, 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 (Summerfield *et al.* 1980).

Chickpeas have been variously described as long-day plants (Mathon 1969; Moursi and Abdelbawad 1963; Nanda and Chinoy 1960a and b; Pal and Murty 1941; Pandey *et al.* 1975; Roberts *et al.* 1980), quantitative long-day plants (Maesen 1972; Sandhu and Hodges 1971), day-neutral plants (Allard and Zaumeyer 1944; Mateobox 1961); and, in one case, as short-day plants (Bhardwaj 1955). Evidence has been summarized as showing that chickpeas are only moderately sensitive to photoperiod (Maesen 1972), whereas others have described cultivars that 'display tremendous variation in photoperiodical response' (Ladizinsky and Adler 1976). It now seems increasingly clear that many genotypes respond to photoperiod in a manner typical of quantitative long-day plants (Roberts *et al*. 1980; Summerfield *et al*. 1980; Summerfield *et al*. 1981). This characteristic has been exploited by breeders at ICRISAT (Saxena *et al*. 1980) and ICARDA (M.C. Saxena, personal communication) who have accelerated the rate of generation turnover by extending natural short days with incandescent lamps. The critical illuminance seems to be higher for late-maturing cultivars than for short-duration types, but a value of only 6 lux is sufficient to ensure the earliest flowering of both (Saxena *et al*. 1980).

Cultivars may flower earlier 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 1980; Summerfield *et al*. 1980), depending on the range investigated. Early flowering may or may not lead to low yields (Singh 1970) depending on aerial and edaphic conditions post-flowering and on the duration of the cropping season available.

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. What is clear from recent factorial experiments in precisely-controlled environments is that the opposing effects of longer days, which hasten flowering, and of cooler temperatures, which delay it, can offset each other exactly (Roberts *et al*. 1980; Summerfield *et al*. 1980; Summerfield *et al*. 1981). Thus, interpretation of data from multilocation trials or from date-of-planting experiments is likely to be difficult unless they have been located or designed in a manner which seeks to mitigate such eventualities.

The production of larger and more stable yields from chickpea crops is of paramount importance as progressively larger areas of the better arable lands are sown to wheat in the Indian subcontinent (Rao and Subba Rao 1981) and perhaps elsewhere. Improved understanding of reproductive biology and phenological development in diverse genotypes is essential if materials are to be released which are well adapted to the environments and cropping seasons for which they are intended (Byth *et al*. 1981).

Lentils (*Lens culinaris* Medik.)

Little is known about genetic variation in, or environmental regulation of, the induction, initiation, or development of lentil flowers. The available information has been reviewed elsewhere (Summerfield 1981; Saint-Claire 1972).

The period of vegetative growth in lentil crops in countries such as Lebanon, Iran, Italy, Spain, and Turkey coincides with progressively lengthening days and warmer temperatures. In comparison, crops in India and Pakistan will experience shortening days and cool, or even cold (0-2^{o}C), air temperatures at this stage of development (Sinha 1977). Seasonal changes in photothermal conditions are likely to be important determinants of the rates of reproductive development of crops in these regions.

Some cultivars are responsive to cold temperature vernalization. The consequences of such treatment depend on the genotype tested and the severity and duration of the cold temperature imposed. Chilling imbibed seeds for 32 days at 6^{o}-9^{o}C shortened the subsequent vegetative period by 33% compared with plants grown from non-vernalized seeds (Shukla 1953). In comparison, when somewhat colder temperatures (4^{o}-6^{o}C) were imposed for slightly longer (35 days), the vernalized plants of a different cultivar had produced only four fewer leaves than the controls when they came into flower. Until then, they were slightly heavier (Chakravorti 1964). Although these data are from poorly replicated treatments, they cannot be dismissed as "of little interest when the practical aspect ... is considered" (Williams 1974). A modest vernalization requirement may be advantageous in Mediterranean climates and for rabi (postrainy season) crops in Asia. Flowers would be less likely to appear before winter and until plants were well established.

If genetic diversity for 'cold requirement' exsits in lentils, this may normally be masked in locations to which particular genotypes are adapted because of the frequent occurrence of cool temperatures. In such situations, breeders may select unconsciously for progeny with a vernalization requirement, or may disregard as 'unadapted' some genotypes from multilocation trials which, in fact, could be well adapted to warmer sites other than for their vernalization requirement (Sinha 1977).

A pronounced juvenile phase, during which plants are insensitive to normally inductive conditions, has not been reported in lentils. However, this possibility is not excluded since several cultivars first flower only after a minimum number of leaves (about 11) have expanded (M.C. Saxena, personal communication).

The few genotypes examined so far show that lentils flower sooner in longer (16-24 hr) than in shorter (6-12 hr) photoperiods. Some cultivars respond as qualitative (obligate), others as quantitative long-day plants and some have been described as 'day-neutral' (Kassam 1981; Moursi and Abdelbawed 1963; Pavlov and Ganera 1973; Saint-Claire 1972; Shukla 1955). Warm temperatures also hasten flowering (Moursi and Abdelbawed 1963; Saint-Claire 1972), but which factor is more significant, photoperiod or temperature, remains purely speculative and merits prompt investigation in quantitative detail (Summerfield 1981).

The effects of other environmental factors (e.g. edaphic conditions, water stress, and mineral nutrition) on flower formation are unknown. However, from research on other grain legumes (Sinha 1977) it seems likely that these factors, whilst they may have serious effects on growth, are unlikely to be major determinants of the rate of progress of plants towards flowering. Of course, they may have striking effects on flower abscission and the relative success of pod set, possibilities which are discussed for legumes in general elsewhere (Summerfield 1980).

Concluding Remarks

The opportunity to breed new varieties that will be well adapted throughout wide geographical areas occurs only rarely and, when it does, it must be followed by diversification to provide varieties which can exploit local potential (Hutchinson 1974). ICARDA has a responsibility for promoting food production for some 300 million people in 22 countries in the West Asia-North Africa region. The Center's mandate for the three grain legume crops reviewed here emphasizes the complementary role of international and regional programs in crop improvement. The value of such complementary roles is emphasized by the fact that the climates in the region served by ICARDA are extremely diverse. Collectively, the 22 countries concerned cover tropical, subtropical, and temperate thermal climates with warm and cool variations due to latitude and altitude, and oceanic and continental differences due to land - sea configurations (Kassam 1981). Rainfed agriculture is the main food-producing industry of the region; it is the work base and way of life for at least 60% of the people who inhabit the area - many of whom live at or near the subsistence level (Darling 1979). Such farmers are typically averse to risk (Anderson 1974) and since climatically-induced risks are a major component of their traditional production systems they need to be quantified. However, although it may become possible through appropriate research to specify the conditions conducive to heavy yields for the principal crops of the region, to predict the ways in which plants will respond to climate and weather, and to explain (even if in retrospect) why crops produced the yield they did, will not help the subsistence farmer much unless we can alter the relationships between plants and weather to his advantage. Perhaps the major opportunity to do this depends on altering the genotype, especially in situations where cropping season (the periods and durations each year when the crop can be grown in different locations) are more or less fixed and inflexible, as they are in many farming systems in this region.

Breeding for larger crop yields, even when the main objective is to lessen the effects of diseases and pests, always includes a conscious or unconscious attempt to produce varieties or populations that are able to make more productive use of the environments for which they are intended. It is seldom possible to change the environment to suit particular genotypes nor to screen a wide range of accessions against every factor likely to influence their relative success (Burt 1980). Thus, we need a thorough understanding of not only the genetic factors which control phenological processes and crop durations, but also of the major environmental factors which react with them (Aitken 1975). Genotypes and environments can interact to produce what seems to be a bewildering diversity of growth habits and responses to climate, especially in grain legume crops which, collectively, are notoriously sensitive to the vagaries of weather and climate. Clearly, the breeder needs to be able to group genotypes into response classes so that he is better able to identify promising parental material for breeding new varieties either with specific adaptation to particular ecological niches, or with wide physiological adaptability.

In the rainfed agricultural systems in the region served by ICARDA, seasonal changes in temperature and photoperiod, in the amount and distribution of rainfall, and in the availability of nitrogen and phosphorus are the major determinants of productivity of the principal annual crops. Our understanding of the relative importance of these factors, of their interactions with each other, and of the proportions of any differences between genotypes which may represent useful genetic variability is poor (Smith and Harris 1981).

Plant breeders are increasingly aware of the potential for selection for morphological, phenological, and physiological components of economic yield since these can be of prime importance in crop productivity and adaptation (Coyne 1980). Nevertheless, they still need help in developing screening techniques which are reliable, rapid, and applicable to large numbers of plants, and which involve only minimum labor and are as inexpensive as possible, before they are likely to be able to include a search for such traits and responses among their principal selection criteria. Too often, especially with grain legume crops, neither the basic information nor an appropriate technique is available - though there are exceptions (Hadley et al. 1983 for cowpeas). There is a 'negative role' for this type of information and strategy in crop improvement programs too: plant breeders must be careful that in selecting for other desirable characters they do not concurrently and unknowingly select against desirable morphological, phenological, and physiological attributes - as has occurred in some breeding programs (Summerfield 1980).

Thus the challenges for the researcher committed to improving productivity of the rainfed agricultural systems of the region served by ICARDA, where small increments obtained at relatively small cost from a large number of farmers can mean large totals when measured nationally (Darling 1979), are many and varied. Essentially, they need to develop varieties and systems that are able to adapt to and exploit the variability in growing season durations, expected or otherwise, in the tremendously diverse climates which prevail in the region. Ecological zones vary from the low elevation littoral at altitudes below 700 m with a distinctive Mediterranean climate of cool, moist winters and hot, dry summers, through high plateau areas (1200-2000 m) with extremes of winter cold and summer heat, and with snow cover for perhaps as long as 5 months each year, to mountainous parts of North Africa (Darling 1979).

Clearly, improved understanding of the photothermal regulation of reproductive development in species potentially well adapted to particular environmental niches, of the underlying genetic mechanisms involved, and an ability to screen germplasm rapidly and reliably for responsiveness to these factors are prime requirements if appropriate materials are to be released to farmers.

Acknowledgements

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Discussion

K.B. Singh

In addition to photoperiod and temperature, availability of water is also important. For example, crop sown during main season from November to June will mature irrespective of continuous irrigation; whereas the crop sown in off-season from June end to October end, if provided with irrigation, will continue growing and will not mature. So in my opinion in future studies on day length and temperature, moisture may also be given consideration.

R. Summerfield

As requested, I discussed the 'Environmental Regulation of Flowering,' not crop longevity. Water stress, deficiency or excess, during vegetative growth can be disastrous for drymatter production but stressed plants will still come into flower after more or less the same time as non-stressed ones. Therefore, during the reproductive period, changes in photothermal regime and in water supply will, I agree, combine to influence the timing of 'death'.

Proceedings of the International Workshop on Faba Beans, Kabuli Chickpeas, and Lentils in the 1980s (Saxena, M.C. and Varma, S., eds.), ICARDA, 16-20 May 1983, Aleppo, Syria.

Morphological and Physiological Requirements of a Productive Plant of Chickpea

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Chickpea (Cicer arietinum) is an important pulse crop in India. Most of the chickpeas are grown in north India because of suitable agro-climatic conditions there (Sinha 1977). In the recent past, there has been a considerable change in cropping pattern, and a consequent change in required crop characteristics. Chickpea was essentially an unirrigated crop in the past, sometimes grown as a mixed crop with wheat or barley. It was generally believed that irrigation promoted vegetative growth at the cost of reproductive growth and thus had adverse effect on grain yield. Thus, breeders selected only for unirrigated or dryland conditions. Also, the agronomic practices developed were for such situations. The characteristics of the production system were: early sowing (October) to ensure germination in dryland, low plant population, and low inputs of fertilizers and plant protection chemicals.

In the last decade, rice has become an important crop of the Kharif (monsoon season), and is usually harvested early in November. There has been a considerable increase in irrigation facilities (75-85%) and availability of inputs. Thus, double cropping with chickpea has become a common feature. Therefore, there are new requirements for the crop. These include: suitability of the genotypes of chickpeas for sowing in late November, and ability to respond positively to irrigation, fertilizer application, and higher than conventional plant density. As a result the following questions must now be considered:

(i) How is the phenology of chickpea affected by late sowing?

(ii) How are dry-matter accumulation and partitioning affected?

(iii) Do desi and kabuli types differ in their growth characteristics?

(iv) Is early sowing optimum for obtaining best yields even with irrigation?

Our studies in the past few years have attempted to answer these questions.

Growth Pattern

There is no significant difference in the growth pattern of desi and kabuli types as shown in Fig. 1. They all have an initial slow

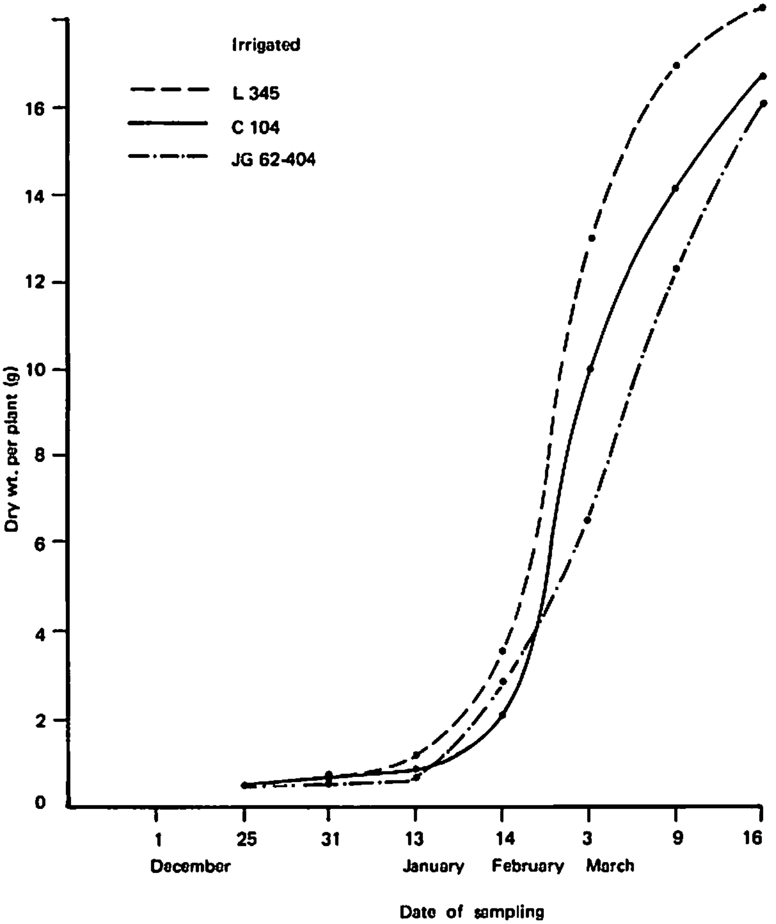

Fig. 1. Growth pattern of Kabuli (C 104) and desi cultivars, brown (JG 62-404) and green (L 345).

growth rate for a period of 40-45 days, due to very slow rate of leaf-area development. At maturity there is no significant differences in dry-matter production between different types. The active growth period is of 8 weeks when the crop growth rate is 9.5 $g/m^2/day$. The crop growth rate of wheat is 17.34 $g/m^2/day$ during the same period.

From the date-of-sowing experiments, it has been possible to establish the date for maximum harvest index (Fig. 2). Sowing on 15 Nov resulted in the best harvest index.

The pod weight and seed weight at different nodes are shown in Fig. 3. The productivity of individual nodes is very poor in comparison with soybean or faba beans, possibly due to the small leaf area at the individual nodes. From the base upward there is a gradual decline in the productivity of each node, suggesting limitation in photosynthate availability. Thus, there may be a need to increase the leaf area at each node in order to increase the productivity per node.

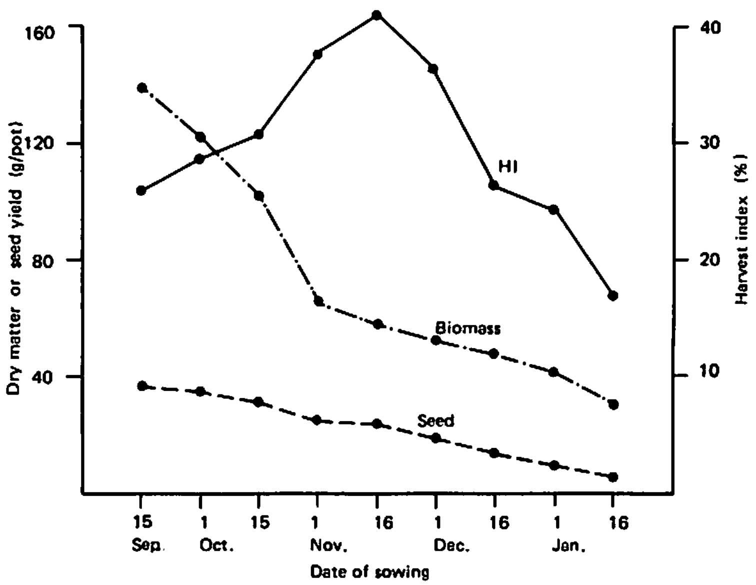

Fig. 2. Effect of the date of sowing on biomass, grain yield,and harvest index in *Cicer arietinum*.

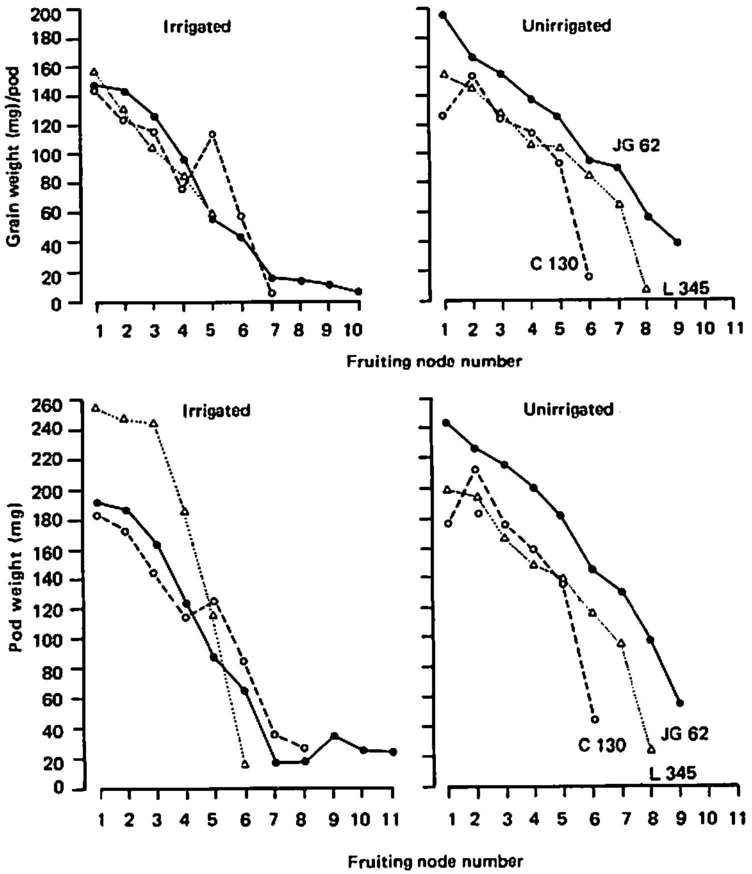

Fig. 3. Effect of pod position on the pod and seed weight per pod. Fruiting node number 1 being the first node on primary branch on which the first pod developed.

Flowering, Fruit-set, and Harvest Index

The time of flowering is strongly influenced by latitude, because of changes in temperature and day length (Sinha 1977). Thus, when three genotypes of chickpeas, including one kabuli type, were grown at Delhi, Indore, and Hyderabad, the time taken to the first flower opening was longest at Delhi and shortest at Hyderabad. The percentage of fruit-set from the first opened flowers was affected

(Table 1). The flowers appearing in Delhi in late December or January (mean daily temperature and minimum temperature 16°C and 10°C, respectively) set no fruits. The relationship of fruit-set to temperature is shown in Fig. 4. A mean temperature of about 18°C appeared best for fruit-set. This aspect was further investigated by determining the pollen germination and pollen tube growth (Savithri et al. 1980). Both germination and pollen tube growth were inhibited at low temperature (Fig. 5). However, a genotype was identified which set fruits at low temperature, the pollen germination and tube growth of this line were less sensitive to low temperature. Such genotypes could be useful in breeding programs.

When chickpeas are sown early in north India, they come to flower in late December or early January. If there is rain or the crop is irrigated during flowering these flowers do not set fruits. However, such flowers do set fruits in dryland conditions where the canopy temperature is 2-3°C higher. The late-sown crop flowers in early February, and consequently the fruit set is not affected by low temperatures. Nonetheless, for irrigated conditions, it would be desirable to obtain genotypes capable of fruit-set at low temperatures.

Nitrogen Fixation and Partitioning

It has often been stated that nitrogen fixation limits the yields of pulses including chickpeas. It is evident that nodulation is severely affected at the commencement of fruit-set. However, a comparison of nitrogen harvest index (N HI) between wheat and chickpeas clearly demonstrates that the incorporation of total plant nitrogen into grains is much higher in wheat (75-80%) than in chickpeas (30-40%). Thus, it seems the chickpea crop needs to be improved to make better partitioning of nitrogen already assimilated by the plant. Possibly, plant morphology and control of leaf senescence may be important in this context.

Since chickpeas are often grown as an unirrigated crop, it has been argued that nitrogen fixation might be adversely influenced

Table 1. Percentage fruit-set of the first formed flowers in chickpea genotypes. Flowering time was late December to early Janauary.

	Genotype		
Location	JG 62-404	L 345	C 104
Hyderabad	65	65	58
Indore	88	68	92
Delhi	0	0	0

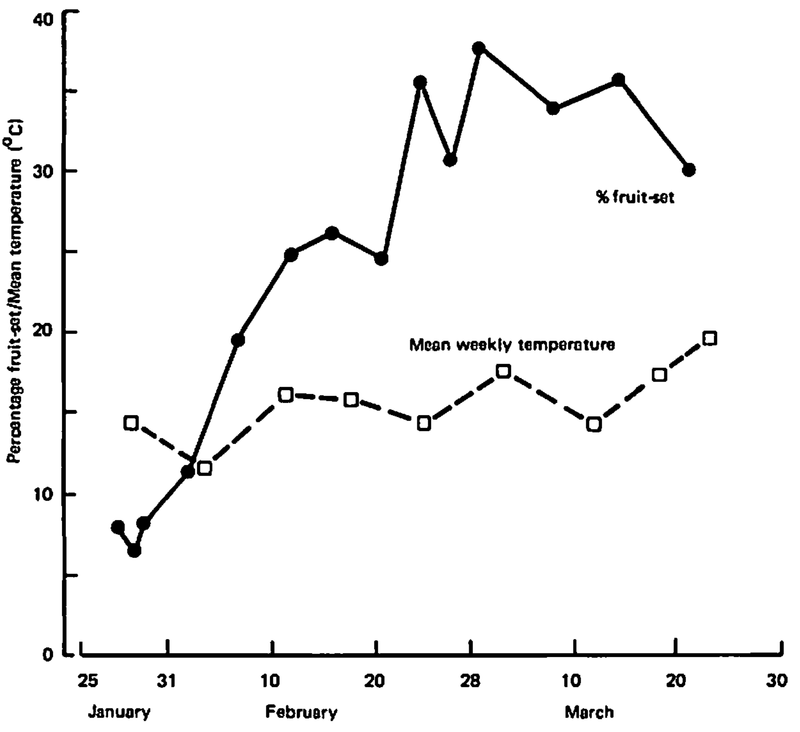

Fig. 4. Fruit-set in chickpea (*Cicer arietinum*) in relation to mean daily temperature.

due to water stress. Most studies in this respect are based on experiments where the whole plant was stressed. This inevitably influences photosynthesis and consequently nitrogen fixation. Our recent experiments using a technique whereby the nodule-containing zone of the soil is dried but plant is not water stressed indicate that under such conditions nitrogen fixation is inhibited by 25% or less. Even this loss is recovered within 24-48 hr if the soil-moisture level is restored.

Varietal differences in nitrogen fixation are observed even at the seedling stage, but the mechanism involved is not yet clear.

Obviously, greater attention needs to be paid to partitioning of assimilated nitrogen, than nitrogen fixation alone.

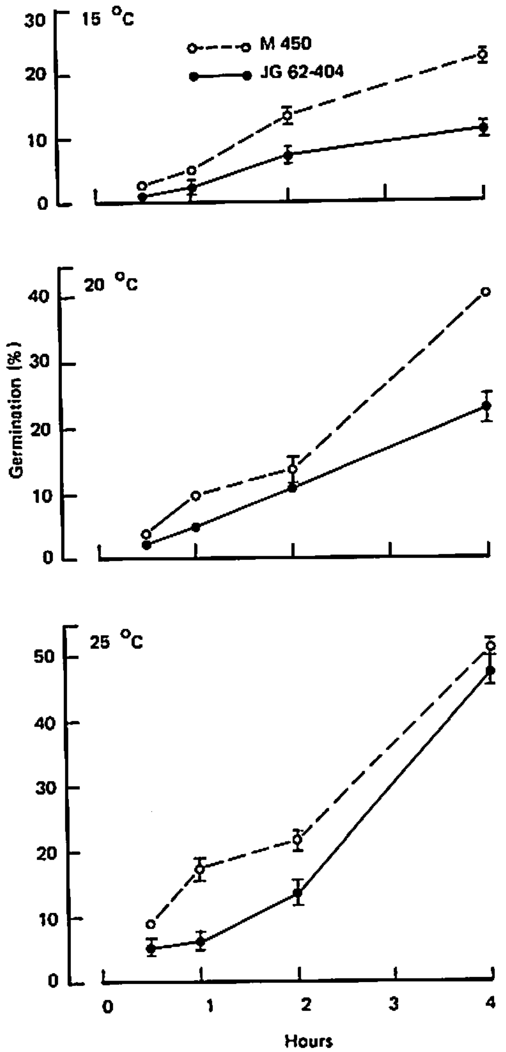

Fig. 5. Effect of temperature on pollen germination percentage in *Cicer arietinum* cv. JG 62-404 and M 450.

Response to Late Sowing

An experiment on the effect of date of sowing on harvest index in chickpea showed that early sowing led to production of more dry biomass, but poor harvest index (Fig. 2). The highest harvest index was obtained from the 16 November sowing, though less dry matter was produced. Thus, the so-called 'normal' sowing results in poorer dry-matter partitioning but ensures proper germination and crop stand. This prompted us to compare dry-matter production and yield in several genotypes from early and late sowing dates (Fig. 6). The results clearly established that mid- to late-November sowing was desirable in terms of yield of chickpeas.

Two characters, namely, faster seedling growth, particularly a higher rate of leaf expansion, and early flowering are important in selecting genotypes for late sowing.

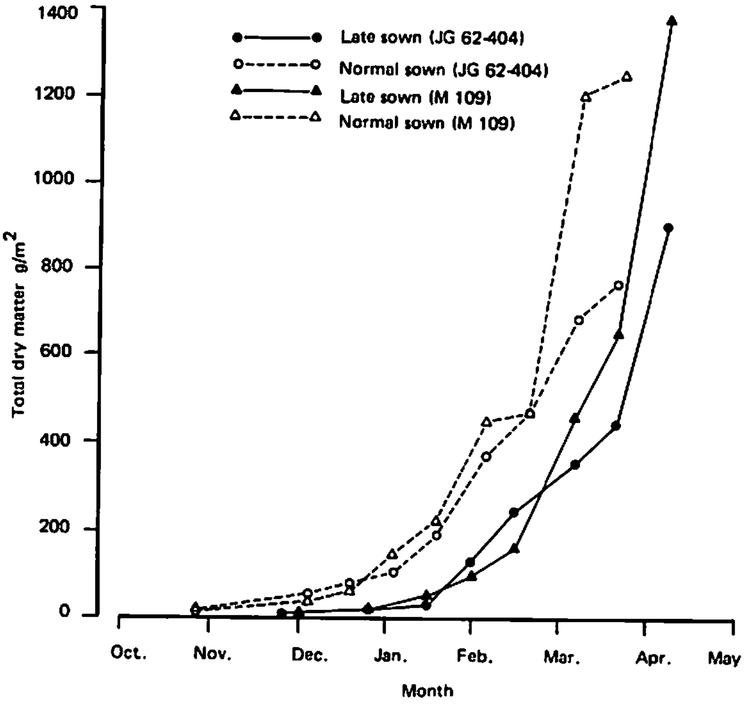

Fig. 6. Effect of late sowing on growth and dry matter accumulation in JG 62-404 and mutant M 109.

Response to Irrigation

The existing varieties, which were essentially selected for unirrigated conditions, have usually been employed in studies on the response of chickpeas to irrigation. When both soil and atmospheric conditions are dry, the response to irrigation is good, as observed at Hyderabad (ICRISAT 1981), but when the conditions are not very dry, response to irrigation is insignificant. A major effect of irrigation after flowering is the excessive vegetative growth. Thus, there is an increase in dry-matter production, but it is not partitioned into grains. Selection for reduced vegetative growth after flowering is an important objective, for which some variability exists. However, much greater and organized effort would be needed for selecting genotypes suitable for irrigation. A comparison between cultivar JG 62 and one of its mutants shows that efforts in this direction may be fruitful (Fig. 7).

Efforts have also been made to understand the capacity of genotypes to recover from stress. It was observed that flowering stage is most sensitive to water stress in terms of yield reduction. Thus, we are faced with a very unique situation in this crop: both a shortage as well as a little excess of water are detrimental to grain yield. This effect can be further compounded by temperature. Very little is known about the interaction between water availability and temperature in relation to fruit-set and grain yield. The work so far has only been able to define the problem of response to irrigation by chickpea. Efforts now have to be made to look for characters enumerated in this section.

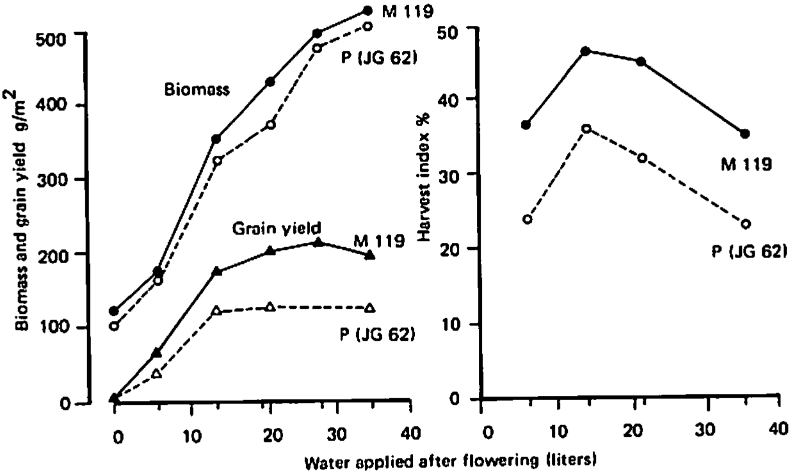

Fig. 7. Effect of water availability after flowering on biomass, grain yield,and harvest index in *Cicer arietinum* genotype JG 62 and one of its mutants, M 119.

Conclusion

It is impossible to suggest a generalized ideotype of chickpeas, irrespective of location and management requirements. Obviously, the genotypes which are suitable for low population and low inputs are not necessarily the best for high levels of plant density and inputs. The situations should be analyzed specifically to define the requirements. Nonetheless, a comparison between chickpeas and some high yielding grain legumes, such as soybean and faba beans, might be important for suggesting an ideotype for chickpeas. In soybean and *Vicia faba* the flowering node bears several flowers and is capable of producing several fruits. Each node is supported by a large leaf area. Most of the fruits are retained on the main stem or primary branches. These features help in putting a higher plant density per unit area, without seriously impairing the expression of yield components. Restructuring the chickpea plant to meet such requirements is, at present, a remote possibility. However, the simple leaf mutants could possibly help increase leaf area at flowering nodes. Further, reduction in the number of flowering nodes and locating them mainly on primary branches could help in improving the plant structure. Selection for behavioral traits could be attempted later or consecutively.

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Biological Nitrogen Fixation by Food Legumes in Dry Areas-The Scope for Increase by Improved Management

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In the Mediterranean region, areas of sedentary agriculture with restricted and uncertain rainfall are generally resource poor. Increasing population, and the consequent increased demand for food production in these areas, requires that proposed agronomic strategies for improvements in productivity should, in general, avoid high input costs in order to maximize the likelihood of their rapid acceptance by the farming community. Inorganic nitrogen fertilizer is becoming an increasingly expensive input. Thus, research strategies which aim to ensure the maintenance of an acceptable soil fertility without requiring large addition of nitrogen fertilizer warrant active development.

In the series of trials reported in this paper we have examined two major issues: (1) to what extent food legume crops, specifically faba beans, kabuli chickpeas, and lentils, are able to yield satisfactorily under nitrogen-limiting conditions in a cereal/legume two-course rotation without large inputs of inorganic nitrogen fertilizer; (2) what variability in amounts of biologically fixed nitrogen can we expect when minimum input "farmer practice" management is compared to our current improved agronomic package.

Materials and Methods

In the 1980/81 season an experiment measuring biological nitrogen fixation in a range of food and forage legumes was carried out at Tel Hadya, ICARDA's main research center in northern Syria. From this experiment, selected treatments for faba bean (Vicia faba), kabuli chickpea (Cicer arietinum), and lentil (Lens culinaris) are presented in Table 1. Plot size was 6.3 x 10 m. A randomized complete block design with four replications was followed. The experimental year followed a previous cereal crop and an initial soil test of the experimental site showed low available nitrogen and phosphorus contents and a high pH. All treatments received 10 kg N/ha at planting; the central microplots (at least 1.8 m^2) received ^{15}N-enriched ammonium sulphate with 5% atom excess (a.e.) and all treatments received 100 kg/ha of triple superphosphate (48 % P_2O_5). Lentils and faba beans were not inoculated. Chickpeas were inoculated with Cicer Rhizobium as the native rhizobia population of the soil was insufficient to guarantee good nodulation. Nodulation was satisfactory in all treatments.

Table 1. Experimental treatments, 1980/81.

Crop	Cultivar	Planting time	Row spacing (cm)	Plant spacing (cm)	Harvest date
Lentil	Syrian local small	Nov	22.5	1.5	18/5/81
Faba bean	ILB 1814	Nov	45.0	10.0	22/5/81
Chickpea	ILC 482	Nov	22.5	10.0	20/5/81
Chickpea	ILC 482	Feb	22.5	10.0	22/6/81
Wheat	S 311 x Norteno	Nov	22.5	1.5	1/6/81

At harvest a 1-m row was taken from each of the ^{15}N labelled micoplots for total nitrogen determination by NIR spectrophotometry and macro-Kjeldahl methods. The ^{15}N analysis was carried out through the courtesy of the International Atomic Energy Agency (IAEA), Seibersdorf Laboratory. The percentage of N derived from symbiotic fixation was calculated in the manner of Fried and Broeshart (1975) which is described by Saxena (1982). Yield estimates were made from an area of 2.7 m x 8 m after discarding border and guard rows.

In the 1981/82 season, treatments described in this paper were again selected from a larger experiment (Table 2). The experiment was conducted at eight locations in northern Syria which were chosen to span the large isohyetal gradient (600-200 mm annual precipitation) experienced in this region (Fig. 1). Three locations, Jindiress, Tel Hadya, and Breda are ICARDA's semi-permanent research sites (Cooper et al. 1981) and the remaining five locations were farmers' fields. At each site, crops and treatments were selected in accordance to local practice. Thus, faba beans were only grown at the two wettest locations. Lentils were grown at the six drier locations and chickpeas were only grown

Table 2. Experimental treatments, 1981/82.

Crop and management treatment	Genotype	Planting time	Row spacing (cm)	Plant spacing (cm)	Rhiz. inoc.	Phosphate (60 kg P_2O_5)	Carbofuran 1.5 kg a.i./ha
Faba bean (I)*	ILB 1814	Nov	45	10	+	+	-
Faba bean (L)**	ILB 1814	Nov	45	10	-	-	-
Lentil (I)	ILL 4401	Nov	22.5	1.5	+	+	+
Lentil (L)	ILL 4401	Dec	45	0.75	-	-	-
Chickpea (I)	ILC 482	Nov	22.5	10	+	+	-
Chickpea (L)	ILC 482	Mar	45	5	-	-	-
Wheat/barley	S 311 x Norteno/Beecher	Nov	22.5	1.5	-	+	-
Wheat/barley	S 311 x Norteno/Beecher	Mar	22.5	1.5	-	+	-

* Improved management package developed at ICARDA 1977-1981.
** Local management practice with minimum inputs.

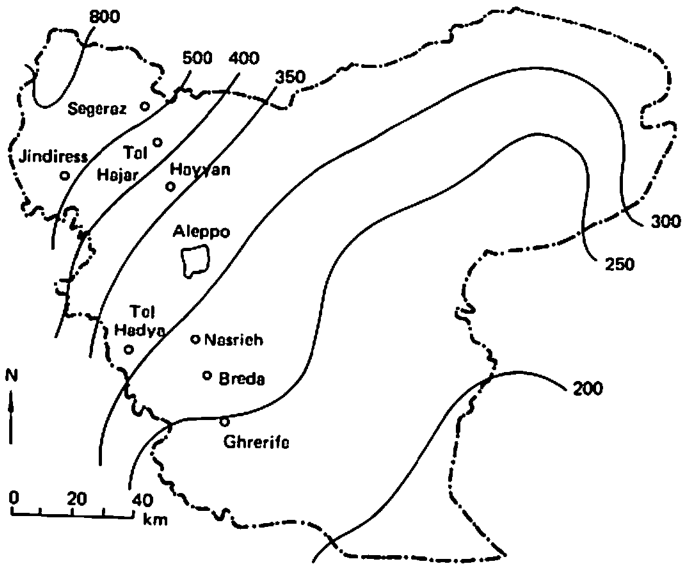

Fig. 1. Experimental site location in Aleppo Province.

with both an improved and a local management practice at the five wetter locations. In all cases the trials were carried out following a previous cereal crop (wheat or barley). Plot size was 4.5 x 6 m. The experiment was laid out in a randomized complete block design with three replications. All treatments received 20 kg N/ha at planting, of which the central microplots (2 x 0.9 m) received ^{15}N-enriched ammonium sulphate as 5% a.e.

At harvest, yield estimates were made from at least 3-m rows per replicate from the central microplot, the central row of which was used for total nitrogen determination and analysis of ^{15}N content. These analyses were performed as described for the 1980/81 experiment.

Results

Full results are shown in Table 3 for 1980/81 experiment and in Table 4 for 1981/82 experiment with the exception of chickpea treatments at Hayyan which were destroyed by frost, in the case of the winter-planted treatment, and by vandalism in the case of the spring-planted treatment. Lentil treatments at this site were fortunately less seriously affected by these agencies.

Table 3. Yield of biologically fixed nitrogen (BNF) through recoverable dry matter at maturity, Tel Hadya 1980/81*.

Crop	BNF (kg/ha)	% N from BNF
Faba bean	90.5	89.9
Lentil	33.9	86.2
Winter chickpea	75.0	86.2
Spring chickpea	42.3	85.0

* Seasonal rainfall 345 mm.

Results in Tables 3 and 4 indicate that there is considerable variability across sites, years, and treatment not only in the amounts of nitrogen fixed but also the proportion of total nitrogen supply contributed by biological nitrogen fixation (BNF). Owing to the preliminary nature of these findings we have not adopted a rigorous statistical approach, as we feel that this is inappropriate at this juncture while our results remain tentative. A fuller analysis will be feasible when the results from one more season's trial are at hand. Some general trends evident from the present studies are outlined below:

1. Satisfactory yields of dry matter were obtained in both years and at most sites without large additions of supplemental inorganic nitrogen. All crops were generally able to supply 50-80% of their nitrogen requirement from symbiotic fixation.

2. Crop productivity was clearly influenced by a factor associated with reduced rainfall. A reduction in seasonal rainfall from over 300 mm to close to 200 mm resulted in BNF falling from values around 50-100 kg/ha to below 20 kg/ha. This is likely to be a complex interaction between soil moisture stress and nutrient availability. It is notable in Table 3 that 1981/82 was an atypical season where the sites expected to receive more assured rainfall were drier than usual and drier sites had a wetter than average year. Nevertheless, large differences in BNF were noted between the wet and dry sites and it is perhaps a pointer towards a more complex nutrient or rhizobial effect that the proportions of BNF to total N were generally lower at dry sites.

3. Improved agronomy significantly improved the dry-matter production and BNF in the majority of site treatment combinations. It was notable that major differences in BNF were observed between winter- and spring-planted chickpeas.

Table 4. Yield of biologically fixed nitrogen (BNF) thorough recoverable dry matter (RDM) at maturity at different sites, 1981/82*.

Crop/Management	Site	BNF (kg/ha)	% N from BNF	RDM (kg/ha)
Faba bean (I)**	Jindiress	107.8	80.7	4980
Faba bean (I)	Jindiress	66.3	82.7	3040
Chickpea (I)	Jindiress	98.6	82.1	6510
Chickpea (L)***	Jindiress	12.1	34.0	1740
Faba bean (I)	Segeraz	116.6	64.0	6590
Faba bean (L)	Segeraz	117.4	56.6	7090
Chickpea (I)	Segeraz	54.3	54.0	7090
Chickpea (L)	Segeraz	36.2	41.1	3590
Chickpea (I)	Tal Hajar	119.7	84.3	6330
Chickpea (L)	Tal Hajar	18.2	27.3	2880
Lentil (I)	Tal Hajar	128.9	86.6	6440
Lentil (L)	Tal Hajar	91.8	84.0	4110
Lentil (I)	Hayyan	79.6	84.8	4280
Lentil (L)	Hayyan	36.3	74.9	2210
Faba bean (I)	Tel Hadya	52.4	77.5	2620
Faba bean (L)	Tel Hadya	53.8	76.8	3090
Chickpea (I)	Tel Hadya	27.8	50.8	2940
Chickpea (L)	Tel Hadya	16.6	44.9	1850
Lentil (I)	Tel Hadya	66.5	86.6	3450
Lentil (L)	Tel Hadya	40.0	61.4	2920
Chickpea (I)	Nasrieh	29.2	82.2	2000
Lentil (I)	Nasrieh	72.5	81.4	4130
Lentil (L)	Nasrieh	23.9	76.9	1400
Chickpea (I)	Breda	3.2	15.3	790
Lentil (I)	Breda	17.2	47.9	2140
Lentil (L)	Breda	6.5	30.7	1000
Chickpea (I)	Ghrerife	14.1	80.1	850
Lentil (I)	Ghrerife	10.4	39.0	1230
Lentil (L)	Ghrerife	4.8	31.9	790

* Seasonal rainfall (mm): Jindiress 350.3, Segeraz 398.1, Tal Hajar 353.5, Hayyan 353.6, Tel Hadya 337.6, Nasrieh 342.9, Breda 324.0, and Ghrerife 261.3.
** Improved.
*** Local.

Spring-planted chickpeas were, on the whole, poor fixers of nitrogen and derived more than 50% of their nitrogen requirements from non-symbiotic sources.

Discussion

Larue and Patterson (1981) have recently reviewed the available literature concerning field-scale estimation of the amounts of BNF by legume crops. They conclude that the number of reliable estimates currently available are extremely limited considering the volume of research work recently conducted. For crop production specifically in dry areas this paucity of information is particularly large, and it is hard to find a suitable basis of comparison for our results. Rizk (1966) has estimated BNF in Egypt, under irrigated conditions, by the "difference method" (see Larue and Patterson 1981) which is less precise than the use of the ^{15}N dilution technique. However, the following estimates of BNF are reported by him: faba beans 121-171 kg N/ha, chickpeas 67-141 kg N/ha, and lentils 62-103 kg N/ha. These figures are not too different from what we have found under improved agronomy and wetter conditions.

It is encouraging to note (Table 3) that all three crops, under acceptable environmental conditions, are able to fix biologically a large proportion of their nitrogen requirements. However, it is also clear that all crops use soil nitrogen as well. Therefore, available nitrogen may not accumulate to the same extent under legume crops as is observed under fallow conditions in this environment. This implies that there could be a reduction in the productivity of a following cereal crop which must either be compensated for by a sizeable legume crop yield, or be minimized by a significant residual effect from the legume crop residue, or by a combination of both factors. Data from a residual trial on the site of the 1980/81 experiment at Tel Hadya suggest that the residual response can be sizeable (Saxena, unpublished data). Residual trials at some of the locations of the 1981/82 experiment are currently in progress to further examine the magnitude of these effects.

It is reassuring to see from the results in Table 3 that improvements in management practice usually significantly increase BNF. This implies that more judicious management would allow much more scope in maintaining or improving the available nitrogen levels in the system. Precisely which components of the package employed are most economically effective in increasing BNF is unknown at present but experiments designed to investigate this question are planned for the 1983/84 season. However, it is probable that phosphate application is an important factor in this area where unfertilized soils are generally in the medium to low extractable phosphorus class (P-Olsen) at the surface and low at depths below 20 cm (Cooper et al. 1981). Sizeable responses to P fertilizer in nodule dry weights have been noted in *Phaseolus vulgaris* crops by Graham and Rosas (1979) and in active nodule longevity by Andrew

(1977). Inoculation by suitable Rhizobium species may also prove to be an important factor, as the poor N fixation performance of spring-planted chickpeas (Table 4) can possibly be attributed to an ineffective inoculation by native Rhizobium species. Alternatively, the delay in maturity of spring-planted crops to a time in which environmental conditions are more hostile than in winter-planted crops suggests that heat and drought stress effects may be active in suppressing BNF. This would be a possibility from the findings of Small *et al.* (1968) and Sprent (1976).

Larue and Patterson (1981) warn that the yield gap between experimental residual trials and the residual responses in farmers' fields would be mirrored in terms of BNF and our results should be seen in this context. Nevertheless, the scope for reducing the dependence of agricultural systems in dry areas on inorganic fertilizer nitrogen currently would seem to be reasonable, but a large research investment still is required in this area if improved BNF on farmers' fields is to be widely realized.

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Discussion

K.G. Cassman

1. Does the ICARDA "Improved" recommended package for faba bean, lentil, and chickpea include a recommendation for 20 kg fertilizer-N/ha?
2. Were the estimates for total input from nitrogen fixation using the ^{15}N method and the N-difference method (wheat as the indicator crop) similar?

D. Keatinge

1. No.
2. Yes, very similar.

S.K. Sinha

In your experiments at a drier station, contribution of biologically fixed nitrogen was less as compared to wet station. Was it due to reduced drymatter accumulation or reduced nitrogen fixation?

D. Keatinge

In dry areas moisture stress effects acted on both processes in my opinion. If the plant is stressed BNF will inevitably be reduced. Whether BNF can be affected by stress without affecting drymatter production is unknown currently but, I believe, is most unlikely.

A. Slinkard

Symbiotic nitrogen fixation is much more sensitive to stress than is either drymatter yield or microbial growth. Conversely, symbiotic nitrogen fixation is more responsive to beneficial practices, e.g. phosphorus fertilization under phosphate deficient conditions, than is either drymatter yield or microbial growth.

S. Chandra

Dr. Keatinge, do you also have data on the BNF at varying levels of available P either applied to soil or made available to plant through microbes like vesicular arbuscular mycorrhiza

D. Keatinge

Studies at ICARDA in the food legume improvement program have quantified the BNF by lentils and faba beans under different levels of phosphate fertilization and the beneficial effect of P application under low available soil phosphorus status has been demonstrated. We will examine this aspect under different rainfall situations in the 1983/84 season.

Proceedings of the International Workshop on Faba Beans, Kabuli Chickpeas, and Lentils in the 1980s (Saxena, M.C. and Varma, S., eds.), ICARDA, 16-20 May 1983, Aleppo, Syria.

Agronomy of Faba Beans, Lentils, and Chickpeas

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The productivity of any crop species depends on its genetic potential, the environment, and their interaction. Although the ceiling is set by the genetic potential, the manipulation of the environment is essential to allow full expression of the genetic potential. Agronomic studies are important in elucidating the genotype x environment interaction and in identifying the practices that increase crop productivity by optimizing the controllable component of environments.

This paper reports the results of recent studies on growth and yield responses of faba beans, lentils, and kabuli chickpeas to agronomic practices conducted at ICARDA.

Faba Beans

Genotype x Environment Interaction

Faba beans are grown over a wide range of latitudes (15-60^{0}N) and the optimum temperature requirement for growth is between 10-30^{0}C. The crop will grow where altitude and latitude combinations permit these temperatures (Saxena 1979). In the ICARDA region faba beans are grown with irrigation except in high rainfall areas near the coast. A cooperative experiment (with the European Economic Community faba bean research group) is being conducted at Tel Hadya and other locations which vary in basic environmental factors such as temperature, day length, irradiance, and rainfall. Diverse genotypes originating from Europe and the Mediterranean region are used. In 1981/82 the results at Tel Hadya revealed that the Mediterranean genotypes (Aquadulce and Giza 3) outyielded the European (Minica and Herz-freya) emphasizing the role of adaptation to environment. When optimum growing conditions with respect to moisture and nutrients were provided, the productivity of the well adapted genotypes was four times that of the rainfed control. The study revealed that the major constraint for increased yields of faba bean at Tel Hadya was soil moisture (Table 1).

Table 1. Yields, and water-use efficiency of four faba bean genotypes as affected by soil moisture and soil fertility treatments at Tel Hadya 1981/82. (TBY = Total Biological Yield; WUE = Water-Use Efficiency).

Genotype	Soil environment[1]	Yield: TBY (kg/ha)	Yield: Seed (kg/ha)	Harvest index	Seasonal water supply	WUE (kg/ha/mm): TBY	WUE (kg/ha/mm): Seed yield
Minica	A	9414	4578	0.49	515	18.28	8.89
	B	6263	3131	0.50	515	12.16	6.08
	C	2061	970	0.47	335	6.15	2.89
	Mean	5913	2893	0.49			
Aquadulce	A	11345	6008	0.53	500	22.70	12.02
	B	8121	4909	0.60	500	16.24	9.80
	C	2909	1620	0.56	335	8.68	4.83
	Mean	7461	4179	0.56			
Giza 3	A	9818	5689	0.58	500	19.64	11.38
	B	7333	4101	0.56	500	14.67	8.20
	C	2828	1479	0.52	335	8.44	4.41
	Mean	6660	3756	0.56			
Herz-freya	A	7636	3317	0.43	515	14.82	6.44
	B	6909	2812	0.41	515	13.41	5.46
	C	1495	578	0.39	335	4.46	1.72
	Mean	5347	2236	0.41			

1. A = Artificial rooting medium + 4 times 100 kg N + 33 kg P + 33 kg K/ha (as a liquid feed) + irrigation.
   B = As for (C) + Irrigation (12 trickle irrigations of 15 mm each).
   C = Control (indigenous soil, 100 kg TSP/ha, no irrigation).

Rainfed Faba Beans Under Low Rainfall Conditions

Introduction of faba beans in lower rainfall areas without supplementary irrigation must be preceded by the availability of drought-tolerant genotypes. Two approaches are being used to select for drought-tolerant material in the breeding program: (i) genotypes identified for rainfed conditions are grown at locations varying in rainfall, and (ii) the same genotypes are grown at Tel Hadya under different soil moisture regimes. In addition to yield a number of growth characters and water-use efficiency are evaluated in the experiments conducted at Tel Hadya, the objective being to identify the characteristics which could be associated with drought tolerance. This information should again be used in the breeding for drought tolerance.

Reduced moisture supply reduced growth and yield of all test genotypes, but ILB 277, 605, 1933, 1816, and 269 were affected much less than the others. Genotypes ILB 277 and 605 also had higher water-use efficiency.

Plant Type Studies

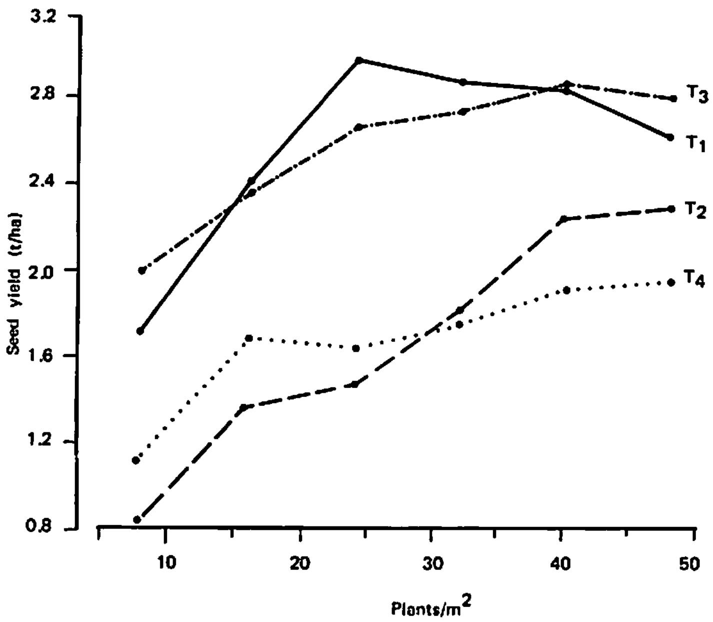
Studies to evaluate the performance of different plant types have been conducted at Tel Hadya using two approaches: (i) comparing different genotypes, and (ii) manipulating the same genotypes to produce different plant types by debranching and detopping. The objective is to investigate the possibilities of alternative plant types which can better utilize a given environment. It is believed that a determinate plant type under the irrigated conditions of Egypt and Sudan could respond more to increased soil moisture and fertilizer application.

Under low-rainfall conditions, results at Tel Hadya have demonstrated that a moderately branched indeterminate plant type (Treatment 1 and 3) outyields the other plant types (Fig. 1). The ideal material to evaluate plant types is isolines. In the absence of these materials, the information generated from the present approaches still gives good indication of the performance of the different plant types.

Date of Planting and Plant Population

Trials have been conducted at Tel Hadya and at several other locations in the ICARDA region using local landraces of faba beans to evaluate the effect of date of planting on their performance. Results reveal that delaying sowing beyond the middle of December reduces both the total biological and seed yields (Fig. 2). In some years some locations experienced sub-zero temperatures during spring, coinciding with the flowering stage of the early plants. Where this happened, as for example in Terbol (Lebanon) in 1981/82, advancing sowing into October/early November did not lead to corresponding seed yield increases. This was owing to the frost damage to the reproductive growth.

Increasing the plant population from 16.7 to 33.3 plants/m^2 increased the seed yield only at Tel Hadya in 1980/81 season (Table 2). The lack of response to variation in plant population levels implies a high degree of plasticity in the local cultivars. This behavior has been well documented (Hodgson and Blackman 1956).



T_1 = natural, moderately branched, indeterminate control;
T_2 = monoculmed, indeterminate model developed by debranching;
T_3 = almost natural, indeterminate model with 3 shoots per plant developed by removing any additional branch;
T_4 = moderately branched determinate model developed by detopping all shoots.

Fig. 1. Effect of plant population on the yield of different plant-type models, developed by debranching and detopping of the moderately branched indeterminate faba bean, ILB 1814.

Fertilizer and Nitrogen Fixation

It has been shown that faba bean fixes more nitrogen (135 kg N/ha) than lentil and chickpea (Rizk 1966), and that it responds positively to P and K application (Saxena 1979).

Fertilizer trials have been conducted at various locations in the ICARDA region for a number of seasons to try and evaluate the responses of faba beans to N, P, and K and to inoculation. The application of up to 50 kg P_2O_5/ha increased nodulation and yield in soils containing 3.5 and 2.0 ppm P at Breda and Tel Hadya, respectively, in the 1980/81 season. There was no response to K

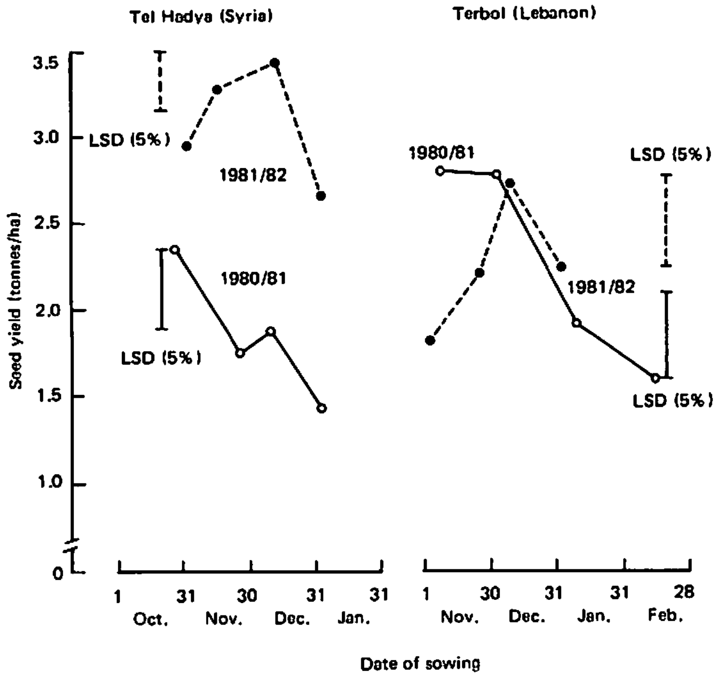


Fig. 2. Effect of dates of planting on the seed yield of faba beans in 1980/81 and 1981/82 seasons at Tel Hadya, Syria and Terbol, Lebanon.

fertilizer, because of the high available K content in these soils (>400 ppm). Inoculation did not have any significant effect on seed yield, implying that the soils had compatible indigenous rhizobium strains. However, evaluation of faba bean rhizobium strains in relation to host genotypes at Tel Hadya (1980/81) indicated that an increase of 24.6% in yield could be obtained with one of the strains. The improved nitrogen-fixing efficiency of the introduced strains was confirmed with the Green Windsor cultivar using the acetylene reduction technique. Studies to evaluate the effect of small starter nitrogen doses revealed that cultivars nodulated better and showed higher nitrogenase activity with starter nitrogen, thus implying that the improved early growth due to starter nitrogen could have improved subsequent activity of the rhizobium.

Table 2. Seed yield (t/ha) of faba beans as affected by plant population at Tel Hadya and Terbol in 1980/81 and 1981/82.

Plant population (per m^2)	Seed yield (t/ha)			
	Tel Hadya		Terbol	
	1980/81	1981/82	1980/81	1981/82
16.7	1.69	3.01	2.15	2.04
20.0	1.68	3.02	2.21	2.35
25.0	1.89	3.15	2.31	2.34
33.3	2.18	3.16	2.42	2.20
LSD (5%)	0.369	NS	NS	NS
CV (%)	24.7	7.8	15.7	18.4

NS = Not significant.

Lentils

Environment x Genotype Interaction

Information from ICARDA Lentil Adaptation Trials (LAT) revealed that genotypes originating from West Asia and South Europe are very late to flower when grown in southern Asia with photoperiods of less than 11 hr. In these areas the introduced varieties produce few or no pods, because they start the reproductive growth phase when the conditions are increasingly hot and dry. Results from these trials also suggested that high temperatures during the vegetative period can partly off-set the effect of shorter photoperiods in these latitudes. In view of this information, photoperiodic and thermal responses of a set of diverse genotypes have been under study at ICARDA for at least five growing seasons. The main objective is to identify genetic materials for breeding work for wider adaptability.

Results from the last three seasons show that longer days (16 hr light period) and higher temperatures (as obtained by heated plastic house) hasten the onset of reproductive growth (Table 3) in comparison to the natural day length (gradually increasing from 9.75 hr to 13.5 hr) and low temperatures. However, genotypes ILL-784 (Egypt), ILL 2526 (India), and ILL 4605 (Argentina) show less sensitivity than the other genotypes. These have thus been used in the breeding program to develop types suitable for southern latitudes.

Table 3. Effect of long-day (LD) vs normal-day (ND) conditions on the days to flower bud appearance of lentil at low and high ambient temperature. Results are based on means of 20 plants.

Genotype	Origin	Days from planting to first flower bud											
		1979/80				1980/81				1981/82			
		High temp.		Low temp.		High temp.		Low temp.		High temp.		Low temp.	
		LD	ND	LD	ND	LD	ND	LD	ND	LD	ND	LD	ND
ILL 58	Iraq	74.7	88.0	87.5	111.0	67.7	91.4	89.5	102.2	63.0	85.9	92.1	160.1
ILL 92	USSR	77.0	91.8	88.0	125.0	74.4	97.4	92.7	113.0	68.0	119.4	109.7	154.0
ILL 183	Turkey	75.0	88.4	88.0	121.7	73.4	97.0	88.2	105.7	66.5	109.0	98.9	158.7
ILL 204	Ethiopia	76.0	84.5	88.0	118.2	69.2	92.0	83.5	106.7	64.6	104.3	95.5	147.0
ILL 784	Egypt	69.2	83.4	88.3	102.0	64.5	72.0	71.2	76.5	58.9	71.9	95.6	98.4
ILL 4401	Syria	67.7	80.2	83.6	102.0	64.6	87.2	74.0	91.7	53.6	77.6	96.2	143.6
ILL 4349	USSR	-	-	-	-	73.6	102.6	86.0	106.0	64.1	110.9	102.0	161.0
ILL 2526	India	-	-	-	-	64.6	72.6	73.5	76.7	61.5	67.0	93.6	92.1
ILL 854	Algeria	-	-	-	-	69.1	97.0	88.2	106.0	63.8	118.9	88.7	147.0
ILL 4605	Argentina	-	-	-	-	-	-	-	-	64.5	67.3	84.5	91.0

Date of Sowing and Plant Population

The optimum planting date of lentils varies from location to location. In regions where winters are very cold, such as Iran, the optimum sowing date is mid-March (Saxena 1979). In India, where winters are mild, the optimum date is mid-October (Saxena 1981). In Syria, Lebanon, and Jordan, lentils are normally sown in December and January. Trials conducted in these countries have consistently shown that yields are significantly reduced when sowing is delayed beyond the end of December. The reduction in yield has been attributed to the reduction in growth due to shorter growing period (Table 4).

In years when late frost was experienced, the reproductive growth of the early crop was adversely affected, and the advantages of early sowing were not fully realized.

In a trial in 1981/82 at Tel Hadya, early planting improved water-use efficiency. The early-sown crop also tended to extract more water (Fig. 3), probably due to better root development. Since one of the constraints to crop productivity in the lentil-growing areas is the limited soil moisture, a production technology which can improve water-use efficiency assumes a high priority.

Reviewing the responses of lentil to planting density, it was pointed out that many common cultivars show high degree of plasticity (Saxena 1979). Trials conducted in Lebanon and Syria to find the optimum population levels of the local landraces have confirmed this. Varying the plant population levels from 133.3 to 333.3 plants/m^2 by reducing the row width led to no significant changes in seed yield at Terbol (Lebanon). Only when the population levels were reduced to 133.3 plants/m^2 was the seed yield significantly reduced at Tel Hadya (Syria). Productivity could be increased by selecting new varieties which can respond more positively to plant population levels.

Nutrient Requirements

It has been pointed out that a lentil crop yielding up to 2 t/ha might take up to 100 kg N, 28 kg P_2O_5, and 78 kg K_2O/ha (Saxena 1979). Thus to get a good yield from poor soils fertilizer nutrients might be essential. Under good symbiotic association, up to 80% of N required by the lentil crop comes from symbiosis (Rizk 1966). This might explain why there has not been a positive response to N application at Tel Hadya. However, on poor sandy soils a small starter of 25 kg N/ha is known to improve symbiotic nitrogen fixation (Saxena 1981).

Generally, the soils on which lentils are grown have low P content, and economic responses have been obtained to P application in India (Saxena 1979). Conversely, trials conducted at Izra'a and Tel Hadya (1980-82) revealed no positive response to P fertilizer application on soils where the available P was 8.0 ppm or more.

Table 4. Effect of date of planting and plant population on seed yield (kg/ha) in 1981/82 of lentil cvs ILL 4400 at Tel Hadya and ILL 4399 at Terbol.

Plant population (per m^2)	Terbol (Lebanon)					Tel Hadya (Syria)				
	Date of planting					Date of planting				
	4 Nov	24 Nov	20 Dec	1 Jan	Mean	23 Nov	13 Dec	10 Jan	2 Feb	Mean
333.3	1414	1803	1876	1723	1703	1517	1937	1389	1078	1480
222.2	1785	1861	2018	1378	1761	1743	1536	1251	1314	1461
166.7	1914	1982	1651	1296	1711	1543	1755	1222	1150	1418
133.3	1658	1725	1759	1274	1604	1601	1489	1071	782	1236
Mean	1692	1843	1826	1418		1601	1679	1233	1081	

CV (%) main plot (D) = 16.6 | 10.4
CV (%) subplot (P) = 14.0 | 14.0
LSD at 5% D = 225; P = NS; D x P =340 | D = 116; P = 140; D x P = 282

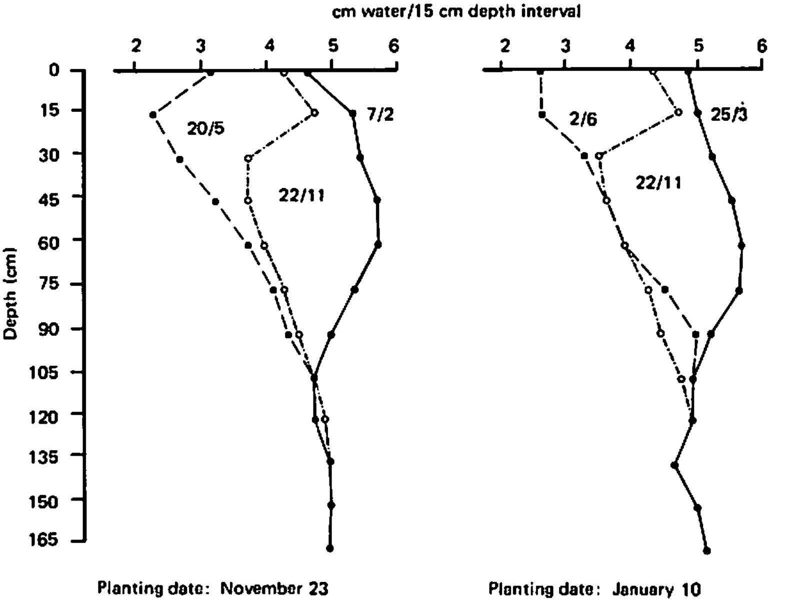


Fig. 3. Recharge/discharge curves for soil moisture in different layers under two different dates of planting of lentil (ILL 4400) at Tel Hadya 1981/82.

Work done in India suggests that a poor stand resulted where P fertilizer had been in contact with lentil seeds and this in turn led to reduction in seed yields. The application of 50 kg P_2O_5/ha as triple superphosphate mixed with seed had no adverse effect on seed yield in studies at ICARDA.

Trials conducted at many locations in northern Syria have revealed no positive response to K fertilizer application. This could be attributed to the high available K in those soils (>400 ppm).

Production Practices Package

In the 1980/81 growing season a trial was conducted at Tel Hadya and on farmers' fields to evaluate different production practices for lentils. The season was characterized by severe cold. The maximum production was obtained when all the improved practices were carried out (Table 5). On farmers' fields the single practice which contributed most was early planting. At Tel Hadya, with low available soil P (<2 ppm P), phosphorus application also proved a major factor in increasing the productivity, particularly by improving the frost tolerance of the crop.

Table 5. Effect of different production practices on lentil yields (t/ha) in on-farm trials at 13 locations and at Tel Hadya, northern Syria in 1980/81.

Treatment	Farmers' field		Tel Hadya	
	Seed yield	%	Seed yield	%
Normal date of planting (ND) and farmers' method of planting (FMP)	0.99	100	0.87	100
Early date of planting (ED) + FMP	1.15	116	0.80	92
ED + FMP + Carbofuran (C) 1.5 kg a.i./ha	1.17	118	1.41	162
ED + C + drill planting (D)	1.28	129	1.58	182
ED + C + D + 50 kg/ha P_2O_5 as TSP	1.29	130	2.13	245

Lentils for Drier Areas

The area under lentil production could be increased by developing varieties which can yield reasonably under low rainfall (about 250 mm annual precipitation) areas which are at present exclusively under barley/fallow rotations. Two concepts are used in selecting materials for dry areas: drought avoidance, i.e. material completes the life cycle before the onset of drought conditions, and drought tolerance, i.e material which experiences the drought stress but survives. It was with the second approach in mind that studies were initiated at ICARDA to evaluate the field methods of screening for drought-tolerant genotypes.

Some genotypes which had been selected for good performance under dry conditions were grown under three moisture regimes at Tel Hadya: (i) assured moisture by supplementary irrigation; (ii) rainfed, and (iii) reduced soil moisture, where rainfall was limited by covering the ground with polyethylene sheets. In addition, the same genotypes were grown at two other locations with differing rainfall. In 1980/81, reducing the soil moisture at Tel Hadya had least effect on the performance of ILL 101, 470, 4354, and 4401 (Fig. 4). In 1981/82, when the same genotypes were again evaluated, the moisture studies revealed that genotypes ILL 101, 223, 470, 4400, and 4401 had higher water-use efficiency in terms of seed yield (Table 6). These could therefore be of use in breeding for improved water-use efficiency.

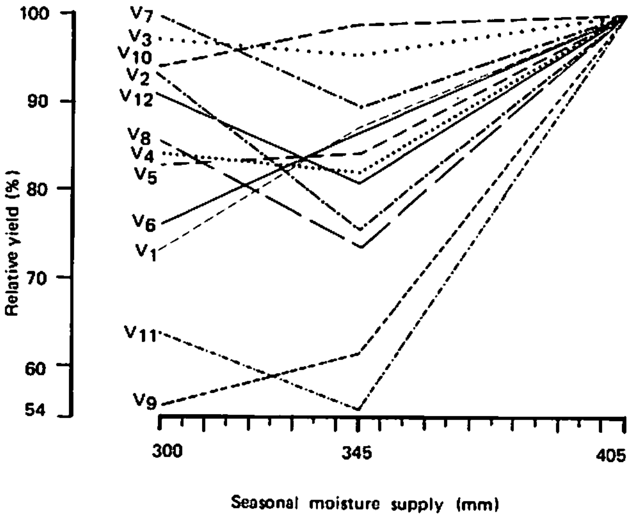


Fig. 4. Relative yield of lentil genotypes as affected by moisture supply. Genotypes V_1 to V_{12} refer respectively to ILL 4401, 793, 1861, 2501, 1877, 4349, 101, 4400, 1744, 470, 223, and 4354. Tel Hadya 1980/81.

Table 6. Total extractable moisture (EM, mm), evapotranspiration (E_t, mm), and water-use efficiency (WUE, kg/ha/mm) for total biological yield (TBY) and seed yield (SY) for different lentil genotypes under rainfed conditions in Tel Hadya during the 1981/82 season; E_0 was about 680 mm for the same duration.

Genotypes	Date of maturity	EM (mm)	E_t (mm)	Yield (kg/ha) TBY	SY	WUE TBY	SY
V_1 ILL 4401	May 25	105.8	288.9	4380	1391	15.2	4.8
V_2 ILL 793	June 8	136.6	329.9	3970	1363	12.0	4.1
V_5 ILL 1877	June 8	134.1	322.7	3824	1223	11.8	3.8
V_6 ILL 4349	June 8	151.9	335.5	4606	1147	13.7	3.4
V_7 ILL 101	June 1	131.7	312.5	4703	1721	15.0	5.4
V_8 ILL 4400	June 1	130.3	316.8	4082	1644	12.8	5.2
V_{10} ILL 470	May 25	110.8	293.7	3818	1566	13.0	5.3
V_{11} ILL 223	May 25	107.8	285.7	4676	1847	16.4	6.4

Chickpeas

Date of Planting and Plant Population

Chickpeas in West Asia are planted from early winter to late spring depending on the local ecological conditions. In the Mediterranean region, where winters are not cold enough to prevent winter planting, farmers still plant in spring. Spring-sown chickpea is subjected to moisture stress. It is also exposed to high temperature during the early phase of reproductive growth, thus resulting in reduced yield. The main constraint to winter-chickpea plantings was demonstrated to be ascochyta blight and not frost (Hawtin and Singh 1984). Trials conducted in Lebanon (Table 7) and northern Syria (Table 8) using ascochyta-resistant varieties have consistently shown that winter-sown chickpeas significantly outyield those sown in spring and that there is an advantage in advancing the planting date within the spring season itself (Saxena 1980). Sometimes, an extremely cold winter can off-set the advantages of early planting through frost damage. The importance of cold-tolerant varieties for winter planting is therefore obvious.

In studies on the response of both winter- and spring-planted chickpeas to increasing plant populations from 16.7 to 50 plants/m^2, winter-sown crops showed positive responses, especially in the wetter locations.

Nutrient Requirements

International fertility-cum-inoculation trials were conducted at various locations in 1980/81 and 1981/82 to investigate the need for

Table 7. Effect of date of planting and plant population on the grain yield (kg/ha) of Lebanese local chickpeas at Terbol and Kfardan, 1979-81.

	Grain yield (kg/ha)		
	1979/80	1980/81	
Treatment	Terbol	Terbol	Kfardan
Date of planting			
D_1	1500	1431	1019
D_2	1502	1457	1048
D_3	1288	1514	972
D_4	1010	886	766
LSD (5%)	182	325	157
Plants/m^2			
33.3	1343	1432	997
25.0	1337	1347	922
20.0	1377	1321	916
16.7	1244	1187	970
LSD (5%)	NS	NS	NS

	Date of planting			
	D_1	D_2	D_3	D_4
Terbol 1979/80	Nov 17	Dec 12	Jan 22	Mar 26
Terbol 1980/81	Nov 19	Dec 17	Jan 9	Mar 20
Kfardan 1980/81	Dec 12	Jan 1	Feb 10	Mar 13

P, K, or inoculum application at the particular locations. Results from both seasons revealed no significant response to either fertilizer or inoculation, except to P application at Kafr Antoon in 1980/81 and at Breda in 1981/82. At these locations the soil P status was very low (1.5 ppm at Kafr Antoon and 2.5 ppm at Breda).

Lack of response to fertilizer application at the other locations does not necessarily mean that P alone would be adequate on farmers' fields. On-farm trials should be conducted before any recommendation can be made. Similarly, on introducing chickpeas into new areas there might be a need for seed inoculation with effective strains of *Rhizobium*. Various strains of *Rhizobium* have been tested for chickpeas both in winter and spring sowing; IC-26, a *Cicer Rhizobium* strain, has proved best, resulting in the highest nitrogenase activity and increased seed yield.

Table 8. Seed yield of ILC 482 and 202 at different plant population levels under winter (WS) and spring (SS) sowing at various sub-sites in north Syria, during 1980/81 and 1981/82 seasons.

Genotype and Sowing time (M)	Plants/m^2 (S)	1980/81 B	1980/81 KA	1980/81 TH	1980/81 J	1981/82 TH	1981/82 L	1981/82 J	1981/82 B
ILC 482 WS	50.0	552	981	2425	3666	1849	1848	1170	344
	33.3	549	426	1617	3291	1304	2256	1198	237
	25.0	479	588	1065	2701	1267	1876	1215	172
	20.0	421	778	1097	2830	1197	2234	859	127
	16.6	394	718	613	1435	1219	1176	897	114
ILC 482 SS	50.0	223	823	913	1593	1520	1242	919	321
	33.3	133	760	693	1214	946	1718	734	201
	25.0	115	736	840	1047	815	1147	584	162
	20.0	110	621	622	1218	828	1292	650	168
	16.6	115	616	735	1132	728	1252	550	131
ILC 202 WS	50.0	379	921	1841	2411	1557	1898	1218	268
	33.3	330	663	1683	1550	1407	1207	1140	182
	25.0	394	767	1306	1516	1183	1088	958	165
	20.0	289	692	1258	1337	1157	1096	971	93
	16.6	307	656	1082	1511	1090	1150	745	115
ILC 202 SS	50.0	72	926	779	650	712	1842	600	19
	33.3	70	771	804	657	629	1429	508	20
	25.0	61	680	582	332	452	1273	442	21
	20.0	73	659	485	648	483	1116	497	15
	16.6	26	605	457	636	458	896	308	6
CV (%) for S		26.2	25.5	26.7	32.2	28.2	25.4	18.6	36.6
LSD (5%) M		134.9	NS	420.0	344.0	465.1	110.4	207.2	57.8
S		55.6	152.0	233.0	394.0	244.2	307.9	125.4	44.0
M x S		NS	NS	466.0	NS	NS	NS		

B = Breda; KA = Kafr Antoon; TH = Tel Hadya; J = Jindiress; and L = Lattakia. NS= Not significant.

In calcareous soils, some varieties of chickpeas show temporary symptoms of iron deficiency. However, iron application has shown no significant effect.

Role of Legumes in Cropping Systems

The role of food legumes in the rainfed two-course rotation has been studied at Tel Hadya since 1977/78. Results have revealed that a cereal crop following a well-managed legume crop does as well as that following fallow, and much better than that following a cereal crop (Table 9). The beneficial residual effect for the subsequent cereal crop seems to be partly due to improved nitrogen supply. More intensive studies are needed to further elucidate the factors responsible for this improved performance of cereals following legumes.

Table 9. Effect of cropping treatments in 1979/80 and 1980/81 seasons on the grain yield of a following crop of rainfed Norteno x S311 wheat receiving different levels of nitrogen fertilizer (N_0=0, N_1=30, N_2=60 and N_3=90 kg/ha).

Preceding cropping treatments (C)	Residual effect in 1980/81					Residual effect in 1981/82			
	Grain yield of wheat (kg/ha)					Grain yield of wheat (kg/ha)			
	N_0	N_1	N_2	N_3	Mean	N_0	N_1	N_2	Mean
Lentil (L)	1624	1983	2207	2411	2056	1456	1929	2199	1834
L + carbofuran	1547	1817	2024	2235	1906	1200	1837	1898	1645
L for green forage	2143	2517	2817	2393	2468	1592	1847	2022	1821
Winter Chickpea (WC)	1629	1860	2729	2632	2212	875	1188	1566	1209
Spring Chickpea	1650	2142	2399	2369	2140	630	1350	1522	1167
Faba bean	1677	2389	2419	2169	2164	1320	2072	2228	1873
Peas	-	-	-	-	-	1260	1755	1994	1680
WC + wheat intercropped	-	-	-	-	-	532	1288	1655	1158
WC + barley intercropped	-	-	-	-	-	264	1225	1820	1103
Wheat at 20 kg N/ha	-	-	-	-	-	533	1369	1539	1147
Wheat at 60 kg N/ha	831	1132	1459	1887	1328	394	1249	1371	1004
Fallow	1721	2792	2915	3201	2659	824	1396	1572	1264
N rate means	1603	2079	2371	2412		907	1544	1775	
CV (%) for C		15.0					23.3		
LSD (5%) for C		286					274		
C x N		493					NS		

NS = Not significant.

Looking Ahead

Studies at ICARDA have served to illustrate the point that there is considerable scope for improving the yield of food legumes through improved agronomy. Agronomic requirements are location specific, and have to be studied in the different production areas. Realizing that relatively little efforts have been devoted to agronomic studies of food legumes within the region, a set of International Agronomic Trials was started; these trials were well received by the cooperating scientists from the region. It is hoped that these trials will act as a catalyst to increase the efforts on agronomic research on food legumes in the region, and that the production practices so identified will be evaluated under farmers' conditions through on-farm and farmer-managed trials so that realistic recommendations can be made.

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Sixth Session

Some New Concepts of Food Legume Quality Evaluation at ICARDA

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ICARDA's Food Legume Improvement Program covers three crops, chickpea (Cicer arietinum), faba bean (Vicia faba), and lentil (Lens culinaris). The chief objectives are to improve production and consumption of food legumes in the Middle East. The Quality Laboratory was established during 1980 to assist breeders in their selection, to evaluate and monitor the quality of advanced and standard cultivars, and to protect ICARDA and the food legume industry from the licensing and growing of cultivars with any inferiorities in quality. Straw is a very important aspect of crop quality, particularly in lentil, and ICARDA is testing advanced cultivars of lentil for straw protein and digestibility.

Consumer and Nutritional Quality

"Quality" in any crop implies processing, consumer, and nutritional quality. In the case of lentil, and more recently chickpea, the fourth factor is export quality, where the demands of importing nations must also be studied and standards established before export. The most important quality parameters of the three crops are listed in Table 1.

Seed Size and Size Distribution

Seed size and size distribution are important for the export market. Syria is a major exporter of lentils, and two sizes are favored: large- and small-seeded lentils. Large-seeded lentils are greyish green with yellow cotyledons, and should have an average size (diameter) of about 6.5 mm. Small-seeded lentils are brownish-reddish purple with orange cotyledons, and a diameter of 4.2-4.5 mm is preferred. Genotypes with unusual colors are discarded, but may be used as parents if they possess some outstanding favorable feature. If large-seeded lentils are too small, a high proportion of seeds is lost on grading for export, and

Table 1. Quality parameters of food legumes.

Parameter	Chickpea	Faba bean	Lentil	Method
Seed size (g/100 seeds)	*[1]	*	*[1]	Manual
Seed size distribution	*[1]	*	*[1]	Sieves
Protein	*	*	*	NIRS
Hard-seed-coatedness	*	*	*	Hydration
Cooking time	*	*	*	Refluxing
Cooking quality	*	*		Organoleptic
Decortication loss			*[1]	Abrasion
Lysine	*	*	*	NIRS
Methionine	*	*	*	NIRS
Color			*[1]	Visual
Protein digestibility		*	*	Enzymic
Anti-nutritional factors		*[2]		NIRS

1. Important for export as well as domestic use, these parameters are discussed from aspects of consumer and nutritional quality, and from the standpoint of the exporter.

2. Mainly vicine and convicine in connection with favism; also trypsin inhibitors, tannins,and flatulence factors.

has to be used locally as food or feed. If small-seeded lentils are too large, e.g., over 5 mm, they are too small and of the wrong color to be included with large lentils, and if they are to be decorticated and split for export they require readjustment of all milling equipment, which is laborious and time-consuming.

Seed size is important in chickpea also; in general, the larger the seed the better. ICARDA's chickpea program is dedicated to the kabuli type of chickpea, which are large seeded and pale in color. A recent survey in Syria of stores selling chickpea-based foods showed that for Homos Bitiheneh and Falafel, for which the chickpeas are milled to a paste, size was not of supreme importance, provided that the seeds were reasonably large. The larger seeds were preferred for Tisqieh, a dish more popular in southern Syria, and for which the whole seed is used. Seeds not large enough were unacceptable for selling as snacks, either raw or sugar-coated. For export, an average size of over 8 mm is needed, and uniformity in size and color is also essential.

Protein Content

Food legumes are regarded as a protein supplement in the human diet, and although the protein content is usually substantially higher than that of cereals, care must be taken that as high a protein content as possible is maintained, commensurate with yield improvement. The well documented negative correlations (from -0.2 upwards) between yield and protein content which often occur in cereals under "normal" growing conditions are also found in food legumes. These correlations are usually of a magnitude which permits the possibility of selecting cultivars where protein content is sustained despite increased yield.

Cooking Quality

Cooking time is an important component of cooking quality; taste, texture, smell, appearance, and after-taste are other important components. Recent studies at ICARDA have shown that cooking time may not be of such significance as is generally believed. The first series of studies showed that cooking time is closely related to mean seed size, which in lentil and chickpea in particular is a highly heritable characteristic. The relationship between faba bean seed size and cooking time was not so clear cut, partly because of a higher variability in size between seeds from the same pod, and partly as a result of outcrossing, which affects the size of pods on the same plant. Table 2 summarizes these correlation and heritability data.

Table 2. Heritability of seed size (SS), and relation of seed size to cooking time (CT) in food legumes.

Crop	SS[1] Heritability	CT:SS
Faba bean	0.54	0.58
Chickpea	0.95	0.68
Lentil	0.98	0.92

1. Based on average of intercorrelations between seed sizes from four different locations for each crop.

The second series of experiments showed that both cooking time and variance within a series of genotypes was very significantly reduced as a result of overnight soaking. Most food legumes are soaked before food preparation to reduce the time of boiling to tenderness, and therefore the consumption of fuel. Sometimes bicarbonate of soda is also used to reduce cooking time even further in lentils and chickpeas, but not necessarily with faba beans. These data are summarized in Table 3.

Table 3. Influence of soaking on length and standard deviation of cooking time.

	Dry seeds		Soaked (water)		Soaked + $NaHCO_3$ (0.5%)	
	Mean time (min)	SD	Mean time (min)	SD	Mean time (min)	SD
Faba bean (S)	171	22.8	34	5.6	31	8.1
Faba bean (I)	216	30.7	56	6.3	63	18.0
Faba bean (L)	274	52.4	76	9.5	97	16.0
Chickpea (S)	127	18.3	49	9.1	28	4.9
Chickpea (L)	137	18.2	42	4.2	28	4.9
Lentils	27	7.7	7	3.9	5	2.6

S = Small; I = Intermediate; L = Large seed size.

Varietal differences tended to be retained in some cases, despite the reduction in cooking time. The greatly reduced standard deviation means that differences in cooking time between cultivars were reduced on soaking to the point where they were of little significance to the consumer. For example, the range of cooking time between large-seeded faba bean cultivars was reduced from 152 to 29 minutes, and in small-seeded lines from 80 to 14 minutes. In large kabulis, reduction was from 48 to 10 minutes. Difference between cooking times in lentil cultivars after soaking was only about 5 minutes.

The chief implications of these findings are that:

1. As a criterion of quality, cooking time is of less significance than had previously been considered.

2. Cooking time can be predicted from seed size with sufficient accuracy so as to avoid actual cooking time tests, particularly in early generation material.

3. The reported effects of growing location and season on cooking time are likely to be affecting seed size, rather than cooking time _per se_.

4. Cooking time is considered to be a function of permeability of the seed coat, followed by the rate at which the hot water causes the gelatinization of starch and denaturation of cell wall material in cotyledons.

This last factor is affected by the physical distance that the hot water must penetrate, which is in turn governed by seed size. Permeability of the seed coat is an important factor in hard-seed-coatedness. This condition affects hydration of the seed and may double the cooking time. Agronomically, hard-seed-coatedness also affects germination, and may become very important in breeding programs where it is desirable to plant nurseries in alternative areas, so as to obtain two generations per year. Hard seed coats can be readily detected by soaking the seed for 16 hours, as in the Hydration Capacity Test. The seeds with hard coats do not imbibe cold water, and remain unswollen. Their weight is virtually unchanged from the original. Hard seeds are influenced by growing environment, and it is possible that there is a relationship between the ambient temperature during the maturation of the seed and the development of hard-seed-coatedness, the incidence becoming higher at higher temperatures due to the more rapid dehydration of the outer layers of the seed.

Cooking time is not necessarily related to cooking quality. Cooking quality is assessed by consumer acceptance of the commodity in its final cooked form. The factors which make up consumer acceptance include color and general appearance, taste, odor, texture ("bitability"), and after-taste. The chief forms in which food legumes are eaten in the Middle East are summarized in Table 4.

Table 4. Legume-based foods of the Middle East.

Bean	Chickpea	Lentil
Ful Medames	_Homos Bitehineh_	Soup
Ful	_Falafel_	_Mujedareh_
Green (whole)	_Tisqieh_	
Snacks (whole)	_Snacks_ (whole)	

Most of these foods, except chickpea and bean snacks (whole, candied or salted seeds), require soaking and/or boiling, steaming or stewing. _Falafel_ is deep-fried. With the exception of green beans, the final flavor of all of the foods is enhanced by adjuncts such as garlic, salt, lemon juice, _tiheneh_ (sesame), and other herbs. However, the basic flavor and texture is provided by the legumes.

At ICARDA's legume quality laboratory a taste panel technique has been developed for organoleptic evaluation of actual cooking quality. To date the only legume studied in detail is the chickpea, using the medium of _Homos Bitehineh_. Up to 25 individuals are invited singly to test 2 to 4 samples. A card system is used to score the samples for appearance, odor, texture, flavor, and after-taste. Scoring is on the basis of "Excellent", "Good", "Fair", and "Poor" for the first four categories, and "Strong", "Definite", "Faint", and "None" for after-taste. Panel members are asked to record the type of after-taste, e.g. "bitter". Maximum score is 20. This technique has been used successfully to evaluate the eating, or consumer quality of winter- vs spring- planted chickpeas, seed size, and the effect of decortication of desi-type chickpeas. The technique will shortly be extended to evaluate faba beans via Ful Medames.

Amino Acid Content

Food legume proteins are rich in lysine and poor in methionine, so food legumes are generally regarded as the ideal protein supplement to cereals in which the opposite is the case. It is important to maintain the high concentration of lysine if food legumes are to be useful as a lysine supplement, and monitoring of genetic material for lysine is important. The methionine content of the common food legumes is low to very low compared to cereals (Table 5).

Table 5. Methionine content of common food legumes compared to principal food cereals.

Source	Methionine (mg/g of protein)
Faba bean	30
Chickpea	80
Cowpea	100
Lentil	50
Pea (*Pisum sativum*)	70
Phaseolus bean	60
Pigeonpea	80
Millet	150
Rice	180
Sorghum	120
Wheat	110

Breeding and selection for individual amino acids has received renewed attention since the application of the rapid technique of near-infrared reflectance spectroscopy (NIRS) to the determination of amino acids in food legumes. This technique enables simultaneous estimation of protein, lysine, methionine, and other constituents in up to 350-400 samples per day. Table 6 gives typical wavelengths used in determination of methionine, and protein in peas (*Pisum sativum*), together with analytical accuracy, using the first derivative of the log 1/R.

The fact that wavelengths for protein and methionine are quite different verifies that a true measurement of methionine was being made. Negative correlations of up to -0.6 between protein content and methionine as a percentage of the protein, cited in the literature, have acted as a deterrent to attempts to breed for

Table 6. Wavelengths(nm)and accuracy of prediction of methionine and protein in peas.

No.	Methionine	Protein
1	1662	2154
2	1103	2324
3	1762	1446
4	1774	2010
SD*	0.018	0.31
r*	0.98	0.99

* Standard deviation of differences, and coefficient of correlation between NIRS and standard results, respectively.

higher methionine. The NIRS technique enables the screening of very large numbers of genetic materials necessary to identify the elusive methionine-rich lines.

Protein digestibility is comparable in most cooked food legumes to that of cereals (Table 7). Digestibility may fall as low as 50-60% in faba beans, while chickpea and lentil are usually significantly higher. It is affected by the presence of trypsin

Table 7. Apparent protein digestibility.*

Crop	Species	Digestibility (%)
Field Pea	Pisum sativum	71 - 94
Lentil	Lens culinaris	80 - 93
Cowpea	Vigna sinensis	76 - 90
Chickpea	Cicer arietinum	76 - 90
Pigeon Pea	Cajanus cajans	77 - 91
Common Bean	Phaseolus vulgaris	69 - 84
Faba Bean	Vicia faba	59+
Lima Bean	Phaseolus lunatis	34+

*a. Nutritional standards and methods of evaluation for food legume breeders. IDRC-TS7e Ottawa, Canada, 1977.

b. Nutritional improvement of food legumes by breeding. Protein advisory group of United Nations. New York, U.S.A. 1973.

inhibitors, and although these are destroyed by heat, while cooking, differences in digestibility persist, probably due to differences in degree of heat denaturation of proteins. Protein digestibility is time consuming and expensive to test and unless a simple characteristic can be found which correlates with digestibility to an extent whereby digestibility can be predicted with confidence, testing for protein digestibility will be limited to advanced material.

Anti-Nutritional Factors

In addition to trypsin inhibitors, tannins, and hemaglutinins, food legumes often carry anti-nutritional substances which may be severely debilitating or toxic. Perhaps the best known of these are the trisaccharide sugars, raffinose and stachyose, which are responsible for flatulence in soybean-based foods. The faba bean contains three compounds, vicine, convicine (glycosidic pyrimidine derivatives), and DOPA (Dihydroxyphenylalanine), which are believed to be responsible for the disease known as favism. Favism has been extensively researched in Italy, and to a lesser extent in Egypt and elsewhere. The disease is practically confined to subjects suffering from glucose-6-phosphate dehydrogenase deficiency, and is particularly prevalent in infants.

Vicine and convicine contents in the plant tend to complement each other, and combined vicine/convicine contents ranged from 0.6 to 1.2% in a large series of samples studied at the University of Manitoba, Winnipeg. The concentration of DOPA was much lower. Recently, wavelengths have been selected for determination of vicine and convicine by NIRS, which again enables the screening of large numbers of samples. Before embarking upon a breeding program aimed at minimizing vicine and convicine there are a number of questions which need to be addressed. These are:

1. Since the minimum combined amount of vicine and convicine seems to be about 0.6%, what can be regarded as a "safe" level to aim for? A concentration of 0.6% would provide 300 mg of vicine/convicine in a serving of about 50 g of cooked faba beans, which is a relatively large amount.

2. In view of the fairly high concentration in "low" vicine/convicine faba beans, what unshakeable evidence has been reported that irrefutably relates favism to vicine/convicine content?

3. What functions do vicine/convicine perform in the plant? Perhaps low vicine/convicine contents are associated with undesirable physiological and agronomic characteristics.

4. Are high vicine/convicine contents associated with any easily visible plant characteristic such as flower or seed color?

Finally, cooking procedures influence vicine/convicine levels. Green faba beans are about twice as high as mature beans in vicine/convicine, and the level in mature beans is significantly reduced by boiling or stewing.

Export Quality Requirements

The above comments refer to characteristics which affect consumer and nutritional quality of food legumes. The Middle East contributes nearly 40% to the world lentil production and is responsible for about 73% of world exports. Syria exports 40-50% of her annual lentil production, partly whole and partly as splits. Recently, Syria began to export her surplus of kabuli-type chickpeas. The selection of improved genotypes in breeding programs must take cognizance of the quality parameters needed for the export, which in turn depend on the uses to be made of the commodities in customer nations.

Chickpea

Kabuli-type chickpeas are exported as whole seeds after cleaning (removing foreign material and broken seeds) and grading. Seed size and size distribution are the most important criteria for selection of genetic material for potential export standards. After consultation with Mr. Jacob Jacob, Manager of the Aleppo chickpea and lentil factory, ICARDA's quality laboratories have developed export standards for selection of chickpeas and lentils. Seed size is a highly heritable characteristic, but it can be affected by up to 25% by growing location, season, and diseases such as ascochyta blight. Consequently, in order to ensure a consistent supply of material suitable for export the selection standards must be more rigorous than for domestic consumption.

Sieves with round holes from 3 to 10 mm in diameter have been fabricated at the ICARDA workshop, Tel Hadya. These are used in sets of four or five to grade the seeds. In the case of chickpeas only those with the largest seed size (weight per 100 seeds) are graded. Sieves used for chickpea grading have round holes of 9.0, 8.0, 7.0, and 6.0 mm diameter. A minimum of 75% of seeds over 8.0 mm is acceptable for potential export quality. This calls for a grain weight of about 34-35 g/100 seeds.

The danger in allowing a variety with smaller seeds to become widely established is obvious. Farmers all over the world are like businessmen; if they can obtain a substantial increase in yield by planting in the autumn they will do so to the exclusion of spring planting. Autumn-planted chickpeas outyield spring-planted chickpeas by up to 100%, but the seed size is about 8% smaller. If farmers can see a highly significant economic advantage of autumn-sown chickpeas over lentils they will rapidly flood the market with chickpeas which are not suitable for export. The domestic market will become saturated with chickpeas suitable for domestic cooking, and large surpluses of inferior quality chickpea are likely to ensue. At the same time the supply of lentils will be reduced, due to replacement by autumn-sown chickpeas, so that Syria will be unable to fulfill its commitments for lentils. Export markets are based on quality and consistent supply, and overproduction of inferior chickpeas at the expense of lentils could have serious consequences for future markets.

Another important criterion used in ICARDA's screening is the standard deviation of seed size. As high a standard deviation as possible is sought, since a low standard deviation means even distribution of seeds on the four or five sieves. In that event the sample will possess a large range of seed sizes, which is undesirable to the exporter. This is illustrated in Table 8, which gives two examples, a sample with a high standard deviation about a satisfactory mean, and a sample with a low standard deviation. With example B, although the export factory standard of over 50% above 8 mm is met, the sample is variable and contains nearly 40% smaller seeds. With different growing conditions this variety could easily fall below the export factory standard. Sample A contains over 80% above 8 mm, and would be more likely to meet export factory standards under any growth conditions.

Table 8. Examples of high and low standard deviation (SD) of seed size distribution.

Sieve size mm	% retained A High SD	% retained B Low SD
9.0	12.7	30.1
8.0	68.9	34.6
7.0	15.0	20.6
6.0	4.6	16.7
SD	29.4	8.3
Mean size[1]	8.0	7.9

1. Weighted mean.

Lentils

Lentils are of two main types, small seeded (up to 4.5 mm) and large seeded (up to about 7 mm in diameter), as referred to earlier. The same system is employed for grading lentils as for chickpeas, except that screen sizes are of 7, 6, 5, 4 mm for large, and 4.5, 4, 3.5, and 3 mm for small-seeded lentils. The criteria for selection are mean seed size and standard deviation, as for

Table 9. Loss on decortication of lentils according to size seed.

Seed size (mm)	% Loss
5	8.1
4.5	8.7
4	8.8
3.5	9.8

chickpeas. Loss on decortication is important to the lentil exporting factory. Lentils are moistened before decortication, and this principle is practised at ICARDA, where a laboratory decorticator has been developed. Decortication loss is related to seed size. The smaller the seed, the higher the loss, proportionally, due to the larger surface area of seed presented to the carborundum stones. At ICARDA, either 50 or 100 g of lentils are moistened, allowed to stand, then decorticated. This operation is carried out after seed sizing (sieving), and the decorticator stones are set at different distances apart, depending on the weighted mean seed size. The mixture of decorticated lentils and hulls is passed through a Carter dockage tester which quantitatively separates the hulls from clean seeds. Table 9 gives percentage decorticator loss according to seed size.

Discussion

Laila Hussein

What is the minimum amount of samples required for analysis by the near-infra red method? The wavelengths used for measuring methionine are quite wide.

P. Williams

We can use less than 1 g, but prefer at least 8 g because of grinding and sampling errors.

All of the wavelengths quoted are used at the same time. The NIR instrument (FQA51A) can use 12 wavelengths simultaneously. The most important feature is that the wavelengths used for methionine and protein are quite distinct from each other.

S. Sithanantham

Do you consider that you can reasonably judge the consumer acceptance, based on cooking time/cooking quality - considering that the common foods prepared from these legumes may differ? For instance, chickpeas are being cooked as homos, falafel, and tisqieh.

P. Williams

Yes, it is impossible to prepare taste panels with a wide range of foods, and many foods require highly flavored additives, such as garlic, which detract from the flavor of the food legumes. I believe that an evaluation procedure based on cooking time and a few very popular foods is adequate for a program such as ICARDA's.

J.I. Cubero

In table 2 your heritabilities seem strict.
What materials have you used to calculate those coefficients? I would suggest to mention them in the paper because the heritability can drastically change depending on the materials included in the study.

Abdullah M. Nassib

Few years back, Egypt imported faba beans from U.K. for local consumption. They were fast cooking compared with Egyptian beans, but there was only one complaint that the cooked seeds did not keep intact, i.e. most of the constituents moved out of the seed into the liquid medium while cooking. This is an undesirable character. Thus, I would suggest that this parameter may be added to other faba bean quality parameters mentioned in Dr. Williams' paper.

Proceedings of the International Workshop on Faba Beans, Kabuli Chickpeas, and Lentils in the 1980s (Saxena, M.C. and Varma, S., eds.), ICARDA, 16-20 May 1983, Aleppo, Syria.

Antinutritional Factors in Faba Beans

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Faba beans are an excellent source of protein, but they contain certain biologically active compounds which can cause physiological disorder when eaten in large quantities over a long period (Liener 1973, 1980; NAS 1973). The disorder manifests as a reduction in growth rate or food conversion efficiency.

The "antinutritional factors" found in faba beans include protease inhibitors, tannins, lectins, flatus-producing compounds, pyrimidine derivatives (vicine and convicine) that cause acute hemolytic anemia (favism) in certain susceptible individuals; and phytic acid, which causes reduction in mineral utilization.

Protease Inhibitors

There are two potential digestive enzyme inhibitors: (a) specific protease inhibitors of a protein nature present in the cotyledons and (b) non-specific protease inhibitors of a polyphenolic nature present in the seed coats (hulls).

Specific Protease Inhibitors

History. The existence of protease inhibitors in faba bean seeds was not realized until recently. Early investigations by Borchers and Ackerson (1947) and Hussein et al. (1974) revealed no trace of inhibitory activity. In 1958, Learmouth reported the presence of a proteolytic inhibitor in the germ of Vicia faba. Later work by Wilson et al. (1972), Warsey et al. (1974), Marquardt et al. (1975), Abbey et al. (1979), and Griffiths (1979) confirmed the presence of protease inhibitors in faba bean seeds but at much lower levels than those found in soybeans. In 1972, Wolf succeeded in locating the trypsin inhibitor in the cytoplasm in the 2 S fraction of water-extractable protein; the trypsin inhibitor is among the minor proteins which are found outside the protein bodies.

McFarland and Ryan (1974) and Ryan and Sanitarius (1976) discovered that protease inhibitors in the plant are part of the defense mechanism against invading microbes and insects, and which protect the cytoplasm from rupture of the protease-containing bodies. Synthesis of the protease inhibitor in the plant is induced by a protease inhibitor-inducing factor.

Physical properties. Warsey et al. (1974) isolated four protease inhibitors from faba bean seeds by using a combination of extraction with 2.5% trichloracetic acid, ammonium sulfate fractionation, column exchange chromatography on CM 52-cellulose and CM 50-sephadex. The authors described the properties of two purified isoinhibitor preparations, BBP_1-1 and BBP_1-2, with similar molecular weights of 11,000 and isoelectric points of 8.5 and 7.5, respectively. They inhibited a large range of protease from widely different sources including trypsin, chymotrypsin, pronase, thrombin, and papain; whereas pepsin, subtilisin, and carboxypeptidase A and B were not inhibited by faba bean protease inhibitors. Moreover, the purified faba bean protease inhibitors were capable of simultaneous and independent inhibition of both trypsin and chymotrypsin in the fashion of double-headed inhibitors (Birk et al. 1967). These double-headed inhibitors are common in leguminous seeds, and are evolved from an ancestral gene by internal gene duplication and subsequent mutation, causing differences in the reactive sites.

Mechanism of action. A common feature of all protease inhibitors is the presence of a disulfide linkage containing a lysine-X or arginine-X bond in a conformation such that it is readily exposed to tryptic attack. Trypsin inhibitors combine stoichiometrically with the active enzyme to form tightly bound enzyme/substrate-like complexes. The inhibitors differ from normal substrates in that the complex formed is stable because of a very close fit, and the accumulation of weak, non-covalent bonds at the contact zone. According to Green (1953), the affinity of trypsin for the inhibitor is much greater than that for the natural substrates. The complex formation between trypsin and soybean trypsin inhibitor has an association constant of 10^9 compared with figures of 10^2 and 10^5 for the association constants for natural (casein) and synthetic (benzoyl arginine p-nitroanilide) substrates, respectively. It is noteworthy that the reduction of the disulfide linkage of the inhibitor with 2-mercaptoethanol results in the immediate dissociation of the enzyme/inhibitor complex. Hochstrasser et al. (1968) reported that the rate of trypsin liberation on reduction of faba bean protease inhibitors is much faster than that observed with other protease inhibitors, suggesting a weak association constant between faba bean protease inhibitor and trypsin.

Protease inhibitor activity among different faba bean genotypes. Considerable differences in the protease inhibitor content of faba bean have been reported within and between cultivars and varieties of widely differing protein contents and diverse geographical origin. A 16-fold difference in trypsin inhibitor activity has been reported by Bhatty (1974). Sjodin (cited by Kakade et al. 1976) was able to select from 100 faba bean lines, two lines, one containing a high level and the other a low level of trypsin inhibitor. Marquardt et al. (1975) demonstrated minor variations in trypsin inhibitor activity among eight faba bean cultivars from six locations in Saskatchewan, Canada (Table 1). Griffiths (1979) found not more than two-fold variation in the protease inhibitor activity among a wide range of faba bean varieties and genotypes (Table 2). The highest value was still only 20% of the trypsin inhibitory activity of soy- or navybeans.

Nutritional significance of faba bean protease inhibitors. Information on the deleterious effects of protease inhibitors in the seeds of faba beans has been reported by several workers (Anantharaman and Carpenter 1969; Hochstrasser et al. 1968; Marquardt et al. 1975; Sohomie and Ambe 1955; Warsey et al. 1974; Wilson et al. 1972).

Pancreatic enlargement takes place in rats and chicks in response to dietary trypsin inhibitors. Pancreatic hypertrophy is the consequence of the release of the hormones pancreozymin (PZ) or cholecystokinin-pancreozymin (CCK-PZ) from the intestinal wall in response to dietary trypsin inhibitors (Snook 1969). The release of the humoral agents stimulates trypsin secretion in the rat pancreas. Trypsin inhibitor failed to produce pancreatic enlargement in calves, dogs, and growing pigs (Kakade et al. 1976; Patten et al.

Table 1. Trypsin inhibitor activity of seed and seed components in eight faba bean cultivars.

	Trypsin inhibitor units/g*			1000 HU*/g
	Whole seed	Cotyledon	Hull	whole seed
Ackerperle	3.2	2.9	6.7	4.4
Bell	3.2	2.7	5.9	3.9
Blue rock	3.2	2.7	6.4	3.6
Diane	4.3	4.0	5.9	4.4
Erfordia	2.7	2.4	4.0	5.6
Poecnvyje	2.7	2.4	4.0	3.8
Herra	3.2	2.9	5.3	3.4
Kleinkornige	3.2	2.9	5.9	3.4
Average	3.2	2.9	5.6	

* The amount of inhibitor that would inhibit one trypsin unit by using the synthetic substrate BAPA, according to the method of Sambeth, W., Nesheim, M., Sefrari, J. 1967. J. Nutr. 92, 479.

Table 2. Tannin content and protease inhibition of different faba bean varieties and genotypes.

Genotype	Protease inhibition (%)	Tannin %	Genotype	Protease inhibition (%)	Tannin %
Spring			White flower types		
Blue Rock	31.7	7.9	Compacta Dwarf	53.5	
Dacre	34.1	7.1	White flower	39.0	0.37
Danas	25.2	7.42	Lux	48.6	0.35
Dylan	30.2		R. 12	36.2	0.53
Minor	32.8	7.0			
			Colored flower types		
Winter			Tick bean	25.4	
Daffa	32.7	5.5	CS 20d CX Ethiopia	30.0	
Throws M.S.	33.8	5.9	Arallo CX Ethiopia	42.0	
Maris Beaver	31.7	5.3	CS 38b CX Ethiopia	48.3	4.13
			Selection CX Mexico	57.0	4.83

1971). A direct relationship has been established between the size of the pancreas and the kind of response to the trypsin inhibitor; animal species with pancreas in excess of 0.3% of body weight become hypertrophic, whereas those with pancreas below this value do not respond to the trypsin inhibitor. Abbey et al. (1979) found that the levels of trypsin inhibitor required to produce significant decreases in growth parameters and increases in pancreas size were considerably higher than those normally found in faba beans.

It has been suggested that retarded growth rates may be due to the increased secretory activity of the pancreas. This would result in an increased production of pancreatic enzymes, which are rich in sulfur amino acids, and hence in an increased demand for methionine and cystine, thus increasing the minimum sulfur amino acid requirement.

Barnes and Kwong (1965) studied the effect of trypsin inhibitor on the metabolism of several amino acids by using radioactive isotopes. They concluded that the inhibitor interferes with the catabolism of threonine and valine , and with the incorporation of cystine into proteins by blocking the enzyme cystathionine synthetase.

Rackis and McGee (1979) ran long-term feeding studies on rats fed commercially toasted, defatted soy flour diets from weaning to adulthood. Trypsin inhibitor content of the soy diets was 178 mg/100 g, corresponding to 338.2×10^3 trypsin inhibitor unit/100 g. The dietary protein level was 20% with soy providing 75% of the total protein. Rats fed soy diets initially grew at an equal rate to those fed a comparable casein/corn control diet. With continued feeding for about 300 days, body weights of the soy flour fed rats ceased to increase, unless the diet was supplemented with vitamin B 12. The workers stressed that more research was needed to determine whether the nutrient requirements of rats changed substantially during continuous consumption of trypsin inhibitors.

Nonspecific Protease Inhibitors (Tannins)

The presence of tannins in the seed coats of faba beans has been demonstrated by several workers (Guillaume and Belec 1977; Martin-Tanguy et al. 1977; Marquardt et al. 1974). It has been postulated that the evolutionary advantage of a high tannin content is related to their ability to inhibit the pathogenic fungi and the degradation of plant debris (Abbey et al. 1979a)

Physical properties. Martin-Tanguy et al. (1977) and Marquardt et al. (1974) succeeded in isolating tannin preparations from testae of faba beans following successive solvent extractions, and sephadex LH.20 chromatography, respectively. The testae tannins (proanthrocyanidins) are polyphenolic compounds with molecular weights of 500-3000. They are soluble in 90% acetone (Cansheld et al. 1980). Martin-Tanguy et al. (1977) prepared four tannin fractions varying in their catecbin (A), gallocatecbin (B), Leucocyanidin (C), and Leucodelphinidin (D) contents. Fractions (C) and (D), which are both Flaven-3,4-diols, were amongst the most potent antinutritional tannins.

A positive correlation was found between tannin concentration in the seed coat of faba beans and corresponding trypsin inhibitory activity (Elias et al. 1979). Faba bean hulls are higher in their trypsin inhibitory activity than cotyledons (5.6 and 2.9 units/g, respectively). Tannins and their hydrolyzable derivatives (glucosides) inhibit proteolytic enzymes and other digestive enzymes including amylases, lipases, and cellulases (Griffiths 1979). Tannins act by direct inhibition of the proteolytic enzymes (non-competitive) or by forming indigestible complexes with food proteins. Addition of a binder-like polyvinylpyrrolidone (PVP) to the media restores the enzymic activity, since PVP chelates tannin (Griffiths 1977).

Condensed tannin concentration in different cultivars. Marquardt and Ward (1979) tested seven Canadian, and seven European and American cultivars for their condensed tannin concentrations (Table 2) and found considerable intracultivar variation. Martin-Tanguy et al. (1977) reported on four individual tannin fractions present in eight faba bean cultivars (Table 3). Tannin-free cultivars are characterized by white seed coat, white hilum, and white flowers.

Nutritional significance of tannins. Tannin in the diets of rats, chicks, and ducklings depresses organic matter and nitrogen

Table 3. Total tannin content, individual fractions (A-D) and the nutritional value of different faba bean cultivars. (Martin-Tanguy et al. 1977).

		Tannin content							
Cultivars	Origin	A	B	C (mg/g)	D	Total	N-diges-tibility (%)	B.V. (%)	NPU (%)
S 45	England	4.6	38	12	0	54.6	71	34	47.4
G 77	France	3.9	26	7	0	36.0	79.5	61	76.2
Bianka	Holland	0.0	0	0	0	0	80.5	62.5	77.3
972 D	France	10.0	40	9	0.9	60			
48 B	France	8.1	29	12	2.1	51.2			
Ad 23	England	4.0	20	10	0	34			
G 107	Germany	0.9	18	9.5	0	28.4			
Po Ad 74	Poland	6.1	15	7.7	1.1	30			

$$* \text{ B.V.} = \frac{\text{N retained}}{\text{N ingested}} \times 100$$

$$** \text{ NPU} = \frac{\text{N retained}}{\text{N absorbed}} \times 100$$

digestibilities and reduces growth rate, and percentage laying rates of chicks and ducklings (Guillaume and Belec 1977; Martin-Tanguy 1977; Marquardt et al. 1974). Human studies are required to determine the in vivo effects of faba bean tannins on both pancreatic enzyme activity and availability of other essential nutrients.

Phytohemagglutinins (Lectins)

Several investigators confirmed the presence of glycoproteins in the cytoplasm and embryo of faba bean seeds with the ability to agglutinate (clump) red blood cells (Liener 1980; Marquardt et al. 1975; Hussein et al. 1974; Jaffe et al. 1974).

Physical properties. Faba bean lectins consist of two identical subunits, containing two metal-binding sites and a site for a sugar residue and have a molecular weight of approximately 100,000 (Jaffe et al. 1974). The physiological role of lectins is to act as "carbohydrate catchers" for the transport and immobilization of specific sugars.

Mode of action. Faba bean lectins interact with some specific sugars, such as D-mannose and D-glucoseamine residues, which are located on the surface of erythrocytes. Since considerable variation in blood type specificity has been found within faba bean lectins, the latter can be used as a potential blood typing reagent. Hemagglutinating activity of different faba bean cultivars has been examined (Griffiths 1977; Marquardt et al. 1975; Hussein et al. 1974). Hussein et al. (1974) found a level of only 640 hemagglutinating units/g of raw faba beans in an Egyptian cultivar as compared with a mean level of 4000 units/g for Canadian varieties reported by Marquardt el al. (1975). Climatic differences may explain such variations.

Nutritional significance of lectins. Lectins combine with cells lining the intestinal wall causing nonspecific interference with the absorption of nutrients. Support for this hypothesis comes from Etzler and Branstrator (1974) who found that a number of different lectins react with crypts and villi of the intestine at different locations, dependent on the specificity of the lectins. Jaffe (1960) reported that the presence of 0.5% lectin in a rat diet was enough to impair the intestinal absorption, resulting in death. However, no animal deaths have been reported following oral consumption of raw faba beans or on injecting their crude extracts (Palmer and Thompson 1975).

Flatus-Producing Factors

The oligosaccharides, raffinose and stachyose, present in faba beans have been implicated as flatus-producing factors. They are similar in having one or two alpha-D-galactopyranosyl groups attached to sucrose via alpha-1,6-galactosidic linkages.

Owing to the absence of enzymes in the human intestinal mucosa that are capable of hydrolyzing this linkage, the intact oligosaccharides accumulate in the lower intestine where they are fermented by anaerobic bacteria to produce gases and hence, flatulence.

There is as yet no available data for intervarietal differences of oligosaccharide content in faba beans, but some soybean cultivars are reported to have a very low content of raffinose and stachyose (Hymowitz and Collins 1974).

Nutritional significance of flatulence. The characteristic features of flatulence are: cramps, diarrhoea, abdominal rumbling, and the associated social discomforts. Calloway et al. (1971) and van Stratum and Rudrum (1979) showed that rats and humans produce large quantities of intestinal gas composed largely of hydrogen, carbon dioxide, and methane after eating various kinds of beans. Flatulence is also associated with the loss of considerable amounts of nutrients.

Phytates

Faba beans have been reported to be a rich source of phosphorus. However, 40-50% of the total phosphorus content is present in the form of phytates (Griffiths and Thomas 1981). The physiological importance of phytates in the germination of seeds has not been fully elucidated.

Physical properties. Phytates are calcium salts of myoinositol hexadihydrogen phosphate which can form insoluble chelates with various nutrient elements such as zinc, iron, and calcium. Griffiths and Thomas (1981) found a range in phytic acid content of 0.96% to 1.2% in a number of faba bean genotypes (Table 4). Spring types had higher phytic acid contents.

Table 4. Comparison of the phytic acid, total phosphorus and phytate phosphorus contents of different faba bean genotypes (After Griffiths and Thomas 1981).

Variety	Phytic acid (%)	Total P (%)	Phytate P as % total P
Minor	0.99	0.71	39.5
Blue Rock	1.07	0.71	42.8
Dacre	1.03	0.63	46.2
Danas	1.06	0.65	46.0
Dylon	1.20	0.72	47.2
Daffa	1.18	0.76	43.4
Maris Beaver	1.13	0.71	45.0
Throws MS	0.96	0.59	46.1

Nutritional significance of phytates. Phytates reduce the amount of phosphorus and associated metal ions available for absorption in the intestinal tract. Supplementation with mineral salt is not considered practicable for human nutrition on the grounds of both processing techniques and palatability.

Favism-Inducing Factors

The precipitation of a hemolytic disease, favism, in susceptible individuals following consumption of fresh or cooked faba beans has been known since antiquity. The hemolytic effect of faba bean is attributed to the presence of two glycosidic pyrimidine derivatives, vicine and convicine and their hydrolytic products, divicine and isouramil, respectively, which render the red blood cells of glucose -6- phosphate dehydrogenase deficient patients vulnerable to oxidation and destruction (Beutler 1978). Thirteen faba bean cultivars and genotypes grown at the agricultural experimental station Giza, Egypt, have been examined for vicine, convicine, and DOPA (Dihydroxyphenylalanine) concentrations. Green pods were found to have much higher pyrimidine concentrations than the dry seed (Table 5). All varieties tested contain vicine and convicine in the green pods.

Table 5. Level of vicine and convicine and DOPA (g/100 g dry matter) in green pods and dry seeds of 12 different faba bean genotypes grown at the Giza agricultural station, Egypt.

Genotypes	Green pods			Dry seeds		
	Vicine	Convicine	DOPA	Vicine	Convicine	DOPA
Giza 1				0.80	0.21	0.04
Giza 2	1.12	0.33	0.08	0.50	0.13	1.14
Giza 3	1.46	0.40	0.00	0.67	0.22	0.04
Family 402	1.06	0.13	0.00	0.58	0.56	0.06
Aquadulce	0.88	0.31	0.00	0.63	0.22	0.05
Double White		0.00	0.00	0.52	0.15	0.01
Roumy		0.00	0.00	0.48	0.26	0.05
Rebaya 40	2.17	0.76	0.00	0.80	0.23	0.04
Protein 138/78	1.4	0.29	0.00		0.00	0.00
Reina Blanka	1.29	0.69	0.11		0.00	0.00
New Mommoth	1.21	0.64	0.00		0.00	0.00
Seville Giant	1.29	0.42	0.08		0.00	0.00

Conclusions

In view of the comparatively low levels of protease inhibitor and lectins present, it would appear that selecting and breeding for lower protease inhibitor and/or lectin levels would not lead to great improvements in nutritional value.

Condensed tannins, being confined to the seed coat of faba bean, could be easily eliminated providing an economic dehulling process is available. Autoclaving and micronization are effective in destroying the three above-mentioned factors (Hussein 1982; Marquardt and Ward 1979; Ward et al. 1977).

The oligosaccharide levels in faba bean can be reduced by (i) selective breeding (Hymowitz and Collins 1974), (ii) food processing by limiting proteolysis with microbial proteolytic enzymes (Calloway et al. 1971), and (iii) alcohol: water extraction (van Stratum and Rudrum 1979).

Germination is known to reduce the levels of most of the antinutritional factors present in faba beans, in particular the lectins and pyrimidine derivatives (Hussein 1982; Learmouth 1958). More basic studies are needed to elucidate all causative agents of favism. Preliminary work suggests that other factors may be involved in the etiology of the disease. The close cooperation of the plant breeder, the food technologist and the nutritionist is needed for developing faba bean cultivars with improved nutritional characteristics.

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Discussion

Asfaw Telaye

If CX means (1) CS 20 dCX Ethiopia, and (2) CS 38BCX Ethiopia are crosses, then these have to be understood that CS20d and CS 38B are landrace materials from Ethiopia crossed with other Ethiopian landraces which should carry a designated code rather than the word "Ethiopia", or could be put as Ethiopia CX Ethiopia.

J.I. Cubero

The white-flowered varieties have low tannin content. But there are lines with colored flowers and white seed coats. Have you any information about the tannin content of these varieties?

L. Hussein

The criteria for low tannin content in the seed coat of faba beans is white flowers and white hilum. One should not be deceived by the seed color alone.

G. Rowland

At the University of Saskatchewan we found that *Vicia narbonensis* has very little vicine and convicine and thus could be used as a source of low vicine/convicine in the interspecific hybrid with *Vicia faba*.

M.C. Saxena

This is interesting. But there is a problem of unsurmountable magnitude in making these interspecific crosses as Dr. Pickersgil has already indicated in her earlier paper.

Proceedings of the International Workshop on Faba Beans, Kabuli Chickpeas, and Lentils in the 1980s (Saxena, M.C. and Varma, S., eds.), ICARDA, 16-20 May 1983, Aleppo, Syria.

Seventh Session

Seed Production Technology for Chickpea (*Cicer arietinum*) and Lentil (*Lens culinaris*)*

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Advances in plant breeding have led to the development of high yielding superior cultivars of different crops. When a plant breeder develops a new and superior variety, it is important that its seed be multiplied and made available to the farming community. The use of new improved varieties is a simple and most economical way for obtaining higher yields, as seeds are the cheapest input in modern agriculture. Seeds of improved varieties should be:

- true to type,
- high in germination and vigor,
- physically pure,
- free from seedborne diseases, and
- chemically treated.

Production and delivery of seeds of improved varieties meeting these criteria is a highly technical and exacting task separate from plant breeding (Fig. 1).

Method of Seed Production

To produce seeds of high quality, the generation system should be adopted, which consists of using the 'breeders' seed' for production of the 'foundation' or 'basic seed,' which in turn is used to produce the 'certified seed'.

Chickpea and lentil are largely self-pollinated, with little out-crossing. For example, 0 to 2.11% out-crossing, with an average of 0.96%, has been observed in chickpea at ICRISAT, Hyderabad, India (Gowda 1981). Certified seed of these crops may be used for at least three generations to produce high quality seeds, provided sufficient care is taken during seed production.

*Presented by Dr. S.K. Sinha since Dr. Agrawal could not come.

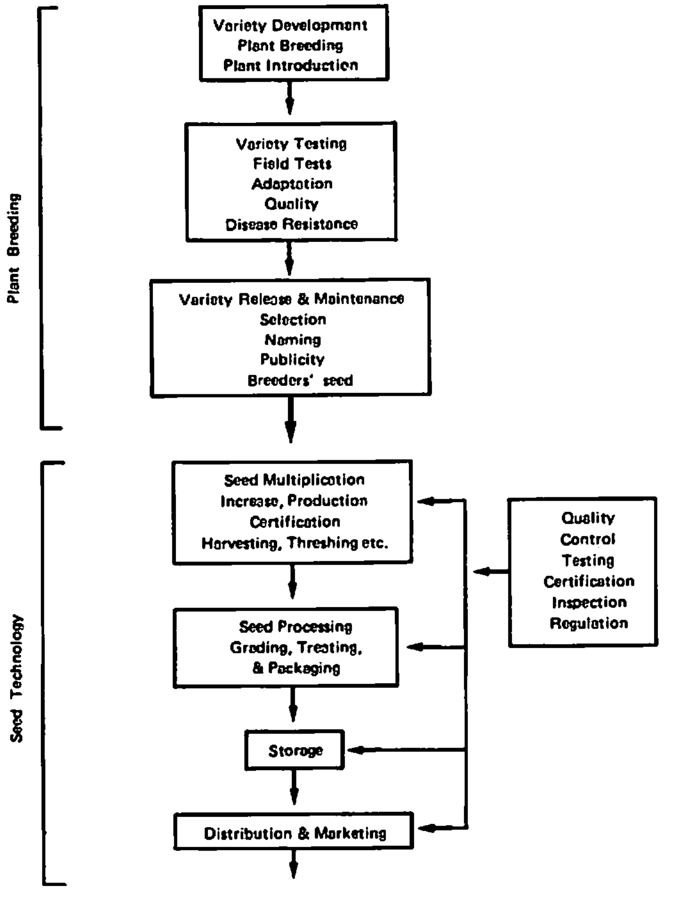

Fig. 1. Relationship between plant breeding and seed technology.

Most of the agronomic practices for seed production are as for crop production, with the addition of the following requirements:

1. Selection of areas suitable for seed production (i.e. low disease incidence).
2. Use of seed from an approved source (e.g. generation system of seed production).
3. Maintenance of adequate isolation to prevent out-crossing.
4. Roguing of plants of other varieties, weeds, diseased plants, etc.
5. Precaution during harvesting and threshing to avoid mixing seed of different varieties.

Seed Certification

To verify that the above-mentioned requisites in seed production have been met, a system of seed certification is needed. The purpose of seed certification is to ensure that high quality seeds of assured genetic identity and purity are produced. Seed certification involves the following five activities:

1. Verification of seed source and isolation and field requirements.
2. Field inspection to verify conformity to the prescribed field standard.
3. Supervision of harvest and post-harvest handling of produce.
4. Evaluation of seed quality for verification of prescribed seed standards.
5. Bagging, tagging, sealing, and storage.

During various phases of crop growth, the seed crop is inspected by competant staff and if it is found to meet a pre-set field standard the crop is field certified. Then it is harvested and threshed and seed evaluated for quality control before the final certification.

Suggested Field Standard for Chickpea and Lentil

1. Field requirement: The crop shall not be eligible for certification if grown on land on which the same crop was grown in the previous season, unless the crop in the previous season was grown from certified seed of the same variety.

2. Isolation distance: An isolation distance of at least five meters should be provided all around a seed crop to separate it from fields of other varieties or fields of the same variety not conforming to the varietal purity requirements. In addition the seed crop should be adequately isolated from disease-susceptible varieties.

3. Field inspection: At least two inspections from flowering to harvest have to be carried out to check for off-types, diseased plants, and weeds.

4. Off types: Maximum permitted percentage of off-types at the final inspection is 0.1% for the 'foundation' seed and 0.2% for 'certified' seed.

Seed Processing

Seed lots which meet the field standard are normally sent for seed processing. As soon as seed is received at the processing plant it is stored to await processing, or dried, or conditioned (Fig. 2). Drying and conditioning depend upon seed moisture content: seed is

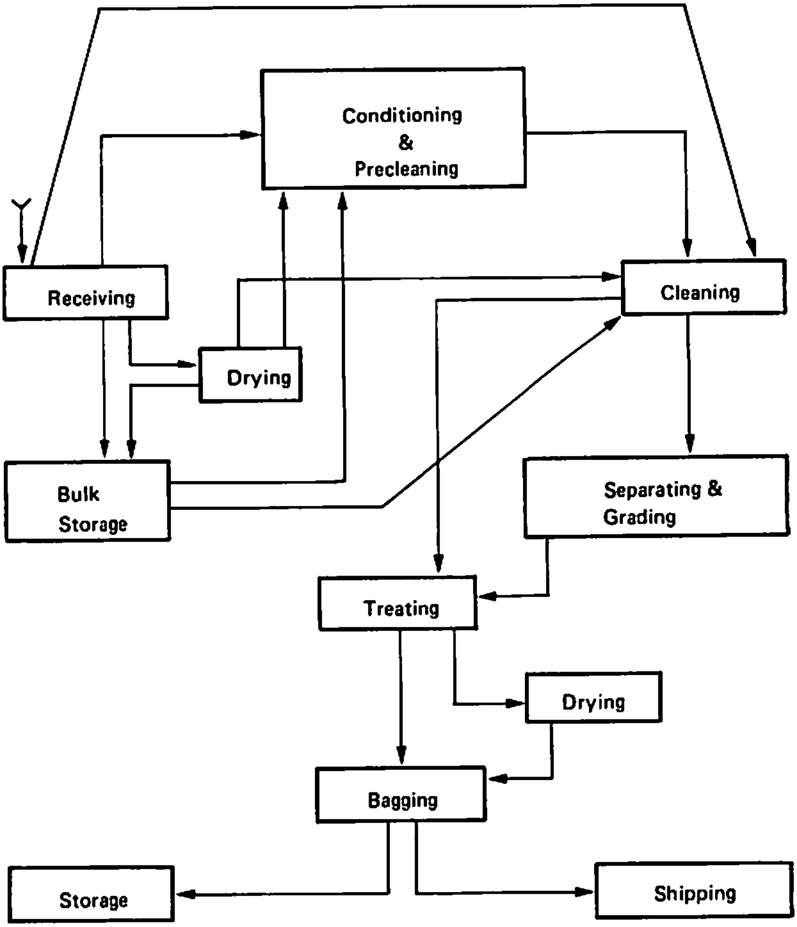

Fig. 2. The basic steps in seed movement through a processing plant (Gregg *et al.* 1970).

dried to about 15% moisture content, or conditioned to increase moisture content if it is too dry when received.

Seed Drying

Seed can be dried by natural (sunshine and natural ventilation) or artificial means.

High temperatures in the seed must be avoided; thus seed must be protected from prolonged direct sunlight, and the seed layers turned regularly. If large quantities of seed are to be dried, natural drying is inadequate, so artificial methods need to be used. This consists of using a system of forced flow of heated air of low relative humidity through the seed.

The maximum recommended air temperature for drying chickpea and lentil seed is 40°C. However, in order to reduce the risk of damage, drying temperature should be lower than the maximum. If seed moisture is more than 19%, the maximum recommended drying temperature is 32°C while with seed of less than 18% moisture content a drying temperature of 40°C may be used.

As the moisture is removed first from the outer layer of the seed, a moisture gradient from the center to the periphery develops. If this gradient is too great, internal stresses will cause cracking, with a resulting loss in storability and germination. The higher the initial moisture content or the larger the size of the seed, the greater will be the stress. Large seeds, like chickpea, which have a high moisture content may be dried in two stages, allowing 24 hr to elapse between stages.

Cleaning and Grading

After drying or conditioning, seeds are cleaned to remove inert materials, weed seed, other crop seeds, and other contaminants. If contaminants are not completely removed during cleaning operations, they will be removed during separating and grading operations. Seeds can be separated and graded using sieves of different sizes. Before doing further processing of seed, which includes treatment with fungicides and insecticide, the seed is tested for quality control.

Seed Testing for Quality Control

After processing, seed lots are tested for germination, moisture content, purity, freedom from seedborne diseases, insect infestation, and damage.

The sample size needed for testing is approximately 1 kg for chickpea, and 0.6 kg for lentil. Samples should be clearly identified and marked with the seed lot. Care must be taken to ensure that samples are representative of their seed lot.

For moisture determination, 100 g of chickpea and 50 g of lentil seed are needed. Chickpea seeds should be ground and dried at 130°C for 1 hr. Lentil seed should be dried whole (without grinding) at 103°C for 17 hr (Anonymous 1976). Seed moisture content may be calculated on fresh weight basis from the difference in weight before and after drying.

For purity analysis, 60 g of lentil and 100 g of chickpea seeds are required. The sample is separated into pure seeds, other crop seeds, weed seeds, and inert matter; and the percentages of the components are determined.

Germination Test

Germination tests require 200-300 seeds in two or three replications of 100 seeds each (Table 1). The seeds during the germination test are categorized in four groups: (1) seeds giving normal seedlings; (2) seeds giving abnormal seedlings; (3) hard seeds; and (4) dead seeds (Anonymous 1976). The germination percentage is reported on the basis of normal seedlings only. Normal seedlings are those which show the capacity for development into normal plants.

Table 1. Method of testing seed germination (Anonymous 1976).

Species	Substrata	Temperature (°C)	First count (days)	Final count (days)
Cicer arietinum	Paper/Sand	20 - 30*	5**	8
Lens culinaris	Paper	20	7	14

* Alternate temperature of 20/30°C, i.e. 20°C for 16 hr and 30°C for 8 hr.

** First count is taken only in paper substratum and not in sand.

Seed dormancy in legumes is generally due to impermeability of the seed coat to water, which is referred to as hard-seededness. The development of impermeability of the seed coat in the Leguminosae is associated with the dehydration of seeds during the later stages of seed maturation. Low relative humidity of the air during ripening results in a considerable increase in hard seeds. In lentil the percentage of hard seeds falls from a maximum immediately after harvest to practically zero after five to six months (Fig. 3).

In evaluating germination tests hard seeds are mostly regarded as viable. If germination testing of hard seeds is required, the seeds should be scarified or the seedcoat punctured or removed. Care should be taken not to damage the root-shoot axis during these treatments.

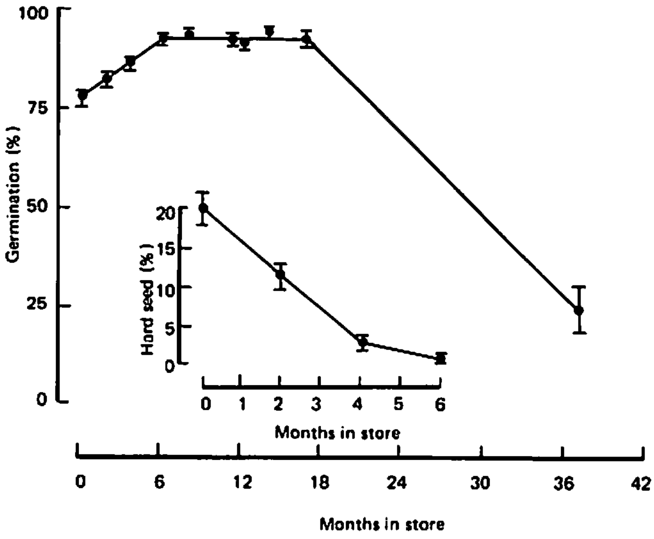

Fig. 3. Changes in germination and hard seeds of lentil during storage.

If the seed lot meets the pre-determined standards it is bagged and certified. An example of seed standards for foundation and certified seed is given in Table 2.

Normally the seed standard is checked after the seed is processed, during which 5-15% of the seed is lost as undersize, broken, or damaged.

Table 2. Suggested seed standards (%) for foundation and certified seed.

	Chickpea		Lentil	
	Foundation (%)	Certified (%)	Foundation (%)	Certified (%)
Pure seed (min)	98.0	97.95	97.9	97.8
Inert matter (max)	2.0	2.0	2.0	2.0
Other crop seeds (max)	None	0.05	0.1	0.2
Weed seeds (max)	None	None	None	None
Germination (including hard seeds)	85.0	85.0	85.0	85.0

Packaging and Storage

The loss in seed viability during storage is due to a number of factors, including insect damage and ageing. In chickpea and lentil the mean viability period is increased with decreased seed moisture content. Before storage, seed should be dried to less than 9% moisture content, which will prevent fungal disease development and insect infestation.

In lentils stored under insect-free ambient conditions in Delhi, India, the germination percentage did not start to fall until after 17 months in storage. After 37 months, germination was 25% (Agrawal 1982; Fig. 3).

Insect infestation drastically reduces storage life: bruchid infestation can cause total loss of viability in 2 to 4 months. Thus, it is essential to avoid insect infestation of stored seed. After threshing and processing, seed should be fumigated with a safe fumigant, such as aluminium phosphide, to kill off any insects or their larvae present in the seed. During fumigation seed moisture must not be more than 12%. To prevent build-up of infestation during storage, maintenance of store sanitation is necessary. If old bags are used for storing seed, they should also be fumigated.

If seed is free from initial bruchid infestation, storage in thick, close-weave bags eliminates the need for insecticide application, since bruchids do not easily penetrate such fabrics.

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Discussion

C. Bernier

Is there any provision in the scheme of seed production you have presented to test seed for presence of seed-borne fungi?

S.K. Sinha

Yes, this is at least at two stages. Field visits before harvest are necessary to certify disease and pest free conditions. After harvest, again the samples are drawn for seed pathological examination, particularly for fungal and other diseases, before certification.

M.C. Saxena

1. The field inspection for disease is carried out and tolerance limits for various diseases are established. After the seed is received in the seed testing laboratory it is inspected for presence of diseased seeds and later seed health testing done before final certification is done. Dr. Nene might like to give more specific details of the tolerance limits.
2. It would be worthwhile that the aspect of outcrossing and maintenance of purity by maintaining the appropriate isolation is given some more consideration by the participants.

Y.L. Nene

I would like to add to the information given by Dr. M.C. Saxena. Two years ago chickpea in north India was severely affected by *Ascochyta* and after a lot of discussions all the seed from areas where the crop was infected was discarded for seed purpose. Everyone should be interested in seed health and in taking all the precautions in preventing introduction of new pathogens into countries, but the concept should not be carried so far that it interferes with reasonable international exchange of seed. For example some countries insist that the germplasm coming from other countries should not be treated with any chemical including fungicides, so that pathogens coming with seed can be identified. I think there is more danger in bringing in seed which is untreated; pathogens might get introduced more easily in such a case.

F. Muehlbauer

Outcrossing in chickpea and lentil is known to be infrequent and estimated at less than 1%, and is therefore not considered to be an important factor in seed production of these two grain legumes. Mechanical mixture, contaminated equipment, etc. are much more likely to be the sources of lack of purity.

Field inspection of certain seed production fields is not always appropriate for certain diseases that can be seedborne; seedborne viruses in particular are difficult if not impossible to detect. Suitable laboratory methods (ELISA) are useful.

K.B. Singh

In view of the seedborne nature of *Fusarium* wilt in chickpeas, it is suggested to treat the seed with Benlate T as a routine, if the seed is produced in an endemic area.

Proceedings of the International Workshop on Faba Beans, Kabuli Chickpeas, and Lentils in the 1980s (Saxena, M.C. and Varma, S., eds.), ICARDA, 16-20 May 1983, Aleppo, Syria.

Mechanization of Production of Faba Beans, Chickpeas and Lentils

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The present level of mechanization in legume production in Syria and ICARDA's mandate region is far lower than that in cereals production. As planting, weeding, and harvesting of legumes are often unmechanized, production costs per hectare of legumes are considerably higher than for cereals. This is reflected in reduced areas of legumes in the region in recent years.

Planting

Lentils

Lentils are usually broadcast by hand over furrows opened by a duck-foot cultivator. The disadvantages of this method are uneven planting depth, a higher seed rate requirement, and uneven field surface after sowing which prevents mechanized harvesting. Also, no intercultivation is possible.

A cereals seed drill with a levelling bar (tabban) can be used for planting lentils without increasing costs. Due to better depth control of seed placement, the seed rate can be reduced to half. Planting the crops in rows allows mechanized interrow cultivation. Since the soil surface is level, mechanical harvesting is also easier.

Chickpeas

The most common method of planting is broadcasting the seed by hand after opening the furrows by a duck-foot cultivator. Other methods are:

- hand placement of seed in furrows, which saves seed but is time consuming.

- hand planting in holes opened by a hand hoe. This might give good depth control, but requires increased labor inputs.

- use of a standard seed drill. This has the same advantages as for lentils.

- use of a precision planter. This has the advantage of establishing a more even plant stand, and thus seed rates can be reduced by 40 - 50%, as compared to the standard seed drill. However, only a small-scale plot-planter has been used so far at ICARDA.

Faba Beans

Hand placement in furrows opened by a duck-foot cultivator is the most common method. Hand planting in holes opened with a hand hoe is also practiced.

There are problems with mechanized planting of the large-seeded faba bean lines (Vicia faba major). A standard seed drill can be used for small-seeded faba beans, but damages the seed and its own metering system, with larger seed. Precision planters have been used for more than 15 years in other parts of the world for up to medium-sized faba bean seeds. It is hoped to have a mechanism available to carry out planting at ICARDA with this system in future.

Weed Control

In addition to machine planting in rows, which allows interrow cultivation, good seedbed preparation facilitates mechanization. A well prepared seedbed ensures best possible growing conditions for the crop and destroys weeds at the time of planting. If the field is smooth after planting, it further eases mechanized weeding and harvesting.

Herbicide application (pre- or early postemergence) is usually the earliest mechanized weed control activity. As soon as the rows of the crop can be clearly seen, interrow cultivation is possible. Protection discs can be fitted to such a cultivator to prevent the soil from being thrown onto the seedlings. However, interrow cultivation will leave all weeds in a 6-8 cm wide strip in the crop row untouched. Also, under Tel Hadya conditions duck-foot implements cannot be operated deep enough to control deep rooted, mostly monocotyledonous weeds, such as volunteer cereals or Phalaris sp., but are successful in controlling most broadleaved weeds, especially when the fields are cultivated early enough. Two or three cultivations are required per season.

A supplementary weed control method for later developing weeds in the crop row has to be combined with early spraying of selective herbicides and interrow cultivation for lentils, which are not very competitive, and chickpeas. Therefore, the application of a non-selective systemic herbicide with a 'weed wiper' has been tested (Fig. 1). This instrument releases the herbicide, i.e. glyphosate, through well wetted wicks set at a given height above the ground, and is therefore limited to weeds which are taller than the crop. Care must be taken not to set the wicks so low as to touch the crop. An advantage of this method is the relatively low consumption rate of the herbicide; for example, 0.5 liter of Lancer/ha. Two or three passes with the 'weed wiper' at different growth stages are required for effective weed control.

Earlier reports (Basler 1980) that lentils are extremely sensitive to mechanical disturbance have not been verified at ICARDA.

Fig. 1. Tool carrier tractor: front, mounted interrow cultivator; rear, 'weed wiper.'

Harvest

Lentils

The need to mechanize lentil harvesting has received a lot of attention during recent years. Available harvesting methods, and their labor requirements, costs, and crop losses are summarized in Table 1. In certain circumstances the straw of the crop is as valuable as the seed.

The main disadvantages of the traditional hand pulling method are the high labor cost and the difficulty of getting the harvest in during the relatively short optimum period of 4-7 days for any given crop. Also, yield losses during collection, drying, and transport might be as high as 20%, if these operations are not carefully executed.

Table 1. Lentil harvesting methods.

Method	Labor requirement	Costs/ha	Loss in % of total yield	Remarks
Hand pulling Sledge threshing Stationary thresher	20 man days 12-14 man days 2-3 hr/ha	500-1000 SL/ha Family business 60-100 SL/ha	5-20% seeds 5% straw 0-2% seeds	Increasingly uneconomical, collection of dried crop is special work
Cutter bar (+ sledge or stationary thresher)	1.5-2 hr/ha + threshing	70-100 SL/ha + collection + threshing	15-25% seeds at cutting 20-40% straw at cutting	Difficult for short or lodging plants, stones, unlevelled soils
Pulling of whole plants by machine	1.1-1.3 hr/ha + threshing	est. 200-300 SL/ha + threshing	Expected to be <2% in seeds and straw	Requires special machine, appr. 50-70000 SL
Cutting of plants with cutter blades	1-1.5 hr/ha + threshing	est. 40-60 SL/ha + threshing	5-10% seeds 2-5% straw	Requires special machine at appr. 8000 - 12000 SL

The simplest mechanical harvester is the standard cutter bar, but results in losses of up to 25 and 40% of seed and straw, respectively. Losses may be much higher when the crop is short or lodged, or where the field is stony or ridged.

Direct combining has been tried and proved not acceptable, as losses and breakage of seeds were too high. Also, no straw collection system is available, and highly valuable leaf material is lost, due to shattering.

Two harvesting methods for lentils are currently being developed:

1. Cutting of plants with cutter blades 2-5 cm under the soil surface (see Appendix 1): With this system there are no measurable losses of straw during harvest, and seed losses do not exceed those occurring with hand pulling. The system has the advantage of low investment costs. The estimated harvesting costs are 40-60 SL/ha, not including transport and threshing. The disadvantage of this system is that it is limited to cutting and piling the crop, and does not allow further mechanization.

2. Pulling of whole plants (see Appendix 2): Plants are harvested before they are completely dry, in order to prevent shattering of the pods. No measurable losses occur during harvest. To the puller could be attached either a windrowing device or a trailer to collect and transport the material immediately to the threshing site. Such a complete system will hopefully be tested at ICARDA during the 1984 harvesting season. The disadvantage of the system is the relatively high investment in a specialized machine, bringing the harvesting costs to an estimated 200-300 SL/ha, not including threshing.

Chickpeas

Chickpea straw is not as valuable as lentil straw, and harvesting losses are not important.

The most common harvesting technique is hand pulling of the crop, followed by threshing by a sledge (jarjar), although direct combining is possible. For direct combining the land has to be as level as possible. Direct combining is 200-300 SL/ha cheaper than the traditional method (hand harvesting, transporting, threshing, and winnowing).

Faba Beans

The most common harvesting system is to pull and thresh the crop by hand. A threshing sledge is only used for larger quantities.

The use of a cutter bar and stationary thresher is a feasible alternative, except in small irrigated fields. Standard rasp-bar threshing drums cause 10-20% seed breakage. However, a flail-finger threshing drum has been designed at ICARDA (Fig. 2) and successfully used in stationary threshers (Diekmann and Papazian 1983). With proper adjustment the amount of breakage is less than 2%.

Direct combining is possible for Vicia faba minor, but creates difficulties with large-seeded varieties of V.faba major. As soon as funds will permit, a plot combine will be tested with the new flail-finger threshing drum, which will permit direct combining of large-seeded varieties.

The costs of direct combining are similar to those of using a cutter bar and stationary thresher. Costs of traditional harvesting methods are not available.

Fig. 2. Single-plant thresher with a flail-finger drum, interchangeable with standard rasp-bars or rigid-finger drums.

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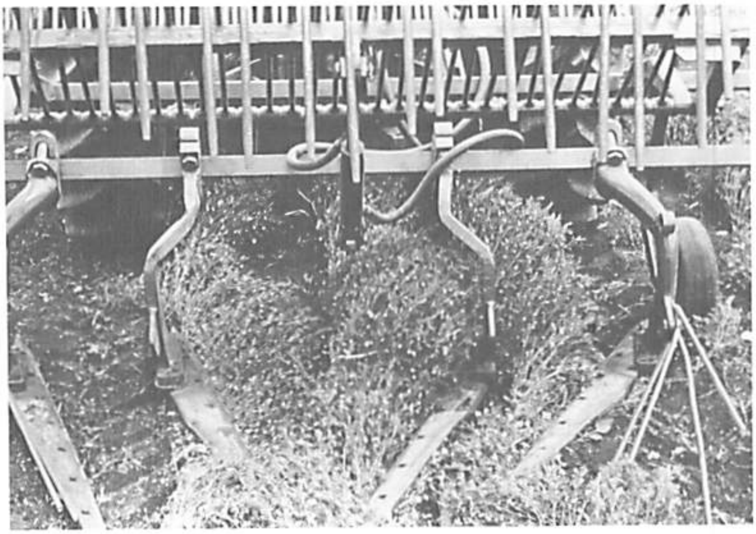
Appendix 1

Lentil Harvesting Blades

Similar to bean blades specified in the John Deere Agricultural Sales Manual, order No. 9515, 4-row bean cutter, or BN 90-278, 4-row bean cutter.



Cutter blades from rear, with rake raised.

Description

Tractor mounted, in the rear. Steel bars on top of the blades windrow the plants. A rake collects the material in piles.

Power source. Principle suitable for either animal draft or small or large tractor. Four blades with 1.9 m working width require a 30-40 h.p. (22-30 kw) tractor.

Crop. Short and tall lentil genotypes.

Main use. Harvest of lentils before the stage of shattering, by cutting plants at 2-5 cm depth, windrowing and piling in order to let plants reach threshing ripeness.

Main advantages. This method has the lowest loss of straw and grain of any mechanized harvesting method. Can be made locally.

Degree of development. Prototype tested. Works acceptably in dry soils.

Brief specification. Three-point mounted tool bar holding two or four shanks, 1 set with 2 blades for 95 cm, or 2 sets with 4 blades for 190 cm working width. Blades are 110-130 cm long with adjustable angle. Iron bars on top of blades for windrowing. Rake behind for collecting and piling of plants, lifted hydraulically. Working depth controlled by adjustable wheels at the tool bar.

Working speed. Approx. 4-5 km/hr.

Front mounted lentil puller, System Tauscher

Appendix 2

Lentil Puller, System Tauscher

Description

Plant puller for the harvest of lentils, either broadcast or row-planted on level or ridged fields. Harvests the whole plant.

Power source. Large tractor (60 h.p./44 kw).

Crop. Lentils, short and tall varieties.

Main use. Harvesting lentils before the stage of shattering is reached. To be used where straw is required for feeding. Can harvest under slightly stony conditions.

Main advantages. Pulls complete plants with no loss of straw. Can operate statisfactorily when fields are not completely free of stones. System represents highest capacity achieved under ICARDA/Tel Hadya harvesting conditions (1.1-1.3 h/ha).

Degree of development. Prototype assembled, ready for large-scale testing during 1984.

Design/drawing available. Mr. Friedrich Tauscher, c/o GTZ, Dag Hammerskjold-Weg 1, 6236 Eschborn 1, German Federal Republic.

Brief specification. Front mounted lentil puller. Plastic rotor blades press the plants against a rubber belt, both driven by a hydraulic motor (in case the available tractor has no front power take off). Lifting and control of working height is by rear hydraulic system via steel cables.

Discussion

F. Muelhbauer
Were lifters used on the cutter bars and combines used for lentil cutting? Lifters might reduce losses during cutting.

J. Diekmann
Lifters were used on cutter bars and improved the efficiency in lodged lentils on flat lands, but when used on lentils planted on ridges they had a negative effect in pushing the lodged plants below the cutter bars. Therefore, we recommend lifters on cutter bars only for crops planted on flat land.

W. Erskine
I would like to add to Dr. Diekmann's presentation on the use of cutter bars in harvesting lentils. The losses can be reduced by harvesting at physiological maturity prior to complete crop drying. The remaining stubble can be grazed and is not lost. Combine harvesting of lentils is also important in many parts of the world.

F. Muelhbauer
Lentil is nearly all harvested mechanically in North and South America; however, the cultivars are tall, and the soils are devoid of stones.

K.G. Cassman
Do the harvest costs shown in your tables include equipment purchase costs, maintenance, and operators?

J. Diekmann
The harvest costs, as far as machinery are concerned, were calculated at two times the present purchase price, and about 20% shorter lifetime than usually expected, i.e. 8 years for the lentil blades, an easily achievable working capacity for a season, and also include the presently charged rate for the use of a rented tractor including fuel and operator.

As for the newly developed items the final market price not being known, I found this the only justified way to determine the expected costs. For already available techniques, i.e. combines, threshers, the presently charged rates in Aleppo province are indicated.

Imru Assefa
Have you done any studies on compatibility of presently used tillage, cultivation, threshing, and harvesting equipments for cereals and legumes (pulses)-particularly faba beans?

J. Diekmann
No compatibility studies were made. However, tillage equipment required for cereals production can surely be used for legumes. Zero-tillage systems will be difficult to apply.

Interrow cultivators are to be used for row crops only. Cereals do not require such cultivation, except corn (maize). The mentioned harvesting equipment for lentils is specially designed to pull this crop and cannot be used on any other crop. The threshing devices can be used for a variety of crops, including cereals. The flail finger threshing drum, specially designed for large-seeded legumes, is interchangeable with a standard threshing drum (rasp bar type) and will approximately cost 350 to 500 US$ for a standard-size stationary thresher (a type requiring 15-20 hp).

Asfaw Telaye

In faba beans threshing from a large-scale (6000 ha) production, collecting and feeding to the machine involves large production costs, or the business does not pay. What is you view?

J. Diekmann

For faba beans two ways of mechanization are suggested:

1. Cutter bar and stationary thresher. The cutter bar should be used for at least 300 ha in its life time, i.e. 5-10 years, bringing the annual working capacity to 30-60 ha. This can also include crops other than faba beans. The thresher will require an annual demand of about 50 ha, but this could also include other crops. The flail finger threshing drum is designed to be exchangeable with the standard drum fitted.

2. A standard combine of approximately 80-90 hp must be used for at least 150 ha per year over a 10-year period. For small-seeded faba beans the standard equipment with the respective sieve size will do. For large-seeded varieties no combine has been used so far, but I hope ICARDA will be in a position to test the above mentioned flail finger threshing drum in a combine during the 1984 harvesting season.

Proceedings of the International Workshop on Faba Beans, Kabuli Chickpeas, and Lentils in the 1980s (Saxena, M.C. and Varma, S., eds.), ICARDA, 16-20 May 1983, Aleppo, Syria.

Economics in the Design, Execution, and Analysis of On-Farm Trials

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Improvement in the productivity and yield stability of faba beans, chickpeas, and lentils is the common objective of all participants in this workshop. Higher yields of these crops can be generally equated with improved welfare of farm families, and improved nutrition of whole nations. Improvement of farm welfare is possible when production becomes more profitable: that is, when the value of the subsequent yield increase more than covers the costs of new inputs. Therefore, considering the farmers' view of production costs is a basic necessity in the process of developing truly "improved" packages of production technology. The speed at which a new technology is adopted by farmers depends heavily on its profitability (Schultz 1976).

How can we learn about the physical environment and production costs of our farmer clientele, and then develop techniques and materials which will be profitably adopted by them? Concepts of Farming Systems Research (FSR) are still in a rapid stage of evolution. Multidisciplinary in nature, FSR has not yet attained international consensus on its own identity as a discipline. The Farming Systems Program at ICARDA is certainly not the exclusive domain for farming systems research at the center. The Food Legume Improvement Program has the longest experience in organizing on-farm trials through the Nile Valley Project in Sudan and Egypt. These trials have been successful in identifying farmers' production constraints and costs, and the relative profitabilities of different faba bean technologies. They have provided feedback for the design of future experiments both at the research stations and on farmers' fields. On-farm trials have also been employed by ICARDA's Cereal and Forage Programs with good results. A question remains as to how we can improve on these results to more quickly develop profitable new technologies.

Farming Systems Research in general is briefly discussed below. As key elements of FSR, three types of on-farm trials are reviewed. The role of economic considerations for on-farm trials is then easily brought into perspective.

Farming Systems Research

Farming Systems Research is a process that identifies problems limiting agricultural productivity and then searches for solutions to these problems. FSR is comprehensive, in that new technologies are evaluated in the light of all the components of the systems, including the complex interdependencies of these components. FSR recognizes the resources and constraints of the farming families (who are both producers and consumers), and seeks solutions that are relevant, useful, and acceptable to these families. This research is undertaken by multidisciplinary teams of scientists that interact continually with farmers for whom the research is intended. This approach should ensure that the research produces appropriate technologies and will, therefore, be more easily and quickly adopted (Nygaard 1982).

The Farming Systems Program at ICARDA perceives its research as a process that passes through four stages (adopted from Gilbert _et al_. 1980):

1. Diagnostic stage. This is an initial and recurring process where the complete system is studied to understand the socioeconomic as well as the agroclimatic environment in which agricultural production is undertaken, and to identify constraints to or potential areas for increasing agricultural productivity.

2. Design or experimental stage. Scientists conduct research on problems which have been identified in stage 1, on research stations, substations or farmers' fields, in an effort to find one or more feasible solutions or strategies that will improve agricultural production.

3. Testing stage. Promising strategies that are developed in stage 2 are tested under farmer's conditions where, initially, production decisions are made jointly by the scientist and the farmer. Trials which are managed totally by the farmers themselves are then undertaken.

4. Extension stage. The final process involves diffusing successful technologies.

The FSR process is dynamic and iterative since we frequently return to previous stages to clarify points as we gain knowledge, confront problems, and consider research alternatives. In addition, the distinction between stages is not sharply defined, there is much overlap, and we work at several stages simultaneously. Nevertheless, by visualizing the research process in this way, we keep our work in perspective *vis-à-vis* other scientists collaborating on projects and the farmer.

On-Farm Trial Designs: On Target

CIMMYT economists (1981) have stated that "on-farm research ... is most efficient when focused on a specific group of farmers who have similar problems and potentials." The concept of a recommendation domain is essential in light of the fact that no single technological package is universally best. Perrin *et al*. (1976) defined a "recommendation domain" as a group of farmers within an agroclimatic zone whose farms are sufficiently similar and who follow sufficiently similar practices that a given recommendation is applicable to the entire group. Soils, climates, disease and pest incidence, costs and prices vary within and between regions. Thus it is necessary to target the research at limited areas and groups of farms where physical and economic conditions are relatively homogeneous.

Much of the early on-farm trial work in the Nile Valley Project was aimed at diagnosing constraints to production and has led to the design and trial of promising packages of techniques in specific locations in Sudan and Egypt following the procedures used at IRRI (De Datta *et al*. 1978). The early trials were almost purely of the researcher-managed type, with the collaborating farmers providing the land and some labor. Agroeconomic surveys were conducted at the same time to learn the local cost, price, and input availability situations of the farmers hosting the trials (Salkini and Nygaard 1982).

Trials managed jointly by researchers and farmers to test the promising packages of inputs were conducted in the 1982/83 season on field plots large enough to allow for good economic estimates. Labor use, especially, is more accurately estimated with large plots than with small ones, and farmers are usually able to make clear statements about the techniques being tried.

The final step towards demonstration and dissemination of new technologies is the farmer-managed trial. In such trials the farmer agrees to apply the recommended package on a large field plot, purchases and applies the necessary inputs himself, and is motivated by the prospect of profiting from the increases in yield value beyond his costs. An agreement to compensate the farmer in the case of crop failure may provide a fair added incentive for cooperation.

Execution

In all three types of on-farm trials (researcher, joint, and farmer managed) regular visits by the research staff should be maintained to gain the best insights and learn the most from the participating farmers. Farmers are typically very rational economic beings as well as keen observers of physical processes. Listening to their explanations and observations can teach a scientist a great deal. The farmer should be considered as part of the research team, involved to some degree in making plans and decisions at all levels and stages and sharing credit for the results (Harwood 1979).

It is important to record data on costs of production in such a way that material costs are clearly separated from labor costs. Also, data collection should be closely supervised in the field (Deuson et al. 1983). A great advantage of researcher contact with the host farmers is that unexpected constraints and factors are most easily discovered. For example, the high economic value of lentil crop residue as livestock feed in Syria was pointed out by farmers surveyed in connection with on-farm trials (Nordblom and Halimeh 1982). The high economic value of residues constitutes a strong deterrent to farmer adoption of new harvest techniques that cause the loss of this material. If technicians are merely sent out to conduct the trials and report the costs and yields, some of the pivotal economic concerns that farmers have about the crop may escape detection by the researchers.

Analysis

Farmers cannot be expected to adopt new inputs or practices, simply because they give significantly higher yields, if they are uneconomical or impossible to apply. Conversely, farmers may wisely prefer a new practice which results in slightly lower crop yields but allows a significant saving in labor or other costs. At first glance, these facts of economic life may seem at odds with our goal of increased production. Yet, if we can adjust our perspective to include the farmer's cost considerations from the beginning, we can be more sure of reaching sound recommendations from the viewpoints of both profitability and increased yields. Our recommendations will not be accepted and used by a farmer if they are less profitable than his current practices. Thus, as nearly as possible, evaluation criteria should be the same as those used by the target group of farmers (Dillon and Virmani 1983).

The challenge before us must be approached with the combined perspectives of biology and economics. However, the economic analysis required is simple and can be handled by almost any biologist. Unfortunately, the tendency for some is to view their work as being simply to find techniques to maximize yield. It is not the concern of such biologists if, later, the "ignorant" farmers do not adopt the yield-maximizing technique because they find it uneconomical.

No sophisticated training is needed in order to draw up budgets of alternative production packages. Furthermore, the farmers hosting our trials can help in developing these budgets better than could an outside expert who is unfamiliar with the area. The time invested by biologists in consulting with their trial farmers (the experts on local costs and practices) can be very well spent, giving high returns in terms of making the research relevant to farmers.

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Discussion

R. Summerfield

Numerous, perhaps relatively small differences in location/soil type/timing/aspect/climate/weather etc. probably combine to ensure that research station yields are 2-3-4-5 times larger than farmer yields. What about seeking to quantify "farming acumen" (there are good, average, and below-average farmers) by inviting the farmer to grow a crop on the research farm - in the manner and at the times he would do on his own land?

M.C. Saxena

Sounds to be an interesting idea. In a way, such an evaluation is done in our farmer managed trials conducted in the Nile Valley Projet of Egypt and Sudan. Although farmers are not invited to plant the crop at research station, they do have opportunity of showing their method in juxtaposition with the improved method under the supervision/monitoring by researchers.

Proceedings of the International Workshop on Faba Beans, Kabuli Chickpeas, and Lentils in the 1980s (Saxena, M.C. and Varma, S., eds.), ICARDA, 16-20 May 1983, Aleppo, Syria.

Eighth Session

Cooperative International Testing Program on Faba Beans, Kabuli Chickpeas, and Lentils

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The Food Legume Improvement Program (FLIP) of ICARDA has a world mandate for research on faba beans and lentils, and a joint responsibility, with ICRISAT, for kabuli chickpeas. One of the major objectives of FLIP is to assist legume improvement programs in countries where these crops are grown.

The main research activities of FLIP are concentrated at Tel Hadya, south of Aleppo in northern Syria, and at Terbol in the Beqa'a valley of Lebanon. The international testing program was initiated in the 1977/78 season to strengthen the research efforts of national food legume improvement programs. This cooperative international testing program on food legumes has the following objectives:

1. To provide promising genetic material that may have potential for release as cultivars.
2. To make available to national programs trait - specific gene pools for such characters as large seed, tall type, and early maturity for use in breeding programs.
3. To provide promising early-generation and advanced breeding lines for selection and evaluation under local conditions.
4. To supply genotypes resistant to diseases and parasites such as *Orobanche* sp., for confirmation under local conditions and use in crop improvement programs.
5. To provide a mechanism to national programs for international testing of their elite materials.
6. To characterize the major environments in which faba beans, kabuli chickpeas, and lentils are grown.

7. To obtain information on agronomic factors which limit crop growth, and to encourage agronomic research in different regions.

8. To provide international cooperation through the exchange of materials, information, and visits.

Development of Nurseries

The regional testing program was initiated in 1977/78 with only two nurseries per crop: a Regional Nursery (RN) and a Regional Preliminary Yield Trial (RPYT). In 1978/79 these nurseries were changed into International Nurseries when the testing program was diversified to include the countries outside the ICARDA region. In 1978/79, adaptation trials (AT) were included, as was recommended at the Food Legume Improvement and Development Workshop held at ICARDA in 1978 (Hawtin and Chancellor 1979).

Later, with the development of breeding programs at ICARDA and feedback from the national programs, the nurseries were further diversified. In 1977/78 only six types of nursery were provided within ICARDA region, whereas as many as 34 different types of nursery have been supplied to national programs both within and outside the ICARDA region during 1982/83 (Table 1). In addition to the trials in Table 1, a few sets of disease screening nurseries for faba beans have been supplied to cooperators in those countries where diseases are a major constraint to production.

The cooperative international testing program broadly includes the following nurseries or trials.

Breeding Nurseries and Yield Trials

International F_3/F_4 Trials (IF_3T/IF_4T)

Bulk segregating populations in the F_3 or F_4 generation are supplied to cooperators for single-plant selection within superior populations. At the same time these allow an estimate of the population's performance across locations, which assists in identification of parents for hybridization.

International Screening Nurseries (ISN)

These comprise selected lines from germplasm and advanced breeding lines from F_5/F_6 generation. The nurseries are unreplicated, with repeated checks. They provide national programs with wide genetic diversity, and provide ICARDA with information for formulating international yield trials.

Table 1. Legume nurseries supplied by ICARDA, 1977/78 to 1982/83 seasons.

Season	Faba beans	Chickpeas	Lentils
1977/78	RPYT-S, RPYT-L*	RN, RPYT	RN, RPYT
1978/79	AT, ISN, IF_3, IABN, FPPT	AT, IYT, ISN, IF_3T, IABN, FPPT	AT, IYT, ISN, IF_3T, FPPT
1979/80	AT, ISN-L, ISN-S, IYT-L, IYT-S, IF_4T, IABN, ION, FIT, DPPT.	AT, IYT, ISN, IABN IF_4T, IYT-W, DPPT, FIT	AT, IYT-L, IYT-S, ISN-L, ISN-S, IF_3T, IF4T, DPPT, FIT
1980/81	AT, ISN-L, ISN-S, IYT-L, IYT-S, IF_3T, IF_3T-E, ION, FIT, DPPT, WCT.	AT, IYT, ISN, IABN, IF_3T-A, IF_3T-B, IF_3T-C, IYT-W, IYT-L, IABN-D, FIT, DPPT, WCT	AT, IF_3T, IYT-S, ISN-L, ISN-S, IF3T-E, DPPT, FIT, WCT
1981/82	AT, ISN-L, ISN-S, IYT-L, IF_4T, ION, FIT, DPPT, WCT	AT, IYT, ISN, IABN, IF_3T-A, IF_3T-B, IF_3T-C, IYT-W, IYT-L, FIT, DPPT, WCT.	AT, IF_3T, IYT-L, IYT-S, ISN-L, ISN-S, ISN-E IF3T-E, DPPT, FIT, WCT
1982/83	ISN-L, ISN-S, IYT-L, IF_3T-E, IYT-S, IF_3T, ION, FIT, DPPT, WCT	AT, IYT, ISN, IABN, IF_3T-A, $IF_3$3T-B, IYT-W, IYT-L, FIT, DPPT, WCT, IET	IF3T, IYT-L, IYT-S, ISN-L, ISN-S, ISN-E, IF3T-E, DPPT, FIT, WCT, LION, LISN-T

* The full name of the trials are given in Appendix 1.

International Yield Trials (IYT)

The international yield trials include the materials which have previously shown above-average performance either in ISNs or in station trials. These trials assess the yield of genotypes across a range of environments and help national scientists to identify lines with local adaptation. More specific trials have been developed for national programs, including large-seeded (L), small seeded (S), early (E), winter-sown (W), and tall (T) subsets.

International Disease and Orobanche Nurseries

These nurseries are used to identify stable sources of resistance to major diseases, like ascochyta blight (AB) for chickpea, and the parasitic weed Orobanche (O) for faba beans and lentils. These nurseries comprise resistant material for evaluation and use by national programs.

Adaptation Trials (AT)

These trials aim to classify legume-growing areas by agroecological zones. The adaptation trials, which comprise cultivars from the main legume production areas, were initiated in 1977/78. The faba bean (FBAT) and lentil (LAT) trials were discontinued after 4 years in 1982/83, but the chickpea adaptation trial is continuing.

Agronomy Trials

Realizing the need for information on the best agronomic management of the food legumes, different agronomic trials have been formulated.

Date of Planting-Cum-Plant Population Trial (DPPT)

The aim of this trial is to identify the optimum date of planting, and the optimum plant population for each date.

Fertility-Cum-Inoculation Trial (FIT)

This trial examines the need for fertilizer application and inoculation with Rhizobium spp. and the adequacy of symbiosis in food legumes.

Weed Control Trial (WCT)

These trials have been developed to quantify the yield losses due to weeds in legume crops and to assess the relative merits of some weed control methods.

Iron Efficiency Trial (IET)

This trial was added in 1982/83 to study the iron chlorosis problem in chickpeas.

Distribution of Nurseries

Each year a list of available nurseries is circulated to national programs. Cooperators are also requested to send seed of their own entries for inclusion in the international trials. However, to date, the contribution of cooperators to the nurseries has been limited.

ICARDA nurseries requested by the cooperators are despatched in August/September.

Conducting and Reporting of Nurseries

Two field books are sent to cooperators with the seed, one for their own use and the other to be returned to ICARDA. The books contain general information about the nursery and its operation, suggestions for recording observations, and blank data sheets. The return of the completed field books to FLIP has been rather poor; in 1980-82, only 45, 41, and 44% of field books were returned for faba beans, lentils, and chickpeas, respectively. It is emphasized that a detailed report of the nursery should be sent by the cooperator even if the trial failed.

The results received from each location are analyzed, printed and circulated. Reports on the international nurseries for 1977/78, 1978/79, and 1979/80 have been published to date, and that of 1980/81 will be published soon.

Progress to Date

Since most of the results have been previously published and presented, only highlights of the international cooperative testing program are given here.

Increasing Interest by the National Programs

The number of trials and nurseries distributed to national programs since 1977/78 are presented in Table 2. In 1977/78 only six types of trial were distributed to 86 cooperators, whereas by 1982/83 these figures had increased to 34 and 925, respectively. The requests for ICARDA trials have always exceeded their availability. This increase suggests heightened awareness of national programs of the importance of food legume crops and ICARDA's increasing role in helping the national programs.

Table 2. Distribution of trials and nurseries over different seasons since 1977/78 for the three legume crops.

Season	Types of trials				No. of trials distibuted				No. of countries		
	Faba bean	Chick-pea	Lentil	Total	Faba bean	Chick-pea	Lentil	Total	Faba bean	Chick-pea	Lentil
1977/78	2	2	2	6	19	34	33	86	9	15	15
1978/79	5	6	5	16	71	105	81	257	14	17	15
1979/80	10	8	9	27	174	216	207	597	25	30	26
1980/81	11	13	10	34	203	309	224	736	31	30	28
1981/82	10	12	11	33	140	384	285	809	27	33	27
1982/83	10	12	12	34	212	410	303	925	28	45	33

Identification of High-Yielding Lines by National Programs

Many faba bean, chickpea, and lentil lines have been identified by the national programs for multilocation testing or for testing in on-farm trials. These are presented in Table 3. The Argentinian national program found the faba bean line ILB 1814 (Syrian local large) to be very promising, and has requested about 20 tonnes of seed from ICARDA. We are multiplying the seed to fulfil the request.

At the request of the Jordanian national program, ICARDA supplied 1.5 tonnes of seed of the chickpea genotype ILC 484 in 1982 for prerelease multiplication and testing in Jordan. Another genotype ILC 482 which was tested in on-farm trials in Syria from 1979 to 1982 was released in Syria for winter cultivation in zone B and C. This is the first varietal release from the international cooperative testing program of FLIP at ICARDA.

Table 3. Promising lines of faba bean, kabuli chickpea, and lentil identified by national programs.

Crop	Country	Accession number
Faba bean	Argentina	ILB 1814
	China	ILB 1266, ILB 1933
	Egypt	ILB 261, ILB 266, ILB 938, ILB 1266, ILB 1269, ILB 1933
	Honduras	ILB 1269, ILB 1811, ILB 1816, ILB 1822
	North Yemen	ILB 320, ILB 1817
	Peru	ILB 19, ILB 1266, ILB 1269, ILB 1270, ILB 1805, ILB 1933
	Syria	ILB 1805
Chickpea	Canada	ILC 451, ILC 464, ILC 604
	Egypt	ILC 249, ILC 484, ILC 1407, ILC 2912
	Jordan	ILC 484, ILC 482, ILC 202, ILC 72
	Lebanon	ILC 482, ILC 484
	Morocco	ILC 482, ILC 484
	Pakistan	ILC 192, ILC 195, ILC 482
	Syria	ILC 195, ILC 202, ILC 482, ILC 3279
	Tunisia	ILC 482, ILC 484
	USA	ILC 90, ILC 102, ILC 171, ILC 232, ILC 517, ILC 650
Lentil	Egypt	ILL 4354
	India	ILL 4605
	Jordan	76TA 66054, 78S 26002, 78S 26013, ILL 4400
	Lebanon	ILL 1880, ILL 4400
	Syria	78S 26002, 78S 26004, 78S 26013, 76TA 66088

In lentils, a germplasm accession, Precoz (ILL 4605), was found to be relatively insensitive to photoperiod, and is the first _macrosperma_ lentil to be adapted to conditions in the Indian subcontinent. Other _macrosperma_ lines have also been selected by the Indian national program.

Identification of Genotypes With Stable Performance

The nurseries have yielded some genotypes which have maintained their superiority over the local checks over a wide range of locations.

The chickpea cultivar ILC 482 exceeded the local checks in eight out of 10 countries in Chickpea International Yield Trials (Winter) conducted during the 1980/81 season (Fig. 1). Similarly, ILB 1805 (Fig. 2) in Faba Bean International Yield Trials (Large Seeded), and ILL 16 (Fig. 3) in Lentil International Yield Trials (Small Seeded) exhibited adaptation to a wide range of environments in 1980/81. Such genotypes may be useful in breeding for wide adaptation in these crops.

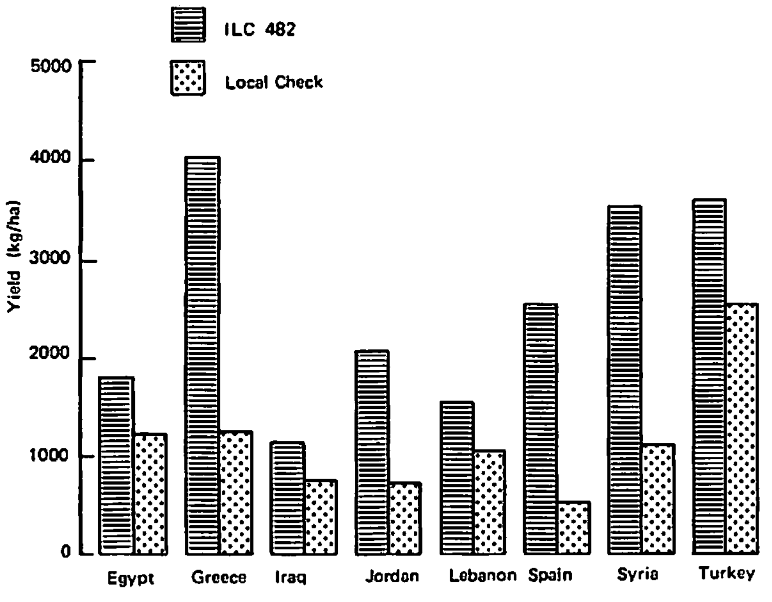


Fig. 1. Performance of ILC 482 chickpea against local check cultivars in CIYT-W, 1980/81.

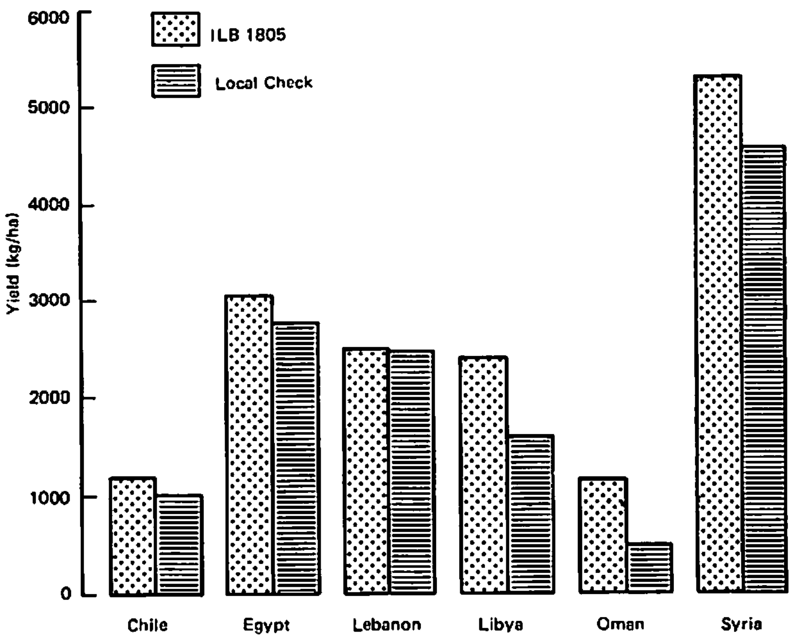


Fig. 2. Performance of faba bean cultivar ILB 1805 against local checks in FBIYT-L, 1980/81.

Identification of Sources of Resistance to Disease

The disease nurseries have identified sources of resistance to ascochyta blight in chickpeas and to chocolate spot, ascochyta blight, and rust in faba beans (Table 4). These lines are being used by ICARDA and national breeding programs for the improvement of genetic stocks.

The CIABN revealed differential reactions of host genotypes to the ascochyta blight pathogen, indicating a number of different isolates of *Ascochyta rabiei*.

Identification of Useful Agronomic Practices

The agronomic trials have shown that early planting results in yield increases in all three crops. This is being further investigated in Jordan, Lebanon, and Pakistan. In addition, planting of chickpeas in winter rather than in spring has given yield increases of almost 100%.

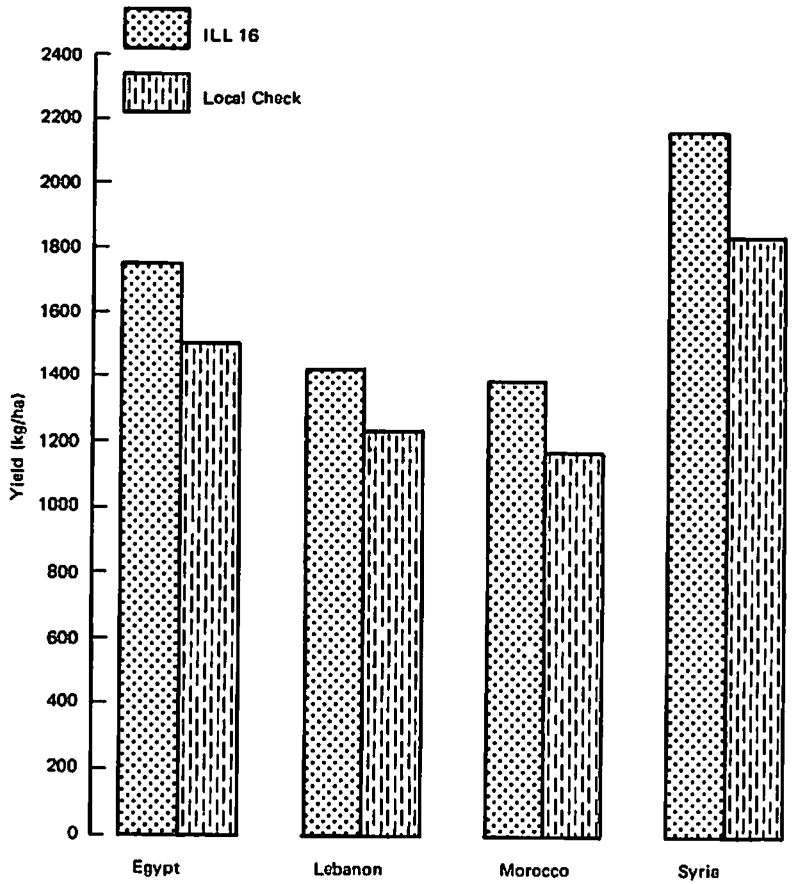


Fig. 3. Performance of a lentil cultivar, ILL 16 against local checks in LIYT-S, 1980/81.

The weed control trials during 1980/81 have revealed that weeds cause heavy losses to all three food legumes, and possibilities exist to control weeds with herbicides.

Zoning of Nurseries

The results of the adaptation trials for 1978/79 to 1980/81 are given in the reports of the food legume nurseries (ICARDA 1981, 1982, 1983). Since neither the genotypes nor the locations are similar over years, a combined analysis over years and locations could not be done. However, an attempt to present highlights from these trials is made here.

Table 4. Lines resistant to various diseases according to country.

Crop	Disease	Country	Resistant lines
Faba bean	Ascochyta blight (*Ascochyta fabae*)	Canada	Sel 80 Lat. 14435, 14422, 14434, 14986, 14998, 15025, 15035, 70015, BPL 2485.
		Syria	Sel 80 Lat. 14435, 14422, 14434, 14986, 14998, 15025, 15035, 70015, 14200, 14336, 14339, 14399, 14427, BPL 2485.
	Chocolate spot (*Botrytis fabae*)	Egypt	BPL 266, 710, 1179.
		Syria	BPL 266, 710, 1179, 1196,1274, 1278, 1390, 1821, 678.
		U.K.	BPL 266, 710, 1179.
	Rust (*Uromyces fabae*)	Canada	Sel 80 Lat. 15563-3
		Syria	Sel 80 Lat. 15563-3
Chickpeas	Ascochyta blight (*Ascochyta rabiei*)	Algeria	ILC 72, 191, 196, 2380, 2959, 3279.
		Jordan	ILC 72, 191, 196, 2380, 2959, 3279.
		Lebanon	ILC 72, 191, 196, 2380, 2959, 3279.
		Pakistan	ILC 72, 191, 194, 196, 484, 2380, 2956, 3279.
		Syria	ILC 72, 191, 196, 2380, 2959, 3279.
		Turkey	ILC 72, 191, 196, 201, 202, 2380, 2956, 3279, Pch 128.

Lentils

Genotypes originating from West Asia and South Europe are very late to flower when grown in the Indian subcontinent, at photoperiods of less than 11 hours. They produce few or no pods because of the onset of adverse environmental conditions during their active reproductive period of growth. For example, one *macrosperma* line, ILL 4400 (Syrian local large), flowered almost at the same time as ILL 784 (Giza 9) from Egypt when grown in Syria. However, the difference was 37 days when they were grown in Pakistan, where the photopeoriod was less than 11 hours.

Such information on the adaptation of the crop has been important in formulating a breeding strategy. It is clear that selection for the Indian subcontinent must be made under appropriate environmental conditions of photoperiod and temperature. In an attempt to initiate this process, two early international nurseries, (LIF$_3$T-E and LISN-E) were developed and supplied to cooperators in the Indian subcontinent.

On the basis of phenology, and photo- and thermoperiods, the zoning of nurseries was attempted for lentil (Table 5). The F$_3$ trials and screening nurseries have specifically been designed for the Indian subcontinent and Nile Valley environments. In addition, two specific nurseries were initiated only for West Asian locations.

Table 5. The number of different breeding trials in lentils with their target region, 1982/83 season.

<table>
<tr><th rowspan="2">Type of trial</th><th colspan="5">Region</th></tr>
<tr><th>West[1] Asia</th><th>North[2] Africa</th><th>High[3] Altitude</th><th>Nile[4] Valley</th><th>Indian[5] sub-continent</th></tr>
<tr><td rowspan="2">Yield trials</td><td>2</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">2</td><td></td><td></td></tr>
<tr><td>Screening</td><td colspan="3">3</td><td colspan="2">1</td></tr>
<tr><td>F$_3$ segregating populations</td><td colspan="3">1</td><td colspan="2">1</td></tr>
<tr><td><u>Orobanche</u></td><td colspan="2">1</td><td></td><td></td><td></td></tr>
</table>

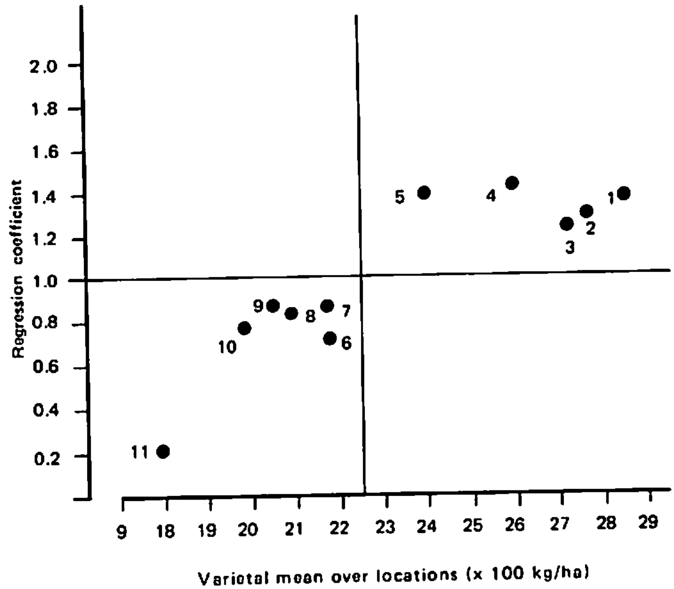
1. West Asia - Syria, Lebanon, Jordan, Iraq, Cyprus.
2. North Africa - Tunisia, Morocco, Algeria, Libya.
3. High Altitude - Turkey, Iran.
4. Nile Valley - Egypt, Sudan, Ethiopia.
5. Indian subcontinent - India, Pakistan, Bangladesh, Nepal.

Faba Beans

Results were analyzed according to the method of Eberhart and Russell (1966), and the salient features are presented in Fig. 4. Small-seeded lines from Egypt, Jordan, Lebanon, Sudan, and Syria are adapted to locations in Egypt, Ethiopia, Iraq, Libya, and Syria (Lattakia site, near the sea coast), whereas large-seeded types had specific adaptation to environments in Italy (Bari and Lecce), Lebanon (Terbol), Spain, and Syria (Tel Hadya, under irrigated conditions). This indicates that seed size is an important characteristic in determining the adaptation of faba beans.

Chickpeas

Preliminary results of chickpea trials indicate the existence of wider adaptation in chickpeas than in lentils and faba beans. Nurseries for the different environmental zones will be prepared after the analysis of the preliminary trials is completed.



1 = ILB 1822 (Violetta di Policoro - Italy)
2 = ILB 1817 (Lebanese local large)
3 = ILB 1266 (Aquadulce - Spain)
4 = ILB 1821 (Turkish local large)
5 = ILB 1814 (Syrian local large)
6 = ILB 1818 (Jordanian local small)
7 = ILB 1820 (Giza 4–Egypt)
8 = ILB 1819 (Giza 3–Egypt)
9 = ILB 1816 (Lebanese local small)
10 = ILB 1811 (Syrian local small)
11 = ILB 460 (Hudeiba 72 - Sudan)

Fig. 4. Adaptation analysis in faba beans using 1979/80 FBAT nurseries.

Future Outlook

Diversification of Nurseries

With the development of new management techniques and to meet the specific needs of the national programs, the nurseries will be diversified. There is a possibility for developing nurseries for irrigated conditions. Zone-specific nurseries will be developed once regions of adaptation are established for each crop.

Exchange of Visits and Meetings with Cooperators

To have close cooperation and interaction between ICARDA and national programs, small group meetings at ICARDA or in different regions may be useful. In these meetings the problems and strategies can be discussed. An international trial officer may soon join the program. This will enable more frequent visits to the trial sites and promote the feedback of data and research problems to ICARDA.

Computerization of International Nurseries

All aspects of the international nurseries, from preparation and printing of field books to the analysis of results and preparation of final reports, will be handled by computer in future.

Acknowledgements

We acknowledge with thanks the contributions of the national programs in the conduct of the trials and returning the data books to us. We also thank all the scientists in the FLIP and the support services who have contributed in the conduct of these trials.

Appendix 1. The abbreviations for different international nurseries.

Full name	Abbreviation
Regional Preliminary Yield Trial	RPYT
Regional Nursery	RN
Adaptation Trial	AT
International Screening Nursery	ISN
International Ascochyta Blight Nursery	IABN
International F_3/F_4 Trial	IF_3T/IF_4T
International Yield Trial	IYT
Fertilizer cum Plant Population Trial	FPPT
Fertilizer cum Inoculation Trial	FIT
Date of Planting cum Plant Population Trial	DPPT
International Orobanche Nursery	ION
Weed Control Trial	WCT
Lentil (Prefix)	L
Chickpea (Prefix)	C
Faba bean (Prefix)	FB
Large (Suffix)	L
Small (Suffix)	S
Early (Suffix)	E
Tall (Suffix)	T

References

Eberhart, S.A. and Russell, W.A. 1966. Stability parameters for comparing the varieties. Crop Science 6: 36-40.

Hawtin, Geoffery C. and Chancellor, George J. (eds.). 1979. Food Legume Improvement and Development. Proceedings of a Workshop held at the University of Aleppo, Syria, 2-7 May 1978. IDRC, Ottawa, Canada. 216pp.

ICARDA 1981. International Nursery Report No. 3. Food Legumes Nurseries 1978/79. ICARDA, Aleppo, Syria. 115pp.

ICARDA 1982. International Nursery Report No. 4. Food Legumes Nurseries 1979-80. 190 pp.

ICARDA 1983. International Nursery Report No. 5. Food Legumes Nurseries 1980/81. 258pp.

Discussion

R.S. Malhotra

What should be the percentage of CV acceptable for yield trials in case of different legume crops in international yield trials?

S.K. Sinha

In India we do not include data for discussion if CV is above 20%, for the purpose of yield.

K.B. Singh

In the past we have been furnishing more of finished material and less of segregating material. I would like to have your views whether we should continue our present policy or we should change our stategy and, if so, in what direction?

J.I. Cubero

Concerning the question raised by Dr. K.B. Singh, I would suggest we discuss this subject thoroughly. One should take into consideration the problems which can arise in some countries which have laws to patent cultivars. A certain firm could register and protect a cultivar obtained from well-finished ICARDA material and no one in that country could use that material without paying royalties. Hence there is a need for getting some kind of a clearance from the national agency before supplying finished material to private seed firms.

Bashir Ahmed Malik

I feel that it is better to supply early and advanced segregating material than the finished material, except the germplasm. This would provide more opportunity to the national programs to have selection under local conditions. But the national programs which do not have enough expertise may get the benefit of finished material from ICARDA.

Aseffa Imru

Although ICARDA has world mandate on some crops and perhaps concentrates more on problems that have wider implications, it is pleasing to see that it has also been addressing to the problems at national programs by way of supplying the breeding material, training, information, etc. However, the question of cooperation is not all that simple. It is expensive to conduct cooperative trials in the first place. Importation of seed material has quarantine implications. To help enhance more cooperation, it is important to have mutual visits of research workers and greater opportunities for exchange of ideas so that the cooperators have the confidence that material coming from the center is going to be useful.

Asfaw Telaye

In the last 5 years of our cooperative research in Ethiopia it has been invariably found that ICARDA's faba bean materials are low in grain yield when compared to local Ethiopian check. It will be good to develop material at ICARDA involving the Ethiopian lines in crossing program and provide the early generation material for evaluation under Ethiopian conditions.

M.C. Saxena

On the comment of Dr. Cubero about the supply of seed to private seed industry which tends to patent the seed, my feeling is that this issue be discussed more and we should identify agency/agencies in each country to which the seed is to be supplied. Personally I feel there is no harm in supplying the seed to any agency that asks for it. But we would like to have feedback from national programs on this.

S.K. Sinha

If private companies can receive seed material without any obligation, it is likely to cause problems. Would such a seed company make some of its material available to ICARDA or other international/national agency? Keeping such considerations in mind it might be a good idea to involve national agencies while supplying seed material.

A. Slinkard

Seeds of protected cultivars of self-pollinated crops are still available as germplasm for use in breeding programs. Hence there should not be any problem. The situation is a bit different for hybrids.

J.I. Cubero

I agree that even the varieties legally protected by patent laws can be used in breeding programs. I do not agree, however, that the finished material can be distributed to both official national agencies and the private firms without problems. For example, big firms always maintain strong research programs, but medium and small firms could find easier and cheaper to obtain new varieties just by receiving finished materials from international centers. They would prefer, in most cases, to stop their relatively expensive research programs (which are never competitive with those of big companies). In this sense, the decision of providing finished material would go against national development instead of helping national research.

Y.L. Nene

On the question of making seed available to any organization wanting it, I wish to share ICRISAT's experience in India. After several discussions, we have come to an understanding that whenever ICRISAT provides seed of any of the five mandate crops to any non-government seed agency, the concerned official of the Indian Council of Agricultural Research must be informed by ICRISAT. This arrangement is to avoid any indiscriminate use of the seed obtained from ICRISAT. The arrangement has been working well.

Proceedings of the International Workshop on Faba Beans, Kabuli Chickpeas, and Lentils in the 1980s (Saxena, M.C. and Varma, S., eds.), ICARDA, 16-20 May 1983, Aleppo, Syria.

Training and Communication Needs for Food Legume Programs

Habib Ibrahim
ICARDA, P.O.Box 5466, Aleppo, Syria

Training and communication efforts have always been an integral part of the activities of the Food Legume Improvement Program at ICARDA. Training of,and exchange of information with food legume scientists in the national programs is viewed as complementary to the research efforts. The food legume training and communication activities are undertaken to:

1. Provide food legume research workers with training opportunities leading to better knowledge of crop improvement strategies and improved technical research skills.

2. Strengthen the network of food legume research workers.

3. Bring together research workers to discuss problems and exchange ideas on the improvement of food legume research.

4. Assess the food legume research efforts needed in the ICARDA region in terms of manpower development and information dissemination.

To achieve these objectives the Food Legume Improvement Program (FLIP) directs its efforts to the following activities:

a. Training of research workers in group courses or as individuals.

b. Production of publications, newsletters, educational and publicity materials.

c. Organization of workshops, conferences, seminars, and field days.

Training 1978-1982

During the period 1978-82 training of food legume research workers at ICARDA focused mainly on group courses, with the main emphasis being placed on middle-level research personnel from the national programs of the region. Table 1 shows the relative emphasis (in terms of time and resources) given to the different food legume training activities during this period. The different courses are described in a later section. The relative emphasis on each course and allocation of resources will change in the future, as is discussed later. We hope that the deliberations at this workshop will help determine the future pathway.

Table 1. Relative emphasis in food legume training activities, 1978-1982.

Training activity	Emphasis (%)
Six-month residential course	75
Short specialized courses	10
Individual training	5
Degree training	5
In-country courses	5

Table 2 shows the numbers of persons trained during 1978-82, by country and training course

FLIP has implemented the recommendations for training made at the Food Legume Improvement and Development Workshop held at the University of Aleppo in 1978. Achievements of the training efforts of ICARDA are evident in the strengthening of the network already built by the ALAD (Arid Land Agricultural Development) program. The network now has scientists from as far as China in the East and Chile in the West. Other achievements include the development of a package of technical manuals, both in English and Arabic.

Relationships with the various donors and regional programs have been strengthened. The support for training from international and regional organizations has increased progressively. The following donors and organizations have contributed funds for training during 1978-82:

Donor agency	Training activity
IDRC	Six-month courses
GTZ	Six-month courses/Ph.D. students
USAID	Six-month courses
AOAD	Six-month courses
IBPGR	Food Legume Germplasm short course
IFAD	Nile Valley Project short courses/M.Sc.,Ph.D. students
Arab Fund for Econ. and Soc. Develop.	Six-month courses
The Netherlands Govt.	Seed Production courses
Ford Foundation	M.Sc./Ph.D students

Table 2. The number of food legume workers trained at ICARDA, 1978-1982.

Country	Six-month courses	Short courses	In-country courses	Individual training	Degree training
North Africa					
Tunisia	5	1			
Morocco	4	1			
Algeria	3	2			
Libya	1				
Nile Valley					
Egypt	2	2			
Sudan	5	1	17		
Ethiopia	2				
West Asia					
Syria	14	5			
Lebanon	3	1			
Jordan	4	1			
Iraq	1				1
Turkey	4			5	
Afghanistan	2	1			
Iran	2				
South Yemen					
N.Yemen					
Indian Subcontinent					
Pakistan	3	3			
India	1				
Bangladesh	2				
Latin America					
Chile	2				
South-east Asia					
China	1				
Europe		2			4
	61	20	17	5	5

Training Priorities

As mentioned earlier, one of the main objectives of the FLIP at ICARDA is to increase the capacity of national programs to conduct research. Training plays a key role in this respect. National research institutions (research departments and universities) are given first priority in training. Thus, the emphasis of the training activities is on improvement of research skills. Training in the dissemination of technical innovations, directed towards extension workers and farmer leaders, is addressed but with far less emphasis. Training is also given in different specialized areas, e.g. seed production and technology, as the need arises, usually in conjunction with other ICARDA programs.

Organization and Structure

The organization and structure of training has recently been changed within ICARDA in order to strengthen training activities. During the period 1978-82 the Training and Communications Program shouldered the responsibility for training, in close coordination with crops research programs. As of 1983 this has been changed, whereby training is now an integral part of the research programs. Within each program there is a senior scientist coordinating training activities, and a system has been established for the overall coordination of training activities across the programs. This system is led by a Head of Training, assisted by a team of support staff to take care of administrative and logistic matters.

Food Legume Training Options

The training opportunities offered by the FLIP range from group courses to individual training. The strategy of the program is to move towards diversification of activities by encouraging individual training, including the participation of senior scientists from national programs and students working for higher degrees, while maintaining an intensive effort in group courses directed towards junior scientists and field technical staff. We hope that discussion in this workshop will lead to the understanding of the manpower needs of the region and individual national programs, so that training can be matched to those needs. The aim of the diversification of training activities is to further expand the network of cooperators to include senior scientists and, if possible, directors of legume research projects.

The Six-Month Residential Course

This course is held annually during February to July, thus covering most of the cropping season period. The course covers aspects of improvement techniques in faba beans, lentils, and chickpeas. It emphasizes field training, with some theoretical coverage as background information. The candidates for this course, who usually number about 15-18, have B.Sc. degrees, or are technicians working in legume research within their national programs. In addition to the general coverage, each trainee is given individual attention so that specific needs, as given by national programs, are met.

Short Courses

Specialized short courses, of two to three weeks duration, are offered, such as the Food Legume Germplasm Training course held at Aleppo during 1982, sponsored by the International Board for Plant Genetic Resources (IBPGR). Candidates for short courses are scientists and their support staff who work in the discipline covered by the course. Their qualifications range from B.Sc. to higher degrees.

In-country short courses are also offered, usually upon request from national programs. In-country courses may cover a whole subregion or a single country. An important feature of these courses is the input from national program scientists in the conduct of the training. ICARDA provides the coordination of the course and training materials. ICARDA scientists also participate as necessary. In-country courses have been held in Sudan and Egypt as part of the training activities within the ICARDA/IFAD Nile Valley Project on faba beans. Such courses are planned for 1984 in Pakistan.

Non-Degree Individual Training

To expand the network of researchers and to provide opportunities for scientific interaction with colleagues at ICARDA, senior scientists from the national programs of the region visit ICARDA for varying periods, and, if possible, conduct research jointly with ICARDA scientists.

Candidates in this category are those conducting legume research in their national programs. Persons attending such training sessions are designated as "Training Research Associates" or "Senior Research Fellows," according to seniority and experience.

Degree Training

ICARDA provides facilities for students registered for higher degrees to conduct their thesis research at the Center on research projects related to the Center's mandated food legume crops and areas of interest. M.Sc. students are referred to as "Research Scholars," while those working for Ph.D. as "Research Fellows."

Funding

Funding for training activities comes from various sources, including scholarships from international or regional donor agencies and government institutions. Such institutes and agencies are encouraged to contact the Food Legume Improvement Program to arrange for the training of food legume scientists in any of the options stated above. A limited number of scholarships are also offered by ICARDA with a view to strengthening the research capability of the national programs in the region and in countries which are important producers of ICARDA's mandated food legume crops.

Educational Material

During 1978-82 intensive efforts were made in the production of educational material. Many technical manuals have been published, covering various aspects of crop improvement and production such as breeding, genetics, pests, and diseases. Other support topics such as statistics and seed production are also covered. These and other ICARDA publications are given to trainees for use during the courses and as reference material when they return to their countries.

Efforts are being made towards providing a complete range of manuals and handbooks. The manuals on breeding, diseases, and pests, which were produced 4 years ago, are being updated. The technical manuals produced are oriented to practical aspects of the subjects covered. Theoretical coverage is mainly intended to supplement field activities. Many of the manuals and most of our educational materials are available in English and Arabic.

As of 1983 audio-tutorial modules have been produced and given to the trainees as part of the educational package. The modules, comprising a slide set and narrated script, are used by the trainees individually or collectively. Trainees are encouraged to take these modules and use them in the development of training activities at their research stations. This should encourage the development of trainers.

Training Needs of National Programs

It has always been the policy of FLIP to tailor its training efforts to the needs of the countries in the ICARDA region, and elsewhere. Exchange of visits by scientists from ICARDA and national programs is important in understanding the training needs of those countries and in directing our training efforts to meet those needs. In addition to these visits, correspondence and direct requests from collaborators and donor agencies have also assisted in the development of training at ICARDA.

As mentioned earlier, training efforts within FLIP will be diversified to include various categories of trainees. This necessitates improvement in the identification of training needs and candidates in the future. The program training officer will visit the different subregions to obtain information about manpower development and to develop contacts with research and training departments.

Assistance to National Training

A few national programs conduct in-service training programs for their staff. The FLIP views in-service training as very important and will extend all possible assistance, within its resources, to national research programs that request it.

Assistance to national program training can take many forms. Country-oriented in-service courses can be offered by ICARDA upon request from national research institutions. By involving training department staff and scientists from research institutions, ICARDA helps them to plan and conduct such courses on their own in future.

Training food legume research scientists in training methodologies (training the trainer) will start in 1984. Ex-trainees at ICARDA or training department staff from research institutions will be invited to join the training team at ICARDA and participate in the planning and execution of courses at Aleppo. Experience gained thereby will hopefully allow these national programs to start their own training efforts.

To further assist national training efforts ICARDA will provide educational material such as technical manuals, visual aids, and relevant ICARDA publications. ICARDA may also assist, within limits and upon request, in the planning and coordination of such courses. Cooperative training efforts with the Syrian national research program are already proving very effective.

Follow-up

The Food Legume Improvement Program views support given to the trainees after returning to their countries as vital. It is important in strengthening the capacity of the national research programs and the buildup of the network among food legume scientists.

Questionnaires are sent to former trainees and their supervisors to get information about the usefulness of the training given, and to obtain feedback which may help ICARDA to improve its training methodologies.

During visits by ICARDA food legume scientists to countries with which we collaborate, ex-trainees, their supervisors, and national training units will be contacted to explore avenues for further cooperation.

Information and publications are mailed to the ex-trainees. Manuals,visual aids, and certain general ICARDA publications will be sent to the various categories of trainees, based on the need of each group.

It is envisaged that in the near future a selected group of ex-trainees may be called to Aleppo for an informal seminar. During this exercise it is hoped to update the knowledge of the participants in the new developments at ICARDA and further strengthen the network.

Exchange of Information

The production of technical publications receives high priority in FLIP. In addition, information is exchanged via such forums as workshops and seminars. The program has created information services for faba bean (FABIS) and lentil research workers (LENS), with generous support from IDRC (International Development Research Centre). The program also collaborates closely with ICRISAT in the production of a chickpea information service. These services aim to:

1. Provide a forum for food legume scientists to publish research results. The newsletters provide a rapid means of exchange of such results.

2. Provide bibliographies and reference reprints.

3. Publish news about scientists and organizations.

4. Make announcements about varieties or other related requests.

The following publications have been produced:

FABIS

1. FABIS Newsletter, issues No. 1-7.
2. Faba Bean Abstracts, Vol. 1-3. Published by the Commonwealth Agricultural Bureaux (CAB) for FABIS.
3. Genetic Variation within *Vicia faba*.
4. Directory of World Faba Bean Research.

LENS

1. LENS Newsletter, Vol. 9, 10(1), 10(2). Produced jointly with the University of Saskatchewan.
2. Lentil Abstracts Journal, Vol. 1 and 2. Published by the Commonwealth Agricultural Bureaux for LENS.

Conferences and Workshops

Since 1978 FLIP has organized a series of workshops and seminars, listed below. These meetings have provided a good forum for technical discussions and the formulation of future research strategies. The following is a list of such activities held so far:

1. Food Legume Improvement and Development Workshop, Aleppo, 1978.

2. Lentil Seminar, Aleppo, 1979.

3. Ascochyta Blight and Winter Sowing of Chickpeas, Aleppo, 1981.

4. The International Faba Bean Conference, Cairo, 1981.

5. Descriptors Meeting for Faba Bean and Lentil, Aleppo, May 1982.

Discussion

C. Bernier
You indicate you have provided follow-up after trainees return to their countries. Can you tell us then how many are still involved in legume research after one year?

H. Ibrahim
The Food Legume Improvement Program has information about many of the trainees. The program is in contact and collaboration with some of them. Still the systematic follow-up as detailed in the paper is just starting as of 1983. In a years' time we can be in a position to give detailed data and its analysis about the situation of retention of legume trainees in legume research.

Proceedings of the International Workshop on Faba Beans, Kabuli Chickpeas, and Lentils in the 1980s (Saxena, M.C. and Varma, S., eds.), ICARDA, 16-20 May 1983, Aleppo, Syria.

Ninth Session

The ICARDA/IFAD Nile Valley Project on Faba Beans

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Faba beans are a staple food item for a large proportion of the population of Egypt, and are commonly eaten throughout much of Sudan, especially in the north. In Egypt, per capita consumption in 1976 was estimated at nearly 9 kg a year. Cereals account for nearly 68% of the per capita protein intake, while pulses (of which faba beans is the major crop in the Nile Valley) account for around 10%. This, however, belies much of their value in terms of enhancing dietary protein quality. This is of special importance for the poorer sections of the population in both Egypt and Sudan who can rarely afford to eat animal protein.

To supplement local production, Egypt has had to import faba beans from Ethiopia, Poland, Morocco, England, and Canada. These imports are expensive and, in some years, difficult to find at any price. Sudan imports only small amounts because of the shortage of foreign exchange, so the Sudanese must depend on local production.

Area and Production of Faba Beans in Egypt and Sudan

In Egypt, faba bean production has fallen in recent years. Area planted to the crop for dry bean consumption decreased from a 10-year average of 147,860 hectares during 1961-70 to 110,953 hectares during 1971-80. This was due to several factors, though mainly due to competition from other winter crops such as wheat and Egyptian clover (berseem). At the same time there has been an increased demand from a rapidly growing population. Egypt imported 37,000 tonnes of faba beans in 1980 to help meet this demand.

With less land devoted to the crop, it is more important than ever that researchers find ways of increasing yields. In Eygpt, approximately 30% of the faba bean acreage is in the Nile Delta, 45% in Middle Egypt, and 25% in Upper Egypt. Approximately 200,000 Egyptian farmers, most of them with small holdings, grow faba beans.

Sudan, in contrast, has enjoyed an increase in both the area planted and the amount of faba beans produced. The largest production comes from the Northern and Nile provinces, with small amounts from the Khartoum and Gezira provinces. In the 10-year period 1961-70, the area planted to faba beans averaged only about 8,500 hectares, but in the following 10-year period the area has doubled. The area planted in 1979/80 was the largest ever at more than 20,000 hectares with a production of 38,000 tonnes.

There has been a long and erratic process of expansion of the faba bean area in Sudan over the past 20 years, during which the yield increased from an average of 1371 kg/ha in the 1960s to 1719 kg/ha in the 1970s. Despite this progress, the demand for faba beans in Sudan is so high that the prices rose to an unprecedented level of LS 540/ardab (about LS 3/kg) during 1983. The government was forced to import considerable quantities from Egypt, Spain, and Turkey and to fix the price at LS 270/ardab (about LS 1.5/kg), which is still a high price for a supposedly cheap source of protein.

Constraints to Faba Bean Production in the Nile Valley

With the exception of certain diseases, many of the major constraints to increasing production are similar in Egypt and Sudan. Chocolate spot (*Botrytis fabae*), rust (*Uromyces fabae*), and the parasitic Angiosperm broomrape (*Orobanche* spp.) are considered to be the main pathological problems in Egypt, while powdery mildews (*Erysiphe polygoni* and *Leveillula taurica*) and viruses are more serious in Sudan. Root rot, wilt diseases, insect pests, weeds, and salinity have all been identified as causing considerable losses both in Egypt and Sudan.

Experimental results both in Egypt and Sudan have clearly indicated possibilities for a dramatic yield increase through the use of improved cultivars and agronomic practices. Yields obtained on experimental stations are frequently 50 - 100% higher than those obtained by farmers.

Agronomic studies have resulted in clear recommendations for many of the components of production, and it is believed that the national yield levels can be raised substantially by application of an appropriate package of practices. There is, however, a need for extensive testing of the recommendations at the farmers' level to ensure their relevance to real farm situations. The development of a strong "on-farm" testing program was thus urgently needed to provide both a means of extending appropriate practices to the farming community and to provide feedback to researchers on the suitability of recommended cultivars and production technology.

Objectives of the Nile Valley Project

After detailed studies of the magnitude of the problems involved in increasing the productivity of grain legumes in Egypt and Sudan, ICARDA came to the conclusion that it would not be possible to handle the problems from the center's location at Aleppo, nor from its core program budget. Consequently, the Nile Valley Project was initiated with funding from IFAD (the International Fund for Agricultural Development). The first 3-year phase, from July 1979 to June 1982, has now been completed, with a total contribution of $3 million from IFAD. The second phase is under way, with a further commitment for support from IFAD.

The overall aim of the Project is to improve productivity of faba beans in Egypt and Sudan. To achieve this the project aims to:

1. Test recommended cultivars and practices on farmers' fields in order to evaluate both the practicality and potential contribution of these recommendations at the farm level and to provide feedback for further research.

2. Conduct back-up research in order to improve current recommendations and to find solutions to problems identified in on-farm tests and field surveys.

3. Encourage a multidisciplinary approach to research and increase collaboration between research organizations involved, both within, and between, Egypt and Sudan.

4. Strengthen and upgrade the capabilities of the national scientists through training, study tours, consultancies, meetings, seminars, and literature exchange.

5. Upgrade and strengthen the national programs' capacity by providing funds for key research facilities such as seed stores, greenhouses, and screen cages.

Strategy for Project Operation and Execution

ICARDA has adopted a unique strategy in project execution and operation. It is unique in that, unlike most other national/international projects, the leadership, coordination, program planning, and execution are the responsibility of senior scientists from the two countries. It is also unique in involving national and international research and development organizations and their personnel. Funds from IFAD, which are channeled through ICARDA, are used for the capital and operational component of the project. The project provides funds for certain support staff and equipment, as well as honoraria for scientists on contract.

As there are no full time ICARDA scientific staff serving the project, the center's role is largely catalytic, providing back-up at scientific, technical, logistical, and administrative levels. Other agencies are involved on a cooperative and complementary basis, including the International Development Research Centre (IDRC) of Canada, which supports legume development programs in both Egypt and Sudan, and the German Technical Agency (GTZ) which also supports legume research at the Universities of Cairo and Alexandria.

The work in the project is carried out by a multidisciplinary team of national scientists drawn from different institutions. ICARDA staff from its headquarters and Cairo office provide the logistical and technical support. During the last year of the phase one (1981/82), 13 senior scientists (plus about 22 supporting scientists) from Egypt, drawn from eight research institutes were engaged in project activities. During the same period, in Sudan, 15 senior scientists (plus about five supporting scientists) from five research centers and Khartoum University were working with the project.

National scientists in the Nile Valley Project represent many different disciplines, including plant breeding, agronomy, soil fertility, plant physiology, entomology, plant pathology, weed control, water management, economics, and human nutrition. Another important feature is the direct involvement of researchers, extension workers, and farmers in the on-farm trials. The farmers' knowledge of the local situation is used to the fullest extent, and they are linked in a working relationship with the extension workers and scientists from their national and regional experimental stations. In turn, national and ICARDA scientists are brought into close contact with farmers to understand their needs, aspirations, and problems.

Field Activities

Field activities can be broadly divided into two categories:

On-farm research. Work is carried out on farmers' fields to evaluate certain test factors, which in previous studies were found to contribute significantly to yield increase. Some of these trials are executed solely by farmers, under the supervision of scientists. Others are jointly managed by farmers and scientists. The objective is to ascertain the contribution of each factor, alone or in combination, to yield increases under farm conditions.

Back-up research. Work is mainly carried out on research stations under strict supervision of the scientists concerned, to evaluate factors such as new cultivars, plant protection measures, and agronomic practices, which are likely to contribute to yield increases.

Sites of these activities in the two countries are shown in Fig. 1.

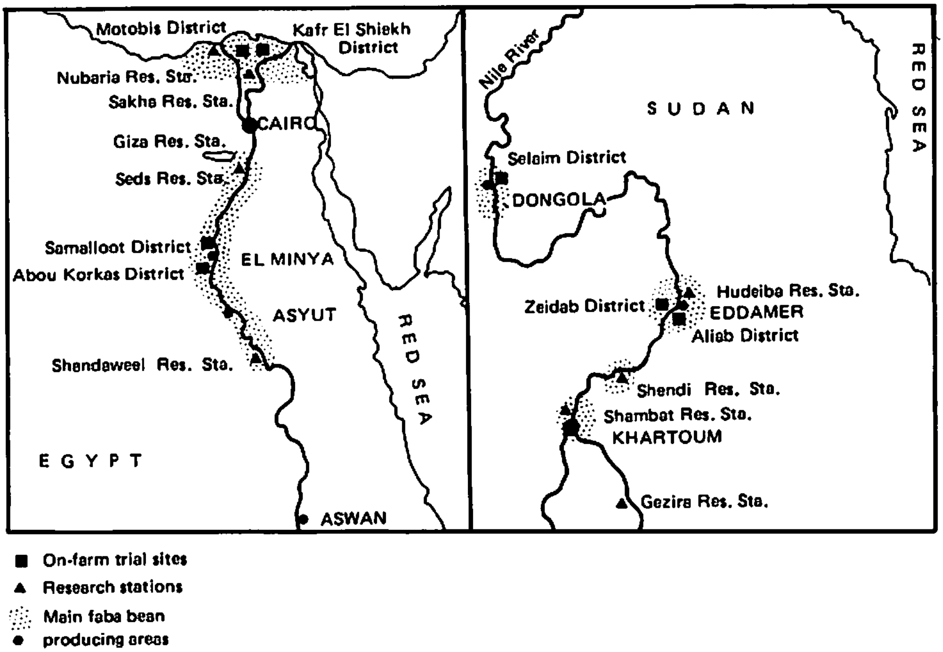

Fig. 1. Major faba bean production areas in Egypt and Sudan, experimental stations involved in the Nile Valley Project, and the location of on-farm trials.

On-Farm Research

On-Farm Trials in Egypt

The on-farm trials were carried out at 26 sites in Minia in 1980, and at 30 sites each in Minia and Kafr El Sheikh during 1981 and 1982. Ten factors (plant population, N and P fertilizers, watering regimes, cultivars, weed control, disease control, micronutrient application, tillage, potassium application, and Orobanche control) were tested at different levels and in combinations in the two provinces. Highlights of the results obtained are summarized below.

Plant Population and Fertilizer

The factors were tested at recommended and farmers' levels. The recommended level of plant population was 41.7 plants/m^2 (1980) and 33.3 plants/m^2 (1981 and 1982). Fertilizers were applied at the rate of 35.7 kg N/ha and 71.4 kg P_2O_5/ha.

On average, the farmers' levels of plant population were 18.8 and 29.6% lower than the recommended levels in Kafr El Sheikh and Minia Provinces, respectively. In Kafr El Sheikh 31 and 19% of the farmers did not apply phosphorous and nitrogenous fertilizers, respectively. Corresponding figures for Minia were 27 and 80%. On average, phosphorous fertilizer levels of Minia farmers were closer to the recommended level than those of Kafr El Sheikh farmers. Differences in seed and straw yield between farmers' and recommended practices are presented in Table 1.

Table 1. Differences in seed and straw yield between recommended and farmers' levels of inputs.

Crop season	Minia				Kafr El Sheikh			
	Seed		Straw		Seed		Straw	
	t/ha	%	t/ha	%	t/ha	%	t/ha	%
	Plant population effect (Pr - Pf)							
1980	0.27*	10.1	0.81	15.4				
1981	0.43	14.8	1.03*	20.3	-0.02	-0.5	0.36	6.1
1982	0.35*	10.2	0.70*	14.4	0.16	6.1	0.57*	13.8
Average	0.37	12.0	0.85	16.9	0.07	3.1	0.47	10.7
	Fertilizer effect (Fr - Ff)							
1980	0.22	8.2	0.37	6.7				
1981	-0.12	-3.8	0.20	3.7	0.28*	7.4	0.30	5.1
1982	-0.02	-0.5	-0.07	-1.3	0.30	11.4	0.50	11.0
Average	-0.01	-0.1	0.12	2.2	0.29	10.2	0.43	8.7
	Combination effect (PrFr - PfFf)							
1980	0.45	19.8	1.18	20.9				
1981	0.31	10.5	1.23*	24.7	0.25	6.5	0.66	11.3
1982	0.34	9.8	0.73*	14.4	0.43*	16.3	0.99*	22.1
Average	0.35	11.5	1.01	24.9	0.37	12.4	0.89	18.1

P = Plant population
F = Fertilizer
r = recommended level
f = farmers' level
* Significant at 0.05 levels.

The lesser response to the recommended level of plant population in Kafr El Sheikh can be attributed to the fact that in this province the farmers' level was close to the recommended level.

No significant response to recommended fertilizer levels was recorded in Minia, while in Kafr El Sheikh in 1981 the recommended fertilizer level produced a significant increase in seed yield of 0.28 t/ha (7.4%).

In combination, recommended plant population and fertilizer rates significantly increased straw yield in Minia in 1981 and 1982, while in Kafr El Sheikh seed and straw yields were significantly increased in 1982. The differences between the two governorates as well as between the two seasons could be ascribed to variation in soils content of N, P, and other macro and microelements, weed competition, and interaction with different irrigation regimes practiced by farmers.

Irrigation

The effect of irrigation practice was tested in Minia in 1980 and 1982. Farmers applied first watering on an average 49.5 days after planting, against 34.3 days at the recommended level. This delay resulted only in one irrigation before the canal closure on 1 January as compared to two waterings at the recommended level.

The effect of irrigation was not independent of plant population and fertilization (Fig. 2). The seed and straw yields were greatest when all three factors were at the recommended levels, giving an increase of 1.41 t seed/ha (53.4%) and 2.18 t straw/ha (55.3 %). The increase due to watering regimes was much lower when farmers' levels of plant population and fertilization were applied, at 0.17 t seed/ha (6.4%) and 0.43 t straw/ha (10.9%).

Orobanche Control

At three Orobanche infested sites in Minia, the tolerant faba bean cultivar, F 402, gave increases in seed and straw yields of 0.67 t/ha (18.4%) and 1.41 t/ha (24.1%), respectively, over the susceptible cultivar, Giza 2 (Table 2). Spraying twice with glyphosate herbicide increased the seed and straw yields of Giza 2 by 0.88 t/ha (24.1%) and 0.95 t/ha, respectively, as compared to the untreated control (Table 2).

Delaying sowing by one month, to mid-November, reduced Orobanche infestation and increased the seed yields of both F 402 and Giza 2. F 402 outyielded Giza 2 by 0.40 t seed/ha (8.8%) and 0.48 t straw/ha (8.4%).

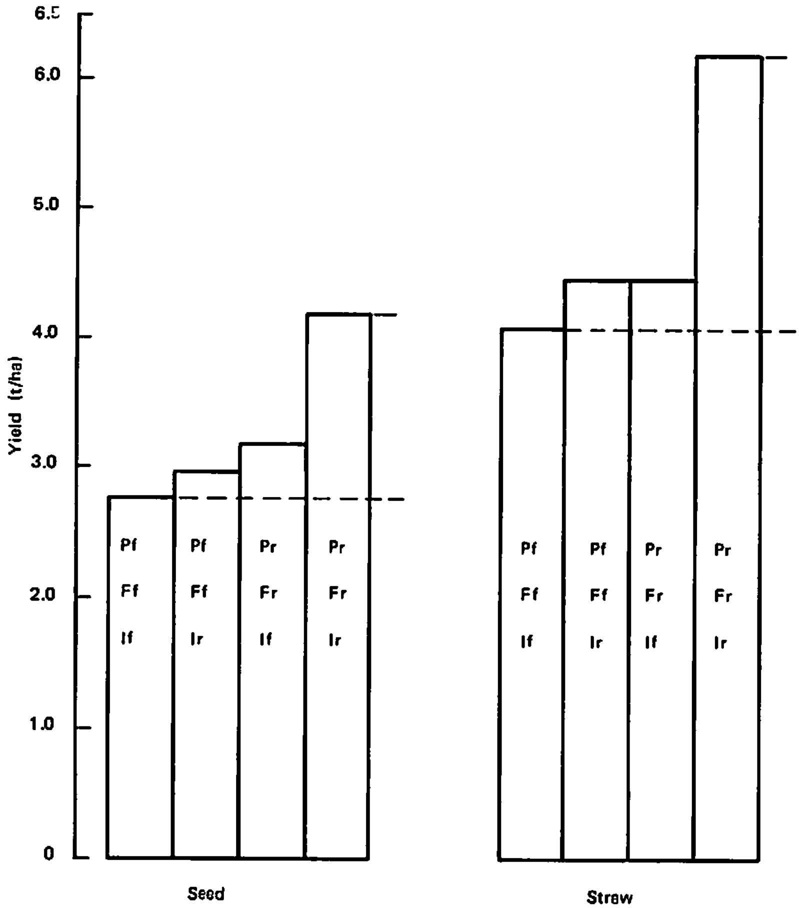

Fig. 2. Effect of irrigation regime (I), fertilizer application (F), and plant population (P) on seed and straw yields of faba bean in Minia, 1982 (f = farmers' level; r = recommended level).

Sowing in non-tilled soil decreased parasite infestation and F 402 gave an increase of 0.43 t/ha (10.4%) in seed yield and 1.27 t/ha (20.6%) in straw yield over Giza 2 in untilled soil (Table 2).

Table 2. Effect of varieties under different chemical treatments, sowing dates, and tillage systems on faba bean yield in Minia[1] (1981/82 season).

	Seed yield (t/ha)		Straw yield (t/ha)	
	Giza 2[a]	F 402	Giza 2	F 402
Glyphosate[2]				
0	3.65	4.32	5.86	7.27
2 sprays	4.53	4.70	6.81	7.65
3 sprays	4.03	4.67	6.16	7.52
Mean	4.07	4.56	6.28	7.48
Sowing date				
15 October	3.58	4.17	6.87	8.78
15 November	4.56	4.96	5.69	6.17
Mean	4.07	4.57	6.28	7.48
Tillage				
No tillage	4.15	4.58	6.17	7.44
Tillage	3.99	4.54	6.39	7.52
Mean	4.07	4.56	6.28	7.48

1 Results taken over three sites with average infestation rates of 97.6, 139.5, and 65.5 kg/ha of air-dry *Orobanche* spikes at bean harvest.

2 Glyphosate applied at rate of 64 g a.i./ha; first spray applied at start of flowering, second and third sprays at three-week intervals.

a Giza 2 susceptible and F 402 resistant to *Orobanche*.

Effect of Additional Factors on Yield

Varieties. During 1982 in Minia, line 109/70/74 gave an average grain yield increase of 0.61 t/ha (15%) over Giza 2 across three sites. In Kafr El Sheikh, line 130/1881/76 gave an average increase in grain yield of 0.24 t/ha over Giza 3 at three sites.

Micronutrient application. Ezablex, containing Iron + Zinc + Manganese, was sprayed twice at the rate of 0.1 g in 100 ml water/m^2 at one month after planting and before flowering at all 30 sites in Minia and Kafr El Sheikh in 1982. The overall effect on seed and straw yields was negligible.

Tillage systems. The effect of zero-tillage on the yield of faba beans following various summer crops was tested. Following cotton or corn in Minia, little effect of tillage practice was observed. However, following rice in Kafr El Sheikh, soil tillage increased seed and straw yields by 0.2 t/ha (8.5%) and 0.3 t/ha (5.1%), respectively, averaged over five sites.

Diathane M 45 application for control of foliar diseases. The fungicide, applied at 250 g/100 liter water four times, starting around mid-January at two-week intervals in farmers' fields in Kafr El Sheikh, resulted in seed yield increases of 0.14 t/ha (3.5%) and 0.33 t/ha (11.1%) in 1981 and 1982, respectively. The straw yield increased by about 0.4 t/ha (7.0%) in both seasons.

Potassium application. In Minia 1982, under a zero-tillage system following corn, potassium application increased seed yield by 0.51 t/ha (11.7%) over four sites, and decreased yield by 0.54 t/ha (10.4%), over five sites following cotton. In tilled soils following either crop, potassium had no effect. In Kafr El Sheikh, following rice, potassium application decreased seed yield by 19.4% in non-tilled and 8.0% in tilled soil.

Zinc sulphate application. In Kafr El Sheikh in 1981, beans sown in untilled soil following rice responded to zinc sulphate applied at the rate of 23.8 kg/ha before planting. The average increases were 0.23 t seed/ha (6.8%) and 0.5 t straw/ha (10.1%), over four sites.

Rhizobia inoculation. This factor was tested at 16 sites in Minia and 14 sites in Kafr El Sheikh in 1981 with the recommended levels of all other agronomic factors applied. Very little effect of seed inoculation was observed in Minia and almost none in Kafr El Sheikh. The uninoculated crop was also well nodulated at all the places showing that the naturalized *Rhizobium* was quite effective.

On-Farm Trials in Sudan

On-farm trials were conducted in three major faba bean producing areas (Aliab, Zeidab, and Selaim) in the northern region. During the 1979/80 season, seven factors (sowing date, seed rate, planting method, irrigation, fertilizer application, weed control, and pest management) were tested in all possible combinations at recommended levels. Two checks, one of which was all factors at the low input level, were also included in the trial. A fractional factorial design was used during 1980/81 and 1981/82 to study the effect of the same seven factors at recommended and farmers' levels of input. The trials were conducted at a total of 25 sites.

The main findings for the three seasons were identical. Average seed yield of different treatment combinations and the mean effect of each in the three regions for 1981/82 are presented in Table 3. At Aliab, treatment 8 (all factors at the recommended level) gave the highest average grain yield of 2.5 t/ha, which was

Table 3. Average grain yield for each treatment combination and mean effect of each factor on grain yield, 1981/82.

	Factor combinations							Yield (kg/ha)		
Treatment number	Sowing date	Seed rate	Planting method	Irrigation	Fertilizer	Weed control	Pest control	Aliab	Zeidab	Selaim
1	-[1]	-	-	+	+	+	-	1978	2682	3068
2	-	-	+	+	-	-	+	2070	2664	2205
3	-	+	-	-	+	-	+	1876	2088	1983
4	-	+	+	-	-	+	-	1934	2133	2187
5	+	-	-	-	-	+	+	1518	2113	2825
6	+	-	+	-	+	-	-	1741	1651	1806
7	+	+	-	+	-	-	-	1928	2709	2216
8	+	+	+	+	+	+	+	2511	2724	3115
9	+	-	-	-	-	-	-	1779	1924	2004
SE±								81	112	234

	Effect of factor (kg/ha)						
Aliab	- 40	+236**	+239**	+355**	+164*	+ 82	+ 99
Zeidab	- 93	+136	-105	+699**	-119	+135	+104
Selaim	+130	-101	-195	+451*	+135	+746**	+213

1. + = recommended level
   - = farmers' level

*,**,and *** refer to significance at 0.05, 0.01 and 0.001 level of probability.

significantly higher than all the other treatments. The recommended levels of seed rate, method of planting, irrigation, and fertilizer application significantly increased seed yield at Aliab, by 236, 239, 355, and 164 kg/ha, respectively. The yield gap between the improved management and farmers' practices was of the order of 732 kg/ha (62%).

The highest average grain yields at Zeidab were given by treatments 8, 7, 1, and 2 in descending order, although the differences among these four treatments were not significant. Examination of the separate effects of the main factors shows that frequent irrigation resulted in a large and significant increase in grain yield. However, no other factor significantly increased yields. All factors at the improved level increased yields by 0.8 t/ha over the farmers' practice.

At Selaim only weed control and irrigation produced significant increases in seed yield. The yield gap between the recommended and farmers' practices was 1.1 t/ha.

Back-Up Research

During phase one a total of 122 and 53 trials were carried out in Egypt and Sudan, respectively, in 10 different disciplines (Table 4). Each of these trials was carried out at three to four sites. The results of these trials are summarized by Saxena and Stewart (1983).

Table 4. Numbers of trials/studies carried out during phase one.

	Egypt			Sudan		
	1979/80	1980/81	1981/82	1979/80	1980/81	1981/82
On-farm research	3	5	4	1	1	1
Back-up research						
Agronomy	5	5	5	1	4	5
Breeding	8	7	4		2	5
Entomology	1	7	6		1	3
Human nutrition		3	3		1	3
Microbiology	3	4	3	1	1	2
Pathology	4	9	7	2	2	2
Plant nutrition	2	5	5	1	2	1
Socio-economics	1	2	2		1	1
Water management	2	4	4	1	2	1
Weed and *Orobanche*	3	6	2	1	4	3
Total	29	52	41	7	20	26

Other Activities

In addition to on-farm and back-up research, a number of other activities are carried out in the project in order to increase the capabilities of national scientists and support staff, and to strengthen cooperation between scientists within and among institutions. These activities are:

Staff Education and Training

Six national program scientists (three each from Egypt and Sudan) are currently undergoing postgraduate training (five Ph.D. and one M.Sc.) in UK, USA, and Canada.

Eighteen research workers from Egypt and Sudan visited ICARDA at Aleppo, Syria, for training courses (one week to six months) during phase one. A special training course on faba bean production and improvement, taught by national program scientists and coordinated by ICARDA's Food Legume Training Officer, was held at Hudeiba Research Station in Sudan in 1982. It was attended by 14 research technicians from Egypt and Sudan.

Senior national scientists (two from each country) undertook study tours to UK, France, the Netherlands, and West Germany (7 - 10 days in each country).

A number of Egyptian scientists visit Sudan each crop season to see the project activities in that country and exchange views with their counterparts. Similar visits are made by Sudanese scientists to Egypt. Selected scientists from each country also visit Syria each year to see the ICARDA program. ICARDA scientists also visit Egypt and Sudan during each crop season for similar purposes.

Conferences and Workshops

Annual coordination meetings are held at the end of each crop season to discuss the results and to prepare the program of work for the following season. These meetings are held in Egypt and Sudan on alternate years and are attended by scientists from Egypt, Sudan, and ICARDA.

In March 1981, the project hosted the first International Faba Bean Conference, in Cairo. The conference brought together leading faba bean specialists from Egypt and Sudan, together with their counterparts from the Mediterranean, West Asian, European, and North American countries. There were nearly 150 participants, and some 50 formal presentations were made. The participants, from four continents, not only contributed their personal expertise, but gained from their experience of the Nile Valley conditions and from close contact with so many of the world's faba bean specialists. The proceedings of this conference were published (Hawtin and Webb 1982).

Consultants

Nine short-term consultants (one week to three months) were engaged by the project to study various aspects of improvement of faba beans in Egypt and Sudan and advise the national program scientists.

Publications and Reports

Based on the work carried out under the project by the national scientists and consultants, a total of 20 reports and publications have been prepared and distributed.

Field and Research Equipment and Supplies

In order to increase the national programs' research capacities, key research facilities such as seed stores, greenhouses, and screen cages for controlled pollination have been constructed. A wide range of field and laboratory equipment, and supplies has also been provided.

The project, in cooperation with Catholic Relief Services (CRS), developed a small multi-crop thresher/winnower for use on experimental plots. The small thresher is a simplified version of multi-cropper developed by CRS. The thresher is fitted with a funnel-shaped intake for single plant threshing. It can thus be used as a head thresher or a plot thresher. By changing a pully to either increase or decrease the drum speed the thresher can be used for all legumes and small grains.

Phase Two

Based on the progress made during phase one, IFAD has agreed to extend its support of the Project into phase two (1982-85), and has approved a grant of US $1.3 million for the first year of the 3-4-year phase. The emphasis in the second phase will be directed towards farmer-managed trials, on-farm trials, and extension. Back-up research will be continued on a limited scale and in certain disciplines. In Sudan, the project activities also include work on lentils and introduction of faba bean into new areas south of Khartoum.

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North African Regional Food Legume Improvement Program

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Amongst the food legumes, faba beans, kabuli chickpeas, and, to a lesser extent, lentils have long been important crops in the North African Region (NAR), making substantial contributions to farmers' incomes, human diets, and soil fertility. Although some portion of the faba bean crop is eaten green, the majority is utilized as dry seeds, as is the case for chickpeas and lentils. All three are used extensively in the preparation of soups and stews, especially during times of high-energy requirements.

Data from FAO on area, production, and yield of the three crops in Algeria, Morocco, and Tunisia during 1969-71 and 1979-81 are shown in Table 1. Libya has been excluded from the table as its production consisted solely of faba beans at around 4000 tonnes for the two periods. In the three countries shown, faba bean is clearly the most important crop, accounting for 50-67% of the total production of the three crops (Table 1), and 40-50% of the total legume production (Hamawi 1979). Chickpeas also account for significant percentage of the production, whereas lentils were only really significant during 1969-71 in Algeria (Table 1). However, there are recent indications that lentils are becoming more widely grown in Morocco. It is also worth noting that within the region which ICARDA serves during 1971-75 the North African countries accounted for 46.8% of the total faba bean production, and 25.4 and 8.9% of the total kabuli chickpea and lentil production, respectively (Hamawi 1979).

For all three crops the average seed yields showed considerable differences between the two periods (Table 1), which is considered to reflect differences in seasonal growing conditions. In spite of the fluctuations in both yield and production, Table 2 shows that in Tunisia and Morocco production in the past has been sufficient to statisfy local demand and allow a surplus for export, whereas Algeria was a large importer of chickpeas and lentils in the two years for which data are available. Information has yet to be obtained to ascertain whether these trends have continued in the

Table 1. Average production (x 1000 tonne), percentage contribution to total production, and average seed yields of faba bean, chickpea, and lentil in North Africa 1969-71 and 1979-81.

	Algeria				Morocco				Tunisia			
	1969-71		1979-81		1969-71		1979-81		1969-71		1979-81	
	P[1]	%[2]	P	%	P	%	P	%	P	%	P	%
Faba bean	19	50	28	60	196	69	106	67	20	65	52	63
Chickpea	11	29	16	34	71	25	40	25	10	32	29	35
Lentil	8	21	3	6	77	6	13	8	1	3	2	2
Yield (kg/ha)												
Faba bean	687		620		1093		627		395		692	
Chickpea	452		385		603		675		354		563	
Lentil	392		206		512		389		329		583	

1. Average production.
2. Percentage contribution to total production.

Table 2. Imports or exports of faba beans, chickpeas, and lentils in Algeria, Morocco, and Tunisia[1] as a percentage of production.

		Faba beans	Chickpeas	Lentils
Algeria:	Imports as % production			
	1974	3	13	3
	1975	1	47	83
Morocco:	Exports as % production			
	1960-64	47	52	51
	1965-69	47	65	46
	1970-74	44	49	78
Tunisia:	Exports as % production			
	1971	5	24	6
	1972	2	30	12
	1973	6	19	6
	1974	7	7	1
	1975	NA (2)	NA	NA
	1976	NA	61	26

1 Source: Food Legumes in Algeria/Morocco/Tunisia. A. Watson, ICARDA, Aleppo, 1980.
NA = Data not available.

past few years, but in all three countries population growth is tending to outpace agricultural production (Table 3). This, combined with a positive income elasticity of demand for each of the three crops, suggests that the present surpluses in Morocco and Tunisia may not last long, unless efforts are made to increase production; in Algeria this would appear to be an urgent problem.

Table 3. Compound growth rates for population and agricultural production in Algeria, Morocco, and Tunisia during 1960-70 and 1970-79.

	Algeria	Morocco	Tunisia
Population increase			
1960-70	2.9	2.6	2.1
1970-79	3.3	2.9	2.4
Agricultural Production			
1960-70	1.5	2.4	0.1
1970-79	0.0	0.6	0.7

Source: The World in Figures. Economist Newspaper Ltd., London, UK, 1981.

ICARDA's Cooperative Efforts in the North African Region

Until fairly recently research on food legumes has generally received less attention and funds than the cereal crops. This would appear to be true in countries in the NAR where there are only modest national research programs on legumes. Since ICARDA was founded in 1977 it has attempted to assist and cooperate with these programs through the distribution of a considerable range of genetic material and, more recently, material necessary to conduct a series of agronomic trials. Also, ICARDA food legume scientists have made regular visits to the national programs, and junior scientists from the NAR have undergone training at ICARDA.

Trial Distribution and Results from the NAR

During 1977/78 to 1982/83 ICARDA distributed 390 breeding trials and nurseries, and 135 agronomy trials to the national programs in the NAR. Full details of all the results reported to ICARDA from these trials have already been published for the 1977/78, 1978/79, and 1979/80 seasons (ICARDA 1978, 1981, 1982), and will soon be published for the 1980/81 season. Relatively few results have been received from the agronomy trials, but sufficient have been reported from the breeding trials to try to assess the effectiveness of ICARDA's breeding strategy for cultivar improvement in the NAR.

Tables 4, 5a, 5b, and 6 give summaries of the available seed yield results from ICARDA international breeding trials of faba beans, chickpeas, and lentils grown in the NAR from 1977/78 to 1981/82.

Table 4. A summary of seed yield results from Faba Bean International Yield Trials from 1977/78 to 1981/82.

Season	Country	Location	Trial[1]	CV %	NGT[2]	SHY[3]	EY[4]
1977/78	Algeria		BRPYT-L	17.6	21	0	3
	Tunisia			48.5	21	0	18
1979/80	Algeria	Sidi Bel Abbes	$FBIF_4T$	34.3	15	3	12
1981/82	Tunisia	Beja	FBIYT-L[5]	68.4	15	0	4
		Kef	"	37.0	15	0	4
		Beja	$FB1F_4T$	64.8	15	0	2
	Morocco	Douyet	FBIYT-L	16.3	15	0	0

1. BRPYT-L Broad Bean Regional Preliminary Yield Trial-Large Seeded.
   FBIYT-L Faba Bean International Yield Trial - Large Seeded.
   $FBIF_4T$ Faba Bean International F_4 Population Yield Trial.
2. NGT Number of genotypes tested (excluding the local check).
3. SHY Number of genotypes significantly ($P<0.05$) heavier yielding than the local check.
4. EY Number of genotypes that outyielded the local check but not significantly.
5. High infection levels of Botrytis fabae and Orobanche spp.

Faba Bean Results

For faba beans (Table 4) relatively limited data are available and the CVs reported are generally high. Significant improvements over the local check were limited to three F_4 populations at Sidi Bel Abbes in Algeria, and unfortunately no further results are available for following years on the performance of these populations. In all but one trial a number of genotypes outyielded the check, but the numbers were rather low.

Chickpea Results

Farmers normally plant chickpeas in spring in an attempt to avoid attacks of ascochyta blight. However, over the last few years work at ICARDA has shown that considerable yield advantages can accrue from winter planting if ascochyta blight can be controlled either genetically or chemically. Prior to the 1979/80 season only spring-sown trials were distributed, but beginning with the 1979/80 season trials for winter and spring planting have been available to national programs. The winter-sown trials comprise genotypes possessing resistance to ascochyta blight, and the results from the two sets of trials are given in Tables 5a and 5b and are dealt with separately below.

Table 5a. A summary of seed yield results from spring-sown chickpea International Yield Trials from 1977/78 to 1981/82.

Season	Country	Location	Trial[1]	CV %	NGT[2]	SHY	EY
1977/78	Algeria	Sidi bel Abbes	CRPYT	14.9	35	34	1
	Tunisia	Ras El Ain	"	27.8	35	15	17
1978/79	Algeria	Sidi Bel Abbes	CIYT	29.8	24	24	0
	"	"	CIF_3T	23.6	24	19	5
1979/80	"	"	CIF_4T	26.6	24	0	13
1980/81	Morocco	Merchouch	CIYT	35.8	24	0	18
	"	Zememra	CIYT	38.7	24	0	17
	"	Merchouch	CIYT-L	29.8	24	0	20
	"	Rabat	CIF_3T-A	47.0	24	1	8
	"	"	CIF_3T-B	26.6	23	0	0
	Tunisia		CIYT*		24	0	19
	"		CIY-L*		24		22
1981/82	Morocco	Douyet	CIYT-W	21.8	15	0	12
	"	Merchouch	CIYT-W	48.0	15	4	10
	"	"	CIYT-L	25.4	19	0	6
	"	Karia-Tissa	CIYT-L	21.8	19	0	15
	Tunisia	Beja	CIYT	21.0	23	3	13
	"	"	CIYT-L	23.7	19	3	14

1. CRPYT : Chickpea Regional Preliminary Yield Trial.
   $CIF_{3/4}T$: Chickpea International F_3/F_4 (population) Yield Trial.
   CIYT : Chickpea International Yield Trial.
   CIYT-L : Chickpea International Yield Trial (large seeded genotypes).
   CIYT-W : Chickpea International Yield Trial (ascochyta blight resistant genotyes).

* No statistical analysis.

2. See Table 4 footnotes.

Spring-sown Trials

In the 1977/78 and 1978/79 seasons a large number of genotypes and F_3 populations showed significant improvements over the local check in Algeria and Tunisia. However, it is noteworthy that of the 12

Table 5b. A summary of seed yield results from winter-sown chickpea International Yield Trials (CIYT-W) from 1977/78 to 1981/82.

Season	Country	Location	CV%	NGT[1]	SHY	EY
1979/80	Algeria	Khroub	15.1	9	7	1
1980/81	Morocco	Douyet	43.6	18	0	1
	"	Merchouch	19.4	18	0	3
	"	Zememra	24.9	18	14	3
1981/82	"	Douyet	34.0	15	0	14
	"	Merchouch	35.8	15	1	6
	"	Zememra	25.0	15	0	3
	"	Sidi Kacem	39.9	15	14	0
	"	T. Shaim	29.7	15	0	8
	Tunisia	Bourbia	22.5	15	5	9

1. See Table 4 footnotes.

Table 6. A summary of seed yield results from Lentil International Yield Trials from 1977/78 to 1981/82.

Season	Country	Location	Trial[1]	CV %	NGT[2]	SHY	EY
1978/79	Algeria	Sidi Bel Abbes	LIYT	14.5	24	0	0
1979/80	Algeria	"	LIYT-L	14.0	14	0	4
1980/81	Morocco	Merchouch	LIYT-L	20.5	14	4	4
	"	"	LIYT-S	22.9	23	0	7
	"	Douyet	"	36.7	23	0	18
1981/82	"	Merchouch	LIYT-L	65.0	14	2	11
	"	"	LIF_3T	8.5	17	3	6
	"	Sidi Laidi	LIYT-S	26.6	22	15	4
	"	Merchouch	LIF_3T-E	32.9	32	0	12
	Tunisia	Beja	LIYT-L	32.4	14	3	10

1. LIYT : Lentil International Yield Trial.
   LIYT-L : Lentil International Yield Trial-large seeded (>4.5g/100 seeds).
   LIYT-S : Lentil International Yield Trial-small seeded (<4.5g/100 seeds).
   LIF_3T : Lentil International F_3 (population) Yield Trial.
   LIF_3T-E: Lentil International F_3 (population) Yield Trial-early types.
2. See Table 4 footnotes.

populations common to the F_3 and F_4 trials in Algeria over two seasons, all significantly exceeded the local check in the first season but none did so in the second season. The reason for this change is not clear from the data available, and illustrates the difficulty in assessing the effectiveness of ICARDA's breeding strategy. Furthermore, the apparent success in the first two seasons was not repeated in the later seasons in Morocco and Tunisia, in which only few genotypes and/or populations significantly outyielded the local checks, although relatively large numbers showed non-significant yield increases over the local check.

Winter-sown Trials

Data from three seasons show that a number of genotypes significantly outyielded the local check in Algeria, Morocco, and Tunisia. However, it should be noted that the local check cultivars used in these trials rarely possessed resistance to ascochyta blight. Thus, under circumstances of ascochyta blight infection, the significant yield improvements evident may have reflected differences in ascochyta resistance rather than a higher seed yield potential _per se_. However, the much heavier seed yields obtained from winter-planting trials in all three countries has emphasized the necessity of introducing this practice to farmers and identifying the most suitable genotypes for local conditions.

Lentil Results

During the 1978/79 and 1979/80 seasons no significant improvements over the local check were evident in the two trials in Algeria. However, it is encouraging that in Morocco in both the 1980/81 and 1981/82, and in Tunisia in 1981/82, significant improvements were evident, and that relatively large numbers of other genotypes also outyielded the local check, though non-significantly.

General Considerations

The international yield trials reported above are the final stage of selection in the ICARDA legume breeding program. The promotion of genetic material to these trials is largely dependent on a superior seed yield performance in preliminary yield trials conducted in a relatively restricted area of the Near East (Jordan, Lebanon, and Syria). However, data published (and soon to be published) in the ICARDA international trial reports (ICARDA 1978, 1981, 1982) show that there is little, if any, similarity in genotypic performance for seed yield between locations in the Near East and in the NAR.

In spite of this constraint, the trial results show that in the NAR significant improvements for chickpeas and lentils have been achieved over the years. In the winter-planted chickpea trials in 1981/81 the seed yield of the three best genotypes showed large improvements over the local check in both Tunisia and Morocco, with the increase being statistically significant in Tunisia (Table 7a).

Again in all three trials the increase will have partly reflected the higher level of ascochyta blight resistance of these genotypes. In the spring-sown trials (Table 7b) similar large and significant increases were evident in Tunisia, but yield increases were lower and non-significant in Morocco.

Table 7a. Seed yield expressed as a percentage of the local check cultivar (%lc) of the three heaviest yielding chickpea genotypes in a winter-planted trial[1] in Morocco and Tunisia in 1981/82.

Country	Location	Genotypes	% lc	Trial cv(%)
Morocco	Douyet	ILC 183	202	NA
		ILC 200	200	
		ILC 195	194	
Morocco	Sidi Kacem	ILC 2548	253	NA
		ILC 195	267	
		ILC 3279	199	
Tunisia	Bourbia	ILC 2912	<u>175</u>[2]	22.5
		ILC 249	<u>158</u>	
		ILC 482	<u>156</u>	

1. CIYT-W: Chickpea International Yield Trial-winter.
2. Values underlined significantly exceeded the local check.
NA = Not available.

Table 7b. Seed yield expressed as a percentage of the local check cultivar (% lc) of the three heaviest yielding chickpea genotypes in a spring-planted trial[1] in Morocco and Tunisia in 1981/82.

Country	Location	Genotype	% lc	Trial CV(%)
Morocco	Merchouch	ILC 629	129	25.4
		ILC 134	123	
		ILC 613	115	
Tunisia	Beja	ILC 136	<u>189</u>[2]	23.7
		ILC 83	<u>150</u>	
		ILC 116	<u>146</u>	

1. CIYT-L: Chickpea International Yield Trial-large seeded.
2. Values underlined significantly exceeded the local check.

For lentils the increases were again larger in Tunisia than in Morocco (Table 8). Only one genotype significantly outyielded the local check in Morocco, while in Tunisia all three lines were significantly higher yielding. Interestingly, the genotype ILL 28 significantly exceeded the local check by a big margin in both countries indicating a good adaptation to environmental conditions in the NAR.

The results for faba beans are less encouraging with no genotypes significantly exceeding the local check in either Morocco or Tunisia. Indeed the seed yield of the best genotypes was only marginally better than the local check, except at Beja in Tunisia, where a very high CV made any interpretation of the results difficult. The lack of improvement is particularly unfortunate, as not only are faba beans the most important of the three crops in the NAR (Table 1), but also nearly 50% of the faba beans grown in ICARDA's mandated region are produced in the NAR.

The contrasting results for the three crops would tentatively suggest that the selection of widely adapted genotypes is feasible for chickpeas and lentils, but is and will be difficult for faba beans. If significant improvements are to be obtained in faba beans it would appear necessary to practise selection under local environmental conditions; such a system would also be likely to improve the selection efficiency, and hence yield advances obtainable, for chickpeas and lentils.

Early-generation population trials were initiated in an attempt to overcome the problem of differing environmental selection pressures, and which allows national programs to practise their own

Table 8. Seed yield expressed as a percentage of the local check cultivar (% lc) of the three heaviest yielding lentil genotypes in a trial[1] grown in Morocco and Tunisia in 1981/82.

Country	Location	Genotype	% lc	Trial CV(%)
Morocco	Merchouch	ILL 28	224(2)	65.0
		ILL 1042	188	
		ILL 4400	164	
Tunisia	Beja	ILL 28	253	32.4
		ILL 262	253	
		ILL 15	218	

1. LIYT-L: Lentil International Yield Trial-large seeded.
2. Values underlined significantly exceeded the local check.

selection in the best adapted populations. Unfortunately, the national programs in the NAR have not, until recently, been able to effectively utilize either these population trials or the improved material evident in the other trials. This is a reflection of a combination of too few scientists and technicians trained in food legume research and insufficient funds to develop the necessary research programs. Under such circumstances ICARDA's past efforts in trial distribution and brief scientific visits probably had little impact in assisting in the development and strengthening of the national programs.

As a result of the above considerations, and to try and more effectively assist the national programs, it was decided that a more direct involvement of ICARDA in North Africa was needed. Accordingly, a legume breeder, supported by a research associate, was posted to Tunisia in 1981, to both assist in the development of the Tunisian national program, and to lay the foundations of a regional program for the NAR.

Present and Future Strategy in the NAR

Initiation

At the start of the cooperative program in Tunisia there was little breeding material locally available. Accordingly, the program on the three crops was initiated in the 1981/82 season by growing a range of ICARDA international breeding trials and nurseries. The results from these trials have been given earlier. In the present season the best material is being tested in multilocation yield trials, while a further range of ICARDA-derived material is again being tested for adaptation to North African conditions. Work in Morocco and Algeria has initially involved visits to the research programs to ascertain both the constraints to production and the future ways in which ICARDA can best cooperate and assist in strengthening these programs. In the future it is hoped that more active cooperation will develop.

Constraints to production Priorities

Diseases and pests have been noted as recurrent problems in the NAR. This was highlighted in the first season in Tunisia, where the majority of the faba bean crop was destroyed by chocolate spot *Botrytis fabae*, and *Orobanche* is a well known and perennial problem. Symptoms of stem nematode (*Ditylenchus dipsaci*) were locally severe in some areas, and attacks by the stem borer (*Lixus algirus*) were found wherever plants were sampled; however, the economic importance of these last two pests has yet to be assessed. For chickpeas, ascochyta blight always poses a potential threat and a wilt/root rot complex also appears to be a relatively widespread problem. On the other hand, lentils appeared to suffer few disease problems, although an attack of *Sclerotinia* spp. was noted in experimental plots at one location following heavy rain, which caused lodging.

The above diseases have been noted in other countries in the NAR, but, as in Tunisia, their severity varies from year to year, and regular surveys will be necessary to ascertain the economic importance of the different diseases.

Priorities

With the above disease problems, combined with a lack of resistance/tolerance in the local cultivars and the annual fluctuations in environmental conditions, farmers' yields show large seasonal fluctuations. Thus, although increased seed yield is the ultimate criterion, it would seem that the first priority under these conditions is an improvement in yield stability by the incorporation of resistance to the major diseases into well-adapted genotypes. Resistance sources to a number of major diseases have been identified at ICARDA and are being assessed under local disease conditions in the NAR. At the same time such sources are being crossed with local cultivars, and the segregating populations will be screened locally. In the longer term it is envisaged that national crossing programs will develop while attempts are made to identify heavier yielding genotypes under disease-free conditions. As the cooperative program in Tunisia develops, it is foreseen that regional trials specifically for distribution in the NAR will be developed.

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Lentil Improvement in the Americas

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Lentil production has increased dramatically in the Americas since 1976 and this has resulted in increased research toward improved cultivars and management methods. The recent trend in most lentil producing countries in the Americas has been toward increased area sown, while average yields have remained static (Table 1). The lentil producing countries of the Americas, in order of importance in the early 1980s, include the USA, Canada, Argentina, Chile, and Columbia (Table 1), and, to a lesser degree, Mexico, Uruguay, Brazil, Equador, and Peru.

Regional research programs are under way in most of the important lentil-producing countries, though in nearly all cases resources and personnel are limited. This report summarizes past accomplishments, outlines current research status, and indicates prospects for lentil improvement in the Americas in the current decade.

Table 1. Lentil production in the Americas (from FAO 1980, and Nygaard and Hawtin 1981).

	Annual production (x 1000 tonnes)			Area ($\times 10^3$ ha)	Seed yield (kg/ha)	Relative change (%) 1969-71 to 1978-80	
Country	1961-65	1969-71	1978-80	1980	1980	Area	Yield
USA	25	37	59	53	1148	+ 79.3	-12.2
Canada	-	-	15	44	450	-	-
Argentina	11	11	29	40	875	+ 95.0	+35.2
Chile	13	10	26	53	507	+181.2	-10.2
Columbia	-	13	7	17	353	- 20.0	-32.1

Production problems in the USA and Canada differ markedly from those in South America. Production problems in the USA, currently the largest producer of lentils in the western hemisphere, but on the verge of losing that status to Canada, Argentina, Chile, or possibly all three, are critical but are being addressed by the ongoing research program. These problems include susceptibility to environmental stress (heat and drought) during critical fruiting periods, seed or pod shattering, and susceptibility to lygus bug and aphid attack (Summerfield et al. 1982b) and susceptibility to viruses (Muehlbauer 1978; Haddad et al. 1978). Susceptibility to environmental stress and diseases, particularly Ascochyta sp. (Morrall and Sheppard 1981), is also a problem in Canada. By contrast, diseases seem to be more critical in South America, where in Chile, Argentina, Brazil (Manara 1977), and other countries (Izquerdo and Morse 1975), rust (Uromyces fabae) has been responsible for low yields and sharply reduced production during the 1960s and early 1970s. However, production in South America has rebounded in response to strong market demand, though the disease problem remains. With these problems in mind, the objectives of the national research programs in the Americas have been as follows:

1. Yield improvement
2. Ascochyta blight resistance (Canada, in particular)
3. Virus resistance (USA)
4. Rust resistance (Argentina, Chile, and most of S. America)
5. Improved seed quality traits such as absence of mottling (USA, Canada, Chile, Argentina, and most others) and ability to not discolor in storage (Canada and USA).
6. MCPB herbicide tolerance (Canada)
7. Improved methods of weed control
8. Wild species collection and evaluation (USA)
9. Lygus bug control and possibly host plant resistance (USA)
10. Understanding the empty pod syndrome (USA and Canada)
11. Improved cooking quality
12. Stress tolerance (USA and Canada)
13. Improved dinitrogen fixation
14. Identifying optimum plant densities
15. Identifying optimum fertilizer use

Yield improvement as a universal goal has been approached primarily through population improvement and various breeding strategies. Indeed most improved cultivars to date are the result of pure line or mass selection and not that of hybridization (Table 2). While it is recognized that there is an upper limit to progress from pureline selection, the method has been instrumental in providing improved cultivars that, to a limited degree, have overcome certain localized problems, e.g. lack of cultivars adapted to the long growing seasons in Canada (Slinkard and Bhatty 1979; Slinkard 1981); overcoming the Vicia rogue problem in the USA (Muehlbauer 1982); and the need for earliness in Argentina (Riva 1975) and rust resistance in Chile (Tay et al. 1981). 'Laird' was licensed in Canada in 1978 as a macrosperma type with yellow cotyledons, extra large seed, and light colored seed coats. 'Laird' also has resistance to the Canadian isolate of Ascochyta lentis and the South American race of lentil rust. A second Canadian cultivar,

Table 2. Cultivars developed in the Americas.

Cultivar	Source	Distinguishing trait	Reference
Tekoa	Pure line selection from PI 251784	Large nonmottled seeds	Wilson *et al.* (1971)
Laird	Pure line selection from PI 343028	Large yields, large nonmottled seeds	Slinkard and Bhatty (1979)
Eston	Selection from PI 179307	Large yields	Slinkard and Bhatty (1979)
Redchief	Hybridization	Red cotyledons, large yields	Muehlbauer and Wilson (1981)
Brewer	Hybridization	Large yields	Muehlbauer (1982)
Precoz	Unknown	Early flowering, large yields	Riva (1975)
Chilean 78	Mass selection from 'Chilean'	Absence of *Vicia* rogues	Muehlbauer (1982)
Araucana INIA	Mass selection from No 1284	Tolerance to rust	Tay *et al.* (1981)

Eston, was licensed in 1980 (Slinkard 1981) as a *microsperma* type with yellow cotyledons and light colored seed coats. 'Tekoa' was released to USA growers in 1970 as a *macrosperma* type with exceptionally large yellow cotyledon seeds. The cultivar is not grown in the USA at the present time because of seed coat cracking and "skinning"; however, it was shown to have rust resistance and is now grown to some extent in Chile. 'Redchief' is a *macrosperma* type with red cotyledons. 'Brewer' is also a *macrosperma* type that is earlier to mature than 'Chilean' and has greater yield potential. 'Chilean 78' is a partially purified landrace that was developed to eliminate *Vicia* rogues that had contaminated common Chilean seed stocks. 'Precoz', developed in Argentina by Riva (1975), is of unknown origin but has become the predominant cultivar grown there. 'Precoz' is distinguished by its exceptional earliness and good pod setting, but is susceptible to rust. 'Araucana-INIA' was recently developed for use in Chile (Tay *et al.* 1981) and is tolerant to rust, and will likely be an important cultivar and breeding line in the future.

Yield improvement cannot be expected to advance from pure-line selection alone. Hybridization to construct favorable gene combinations for large yields is now assuming a central role in most lentil improvement programs even though the methods of generation advance and selection criteria differ. Modification of breeding methodology was made necessary by the indeterminate growth habit of lentils, which complicates testing of breeding material.

That methods of breeding differ with each investigator seems a foregone conclusion. Slinkard in Canada utilizes F_2-derived families to obtain an early assessment of hybrid performance and the likelihood of obtaining improved selections. His method is a modification of the mass pedigree method in which individual F_2 plant selections are maintained and evaluated as individual bulk populations, i.e. F_2-derived bulks or families.

Thus, using one hybrid in the example, the general procedure used by Slinkard is as follows, starting with the F_2:

Generation	Procedure
F_2	Select 100-300 individual plants.
F_3	Increase each F_2 selection as a plant row (F_2-derived F_3).
F_4	Enter most of these in a preliminary yield trial (F_2-derived F_4).
F_5	Enter highest yielding 50% in another preliminary yield trial (F_2-derived F_5).
F_6	Enter highest yielding 25% in yield trials at two locations. Plant one replication extra for pure line selection. Select 100 plants from each of the 10 best lines (F_2-derived F_6 bulks).
F_7	Enter highest yielding 10-15% in yield trials at two locations. Plant individual plant rows of the best F_2-derived F_6 bulks selected the previous year. Select for uniformity within individual plant rows of each F_2-derived bulk and composite plant rows within each F_2-derived bulk after checking for uniformity for seed size, seed coat color, and cotyledon color.
F_8	Enter best 4-5 reselected (for uniformity) bulks (F_2-derived F_8). Remnants serve as potential breeders' seed.
F_9	Continue testing as necessary.

Muehlbauer, in the USA, uses a different approach whereby evaluation is delayed until the F_5 or F_6, when presumably the lines have reached an advanced state of homozygosity. He uses the single-seed descent or single-pod descent procedure that is a simple modification of the bulk method (Muehlbauer et al. 1980; and Slinkard 1981). The procedure was shown to be efficient in the use of space and time, and in maintenance of genetic variability (Haddad and Muehlbauer 1981). The method is amenable to off-season increases in glasshouses or nurseries, but can be quite laborious and perhaps limited (in terms of availability of seeds) when compared to the conventional bulk method. However, it appears to be well suited to regional programs where selection criteria are well defined. Using one hybrid as an example, the general procedure used by Muehlbauer is as follows:

Generation	Procedure
F_1	Grow to produce a large F_2 population, usually in the glasshouse.
F_2	Plants are grown and one seed (pod) is harvested, composited, and used to produce the F_3 (about 600 seeds).
F_3	Plants are grown and one seed (pod) is harvested, composited, and used to produce the F_4 (about 500 seeds).
F_4	Plants are grown and one seed (pod) is harvested and composited, and used to produce the F_5 (about 400 seeds).
F_5	Plants are grown, harvested as individual plants, and later selected for seed traits.
F_6	Plant rows are grown, evaluated, and selected (about 100 of the best rows).
F_7	Selections are evaluated in a preliminary screening nursery (30-50 selected for further evaluation).
F_8	Selections are evaluated in a preliminary yield trial at one location (6 - 10 selections are made based on overall performance, seed quality traits, and uniformity).
F_9	Selections are evaluated in an advanced yield trial at several locations.

Current Breeding Objectives

Yield

Yield is always a primary breeding objective and is the net result of many factors. Yield improvement is being approached differently within the region. Muehlbauer has emphasized the development of cultivars appropriately adapted to the Palouse of the northwest (the primary USA production area). Slinkard has also emphasized environmental adaptation, while resistance to disease is also viewed as essential to large yields. The introgression of microsperma with macrosperma types is viewed as a potentially productive area of hybridization.

Ascochyta Resistance

Ascochyta lentis (leaf, stem, and pod blight) is an important disease of lentils in parts of western Canada where frequent showers occur between flowering and harvest. In some cases seed infection and discoloration is so severe as to make the lentils unmarketable (Kaiser 1981).

The cultivar 'Laird' has good resistance to the prevailing race(s) and is used as the resistant parent in crosses. Natural infection is used for making selections in the cooler, moister parts of Saskatchewan. The mode of inheritance of resistance is unknown.

Rust Resistance

Lentil rust (Uromyces fabae) is important in parts of Argentina and Chile. Several cultivars have resistance, including 'Tekoa' and 'Laird', and are in use in South America. Breeding programs in Chile and Argentina are actively seeking resistance (Paredes and Tay 1981; Riva 1980).

Virus Resistance

Pea seedborne mosaic virus is a potentially serious disease of lentils. The disease can be seedborne and is transmissible by aphids (Muehlbauer 1977). Screening of the USDA collection revealed several accessions that were immune to the virus, and subsequent inheritance studies showed that the resistance is controlled by a single recessive gene (Haddad et al. 1978). Even though not detected in lentil production fields to this date, we (Muehlbauer) have started development of selections immune to the virus. Jermyn (1980), in New Zealand, identified the line P.I. 212610 as resistant to aphids, pea seedborne mosaic virus, and other viruses.

Seed Size, Seed Coat Color, and Cotyledon Color

Traditionally, the Americas have produced large-seeded (macrosperma) lentils with yellow cotyledons and light colored seed coats. These have been exported to South and Central America, Western Europe, and North Africa. However, with recent increases in lentil production, several different lentils have been developed with the view of tapping additional markets. Thus, the USA has developed the cultivar 'Redchief', a _macrosperma_ type with red cotyledons, and Canada has developed the cultivar 'Eston,' a _microsperma_ type with yellow cotyledons. The extent of market penetration by these two new types is unknown since they are just now being grown on a commercial scale.

The _microsperma_ types will outyield the _macrosperma_ types and thus may be grown more widely if additional markets can be developed. However, primary emphasis will be placed on the _macrosperma_ types since traditional markets are available.

Seed size, seed coat color, and cotyledon color are simply inherited traits and are easily selected.

Low Tannin Content

Tannins are concentrated in the seed coat, and range from 0 to 22.9 mg/g seed coat (Vaillancourt and Slinkard 1983). When the seed coat ages, the tannins become oxidized and the seed coats darken. The water-soluble compounds in these darkened seed coats cause the food containing lentil seed coats to darken. Accordingly, aged lentils are discriminated against in the market place.

P.I. 345635 lentil has no tannin in its seed coat and crosses are under way to study the inheritance of tannin content in lentils. In addition, this trait will be transferred to adapted cultivars. However, in other species low tannin lines have reduced disease resistance, and this aspect must be studied in detail before any zero tannin lines are grown commercially.

Resistance to MCPB Herbicide

Weed control is essential for profitable lentil production. Few herbicides are available for effective broadleaf weed control in lentils. However, the line P.I. 179310 has resistance to MCPB (Slinkard 1980) and it may be possible to develop a lentil cultivar with this resistance and thus increase the number of broadleaf herbicides available for use on lentils. It is proving difficult to study the inheritance of resistance to MCPB since it is a quantitative trait in a plant with an indeterminate growth habit. However, several F_4 lines have good resistance and more will be tested.

Maturity

Maturity is difficult to select for in some environments due to the indeterminate growth habit of lentils. Breeding populations and selections are being made to develop types that have a greater tendency toward annualness. Studies of daylength responses and interactions with vernalization have indicated the importance of the number of consecutive long days in bringing about flowering.

Vernalization seems to be capable of advancing flowering by about 10% when compared to nonvernalized controls.

Basal Pod Height

Basal pod height is critical for mechanical harvesting, as well as erect growth habit. 'Chilean 78' has a semi-erect growth habit and lodges early, making mechanical harvesting difficult. 'Eston' has a short, upright growth habit, whereas 'Laird' has a tall, upright growth habit, facilitating mechanical harvesting.

Food Quality

Cooking time for lentils is much shorter than for other pulse crops such as peas and beans. Lentils cook quickly, yet retain their form. Bhatty et al. (1983) have developed a method of evaluating lines and cultivars for cooking quality using a Kramer shear press. The cultivar 'Eston' cooks quickly, yet retains its shape. Unidentified environmental variables also have pronounced effects on cooking quality. McCurdy et al. (1978) have demonstrated the use of *Tetrahymena pyriformis* in the evaluation of lentils for protein quality.

Cytoplasmic Male Sterility

Muehlbauer and Ladizinsky (unpublished data) have found a cytoplasmic male sterility restorer system in lentils that may be useful to facilitate crossing in a breeding program. The system may also be useful in understanding the evolution of the crop. Currently, studies are under way to survey lentil germplasm for differing cytoplasmic male sterility restorer systems.

Tolerance to Environmental Stresses

Jana and Slinkard (1979) screened several hundred P.I. lines for salt tolerance by growing them in salt solutions. While differences in salt tolerance were found, the level of salt tolerance was small compared to that found in other crops such as barley. Related studies on genotype/salt level interactions in barley showed that the more salt-tolerant lines were lower yielding in the absence of salt, indicating that the greatest production from a given field would result from using the highest yielding cultivar. Accordingly, research on salt-tolerant lentils was terminated.

Lentil seedlings will tolerate a frost of -2 to -4^{o}C, but more severe overnight frosts will kill the top growth. Fortunately, axillary buds in the axils of the vestigial nodes below the soil surface can initiate regrowth. However, even light frosts are detrimental during flowering and early pod development. With a frost of about -6^{o}C, even nearly mature seeds will have a brown etching on the seed coats where portions of the immature seed coat were damaged by frost.

In the USA a program is under way using controlled environments to identify critical factors in the Palouse environment that limit lentil yields (Summerfield and Muehlbauer 1981a, 1981b, 1981c). Information gained will be used by the breeding program to initiate screening methodology to identify lentil genotypes capable of performing in the presence of environmental stresses typical of the Palouse.

Collection and Utilization of Wild Species

A collection of Lens orientalis, L. nigricans, L. ervoides, and L. montbretii has been assembled (Ladizinsky 1979c; Muehlbauer 1981). The accessions have been increased, and a series of genetic and cytogenetic studies have been made (Ladizinsky 1979a, 1979b). Research has been initiated on the phylogeny of Lens, the potential of the wild species for improving the cultivated types, virus resistance and protein content, and quality. Crossability and cytogenetic studies indicate two distinct types within L. nigricans and strongly suggest an altered classification. L. montbretii was shown not to be a Lens species, but more correctly classified under Vicia (Ladizinsky and Sakar 1982).

Agronomic Aspects

Successful lentil production requires adoption of a package of agronomic practices. Weed control is essential. In Canada, the most common weed control practice is fall-applied trifluralin for wide spectrum weed control, followed by a postemergence application of metribuzin for control of Brassica species not controlled by trifluralin. Other registered herbicides are barban for postemergence wild oat control and diclofop for postemergence control of annual grassy weeds. Triallate is also widely used for preemergence wild oat control, but is not registered yet. In the USA the common practice is to incorporate triallate prior to seeding the crop and to apply dinoseb prior to seedling emergence. Metribuzin is also used either pre- or postemergence. A promising new herbicide is sethoxydim for postemergence control of annual grassy weeds and volunteer cereals. This is of great interest in Canada where most of the lentils are seeded on cereal stubble.

Proper inoculation with the proper strain of Rhizobium leguminosarum is essential, and a sticker solution such as powdered milk solution or a sugar solution is widely used. Fungicidal seed treatment is not used in Canada so rhizobial inhibition by fungicide is not a problem. Yield responses of up to 30% have been reported, primarily due to seeding lentils on low nitrogen stubble fields in the absence of any Rhizobium leguminosarum in the soil. Once the soil in a field has been adequately inoculated there has been no yield response from inoculating again.

Seeding rates used in Canada are about 110 seeds/m^2, but some farmers are of the opinion that heavier seeding rates provide better weed competition and facilitate harvesting.

A soil test is suggested before applying fertilizer. Under Canadian conditions, no nitrogen is recommended unless the soil test indicates less than 35-40 kg N/ha, and then a rate of 35-40 kg N/ha is used. In the USA no nitrogen is recommended, but occasionally "starter" applications of about 20 kg N/ha are applied to overcome the nitrogen hunger phase of seedling development in cold seasons. If the soil test indicates that P_2O_5 fertilization is required, the suggested rate may be drilled with the seed or deep banded with the nitrogen (Slinkard and Henry 1978). Both nitrogen and phosphate fertilizer hasten growth of the lentil seedlings during the lag phase of growth that occurs immediately after emergence.

Harvesting in the USA and Canada involves swathing, using a pickup reel, as soon as the early pods turn brown and the seeds rattle inside. After drying the swaths are picked up with a combine. Some of the lentil producers with larger fields use a desiccant (diquat) and direct combine to reduce shatter losses and avoid weather damage in the swath. Desiccants are not recommended in the USA because of reduced seed size and germination. The lentil crop is South America in mostly mechanically harvested. For further information on lentil production in the USA, see Summerfield _et al._ (1982a) and Youngman (1968).

Lygus bugs were recently found to be an economically important pest of lentils (Summerfield and Muehlbauer 1982; Summerfield _et al._ 1982b). Seedlots affected have deformations referred to as "chalky spot" and are caused by the lygus bug feeding during seed development. Other effects from lygus bug feeding include flower, pod and seed abortion, and reduced yields. Studies are under way to determine economic threshold levels and to determine the optimum time for insecticide application. Determination of economic threshold levels is hindered by lack of a sampling method suitable for lygus bug collection in lentil crops.

Future Priorities

Develop Genetic Background

Intensive research on lentils is relatively new and thus there is little information available on the genetic and cytological background of the genus. This information is needed to improve the efficiency of lentil improvement programs throughout the world. Additional research is also needed on the collection, evaluation and utilization of the wild lentil species.

Identify Stresses and Develop Tolerant Germplasm

Manara and Manara (1983) found that lentils often produced empty pods and low yields in Brazil as a result of high temperatures, short days, and early lodging. Similar results occur in North America under conditions of excess nitrogen and moisture. This "empty pod syndrome" apparently results from the lack of a suitable stress period to bring about partitioning of photosynthate to the seeds rather than to continued vegetative growth. This is most likely an ancestral trait and is an indication of the minimal breeding efforts that have gone into the crop.

Develop Lentil as an Annual Green Manure Crop

Annual legume green manure crops are important in many parts of the world as cover crops and as a source of nitrogen in the rotation. However, many of these annual legume green manure crops require long growing seasons or warm, moist growing seasons. Few annual legumes are adapted to short, dry, growing seasons and most that are require heavy seeding rates and consequently, prohibitive seed costs, i.e., the seed costs more than the amount of nitrogen fixed if it had been purchased as fertilizer.

However, microsperma lentils show promise as an annual legume green manure crop in areas with a short, dry, growing season such as the drier parts of western Canada. The seeding rates would be about 35 kg/ha and, at current prices for seed and nitrogen fertilizer, it would only have to fix 30 kg N/ha to pay for the cost of the seed. Current estimates are that lentils are capable of fixing over 60 kg N/ha under western Canadian conditions. The line currently being evaluated is NEL 481, a microsperma type with a black seed coat. The black seed coat will serve to mark this lentil as a green manure type and will eliminate the tendency to harvest it for seed except as needed for green manure purposes.

Lentil-Rhizobium Interactions

Increased research efforts must be directed to improving the efficiency of the nitrogen fixation process in lentils. This is important in both seed production and for green manure purposes.

Broadleaf Herbicide Research

There are only a few herbicides that provide differential broadleaf weed control in lentils. Therefore, additional research efforts are required to develop cultivars such as the MCPB resistant lentil mentioned previously and perhaps a lentil that is resistant to glyphosate or some other broadleaf herbicide.

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Discussion

A. Slinkard

I would like to comment on the tannin content in the seed coat of lentil. The darkening of seed coat of lentil under ambient storage reduces seed quality. This is associated with the tannin content of the seed coat. We have found a lentil line with zero tannin content and we are crossing this line into adapted material. We have extra seed available and can supply to anyone who would like to have it.

F. Muelhbauer
The low tannin line that Dr. Slinkard mentioned has increased susceptibility to seed and seedling-rot diseases that may be of consideration for breeders in using that line in the breeding program.

A.M. Nassib
What is Vicia rogue problem that you mention in your paper? What is the possibility of breeding against 'empty pod syndrome'? It was observed in Beka'a Valley in 1973 and in Egypt during the last season?

F. Muelhbauer
Vicia rogues are so similar in seed size, shape, and color that they cannot be removed by seed cleaning. Contaminated seedlots produce stands of the crop and the seeds produced from this crop are also contaminated. The seed has poor cooking quality. The species (Vicia sativa var platysperma) was eliminated by pure line selection within the local landrace (Chilean) and designated as Chilean 78.

I cannot comment much on 'empty pod syndrome' because not enough is known of the problem. It does appear to be an ancestral trait that may be modified or reduced by breeding. It can be reduced by environmental stress.

A. Slinkard
The 'empty pod syndrome' seems to be a result of conditions which overstimulate vegetative growth (e.g. abundance of moisture and excess nitrogen) such that pods do not set or if they are set the seeds abort.

W. Erskine
Is there a genotype x plant density interaction in lentils and, if so, how did it affect your spaced plant trial? I ask because plant density has to be carefully considered in single-plant selection in later generations.

F.Muelhbauer
The plants were uniformly spaced 5 cm apart in 30 cm rows that were appropriately bordered. The spacing approximated a field-planted situation. Plants more widely spaced would definitely cause problems of interpretation of the data.

C. Bernier
It may be worth pointing out that in Egypt and in North Africa, especially Algeria, downy mildew of lentils can be injurious; the leaves dry off rather rapidly and the damage can be mistaken for root rot.

W. Erskine
In answer to your query about downy mildew, Peronospora lentis is widespread in Syria but rarely injurious. It tends to disappear as the temperature rises.

M.C. Saxena

The cross between 'Precoz' and 'Laird' should be of interest to us in ICARDA. I was wondering whether the segregating population of this cross has been received and evaluated by ICARDA lentil breeders and whether the segregants of this cross show promise under our conditions.

W. Erskine

The segregants from that particular cross have been under observations at ICARDA. We have also made our own crosses using these two parents.

Proceedings of the International Workshop on Faba Beans, Kabuli Chickpeas, and Lentils in the 1980s (Saxena, M.C. and Varma, S., eds.), ICARDA, 16-20 May 1983, Aleppo, Syria.

Kabuli Chickpea and Lentil in India

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India grows nearly 9 million hectares of chickpea (Cicer arietinum) and nearly 1.5 million hectares of lentil (Lens culinaris) annually. Both crops are grown during the winter season (October/November to March/April), but in different cropping systems. Chickpea is generally grown as a mono-crop in the monsoon fallows where moisture has been conserved in the soil, or may follow a short season monsoon millet crop (about 70-day maturity) grown in areas where sufficient residual moisture is ensured. In rainfed areas with a rolling topography, such as in Central India, chickpea occupies uplands. Lentil follows a full season rice crop in irrigated areas or in areas with an annual rainfall of 800 mm or more. Occasionally, it may be grown in the lowlands in rainfed areas with rolling topographies. There are instances, such as in the Bundelkhand region of Central India, where lentil, like chickpea, would be grown on rainfed lands. Tables 1 and 2 give the area and production of chickpeas and lentils, respectively, for the most important producing areas in India. This accounts for only a part of total area under these crops.

Trends in Production Since 1976/77

Table 1 does not represent kabuli chickpea production per se, because there is, as yet, no organized system in India to assess separately the area planted to kabuli as distinct from desi chickpea. However, a few sample surveys conducted by the survey and surveillance teams associated with pulse development work estimated that 2 to 5% of total chickpea area is devoted to kabuli type (Table 3). By this reckoning, cultivation of kabuli chickpea probably does not exceed half a million hectares in the country as a whole. Almost all kabuli chickpea production is confined to irrigated areas, where it may follow maize or millet.

Table 1. Important districts of chickpea cultivation in India.

District	State	Area (x 000 ha)	Production (x 000 t)	Yield (kg/ha)	% of total area in India
Ganganagar	Rajasthan	521.6	382.3	733	6.3
Bhiwani	Haryana	304.0	243.0	799	3.7
Hissar	Haryana	214.0	172.0	803	2.6
Hamirpur	Uttar Pradesh	189.2	122.4	647	2.2
Banda	Uttar Pradesh	175.1	83.4	476	2.1
Alwar	Rajasthan	170.0	219.3	1290	2.05
Sirsa	Haryana	163.0	129.0	791	1.97
Jaipur	Rajasthan	147.3	133.9	909	1.78
Bharatpur	Rajasthan	142.2.	158.4	1114	1.72
Bhatinda	Punjab	128.0	112.0	875	1.55
Vidisha	Madhya Pradesh	116.1	68.4	589	1.41
Mohindergarh	Haryana	114.0	87.0	763	1.38
Jhunjhunu	Rajasthan	112.3	106.8	951	1.36
Sawai Madhopur	Rajasthan	108.3	94.6	873	1.31
Churu	Rajasthan	106.7	43.7	410	1.29
Jind	Haryana	106.0	101.0	953	1.28
Ujjain	Madhya Pradesh	105.4	37.4	355	1.28
Rohtak	Haryana	99.0	105.0	1060	1.19
Guna	Madhya Pradesh	98.2	37.9	386	1.18
Raisen	Madhya Pradesh	90.9	39.0	429	1.10
Jalaun	Uttar Pradesh	90.1	73.9	820	1.09
Jhansi	Uttar Pradesh	86.8	45.1	520	1.05

Table 2. Important districts of lentil cultivation in India.

District	State	Area (x 000 ha)	Yield (kg/ha)
Jalaun	Uttar Pradesh	52.1	734
Raisen	Madhya Pradesh	42.1	533
Sagar	Madhya Pradesh	39.9	418
Murshidabad	West Bengal	35.7	382
Nadia	West Bengal	34.7	397
Bahariach	Uttar Pradesh	26.3	734
Jabalpur	Madhya Pradesh	25.8	225
Damoh	Madhya Pradesh	23.6	283
Jhansi	Uttar Pradesh	16.9	765
Vidhsa	Madhya Pradesh	16.5	331
Bhind	Madhya Pradesh	16.0	325
Kheri	Uttar Pradesh	15.3	457
24 Pargana (N)	West Bengal	14.7	386
Hamirpur	Uttar Pradesh	14.5	564
Banda	Uttar Pradesh	12.7	721

Table 3. Sample survey of acreage and productivity of kabuli chickpea in some states of India.

Location	Area under kabuli type as % of total chickpea area	Productivity (kg/ha)[1]
Kanpur (Uttar Pradesh)	2.3	1618
Aligarh (Uttar Pradesh)	3.7	1575
Bhatinda (Punjab)	4.5	1761
Ganganagar (Rajasthan)	5.0	1251
Gwalior (Madhya Pradesh)	2.6	582
Dholi (Bihar)	1.8	1683

1. Sample size:Kanpur 17; Aligarh 5; Bhatinda 25; Ganganagar 15; Gwalior 3; Dholi 5.

Over the period 1976-81, the area planted to lentils declined, while its productivity increased by 2.8 kg/ha/yr. In the case of kabuli chickpea estimates show an increase in area planted of 5,000 ha/yr, and an increase in productivity of nearly 16 kg/ha/yr. The increase in kabuli chickpea area seems to be at the expense of field pea (Pisum sativum), a competing grain legume. The growth of agricultural practices catering to urban demands near cities, and the premium market value of kabuli chickpea are the major factors for this diversion of area.

These trends reflect the need to urgently address ourselves to the task of rehabilitating lentil cultivation on the one hand, and to cash in on the favorable trend of rising area and productivity of kabuli chickpea, on the other. The All India Coordinated Project for Improvement of Pulses (AICPIP) had not given a high priority to these crops in the past, but is now giving these crops the attention due to them. It may be pertinent to mention that both lentils and chickpeas had high export demands during the decade 1970-80, but the surplus for export in India was low and has since dwindled further. Nevertheless, these crops are high priority items for the international commerce of India.

Kabuli Chickpeas

Only a limited amount of data on kabuli chickpea improvement over the last few years is available. Only one variety, ICCC 33, which is an intermediate type tending towards kabuli, exceeded the check L 550 in yield and has a seed size on par with the latter (Table 4). It is important to raise at least one of the two attributes, seed size or yield, if a favorable impact is to be made on the cultivators.

The genetic materials being used in developing new varieties of kabuli chickpea in the Indian program are largely developed from three lines, C 104, L 550, and L 144, and sparingly from K 4 and Addis Ababa. Since the first three genotypes have a common

Table 4. Performance of kabuli chickpea varieties in the 1981/82 All India Coordinated Yield Trial, under different environments.

Variety	Overall mean yield[1] (kg/ha)	Yield under rainfed conditions[2] (kg/ha)	100-seed weight (g)
BG 252	1165	1250	22.5
BG (M) 415		1250	21.5
GL 914	1105		21.5
HUG 3	1125	1180	18.5
ICCC 32	1185	1000	22.0
ICCC 33	1414**	1290**	21.0
L 550 (Check)	1250	1180	22.5

1. Mean of 11 locations.
2. Mean of 3 locations.
** Significantly superior to the check variety.

pedigree, the genetic base is narrow. The efforts to improve yield have therefore necessitated incorporating desi chickpea into the crossing program, as can be seen from the pedigree of some newer kabuli lines developed at IARI, New Delhi (Table 5). It is, however, a difficult task to handle the desi x kabuli crosses in the subsequent generations. Thus, there is a great motivation for diversifying the kabuli genetic base of the crossing program.

In the past, efforts to introduce kabuli lines from European or Middle Eastern sources have aborted due to lack of adaptation of these genotypes to Indian conditions. We must address ourselves to the task of identifying the factors for lack of adaptation, such as photoperiod, temperature, nutritional factors, a specific rhizobial interaction, or a combination of these factors. In the meantime, it is necessary to continue to make intervarietal crosses to expand the genetic diversity and, hopefully, to obtain desirable adapted and even superior segregants.

Table 5. Recently developed promising varieties of kabuli chickpea in regional programs in India, 1981/82.

Variety	Parentage
BG 285	(L 550 x GW 5/7) x (K 4 x L 550)
BG 286	(US 613 x BEG 482) x P 9623
BG 287	(P 431 x L 534)
BEG (M) 429	Mutant of 'C 104' (NMU 0.01 %)
BEG (M) 430	Mutant of 'C 104' (EMS 0.1%)
ICCC 34	P 388 x (T 3 x P 836)

While considering adaptation, yield, and genetic diversification of parents in the kabuli breeding program, certain other factors of importance should receive attention. For instance, resistance to fusarium wilt, large seed size, and high harvest index are desirable criteria for the prospective parents. Some sources of tolerance to fusarium wilt among the kabuli germplasm are shown in Table 6. Sources of large seed size available are the genotypes Addis Ababa which is of Ethiopian origin, and L 144, though the latter has the same parentage as L 550 and C 104. Fresh sources could be introduced from the USA, Canada, and Spain, and might not pose problems of adaptation because they are modern lines bred under disruptive selection pressures of one or the other kind.

More data will become available on the improvement of kabuli chickpea in India in the near future as priorities are revised in its favor.

Table 6. Some characteristics of the kabuli chickpea lines with highest[1] resistance to fusarium wilt.

ICC No.	Pedigree	Maturity	Habit	Seed color	Origin
537	P-422	112	Semispreading	White	India
2083	P-1679-2	134	Semispreading	White	Mexico
2299	P-1954	121	Semierect	White	Spain
5727	C-16-1	105	Semierect	White	India
8446	JM-466/D-10-4	108	Semierect	White	Ethiopia
8454	JM-473	121	Semierect	White	Ethiopia
8622	WP-2984-B	108	Semierect	White	Ethiopia
10466	Coll.No.570	99	Semierect	White	India

1. Mortality less than 20%

Lentils

Yields of improved lentil varieties are not very high or stable (Tables 7 and 8), especially when the seed weight exceeds 20 g/1000 seeds. As with kabuli chickpeas, lentils with a higher seed weight (more than 20 g/1000 seeds) command premium prices. Thus, emphasis has been on the large-seeded lentils and experiments were conducted on large-seeded types which resulted in the identification of the variety LG 186 with a 1000-seed weight of about 25 g. However, its yield is only about 35% of that of L 1304, one of the agronomically desirable types. Today a number of varieties are available which have twice the yield of LG 186, but comparable seed size (Table 9).

In order to assess the yield potential of some promising genotypes at various locations in India, plots measuring 2000 m2 were grown with a full package of recommended practices. The results were encouraging as five lines gave more than 2000 kg/ha seed yield during the 1982/83 season (Table 10).

The two major problems associated with lentil cultivation in India are the rust and wilt diseases. Recent research has identified a large number of sources of disease resistance, in addition to those previously known. The sources are:

Resistance to wilt: LWS 4, 6, 10, 14, 15, 20, 21, 23, 24, 25, 26, 27, 28, and 50, were resistant to *Fusarium* spp., while LWS 18, 27, 28, Pusa 3, Pant 234, J 85, and J 1600 were also resistant to *Sclerotium rolfsii* and *Rhizoctonia solani*.

Resistance to rust : A high degree of resistance to rust exists among a large number of genotypes (nearly 30 lines), prominent

Table 7. Performance of some lentil varieties in the 1981/82 All India Coordinated Trial.

Variety	Yield (kg/ha)[1]	1000-seed weight (g)
Pant L 79-8	1365	13
Pant L 406	1245	20
Pant L 639[a]	1300	15
RAU 101	1147	19
JL 1 (check)	1335	25

1. Average of 16 locations.

a. Identified for country-wide cultivation in 1982.

Table 8. Performance of some lentil varieties in the 1982/83 All India Coordinated Trial (bold seed).

Variety	Yield (kg/ha)	1000-seed weight (g)
K 75	1767	28
L 4076	1610	27
Jhansi local	855	27
Sehore 34	711	37
Sehore 74-3	700	32
Sehore 74-7	733	37

amongst which are PL 234, LP 846, JL 674, and JL 1004. Some lines with high yield in addition to rust resistance are KL 44, Pant L 406, KL 113, and LG 178.

Lentil breeding projects in India are using only a limited range of genetic diversity in breeding for disease resistance (Table 11), which needs to be increased. However, the success has been noticeable even with this limited program as the new lines developed possess a good degree of resistance to rust and wilt coupled with a relatively large seed size (Table 12).

Table 9. Yield levels of some new bold-seeded lentil varieties collected from Bundelkhand region in India (wt/1000 seeds ≥ 25g).

Checks	Yield (kg/ha)	
	Mean	Highest
LG 186	910	1130
L 1304	2651	3140
Test varieties (bold seeded)	**Yield (% of best check)**	
	Mean	Highest
BL 12	66	54
BL 14	67	55
BL 15	72	63
BL 18	71	61
BL 25	58	52
BL 29	64	57
BL 48	71	60
BL 49	75	64
BL 53	66	54
BL 54	81	66

Table 10. Lentil varieties that yielded over 2000 kg/ha in 2000 m^2 plots in India, 1982/83.

Variety	Yield (kg/ha)
VL 2	2222
K 82	2083
LG 120	2222
LG 175	2090
L 1304	2200

Table 11. Some of the important lentil crosses being evaluated in the breeding programs at different centers in India, 1982/83.

A. Rust resistant x wilt resistant	
Pant L 406 x JL 80	Pant L 639 x LWS 14
x Pant 234	x LWS 21
x Pusa 3	x Bundelkhand-51
x P 1024	x K 75
x P 279	
B. Disease resistant x agronomic base (or bold seeded)	
Pant L 406 x K 75 (bold)	Pant L 639 x K 81
x L 4076 (bold)	x LG 186
x L 1304	x LL 56
x Local Jhansi	
VL x JLS 1	
x Bundelkhand 46	
x Bundelkhand 44	
x Bundelkhand 27	

Table 12. Spectrum of seed size and flowering time in the new breeding lines of lentil at IARI, New Delhi, India.

No. of lines	1000-seed weight (g)	Days to flowering
A. Microsperma		
Checks (2)	16.5 ± 2.5	80 ± 5
12	16.5 ± 2.5	72 ± 8
69	22 ± 2	77 ± 8
B. Macrosperma		
Checks (2)	33 ± 2	72 ± 3
115	27.5 ± 2.5	80 ± 10
165	33 ± 2	82 ± 12
153	38 ± 2	83 ± 20
56	43 ± 2	83 ± 20
5	48 ± 2	83 ± 20

Future Emphasis

A great amount of research effort is needed in India for the kabuli chickpea and lentil improvement programs, the major emphasis being on yield, large seed size, and disease resistance. The introduction of new germplasm will be investigated with a view to diversifying the genetic base of breeding populations. Resistance to Heliothis spp. in kabuli chickpea and aphids in lentil will also receive priority. The target by the end of the 1980s will be a yield potential of 2000 kg/ha in lentil with a seed weight of about 25 g/1000 seeds, coupled with resistance to wilt, rust, and aphids. In kabuli chickpea, the effort will be to combine a seed weight of 30 g/100 seeds with yield level of 2000 kg/ha, and resistance to Heliothis spp., if possible.

Discussion

K.B. Singh

You mentioned that the national programs on kabuli chickpeas and lentils in India are weak. Now that you have seen our work, do you feel that we can be of any assistance to your program. Of course it can be achieved by furnishing the seed. But we have a problem in doing so as the Indian plant quarantine refuses to release any material which is chemically treated.

S. Chandra

I would not call our program weak, I would say it is limited. We are determined to strengthen it and I am happy that ICARDA is willing to support in strengthening it. We have to study the basis for adaptation of kabuli chickpeas in India, because all exotic introductions have been poorly adapted to our conditions. There is a need for increased genetic input in our breeding work. As far as quarantine aspect is concerned, it is a government policy. It would be good if ICARDA could meet the national regulations and provide the seed the way the national plant quarantine would like to have. This will help Indian plant breeders in getting the required genetic variability.

K.B. Singh

Genetic variability in kabuli chickpeas is quite high contrary to the earlier belief. To cite two examples: The variability for seed size in kabuli varies from 8-67 g/100 seeds as against 9-39 g/100 seeds in desi type. Similarly, we found that there was more resistance to ascochyta blight in kabulis than desis. It was only a question of working more intensively.

S. Chandra

I agree that there is wide genetic variability in kabuli chickpeas for a number of characters. But the kabuli chickpeas that we have in India did not so far provide source for larger yields and the variability existing in the exotic material does not express itself under our conditions for want of adequate adaptation.

A. Slinkard

<u>Lens culinaris microsperma</u>

I would like to comment on Dr. Chandra's distinction between macrosperma and microsperma lentils. Under our environmental conditions in North America our microsperma lentils are larger than most of his macrosperma. They range from 30-35 g per 1000 seeds and our macrosperma range from 60-75 g per 1000 seeds. I suggest that Indian lentil breeders use a major infusion of genes for larger seed size in their material as a means of breeding for increased yield. It appears that the Indian germplasm is prodominantly of the subspecies which is characterised by excessively small seed size.

M.C. Saxena

Are the chickpea lines ICCC32 and ICCC33 that you have found promising in the All India Coordinated Yield Trials true kabuli type?

S. Chandra

Yes, these are what we consider kabuli types.

Plenary Session: Recommendations

Germplasm, Breeding, Seed Production and Quality

A. Germplasm

1. Collect germplasm of chickpeas, faba beans, and lentils with attention to the following:
   a. Timely collection of landraces from areas not represented in the established collections.
   b. To the extent possible, coordinate collection with local institutions and share with them the material and information obtained.
   c. Expand collections of wild relatives of the three crops.
   d. Collect Rhizobia associated with the collections.

2. Organize efforts to evaluate germplasm accessions that include the following:
   a. Suitable check material and standards in adequate frequency to insure that germplasm evaluations are accurate and useful.
   b. Use specific locations where possible to evaluate germplasm for tolerance to environmental extremes, pest resistance, photoperiod etc.

3. Expand work on wild species and wide crosses. Centers of expertise should be identified and cooperative projects initiated for work in this area.

B. Breeding

1. Make early generation breeding material more widely available to cooperating programs with the following considerations:
   a. The type of material made available should be chosen after consideration of the cooperators' specific needs. Objectives, parental material used, and specific traits of the material should be considered.
   b. Encourage exchange of breeding material between cooperating institutions. Requirements of different regions need to be defined and material provided accordingly.
   c. Program funds, manpower, and capabilities of the cooperating program.
   d. Encourage exchange of information concerning the usefulness of breeding material provided.

2. Expand variation in the three crops by conventional and novel means:
   a. Evaluate germplasm and breeding lines where variation is more likely to be expressed.
   b. Utilize breeding methods to allow expression of useful variation (i.e. selfing in faba bean to identify recessive genes for flowering, height, disease resistance etc.. and

assess wild species for traits of economic importance by hybridization, selection, and evaluation in the cultigen background).

c. Consider mutation breeding where the desired variation does not exist in germplasm collections and where techniques for identification of the desired traits are known.

3. Clarify pest (pathogens, insects, Orobanche) problems in the region with respect to:
   a. Prevalence in various countries and the extent of variability within each pest. Institutions with personnel and facilities suitable for handling specific pests should be used in cooperative studies.
   b. Provide information and advice on appropriate breeding and screening methods for particular pest problems.

C. Seed production and quality

1. Produce and make available seed that is free of pathogens, insects, and noxious weeds by utilizing field inspections, disease control, seed treatments, fumigation, and laboratory analyses.

2. Develop suitable registration schemes for placing improved cultivars on recommendation lists. Facilitate seed multiplication by government agencies.

3. Establish suitable storage facilities so that adequate seed stocks of good quality can be maintained.

Microbiology, Physiology, Production Agronomy and Mechanization

A. Microbiology

1. Research to date has not demonstrated clearly whether inoculation with Rhizobium is consistently beneficial or not.

   Effective nodulation does not necessarily imply that symbiotic dinitrogen fixation (SDF) is adequate. Clearly, if breeders are successful in extending either the periods or areas of cultivation then inoculation with appropriate strains of Rhizobium will be important.

2. Screening techniques for SDF appropriate for the region are available (e.g. the difference method) and, it seems, adequate. Of course, improvements can be anticipated but it is clear already that more frequent sampling during crop growth, and based on N accumulation per unit area (not on single plants) will be required to expose useful variation in breeding material (in both seeds and straw, where this is of economic value).

3. Interdisciplinary and cooperative joint program studies involving microbiologists, physiologists, agronomists, and breeders should be encouraged, both on- and, especially, off-station in order to encompass environmental diversity within the region.

4. The ICARDA collection of Rhizobium must be freed of duplicates and contaminants as a pre-requisite to strain evaluation. Once this has been achieved, it will become feasible to evaluate in the field the proportion of nodules originating from introduced strains.

6. Experience with poor quality local inocula suggests that ICARDA could usefully monitor product quality if and when commercial inocula are produced on a wider scale in the mandate region.

7. Rates of progress in identifying problems, establishing screening techniques, and field evaluations in microbiology in general will be dictated to a large extent by resources made available to that program.

B. Physiology

1. Photothermal effects on rates of reproductive development must be quantified and followed by field evaluations, in prudently - selected locations as a pre-requisite to ultimate field - based screening programs. Ecological zoning within the region would be needed to better ensure reliable generalizations of research findings.

2. Appropriate site selection will assist ICARDA researchers to evaluate the relative importance of environmental constraints to productivity; major emphasis should focus on responses to cold conditions and nutrient stress during vegetative growth and responses to heat and drought stress during the reproductive period.

3. Experience elsewhere (e.g. screening techniques for cold tolerance in maize and P. vulgaris, for heat and drought stress in cowpeas and studies on premature flower abscission in legumes in general) should be exploited in the search for reliable methodologies for screening ICARDA crops against environmental stress.

4. The ICARDA research mandate whilst concentrating on dryland farming should not exclude studies on the specific problems of irrigated systems of crop production once the inclusion of legumes in such systems is significant within the region.

C. Production agronomy and mechanization

1. Little is known about rooting patterns and the exploitation of soil resources by legume crops grown in regions where the

physical condition of soil is poor. It seems prudent to recommend that ICARDA pay more attention to tillage operations and rotational effects on long-term soil fertility and crop productivity.

2. Agronomic variables (such as row widths most appropriate for lentil cultivation, depth of seeding for chickpeas and faba beans, and population densities for erect and spreading chickpeas) should be clarified not only for their effects on productivity *per se* but also for their implications for the successful introduction of mechanization on a small or, in time, a large scale.

3. The instigation of an agricultural engineering position at ICARDA is a welcome development deserving economic support from FLIP.

D. General

1. Problems in microbiology, physiology, and agronomy should be considered in the context of the farming system so that limited research resources are used efficiently and results are more easily accepted by farmers.

2. The workshop program gave inadequate opportunity for discussion of the many and diverse problems seen by members of the group to limit legume productivity in the region. Concurrent sessions, with authoritative reviews as general sessions, would be the format preferred for workshops in the future.

Plant Protection

A. Entomology

1. It is recommended that ICARDA entomologists should continue to monitor the pest situation, particularly in relation to newer cultivars and changing cropping systems. One of the countries where this activity should be immediately initiated is Sudan, preferably with special funding. Special attention should be paid to aphids, *Spodoptera*, and potential insect vectors of viruses and mycoplasma-like organisms attacking faba beans.

2. Priority should be given to development of standard procedures for evaluating relative damage due to major insect pests.

B. Pathology

1. Seed pathology
The group is happy to note the recent action by ICARDA to establish a quarantine unit. Importance of seed health, when large amounts of seed materials are exchanged between different regions, cannot be overemphasized. Efforts must be

continued to produce healthy seed needed for international nurseries. All pathogens, including viruses, should be considered.

2. Variability in pathogens causing major diseases
   It is noted with satisfaction that a beginning has been made at ICARDA in understanding the variability in Ascochyta rabiei (chickpea blight) and Botrytis fabae (faba bean chocolate spot). The ODA project on Ascochyta rabiei is also a welcome development. This work must be continued and extended to other important pathogens such as Ascochyta and rust on faba bean. The group also recommends setting up of trap nurseries for Ascochyta rabiei and Botrytis fabae to detect new pathotypes/races. Also the causes of variability in these pathogens need to be understood.

3. Strategies for resistance breeding
   The group has noted with satisfaction the identification of sources of resistance as well as their utilization in the breeding programs of faba bean and chickpea. The time is now ripe for working out strategies for obtaining stable and durable resistance. It is recommended that ICARDA should invite consultants who are experts in the field of disease resistance breeding to advise on the strategies to be followed in the near future.

4. Potentially serious diseases
   The group felt that ICARDA scientists must pay attention to presently minor but potentially serious diseases such as wilt, root rots, and viruses of faba bean and chickpea and wilt, root rots, rust, ascochyta blight and viruses of lentil, with the ultimate aim of obtaining multiple disease resistance. The group is concerned that lentil pathology has received virtually no attention so far. ICARDA cannot afford to take the risk of not being prepared to tackle disease situations which may arise in future as newer cultivars replace old landraces.

5. Attention to other mandate areas
   The group recommends that attention should be paid to important disease problems of specific regions. For example, the disease problems of chickpea and faba bean in Tunisia and other North African countries need to be tackled on an urgent basis.

C. Weed control

1. The group recommends work on the losses in yield due to weed infestation in three legumes in the ICARDA mandate areas.

2. The group strongly recommends additional scientific support in Orobanche control research.

D. Nematology

1. The group has noted the importance of the stem nematode (Ditylenchus dipsaci) in faba bean. It is recommended that a consultant be invited for a period of at least 2 years to evaluate the importance of nematodes in food and forage legumes.

E. General

1. It was felt that there is an acute shortage of trained personnel in entomology, pathology, and weed control in the national programs of the ICARDA region. The group strongly recommends strengthening of training efforts by way of (i) offering short and long term training programs tailored to specific needs of the national scientists and technicians, and (ii) encouraging national programs to sponsor trainees. Also there is a definite need to have additional staff to handle the training needs in plant protection including weed control.

2. Integrated pest control
While pest resistance breeding must continue to receive highest priority, the group recommends that other methods of control should also be evaluated with the objective of integrating them into packages of practices for economic control.

3. Staff support
In view of the scope for substantial increased yields of the three legumes through disease and insect pest control, it is essential that the breeding programs receive strong support from pathologists and entomologists. The group noted with concern the inadequacy of staff in these disciplines. The group recommends that there should be full-time pathologist and entomologist for chickpea and lentils. They should have adequate support staff. Also there is a need to address to the virus problems.

4. Facilities
The group recommends additional facilities such as greenhouses, laboratory, and field equipments.

5. Equipment support to cooperators
In order to make cooperative efforts more meaningful, the group recommends provision of laboratory equipment kits to cooperators who may not be having access to such minimum facilities.

ICARDA-ICRISAT collaboration in chickpea pathology
The group noted the productive collaboration between the two international centers. It is recommended that this fine collaboration must continue.

International Cooperation

A. International nurseries

1. ICARDA prepares and distributes a wide range of international nurseries. This provides an adequate selection for most national programs, which are free to choose whichever nurseries they require to meet their own objectives. Certain countries are able to handle larger nurseries than those currently supplied.

2. The specific requirements of the individual national programs are already taken into account by ICARDA in preparing the international nurseries. However, further moves in this direction are to be encouraged. As an aid in this process, it is recommended that ICARDA, together with the national programs, draw up a list of research issues in order of priority for each crop in each country.

3. It is recommended that ICARDA consider inviting breeders to visit during selection time so that they can select materials which are of potential interest to their own programs. A system of this type is already in operation at ICRISAT and could be a useful model for ICARDA to adopt. However, it is recognized that selection at ICARDA locations for characteristics of low heritability may be of limited value to breeders working in different environments.

4. It is not always possible to send nurseries to some countries in time for planting the following season. However, ICARDA should continue to make every effort to dispatch nurseries as early as possible. Likewise, scientists receiving the nurseries should make every effort to ensure a fast passage of materials through customs formalities. Certain countries have specific quarantine requirements and these should be made known to ICARDA well in advance of dispatch. ICARDA has now established a seed health unit and this should help ensure that only clean, pest and disease-free seeds are dispatched.

5. Cooperators should make every effort to return data to ICARDA at an early date. With the new computer facilities at ICARDA it should now be possible to analyze the trials and return information to cooperators sooner. It is recommended that a system for fast communication of results to cooperators be established which could precede the preparation and distribution of the comprehensive report. The process of data analysis and report preparation will be greatly assisted once the position of international trials officer has been filled. The meeting endorses the need for this position.

B. Training

1. The importance of training was stressed by the meeting. All types of training currently offered by ICARDA are considered

to be valuable in meeting the needs of the various levels of scientists and technicians.

2. The six-month courses are considered particularly valuable. It was recommended that special attention be devoted during these courses to all aspects of trial management including land preparation, layout, planting procedures, plant protection, harvesting, and analysis and interpretation of the results.

3. The need for more specialized short courses and individual training opportunities was also emphasized. Among the topics which could be considered for such courses are pathology, microbiology, weed control, breeding methodology, entomology, agronomy, and seed quality.

4. The problem of medium of instruction for training courses was discussed. In general it was recommended that more attention should be paid to this issue, e.g. by simultaneous interpretation or by holding separate courses exclusively in English or Arabic to be attended only by people fluent in the relevant language.

C. Conferences, workshops, and communications

1. It was recommended that the announcement of conferences and other scientific meetings should be made well in advance of the meeting to allow adequate lead time.

2. Future workshops should consider fewer reports with a greater time devoted to each paper and discussion. Many topics could be covered in poster sessions and it might be possible for some sessions to run concurrently.

3. There is a need for more specialized workshops such as the ones planned for parasitic weeds and favism in 1984.

4. LENS and FABIS are considered suitable publications for announcement and description of new cultivars. Other legume species not covered by LENS and FABIS are either the subject of other specialized newsletters (e.g. Chickpea Newsletter, *Pisum* Genetics Newsletter, and Bean Cooperative Newsletter) or general pulse newsletters (e.g. Tropical Grain Legume Bulletin and Pulse Crops Newsletter).

D. Cooperation with other institutions

It was recommended that collaborative research on lentils and kabuli chickpeas with India and other countries outside ICARDA region should be strengthened.

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