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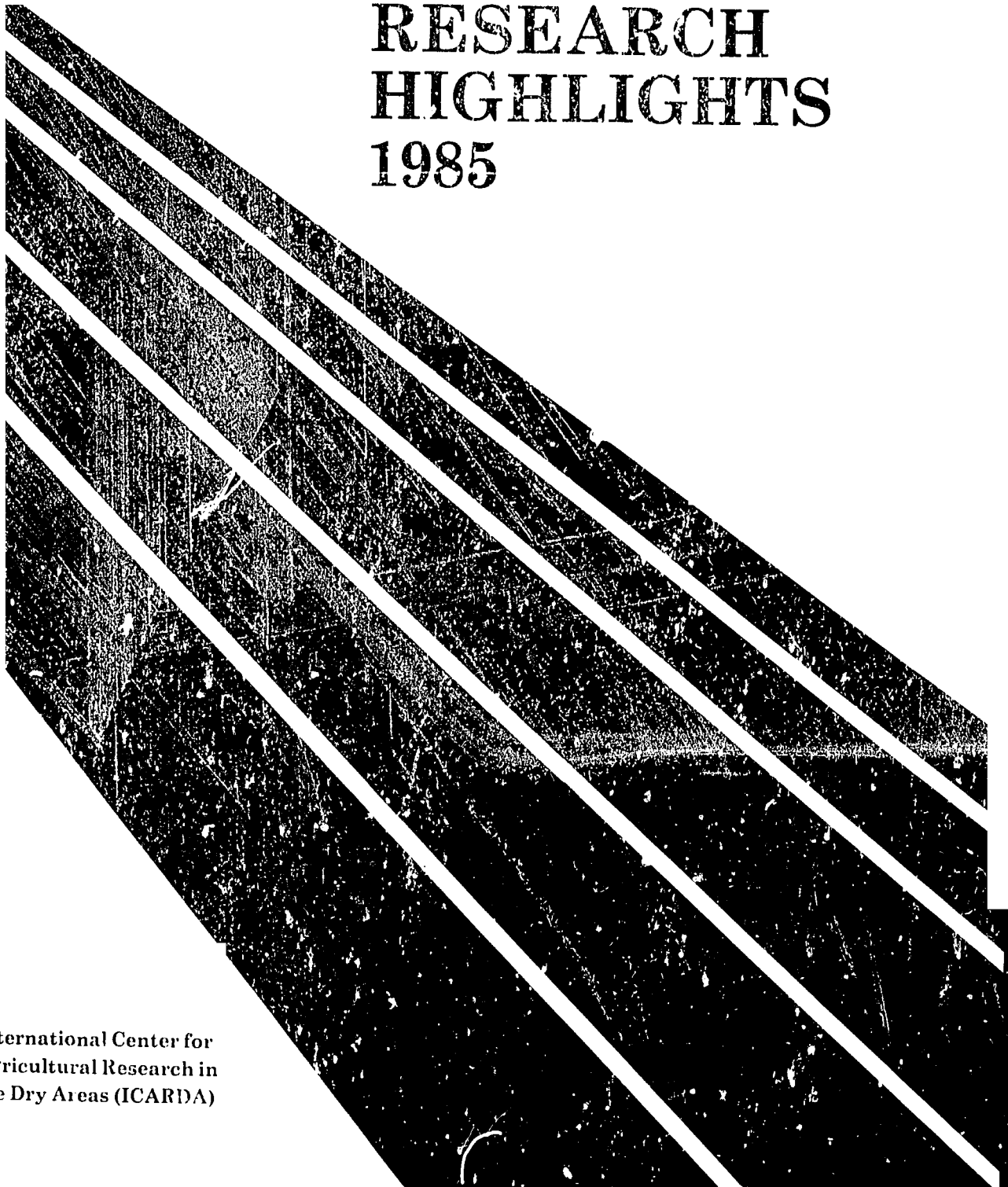
ICARDA RESEARCH HIGHLIGHTS 1985



International Center for
Agricultural Research in
the Dry Areas (ICARDA)

Profile of ICARDA

The International Center for Agricultural Research in the Dry Areas (ICARDA) was established in 1977 to undertake research and training relevant to the needs of developing countries and specifically for the agricultural systems of West Asia and North Africa. Its general objective is to help increase agricultural productivity and food supplies, thus improving economic and social living standards.

The Center focuses primarily on rainfed agricultural systems in areas having a dry summer and where precipitation in winter ranges from 200 to 600 mm. It supports the kind of research that will help small farmers achieve better harvests and is designated a world center for improving barley, lentils, and faba beans, and a regional center for wheat, chickpeas, pasture and forage crops, and farming systems.

Governed by an International Board of Trustees, ICARDA is organized into four scientific programs: Farming Systems, Cereal Crops Improvement, Food Legume Crops Improvement, and Pasture, Forage, and Livestock Improvement. Other key divisions include Genetic Resources, Training, Communications and Documentation, and Computer Services.

Principal financing for ICARDA is arranged by the Consultative Group on International Agricultural Research (CGIAR), and support for its programs in research and training in 1985 was provided by many countries and organizations. The principal donors are listed on page 89.

Headquarters for the Center, including its principal research station, is at Tel Hadya, Syria (35 km south of Aleppo on the Damascus-Aleppo highway). Land for the 948-hectare site was granted by the government of the Syrian Arab Republic. ICARDA also manages other sites where material can be tested under a variety of agro-ecological conditions: at Kafr Antoon, Jindiress, Khanasser, Breda, and Lattakia in Syria, and at Terbol in the Beka'a valley of Lebanon. However, the full scope of the Center's activities can be appreciated only when account is taken of the cooperative research carried out with many countries of the region.

ICARDA RESEARCH HIGHLIGHTS 1985

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Foreword

Progress made during the year by ICARDA and its partners in research and training – the national programs of the region – shows that significant improvements can be achieved in food production in terms of both higher and more stable crop yields. Only through intensifying local food production – with better varieties and technology – can the region which [illegible] West Asia and North Africa hope to improve the lots of [illegible] and lower huge imports. Selected brief accounts of progress during [illegible] this fifth edition of *Research Highlights*. More detailed [illegible] advances are available to you in ICARDA's Annual Report.

Severe drought, temperature and disease stresses are [illegible] constraints limiting production of many crops in that region. [illegible] developed and identified germplasm material resistant to these stresses. [illegible] year of bad rainfall or disease epidemics need [illegible] reported here, stress-tolerant lines of various crops were [illegible] year to national programs for possible selection and multiplication.

Several countries in the region and beyond [illegible] barley lines from ICARDA breeding materials, [illegible] then released them for general cultivation. The same [illegible] Also, other improved lines of these crops are now in [illegible] farmers by national governments.

On-farm trials were expanded in many countries during [illegible] experiences and responses of farmers fed back to ICARDA and [illegible] This type of research is a viable pathway to meaningful [illegible] Perhaps the most important influence of ICARDA on [illegible] increased emphasis on research directly aimed at solving [illegible] National organizations managed more of the on-farm trials [illegible] before. One of the most progressive in this respect [illegible]

Likewise, as national research systems become stronger, ICARDA [illegible] shift from producing readily adopted technologies to support the generation of new technologies by national programs. The process has already started and [illegible] can be found in this publication.

Several new research and training projects began during the year. [illegible] headquarters, a new virology laboratory was established [illegible] of crop losses induced by viruses on cereal and food legume crops. Staff members collected samples of virus-infected plants in four countries and [illegible] observations through laboratory tests. Beginning in 1985, the Center [illegible] executing contractor for a four-year major Government of Pakistan project in the high elevation area of Baluchistan funded by USAID. It is an [illegible] outgrowth of a smaller pilot project which began in 1981.

An agreement was signed with Turkey to exchange advanced cereal breeding materials for testing and to jointly evaluate improved germplasm. Another

collaborative undertaking got underway in Sudan: a two-year wheat project modeled somewhat along the same lines as the Nile Valley Project for faba beans funded by the OPEC Fund for International Development. ICARDA and Sudanese scientists and extension workers are developing a recommended package of technologies to be used in farmers' fields.

We regard the training function as vital to the Center's mission, and the willingness of administrations to continue to release nature's sources for training during 1985 and assure them of positions on their return demonstrates the high regard for the training provided by ICARDA. Year by year the number of participants has grown – from 26 in 1978 to 215 in 1985. Also, more regional and in-country training is being offered in cooperation with national programs instead of all the courses being held at ICARDA.

Plans are underway to officially inaugurate the [illegible] of our new permanent buildings in March 1987 at our central headquarters [illegible] Aleppo, in 1984. This occasion will coincide with ICARDA's 15th Anniversary.

We again voice our deep sense of gratitude [illegible] individual nations and international organizations [illegible] our research and training work.

On a more personal note, I would like to [illegible] become very much a member of the ICARDA [illegible] William B. Ward, Professor of Comparative [illegible] come to Aleppo to collect the contributions [illegible] harmonize these in the annual production [illegible] counsel, and his skills have been much appreciated.

Mohamed A. Nour
Director General

Breeding Strategy for Wheat in High Elevation Areas

Extensive high elevation zones above 1000 meters account for almost 50% of the total wheat area of the ICARDA region, yet they produce only about 25% of the wheat production because yields are low. Although development and research resources in the countries of West Asia and North Africa have been traditionally biased towards the more favorable lowland environments where the returns on investment in research and development are greatest, more attention is now being focused on high elevation areas because of their potential for increasing food production.

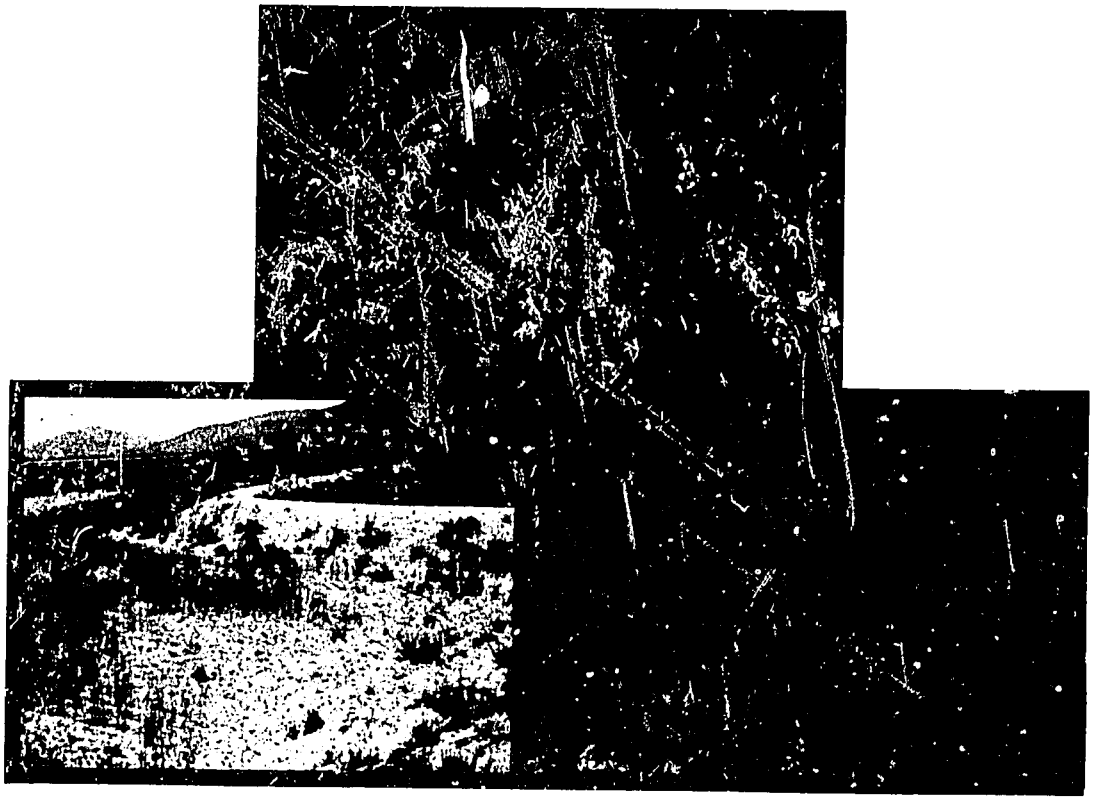
These areas with their fragile ecosystems and extreme weather variations are found in the great mountain belt which stretches from Pakistan in the east through Afghanistan, Iran, and Iraq to the Anatolian Plateau of Turkey. They also exist in parts of Lebanon, Yemen Arab Republic, and North Africa. Except in Turkey, wheat yields average only about 600 kg/ha because of the lack of improved varieties, susceptibility to diseases, poor crop management practices, and harsh environmental stresses.

If improved, better yielding wheat varieties are to be successful, they must survive severe cold winters, short springs, and hot, dry summers. ICARDA and national scientists are making a major effort to identify suitable varieties in wheat germplasm originating from principal winter wheat growing areas of the world. However, out of 10,000 entries tested at Quetta in Pakistan and Annoceur in Morocco, only a few performed satisfactorily.

Also at Quetta, the scientists studied wheat varieties from those same sources to obtain essential information on two important crop growth phases: vegetative (sowing to heading) and reproductive (heading to maturity). They found only small differences in the number of days to heading but large differences in the time taken to mature. The varieties from Quetta (Pakistan), Ankara (Turkey), and Iran took 27, 30 and 35 days, respectively to mature after flowering. The varieties from Oregon (United States) and Cambridge (England) matured in 40 and 46 days, respectively. A variety from Texas (TxlA 562-6) did not mature.

The heading time in Quetta for wheat is about the last week of April and coincides with the period when rains stop and temperatures start rising rapidly with strong, warm, gusty winds. The wheat varieties responded to this changing climate through their genetic adaptive mechanism by hastening maturity. However, the effect of high temperature and reduced moisture on the 1000 kernel weight of the varieties from Oregon, Texas, and Cambridge was much greater. They had a longer reproductive phase compared with varieties from Pakistan, Turkey, and Iran.

These studies revealed that the successful varieties in such environments should have a long vegetative phase to go through the severe winter and a short reproductive phase to cope with rapidly rising tempera-



Bread wheat lines (top) susceptible to cold and in the background tolerant lines at Sarghaya, Syria; below, drought damage (left) and heat damage (right) at Quetta, Pakistan.

tures coupled with moisture deficiency. Based on these results, plant breeders at ICARDA concluded that the type of plant required should have a long vegetative phase, many fertile tillers, a short reproductive phase, and medium-sized heads and grain. These assumptions are supported by the fact that the local and well adapted landraces in these countries possess such traits.

To serve high elevation areas, a breeding and germplasm development strategy was developed with these essential components:

(1) Use of local landrace cultivars.

(2) Screening of parental material at a few representative high altitude sites against the biotic and abiotic factors retarding crop productivity (Figure 1).

(3) Breeding for specific adaptability.

(4) Targeted crosses with winter × winter and/or winter × spring types.

(5) Multi-location testing and selection of early generation material (Figure 2).

(6) Bulking of selected plants to provide buffering capacity to new cultivars to cope with variable agro-climatic conditions.

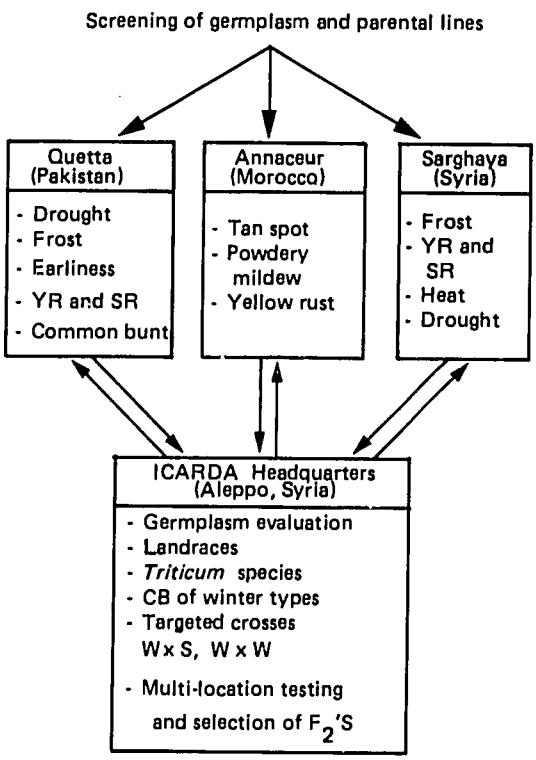
Under this strategy, screening of germplasm and parental lines for various stresses is carried out primarily at three

sites: Quetta (Pakistan), Annoceur (Morocco), and Sarghaya (Syria), with supplementary information gathered from some other sites in Syria such as Lattakia for disease resistance, Breda for drought tolerance, and Hegla for salt tolerance. All the information is funneled to ICARDA's headquarters where a complete set of the material is planted every year to make targeted crosses involving winter × winter or winter × spring types.

The use of local landraces as one of the parents in a majority of the crosses is emphasized. These targeted crosses for specific adaptability are then supplied to the cooperators in countries of West Asia and North Africa for testing and selection (Figure 2). The entire activity is carried out in close collaboration with national scientists and research institutions.

Part of the achievement and success of the wheat breeding program from 1981 to 1985 is shown in Figure 3. The overall selection frequency of ICARDA-supplied winter wheat lines at Annoceur (Morocco) increased from 2% in 1981 to 25% in 1985; Quetta (Pakistan) from 8% to 27%; at Sarghaya (Syria) from 10% to 30%. The most striking result came from the performance of the high altitude bread and durum wheat observation nurseries at Ankara (Turkey) last year: 15% of the lines were selected compared with 1% in 1981 on the basis of their resistance to tan spot and yellow rust diseases and their favorable agronomic score.

Figure 1. Cereal breeding strategy for high elevation areas.



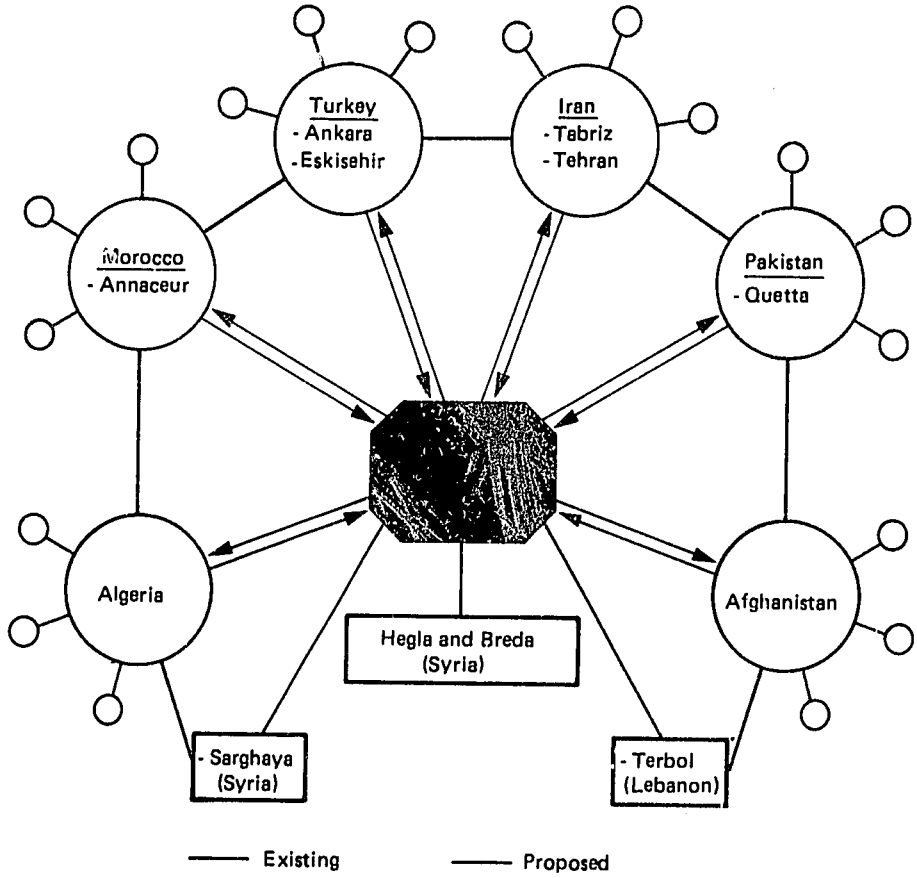


Figure 2 (Above). Multi-location testing and selection network for cereals.

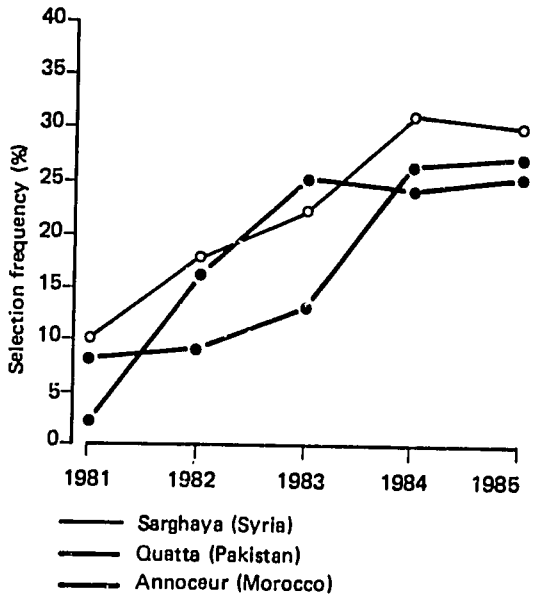


Figure 3 (Left). Selection frequency (%) of winter wheat lines from 1981 to 1985 at three sites in Morocco, Pakistan, and Syria.

Use of Landraces and Wild Species to Improve Durum Wheat Production in Stress Environments

Notable progress is being made in developing improved durum wheat cultivars for dry areas by using landraces and wild relatives of cultivated species in the hybridization program. Landraces, grown for centuries by farmers, are generally low yielders under favorable and high input conditions but they and wild species have specific genetic characteristics adapted to particular ecological environments and provide valuable gene sources for breeders to improve drought tolerance, tillering, and protein content in new scientifically bred varieties.

One of these new durum varieties is Omrabi derived from a cross involving Haurani, a Middle East landrace, and Jori C69, a high yielding cultivar under favorable environments of the Middle East and North Africa. It has outyielded its parents in both favorable and dry environments (Figure 4).

The performance of Sebou, another newly tested durum line, demonstrates the useful exploitation of desirable genes from a wheat relative, *Triticum polonicum*. This durum wheat line comes from a cross involving Crane, a variety adapted to high input conditions, and a strain of *T. polonicum*, a wheat species adapted to arid conditions.

Figure 5 shows the performance over three years at on-farm trials of Sebou compared with Haurani in the dry areas and Gezira in the higher rainfall or irrigated areas of Syria. The results demonstrate that Sebou combines its high yield potential with good yield consistency across the various agroclimatic environments in Syria. This variety has also shown good adaptation both in Jordan and Algeria.

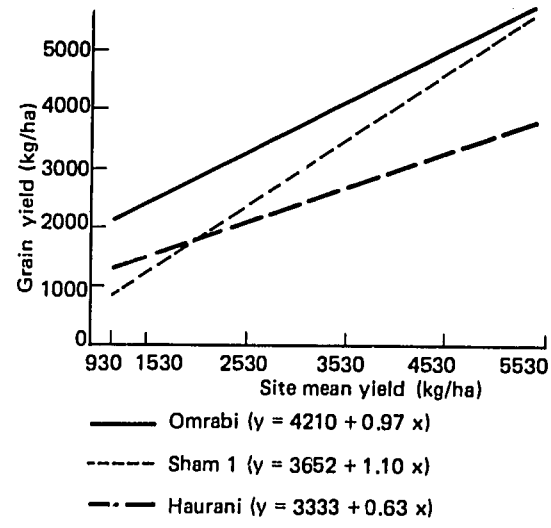


Figure 4. Yield stability of Omrabi, a new durum wheat variety, compared with Sham 1 and Haurani.

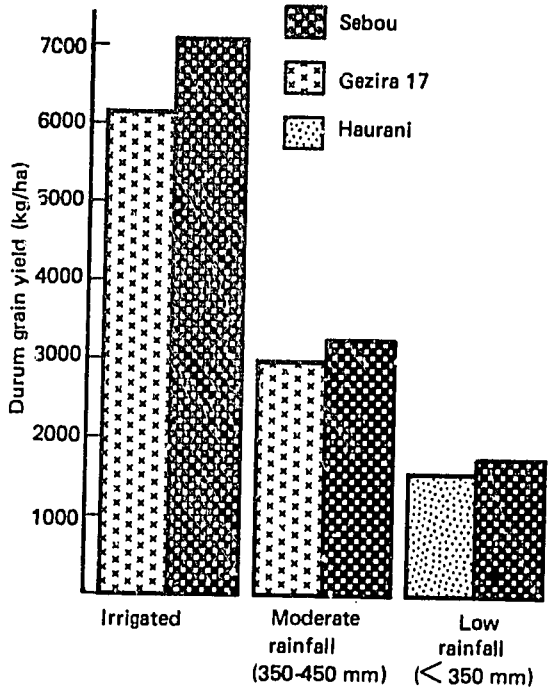


Figure 5. Mean grain yield of Sebou compared with Gezira 17 and Haurani durum wheat varieties at on-farm trials in Syria (1983–85).

Landraces of durum wheat (below) provide valuable gene sources for plant breeders to improve drought tolerance, local adaptation and other desirable characteristics in new scientifically bred varieties.

Variability in Agronomic and Morphological Traits in Syrian Landraces of Barley

Barley growing areas with less than 300 mm of annual rainfall in the Middle East and North Africa are characterized by high inter-seasonal and intra-seasonal variability in the amount and distribution of rainfall. Here barley is grown mainly as animal feed and farmers use both the grain and the straw. The crop is usually under environmental stresses (drought, cold, heat, and salinity) and they, along with low soil fertility and traditional agronomic practices, account for low productivity.

In these agro-climatic environments, landraces and/or selections from landraces are considered to be the most dependable genetic material, but scientists have found it difficult to identify varieties with consistent larger yields, especially where environmental stresses are the major yield-limiting factors.

Although it has been proven that landraces or "primitive cultivars" grown for a long time by farmers are an important source of useful genetic variation and varietal improvement for many crops, scientists lack sufficient experimental evidence of agronomically useful genetic variability in barley landraces in the Fertile Crescent. Therefore, ICARDA scientists are now using landraces as one of their strategies to improve barley yields and yield stability in very dry areas.

The initial phase of this activity is concentrated mainly on the two widely grown Syrian landraces known as Arabi Abiad (white seeded and grown in slightly more favorable environments) and Arabi Aswad (black seeded, grown in harsher environments). Both landraces are two-rowed, with thin stems and high tillering ability.

A random sample of 420 lines derived from single heads collected in farmers' fields at different locations in Syria were

Tadmor, an improved barley landrace, interests farmers because of its yield performance under harsh environmental conditions in Syria. It provides one of the valuable genetic sources for the improvement of barley in very dry areas.

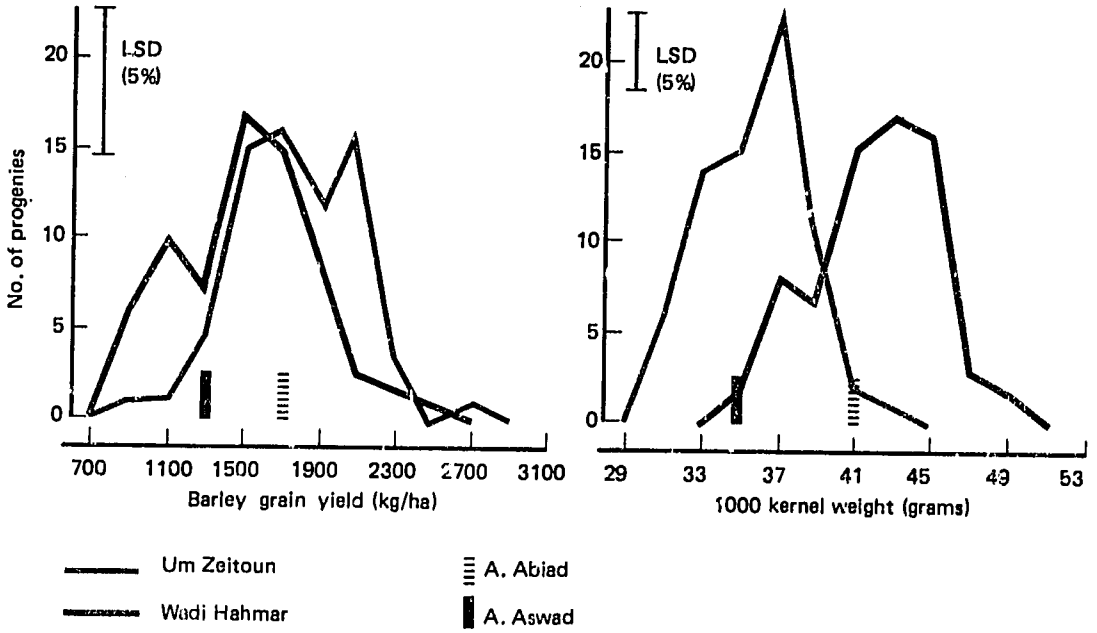


Figure 6. Variability in grain yield and 1000 kernel weight between pure barley lines collected from local landraces at two sites – Um Zeitoun in the south and Wadi Hahmar in the north of Syria. Vertical bars show the mean values of the two standard landraces grown in Syria – A. Abiad and A. Aswad.

evaluated in three trials at the Breda experimental site with a rainfall of 277 mm. A wide range of diversity was found for characters such as growth class, early growth vigor, cold damage, plant height, days to heading and maturity, grain filling duration, 1000 kernel weight, protein and lysine content, grain yield, and resistance to yellow rust, scald, and powdery mildew. An example of this variability is shown in Figure 6 for two collection sites.

As a result of this study, 15 lines were found to outyield one or both landraces, and one line was identified which outyielded the best local cultivars by 49% at Bouider with 178 mm rainfall and by 25% at Breda with 277 mm rainfall (Figure 7).

The information generated in this type of study can be used in a breeding program in at least four different ways:

(1) Release of the highest yielding lines as pure line varieties after testing their stability in different environments (locations and years).

(2) Use of superior lines as parents in the crossing program to introduce additional desirable characters in an adapted genetic background.

(3) Evaluation of multi-lines built with a variable number of pure lines properly characterized for a set of agronomic characters. (This helps achieve a better understanding of the relationship between genetic heterogeneity and stability.)

(4) Lines showing extreme expressions of certain attributes but similarity for others (e.g. tall and short lines with similar levels of cold tolerance, early growth vigor and maturity, or early and late lines with similar plant height, early growth vigor, and cold tolerance) can be evaluated by the stress physiologists. (They can quantify the adaptive role of specific morphological traits, in a given combination with other traits, under stress environments).

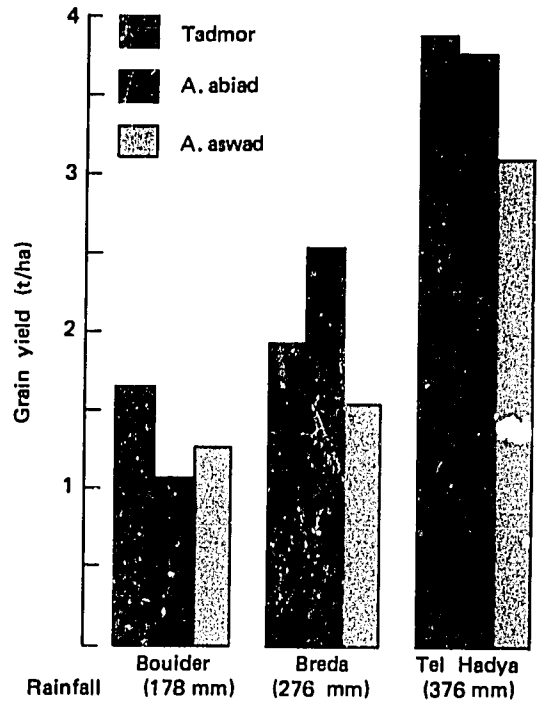


Figure 7. Grain yield of Tadmor, a barley landrace selected at a collection site near Palmyra, Syria, compared with two standard landraces grown at three locations.

Multi-location Testing of Advanced Barley Lines for Disease Resistance

Before new barley material is included in International Nurseries or Farm Verification Trials, researchers gather as much information as possible on the different characteristics of these lines and conduct final yield and quality tests within the Advanced Barley Yield Trials planted in three or four locations within Syria and Lebanon. However, these locations are not sufficient to evaluate the resistance of these lines to various diseases. Few barley diseases occur every year severely enough for a reliable screening of nurseries with a large number of entries planted in relatively small plots.

Furthermore, in the farmer's situation, foliar diseases (such as scald or net blotch) depend for their initial inoculum on the stubble of the previous year's crop. This implies that the disease level of the previous year's crop, which is determined by the environment and the susceptibility of the cultivar grown, influences the disease level of the present crop.

To avoid the chance of barley lines escaping the disease, initial inoculum is applied artificially under controlled conditions. To ensure reliable screening of the germplasm to specific diseases, the nursery is planted in environments known for natural occurrence of disease development. Since 1981, lines present in the Advanced Barley Yield Trials are included in a special disease nursery (Key Location Disease Nursery) planted in a number of "hot spots" both within and outside the ICARDA region where natural infestation is high. Evaluation is carried out in cooperation with the national programs of the countries where this nursery is planted.

Even by planting in these "hot spots," diseases may not occur every year in the same severity. For a reliable estimation of resistance, data sets of different years have

Scientists conducted severe screening in multi-location tests to select barley lines resistant to scald (shown here) and other major leaf diseases.

to be evaluated. As the plant breeder is repeating the best performing entries for both yield and resistance in next year's nursery, more than one year of data is available for the best material. In the 1984/85 Advanced Yield Trials, 78 lines were included for the third year or longer. Severe screening was done in more than one location for more than one year for four major leaf diseases: yellow rust (*Puccinia striiformis*), leaf rust (*Puccinia recondita*), powdery mildew (*Erysiphe graminis*), and scald (*Rhynchosporium secalis*).

Barley lines were selected having less than 15% severity for the rust diseases and for powdery mildew and scald a score of less than 5 on a scale where 0=highly resistant and 9=highly susceptible. If a line was selected in 75% or more of the data sets for a specific disease, it was considered to be resistant to this disease. Of the 78 lines tested over the past three years, 41 were resistant to one of the four diseases, 19 to two different diseases, and five showed resistance to three. Acceptable levels of multiple disease resistance are present in ICARDA's elite barley germplasm.

Yield Potential and Drought Tolerance in Barley

Three experimental sites in Syria's Aleppo province offer the unique opportunity to test early segregating barley populations with different rainfall patterns which represent a range of growing conditions for the crop in the Middle East.

ICARDA's principal experiment station at Tel Hadya, with its higher long-term annual rainfall of 342 mm and better soil fertility, provides information on the yield potential of parents, segregating populations, and advanced lines. Bouider, at the other extreme with a long-term average rainfall of 175 mm and poor soil fertility, supplies information on yield under severe moisture-limiting conditions. In the middle range is Breda (273 mm) which could replace Bouider in exceptionally dry years when crop failures are expected to occur.

Yield (either grain or total biological yield) at Tel Hadya and Bouider for 729 F_3 bulk populations was used to compute the drought susceptibility index (indicated by S). This index quantifies for each particular genotype the yield depression from a favorable to a dry site in relation to the average yield depression of a set of genotypes.

Figure 8 shows an example of six genotypes with different relationships between S, yield potential under favorable conditions, and yield under dry conditions. Low values of S indicate a less-than-average yield reduction and therefore drought resistance. However, the use of S

alone as selection criterion can be misleading as shown by genotypes 1 and 2. Genotype 2 appears more drought tolerant but genotype 1 has the best combination of yield under drought and ability to respond to favorable conditions.

A high and negative correlation coefficient (r=−.769) was found between drought susceptibility index and grain yield at the driest site. But at the more favorable site (Tel Hadya) the correlation coefficient was much lower and positive (r=.249). This indicates that the highest yielding populations in a moisture-limiting environment had a below average grain yield in the more favorable environment. This suggests that characters which are desirable under drought are not necessarily desirable in favorable conditions and vice versa.

The 5% highest yielding populations at Tel Hadya gave an average grain yield of 5367 kg/ha compared with 2508 kg/ha for the 5% lowest yielding populations (Figure 9). However, when these two groups of populations were compared in Bouider their grain yield was 929 and 758 kg/ha, respectively. By contrast, the difference between the 5% highest yielding and the 5% lowest yielding populations at Bouider (1668 and 274 kg/ha, respectively) was significant (at 5% probability level) even when the two groups of populations were compared at Tel Hadya.

Therefore, differences among segregating populations for yield potential under favorable crop growing conditions seem to be of little relevance for a moisture-limited environment. In other words, yield potential under favorable conditions does not appear to be a useful selection criterion to identify superior genotypes for dry conditions.

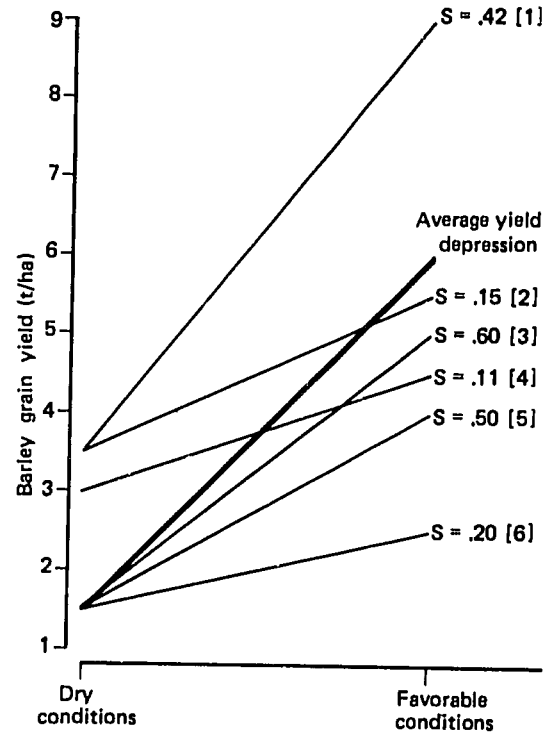


Figure 8. Hypothetical cereal genotypes (in brackets) differing for yield under drought, yield potential, and drought susceptibility index (S).

The main implication of these results: in a breeding program for stress environments it is essential to screen early segregating populations in the target environment to avoid the risk of losing a large fraction of genotypes specifically adapted to dry conditions. This supports the current strategy of ICARDA's barley breeding program which is based on direct selection under stress conditions. Considering the importance of barley in dry areas, these results also suggest the need to reassess the role of specific adaptation to achieve rapid progress toward substantial yield increases under stress.

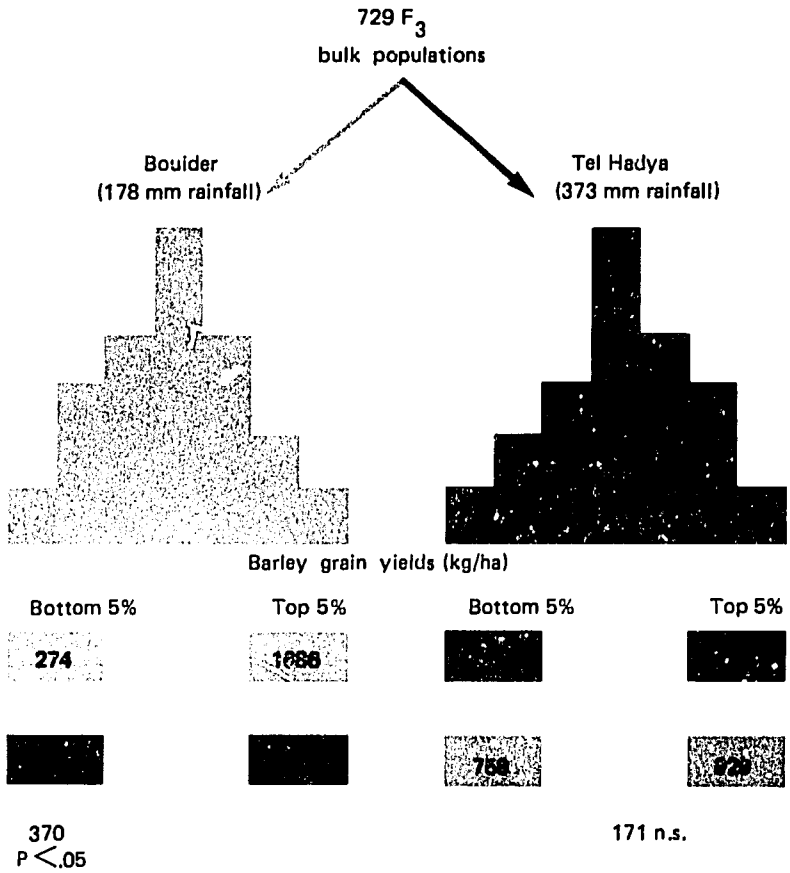


Figure 9. High grain yield for barley under favorable conditions (Tel Hadya) does not appear to be an efficient selection criterion to improve yields under dry conditions (Bouider). Grain yields (kg/ha) at Tel Hadya are shown in orange and at Bouider in yellow. (Each location in northern Syria.)

Increased Adaptation of Bread Wheat Germplasm

There is an urgent need for substantial increases in wheat production in countries of West Asia and North Africa where consumption per capita is the highest in the world and the crop provides over half of the calories consumed by their people and sometimes half the protein. With the exception of Turkey, they deal with chronic and acute cereal deficits and bread wheat accounts for 80% of huge cereal imports.

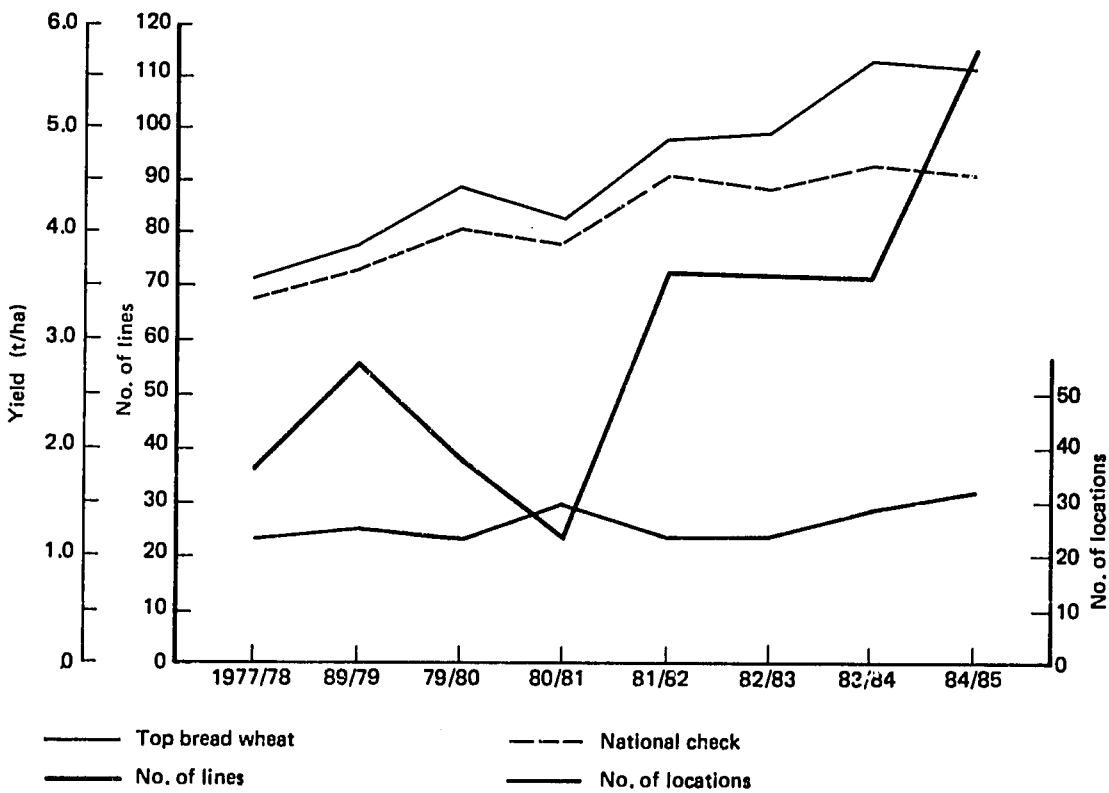
Because environments in the region are so diverse, with weather and disease patterns changing radically from year to year, the scientists test bread wheat germplasm in many locations to ensure adequate exposure to a full range of stresses. This multi-location testing enables them to identify and select superior gene combinations with specific and broad adaptability, high yield potential and stability, disease and insect resistance, and acceptable grain quality.

In an effort to respond to requests from national programs for improved adapted germplasm, the joint ICARDA/CIMMYT bread wheat improvement program distributes advanced lines and early generation F_2 material from which they can select potential commercial varieties. Over the past few years, the yield gap between the top bread wheat lines developed jointly by ICARDA and CIMMYT scientists and the national check varieties has widened. By 1985, the difference

Scientists test bread wheat germplasm in many locations to ensure adequate exposure to stresses. Selecting lines for disease resistance in Tunisia (top photo); evaluating the performance of lines in Ethiopia (lower photo).

amounted to approximately one ton per hectare (Figure 10). Also, the number of bread wheat lines selected by national programs based on their superiority over the national check varieties increased.

Figure 10. Number of bread wheat lines significantly ($P < 0.05$) outyielding the national checks in 21 countries of West Asia and North Africa (1977–85).



Several advanced bread wheat lines with superior grain yield and tolerance to cold are identified in these experiments. The wheat in the light colored strips have been damaged by cold temperatures; those in the green strips are tolerant.

Cold and Drought Tolerance in Advanced Bread Wheat Lines

A large proportion of the semi-arid environments in developing countries can be found in the Middle East and North Africa region. Here low, erratic, and unpredictable rainfall and temperature stress represented by frosts are important constraints limiting wheat production.

Over the past few years, the joint ICARDA-CIMMYT bread wheat improvement program has emphasized the development and identification of germplasm material resistant to these stresses. Several advanced bread wheat lines with superior grain yield, as well as drought and cold tolerance, have been identified. Table 1 shows five of the most outstanding ones. The 1983/84 crop season was characterized by being extremely dry. Total rainfall received at Tel Hadya was 229 mm — 113 mm below the long-term average of 342 mm. Similarly, 1984/85 was an unusually

cold season. Freezing temperatures as low as −10°C were registered for 20–25 days at Tel-Hadya's meteorological station.

Taking advantage of selecting material under these two different seasons, it was possible to identify several lines which were not only superior in yield compared with the checks but also had some degree of drought and cold tolerance. These lines were distributed to national programs in the region for possible selection and multiplication.

Sham 2, a wheat variety released in Syria, was found to be a cold tolerant line in many countries. It did well in the 1984/85 cold season compared with check varieties. Because of its cold tolerance, it produced good yields in southeastern Turkey and in large-scale on-farm tests and multiplication there and elsewhere.

Cross and Pedigree	PWYT 83/84 Rainfed				AWYT 84/85 EP-SIR*			
	LSD (5%)	% MXP*	DTS L	DTS C	LDS (5%)	% Sham 2	CTS* L	CTS* C
C182.24/C168.3/3/Cno*2/7C//Cc/Tob SWM 6828-6AP-2AP-2AP-3AP-0AP	619	146	1.6/3.3		653	119	1.3/2.6	
Chat'S' CM 33090-T-1M-3Y-0M-124B-OK-0AP	714	134	1.0/3.3		407	114	1.3/2.0	
Chr/4/Inia'S'/7C//Cno/G11/3/Pei//Bb/Inia CM 46935-2AP-0AP-6AP-1AP-2AP-0AP	572	141	1.0/3.3		433	121	1.6/1.7	
Jup'S'/4/LR64*2/Sn64//Cc/3/Ska L 764-4L-1Ap-0AP-1AP-1AP-0AP	619	132	2.0/3.3		653	120	2.0/2.6	
Rannaya/Lovrin L3//Tes SWM 8211-4Y-1Y-2Y-0AP	611	145	1.0/2.3		573	120	1.6/2.6	

**MXP=Mexipak 65; DTS=Drought Tolerance Score and CTS=Cold Tolerance Score: 1=Best, 5=Worst; EP=Early Planting; SIR=Supplementary Irrigation; L=Line; C=Check.*

Table 1. Advanced bread wheat lines with superior yield, as well as drought and cold tolerance, compared with two checks (Mexipak 65 and Sham 2) in Preliminary Wheat Yield Trials (PWYT) in 1983/84 and Advanced Wheat Yield Trials (AWYT) in 1984/85 at Tel Hadya, Syria.

Durum Wheat Germplasm Resistant to Yellow Rust Disease

Yellow rust or stripe rust – one of the major diseases of durum wheat in countries of the region – is not confined only to cooler high elevation areas but has become serious in some warm and dry areas where large agricultural schemes are put under irrigation. (For example, Euphrates areas in Syria.) Durum wheat is grown on approximately 8.5 million hectares in North Africa and West Asia – about 45% of the world durum area.

Scientists screen durum wheat germplasm for resistance to yellow rust disease caused by *Puccinia striiformis* f. sp. *tritici* at ICARDA's principal station at Tel Hadya, Syria and in several other "hot spots" under artificially created epidemics or natural infection. A special Durum Yellow Rust Nursery (DYR) has been put in operation to develop a germplasm pool with sources of resistance to the disease. It includes durum wheat lines exhibiting resistance in primary screenings. They are then retested in "hot spots" for several years.

At the Institute for Plant Protection (IPO) at Wageningen in the Netherlands, DYR-1985, with other germplasm, was tested during the year at the seedling stage for resistance to 10 predominant isolates of the yellow rust pathogen. They came from four countries within the region and three from outside: India, Kenya, and Italy.

Twenty-three out of the 36 durum wheat lines in the DYR-1985 were resistant to all 10 pathogen isolates used (Table 2). In a previous field screening in 1983 and 1984 at four sites in Syria and Portugal, they showed good resistance to the yellow rust pathogen. The majority of them were selected for resistance under a Syrian environment at Tel Hadya.

Left, an advanced stage of severe yellow rust or stripe rust disease on a wheat leaf; right, a leaf from a resistant plant.

Most of these resistant lines are carrying the parents Flamingo (Fg) and Gaviotal (Gta) in their pedigrees; eight lines (entries 1, 2, 4, 17, 18, 19, 20, and 21) are used extensively in the crossing program of durum and four entries (5, 10, 14, and 22) are included in the Regional Yield Trials for final yield testing. Entry 23 is released in Syria (as Sham 1), in Portugal (as Celta), and in Cyprus (as Karpasia).

*Table 2. Durum wheat lines resistant to different isolates of yellow rust (*Puccinia striiformis*) in seedling stage testing.**

Entry	Name or cross
1	Pen
2	Jo/Cr//USA 06179/3/Jo/Gr
3	D 4766
4	Memo
5	Kif//Ruff/Fg
6	Gr/S.Cp//St 464/3/Cr/4/Gta
7	Mexi/Gta
8	Snipe//Ovi/Amarelejo
9	Rabi/31810//Snipe/3/Balcarceno Inta
10	Misri/Mexi//Snipe
11	Sco/3/BDI 814//BD 1708/BD 1543/4/ Rok
12	Ggo VZ 385/Gs/4/D. dwarf S15//T.dic. V. Vern/G11/3/Plc
13	Gta/USA 0445
14	Snipe/Magh=Zeroud
15	Gediz/Fg//Gta
16	USA IIIC/Gs//Cr/Cit/3/D 67.2
17	Stellata
18	Cfn/2*Lan/Dwf F_2Lan
19	Br'S'//ZB/PI 298547*
20	Rabi//Gs/Cr
21	Gta//Jo/Cr
22	D. dwarf S15/Cr//3/Plc/CV//Jord 119 =Jordan
23	Plc/Ruff//Gta/Rtte =Sham 1

**Isolates used: 3 Syria (2E16; 6E16; 70E16); 1 Turkey (6(38)EO(16)); 1 Tunisia (6E16), 2 Pakistan ((6(38)E16), 66(74)ED); 1 India (6E16); 1 Kenya (134E150); 1 Italy (108E141).*

Monitoring Response to Selection for Superior Yielding Cereal Genotypes in Regional Trials

Cereal genotypes with improved yielding performance are constantly being identified and delivered to national programs through an international nursery system. In the process of selecting these genotypes, ICARDA and CIMMYT scientists compare new and promising advanced lines with both long-term and improved checks, plus national checks provided by cooperators. Comparison of these entries provides them with an indication of response to selection over long and short periods of time.

A conventional approach in comparing entries is through combined analyses of variance which pool information from all sites. One possible modification involves the tabulation of planned pairwise statistical comparisons across sites, thereby giving favorable and less favorable sites an equal weighting, yet incorporating the error of assessment unique to each site. Frequency of ranks, for example, can be helpful in comparing entries but suffers from a lack of associated probability levels.

To assess the overall performance for grain yield in the 1984/85 Regional Yield Trials, approximately 24,000 planned pairwise comparisons using the LSD procedure were performed and tabulated for 137 trial results (Table 3). About 80% of the locations were from countries in North Africa and West Asia, with the remainder from Europe (primarily Spain, Italy, Greece, and Portugal), North and South America, and East Asia.

Although it is difficult to compare the results from the 137 trials because the locations and checks tended to be quite different, these general observations can be made:

(1) On the average, more new (non-check) entries exceeded the long-term check than the improved check. This was especially true for the Regional Barley Yield Trial (RBYT) with Rihane – the widely adapted and high yielding improved check. No such comparison is appropriate for the Regional Bread Wheat Yield Trials (RWYT) since the improved check was a durum and not a bread wheat.

Monitoring the response of cereals to conditions in Jordan. Scientists compare new and promising lines with checks provided by national programs in several countries.

(2) Approximately two to four entries per location, depending on the level of significance, exceeded the national check. The ranges of number of entries exceeding the national check for the RBYT, RDYT-LRA (Regional Durum Yield Trial-Low Rainfall Areas), RDYT-MRA (Regional Durum Yield Trial-Moderate Rainfall Areas), and RWYT were 0–11, 0–12, 0–22, and 0–18, respectively (P=0.05).

(3) The average number of entries per location exceeding a check was approximately doubled from P=0.01 to P=0.10. The LSD test at P=0.01 is probably too stringent. Research is underway to determine the optimal significance level for variety testing so that truly promising genotypes are not inadvertently discarded.

P*	Long-term barley check (Beecher)	Improved barley check (Rihane)	National check
0.01	1.8	0.5	1.8
0.05	3.0	0.6	2.6
0.10	3.8	1.1	3.2

(26 Locations)

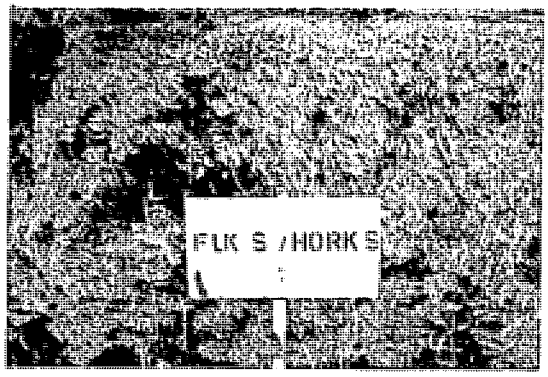
P*	Long-term durum check (Stork)	Improved durum check (Waha)	National check
0.01	2.1	1.9	1.1
0.05	3.4	2.7	2.3
0.10	4.4	3.3	3.1

(30 Locations)

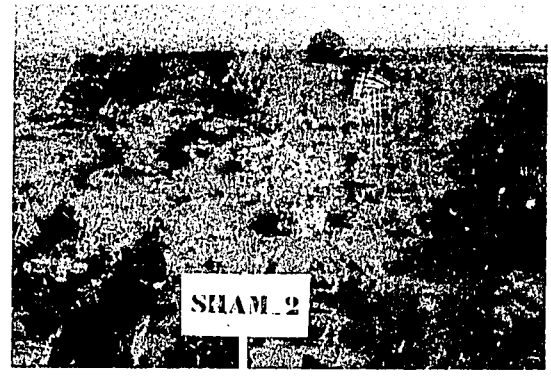
P*	Long-term durum check (Stork)	Improved durum check (Waha)	National check
0.01	2.6	2.0	—
0.05	4.0	3.3	3.3
0.10	4.9	4.2	4.1

**Level of significances, two-sided test, using the LSD statistical procedure for planned pairwise comparisons.*

Table 3. Average number per location of new (non-check) entries in the 1984/85 Cereals Regional Yield Trials significantly outyielding each of three checks.



The best bread wheat line in six trial locations in the Cukurova region of Turkey.



Sham 2 (bread wheat) exhibited excellent tolerance to cold in southeastern Turkey and has been selected for large-scale demonstrations on farmers' fields.

Performance of Improved Cereal Varieties in Turkey

Results of a new collaborative cereals research project between ICARDA and Turkey's Ministry of Agriculture, Forestry and Rural Affairs show that some of the improved varieties developed by the international center performed better than local checks in certain regions of the country, but others did not. These findings provide further evidence that varieties suited to one area may do poorly in another and that extensive location-specific testing is essential before national governments release new varieties for farmer use.

Among the 1985 results, based on both experiment station and on-farm trials and reported by Turkish scientists, are these:

(1) The advanced bread wheat line FLK's'-HORK's' resistant to prevailing diseases, performed reasonably well in three locations in the Aegean Region but not significantly better than the checks. The same was reported for Kourifla in the durum group of improved varieties. Sham 1 (durum) was susceptible to leaf rust and cold weather. Most of the barley matured a little too early in this region and was susceptible to leaf rust and powdery mildew diseases.

(2) Sham 2 (bread wheat) has been selected for large-scale demonstrations on farmers' fields in the southeastern region as a substitute for Malabadi the existing commercial cultivar. Sham 2 exhibited excellent tolerance to cold. Because of an exceptionally cold season, the ICARDA barley material was heavily damaged. Genotypes with better cold tolerance and earlier maturity would be more suitable for this region.

(3) Omrabia performed better than the durum wheat check variety at all six trial locations in the Cukurova region with an average yield of 5.3 t/ha; Kourifla averaged 4.8 t/ha; FLK's'-HORK's' was the best bread wheat line outyielding the three check varieties.

(4) ICARDA-derived spring wheat material fits better in the south and southeastern regions of Turkey but is not adapted to the Aegean and Central Anatolian Plateau regions.

(5) Some lines out of the winter type cereal material from ICARDA were found promising and are being included in preliminary yield trials in the Central Anatolian Plateau and transitional zones in Turkey.

Turkish national program and ICARDA/CIMMYT scientists exchange research experiences and relevant publications and scientists from Turkey attended the 1985 cereal program planning meeting at ICARDA's headquarters. In February 1986, a joint in-country training course will be held at Diyarbakir to discuss approaches and methodologies for improving barley and wheat production in moisture-limiting areas. Scientists from Turkey will review cereal research activities at ICARDA in May and evaluate germplasm for future breeding programs.

Baking Quality of Triticale Flour from Advanced Lines

Tests by the Center's cereal quality laboratory have shown that flour made from several high-yielding advanced lines of triticale (a cross between wheat and rye) is suitable for baking both single and two-layer flat breads – the principal types eaten in the West Asia region. Triticale flours with adequate "strength" behave in a manner similar to bread wheat flours. Also, the advanced triticale material includes lines with good milling quality. Earlier lines of triticale generally produced flour with poor dough handling properties and bread with a heavy texture and a short shelf life.

The laboratory compared blends of triticale flours with those of bread wheat having similar strength characteristics as measured by the farinograph. Also, flours were baked into two-layer flat breads (khobz) and the results for lines differing widely in flour "strength" are included in Table 4. Flour "strength" enables dough to retain gas produced during fermentation and is responsible for the volume and texture ("bitability") of bread of all types. It is chiefly a function of the protein and reflects the elasticity, state of oxidation, and hydration capacity of the proteins.

Khobz bakeries require a high temperature (450–500°C) furnace and are limited to towns and cities where the population provides an incentive to bakers. In the villages and isolated farms, single layer flat breads are baked in a kiln (tannour) or on a saaj (a round, curved metal plate).

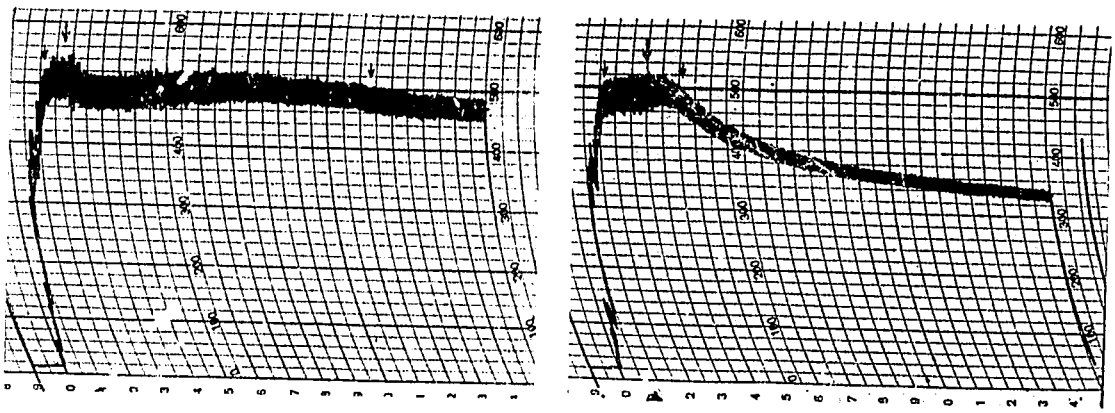
These breads are baked from 100% whole-meal flour milled in village stone mills. The dough may be fermented by a sour dough ("sultani") system or simply mixed by hand, allowed to relax for about an hour, and then divided, rolled out, and baked. (The temperature of a tannour or saaj is not high enough to create the two layers.)

To test the quality of triticales for this type of bread, a blend of triticales was milled in a village stone mill, together with a locally grown durum wheat (Hourani) and bread wheat (Mexipak). The triticale flours were baked in a tannour in two villages and on a saaj in one village by experienced housewives. The triticales and bread wheat were baked alone and in 50:50 blends with durum. Triticale and bread wheat were also blended 50:50. In all three cases, the triticale either alone or in the 50:50 blends was judged "very good" in dough handling properties, biting texture, and flavor by the housewives.

Table 4. Bread baking results of triticale and bread wheat flours. (Two-layer khobz bread.)

Type	F.S.	DD	DS	CT	SC*
Trit.	2.1	2.2	2.2	3.8	29
BW	2.6	2.5	2.0	4.2	32
Trit.	6.1	4.0	4.0	3.0	34
BW	6.5	3.5	3.3	3.3	34
Trit.	8.8	4.0	3.5	4.0	31
BW	8.2	3.5	4.0	3.5	33
Trit.	11.2	4.0	3.5	3.0	31
BW	10.0	2.0	3.5	3.0	33

**Maximum possible score: 45.*
Note: Dough handling properties at dividing (DD) and sheeting (DS) crumb texture (CT) and overall baking score (SC) of triticale flours were similar to those of bread wheat of the same farinograph stability (F.S.) level; a farinograph stability of 4–8 minutes is regarded as optimum for khobz-baking; the appearance of the triticale khobz was also equal to that of the bread wheat flour khobz.



Farinogram on the left shows triticale flour strength similar to bread wheat, the one on the right weak flour strength. Triticale lines differ widely in their dough strength characteristics for flat bread making.

Despite triticale's very good flat bread making quality potential and other advantages such as its yielding ability in stress environments, the research project on this crop was phased out at the end of 1985 because of financial constraints. However, several national programs are continuing the work.

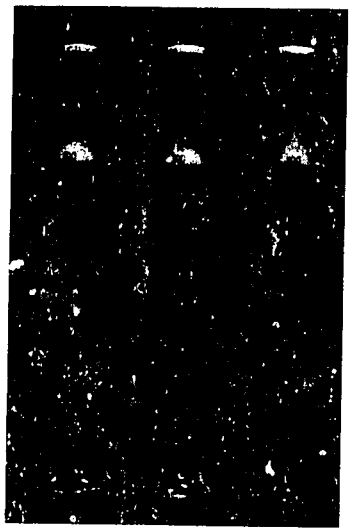
Many village housewives who make single-layer flat breads have given triticale flour, either alone or in blends, a "very good" quality rating.

Quality Parameters and Characteristics of Wheat and Barley for Consumer Acceptability

The end-use potential of cereal grains, with quality a principal prerequisite, is sometimes the "rock" upon which promising genotypes flounder. Therefore, in their screening and evaluation programs, ICARDA scientists define the quality parameters necessary for producing consumer-acceptable products and determine the stability and heritability of these characteristics.

Early generation screening is valueless unless the desired quality parameters can be transferred into subsequent generations and reproduced from season to season under different growing environments with minimal variability. Table 5 summarizes the chief forms in which cereals are used in the Middle East and North Africa, together with the quality parameters associated with them, and Table 6 presents the most important quality parameters in terms of their stability.

One of the objectives of the cereal quality program is to provide bread wheat with optimum baking quality. This involves medium hardness and protein strength, preferably light color, and kernel weight of about 35–40 grams per 1000 kernels. The hardness test is applied first to all early generation material and very hard or very soft lines are eliminated from further testing.



Sedimentation test of durum wheat showing strong flour strength (left), medium (center), and very weak (right).

Table 5. Forms in which cereals are used in the Middle East and North Africa and desired quality parameters.

Cereal	End-product	% of total	Quality parameters
Barley	Malting/fermentation	0- 2	High plump kernel count, 1000 kernel weight, and diastatic power; white or yellow aleurone; low-medium protein* and low beta-glucan, high lysine.
	Animal feed	50-80	
	Human food	5-25	
Durum wheat	Two-layer flat breads	30-40	High protein strength,** protein content, flour or semolina yield, vitreous kernel %, and yellow pigment (especially for pasta and burghul); medium-large kernels.
	Single-layer flat breads	10-15	
	Burghul	10-20	
	Couscous	10-15	
	Pasta	10-20	
	Others (frekeh, etc.)	0- 5	
Bread wheat	Two-layer flat breads	60-70	Medium protein strength and content; high flour yield; medium-hard kernels; white to amber color; good gassing power; medium-large kernels.
	Single-layer flat breads	20-30	
	Other breads	5-10	
	Other uses	0- 5	

**Higher lysine of protein necessary for food and feed but not malting.*
***High protein strength in durum is equivalent to medium strength in bread wheat.*

For durum wheat, ICARDA scientists seek maximum protein content and strength, yellow pigment, and vitreous (translucent) kernel count. They believe that selection of durum genotypes with dough strength and protein content suitable for flat bread baking will automatically possess the characteristics necessary for making good pasta, burghul, and couscous. (For making burghul, the mature grains are boiled, dried, and milled; couscous is made from semolina; both foods are served steamed with meat and vegetables.)

High vitreous kernel count is essential for good semolina milling and burghul-making. The first test applied to durum wheats is kernel weight. Very small or large kernels are eliminated. The SDS sedimentation test is then used to screen for protein strength. By using this selection strategy, most of the undesirable bread and durum wheat lines can be eliminated early in a breeding program and most of the more advanced material will be acceptable-to-superior in quality. This enables the plant breeder to concentrate upon other factors in more advanced generations.

There is a growing interest for malting quality in barley, particularly in North Africa. Low-to-medium protein, maximum plump kernel count, lysine content, diastatic power (converting starch to sugar), and hot water extract identify genotypes

Cereal	Parameter	Optimum value	Approx. stability (%)
Barley	Plump kernel count	80-90%	70-85
	Protein content	11-13% (dry basis)	40-50
	Diastatic potential	180+units	80-90
	Hot water extract (malt)	72-75%	—
	Lysine	0.5%+	50-60
	Color (aleurone)	White, yellow	95-100
	Seed size (1000/KW)	40-45 g	75-95
	Beta-glucan	2-3%	—
Durum wheat	Vitreous kernel %	90-100%	70-80
	Protein strength*	3-6 minutes	75-85
	Protein content	14-15% (dry basis)	30-50
	Yellow pigment	5-7 ppm	80-85
	Seed size (1000/KW)	45-48 g	70-80
Bread wheat	Hardness/fermentation capacity	54-60 NIRI**	90-95
	Protein strength*	4-9 minutes	75-85
	Protein content	14-15% (dry basis)	20-40
	Grain color	White to amber	95-100
	Seed size (1000/KW)	35-40 g	70-80

**Farinograph stability (minutes).*
***NIRI=Near-infrared index.*

Table 6. Important quality parameters of barley, durum wheat, and bread wheat in terms of their stability (approximately equivalent to heritability) and the optimum values.

likely to be superior in malting quality. For feed and food purposes, high lysine and low beta-glucan content are beneficial. Lines which incorporate all of these characteristics are sought in areas where the importance of barley as feed and food predominates.

Table 7 describes some of ICARDA's most promising lines and illustrates the manner in which the quality factors are being incorporated in high-yielding genotypes.

Table 7. Yield and quality characteristics of several advanced lines of barley, durum wheat, and bread wheat compared with check varieties.

Variety/line/pedigree	Yield (kg/ha)	Plump kernels (%)	1000/KW (g)	Protein (%)	Diastatic power units
Barley					
Arabi Abiad (check)	1997	68.8	41.5	8.6	76
Alger/Union, 385-2-2//Krasnodorsky CMB 77A-1267-4P-0SK-1Ap-1AP-1AP-0AP	3850	98.8	47.0	10.9	230
Weiselberger/Ahor 1303-61 ICB 77-0432-1AP-2AP-2AP-2AP-0AP	3505	40.2	46.7	11.1	187

		Protein (%)	VKC* (%)	TKW (g)	YP (ppm)	SDS (ml)
Durum wheat						
Sham 1 (check)	1716	14.6	100	35.5	5.5	22
Shwa/Pt I (1)	3480	14.7	99	36.0	5.7	36
ERP/MAL	2883	15.6	100	35.0	5.7	36

		Hardness (NIRI)*	WMFT* (min.)	1000/KW (g)	Protein (%)
Bread wheat					
Mexipak 65 (check)	**/***	67	65	27.4	13.7
Nai 60/Hn7//Sx SWM 07053-2Y-1Y-0Y-2AP-0AP	3077/2988	55	213	35.1	15.0
Kvz/4/Cc/Inia/3/Cno/Elga/Sn64/5/IWp22 ICW79-0132-1AP-2AP-1AP-1AP-0AP	4022/3177	46	174	34.8	15.4

**VKC= Vitreous kernel count; TKW= Thousand kernel weight; YP= Yellow pigment content; SDS= Sedimentation volume; NIRI= Near-infrared index; WMFT= Wheat meal fermentation time.*
***Advanced line.*
****Mexipak check.*

Winter Sowing of Chickpeas Shows Promise in Northwestern Africa and Southern Europe

Low yields are causing a continuous decline in chickpea production in northwestern Africa and southern Europe. In these areas, the crop is normally grown during the spring on conserved moisture, and it often suffers from drought in the dry season or from ascochyta blight in the wet season. But research and international yield trials have proven that substantial increases can be obtained by advancing the sowing date from spring to early winter and using recently developed lines which are resistant to the blight and tolerant to cold temperatures.

Figure 11 shows that the mean yield of chickpeas in an international trial was about four times greater than the country averages in Morocco and Italy, nine times greater in Portugal, seven times greater in Spain, triple in Tunisia, and double in Greece. The yield of the best chickpea entry demonstrates the potential of the crop in the Mediterranean region, if the right cultivar is chosen and the seed sown during the winter.

Winter sowing was introduced in northwestern Africa and southern Europe during the 1979/80 season by the ICARDA/ICRISAT Kabuli Chickpea Project. Many lines were chosen from the nursery and included in multi-location trials. Here is the current situation in different countries:

Morocco: Three chickpea cultivars (ILC 195, ILC 482, and ILC 484) are in the prerelease multiplication stage.

Tunisia: Lines identified as resistant to both ascochyta blight and fusarium wilt are being further evaluated in an attempt to release a cultivar for winter sowing.

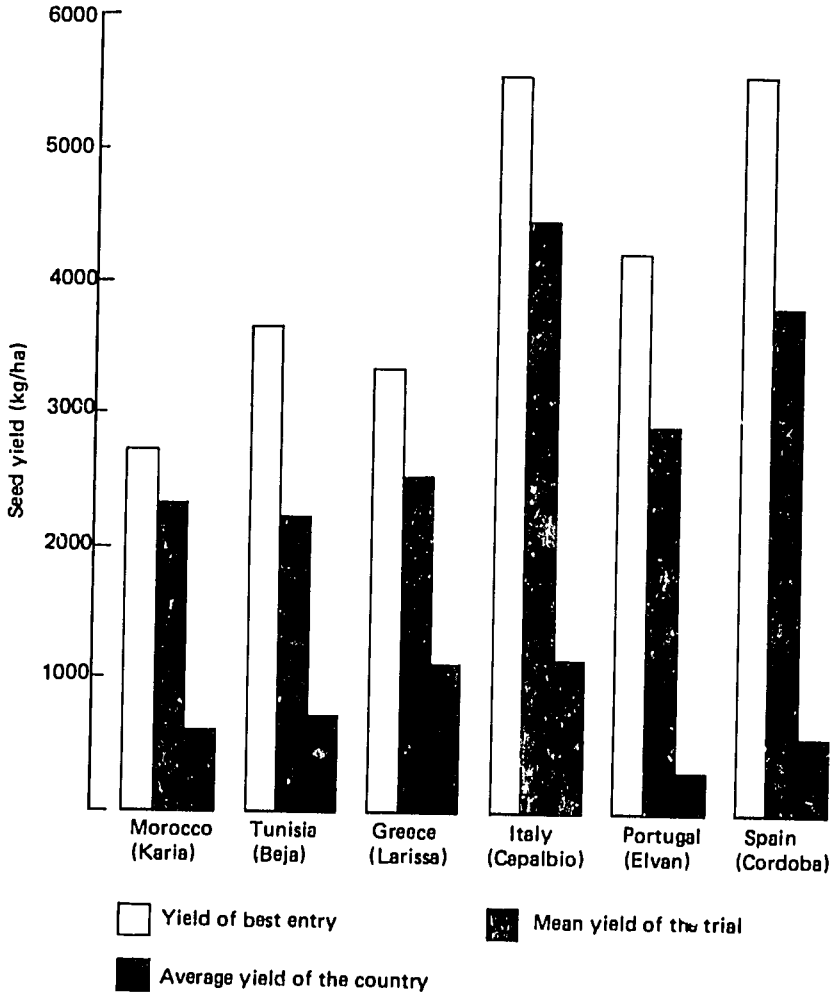
Spain: Spanish plant breeders have submitted four cultivars for registration: Fardon (ILC 72), Zigri (ILC 200) and Atalaya (ILC 200), Almena (ILC 2548), and Alcazaba (ILC 2555).

Italy, Portugal, Greece: Steps are being taken to release cultivars for winter sowing.

The region needs large seeded chickpeas to satisfy consumers' preference and tall plant types to adapt to machine harvesting, and ICARDA has developed such lines. (*Research Highlights* 1984.) Additional countries are expected to select some of them for use in their national breeding programs.

Entries in the chickpea International Yield Trial-Winter being examined at the experimental farm of the University of Perugia, Italy by an Italian and ICARDA scientist. (Spring grown chickpeas in the background.)

Figure 11. Seed yield of the best entry and trial mean of the chickpea International Yield Trial-W-MR (1983/84) and the country average yield.



Chickpeas with Combined Resistance to Wilt and Ascochyta Blight in Tunisia

Any new chickpea cultivar released in Tunisia should ideally possess resistance to both wilt and ascochyta blight and progress has been made in identifying such material in cooperative research between the Institut National de la Recherche Agronomique (INRAT) and ICARDA/ICRISAT scientists.

They started to work on wilt caused by *Fusarium oxysporum* and *Verticillium alboatrum* with the selection of single plants resistant to wilt in the local landrace Amdoun in the 1980/81 and 1981/82 seasons. The large majority of lines stemming from these have maintained a high level of resistance when screened in the wilt-sick plot at the Beja research station.

In yield tests in wilt-infested land, eight lines significantly outyielded Amdoun by a large margin (Table 8) but yields were similar in wilt-free land. One or more of these new lines will be multiplied for release to farmers for spring sowing. These lines have seed quality characters very similar to Amdoun and therefore should be readily marketable.

Table 8. Seed yield and wilt ratings of eight chickpea lines selected from Amdoun and grown in wilt-infested and wilt-free land at Beja, Tunisia.

	1982/83		1983/84		1984/85	
	(Wilt-infested land)		(Wilt-infested land)		(Wilt-free land)	
Line	Wilt rating*	Seed yield (kg/ha)	Wilt rating*	Seed yield (kg/ha)	Wilt rating*	Seed yield (kg/ha)
PL-Se-Be-81- 40	1.3	1620	2.0	1543	1.0	1987
41	1.7	1390	1.5	1506	1.0	1912
Amdoun (local check)	8.7	16			4.0	1869
SE ±		117.2				233.2
PL-Se-Be-81- 6	1.0	1193	2.0	1731	1.0	1715
11	1.0	1243	1.5	1635	1.5	1818
Amdoun (local check)	8.0	49				
SE ±		91.5				
PL-Se-Be-81- 48	1.0	1680	1.8	1737	1.0	1812
87	1.0	1360	1.5	1875	1.0	1831
103	1.0	1490	1.0	1793	1.0	1818
120	1.5	1420	1.8	1653	1.8	1809
Amdoun (local check)	8.5	49	6.0	460	6.0	1914
SE ±	0.4	123.9		155.1		100.1

Note: Lines tested in three different trials in 1982/83, one in 1983/84, and two in 1984/85.
**1=no symptoms, 9=complete kill.*

A large number of ascochyta blight resistant lines from ICARDA have been screened for resistance and yield tested in Tunisia. Although no such lines have significantly and consistently outyielded disease-free Amdoun, five of them had at least equivalent seed yield in trials over three years. Moreover, they possess this major advantage over Amdoun: farmers can safely use them without fear of yield loss from an attack of ascochyta blight (*Ascochyta rabiei*) and benefit from the larger yields of early winter sowing.

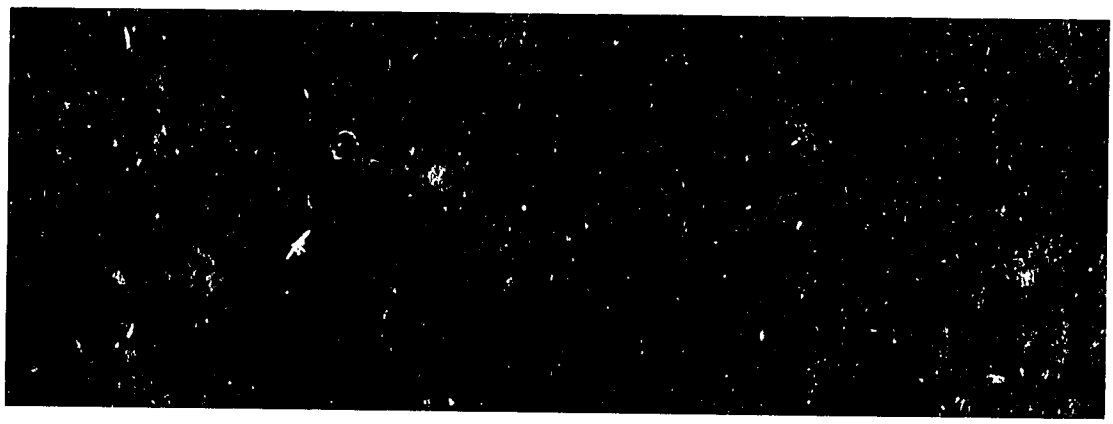
All ascochyta blight resistant lines are field screened in the wilt-sick plot and a few of them have shown tolerance to wilt. Four blight resistant lines had the best combination of seed yield and wilt tolerance in trials in Beja and Kef over the past two years: FLIP 81-67, 82-79C, 81079, and ILC 1985 (Table 9). One or more of them will be considered for pre-release multiplication next season. The major problem with these lines: their seed size is considerably smaller than that of Amdoun.

Seedlings of all lines are also screened in the laboratory in a test tube culture for resistance to isolates of *F. oxysporum* and *V. alboatrum* from the wilt-sick plot. So far there is a good correlation between the wilt ratings in the laboratory and the field for those lines that show symptoms of wilt early in the season. It is expected that further refining of the technique in the laboratory will permit an initial screening (and discarding) of material prior to field screening.

Other recent research on dual resistance involved the screening of F_4 and F_5 progenies from ICARDA population trials and 87 single plants have been selected for resistance to both diseases and will be further evaluated in 1986/87. Also, crosses are being made between ascochyta resistant lines with the heaviest yield in Tunisia and wilt resistant Amdoun selections with the aim of combining dual resistance with a large seed size in a locally, well-adapted background.

Chickpea research is a joint program between ICARDA and another international center (ICRISAT) with headquarters in India.

Table 9. Chickpea seed yield, expressed as a percentage of the local check, and wilt ratings of four ascochyta resistant lines at Beja and Kef, Tunisia in 1983/84 and 1984/85.



Screening Chickpea Germplasm Resistant to Different Races of Ascochyta Blight

After screening more than 14,000 chickpea germplasm under field conditions, scientists identified many sources of resistance to ascochyta blight – a major fungal disease causing serious yield losses in West Asia and Northwest Africa, South Europe, and Northwest India. But they soon found that some of the chickpea lines resistant in one season succumbed the following season, and a few resistant at one location were susceptible in others within the same country. The observations indicate that host-plant resistance broke down because of different physiologic races of the blight fungus, *Ascochyta rabiei*.

The scientists have now identified six races of *Ascochyta rabiei* within Syria and found sources of resistance to all six (Table 10). Out of the 1069 chickpea germplasm and breeding lines screened in greenhouses at ICARDA's principal experiment station at Tel Hadya, Syria in 1985, almost three fourths of the plants were highly susceptible to the blight and died. Races 4 and 6 were the most aggressive and races 1 and 3 the least aggressive.

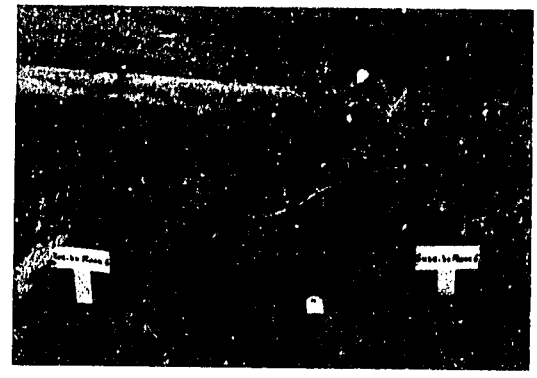
	Reaction of					
Scale*	Race 1	Race 2	Race 3	Race 4	Race 5	Race 6
1	0	0	0	0	0	0
2	1	0	6	0	0	0
3	29	5	53	0	2	2
4	47	10	7	3	7	0
5	33	16	30	5	10	2
6	122	72	163	36	71	37
7	72	75	287	51	83	95
8	29	16	173	19	15	52
9	736	875	350	955	881	881
Total	1069	1069	1069	1069	1069	1069

**Scale: 1=free; 5=tolerant; 9=killed.*

Table 10. Screening chickpea resistance to six races of Ascochyta rabiei *at Tel Hadya, Syria (1985).*

The chickpea lines found resistant to three or more races have shown resistance in several countries where ascochyta blight is endemic, and they will be useful in plant breeding programs of those countries. An important need in West Asia and North Africa is for blight resistant cultivars that can be sown in the winter (Table 11).

The chickpea improvement program is a collaborative activity between ICARDA and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) with headquarters in India.



Scientists have found chickpea lines resistant to one of the most aggressive races of ascochyta blight – race 6.

Chickpea lines	Resistance to race					
	1	2	3	4	5	6
[redacted]						
ILC 3279	R	S	R	T	R	S
ILC 3856	R	R	R	R	S	T
[redacted]						
ICC 3996	R	R	R	S	S	S
ICC 6988	S	R	R	S	R	S

**R=resistant, S=susceptible, T=tolerant.*

Table 11. Chickpea lines showing resistance to three or more races of Ascochyta rabiei.

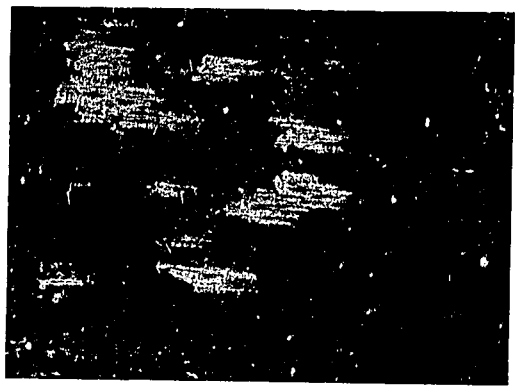
Development of Pure Line Collections of Disease Resistant Faba Beans

Resistance sources have been found in ICARDA's germplasm collection for chocolate spot (*Botrytis fabae*), ascochyta blight (*Ascochyta fabae*), and rust (*Uromyces fabae*) – the three most destructive faba bean diseases causing serious production losses in many areas. Because of the outcrossing nature of faba beans, these sources have to be purified for resistance and other morphological traits so they can be used most efficiently.

Resistance screening has been developed by ICARDA over several years at its Lattakia sub-site where environmental conditions are favorable for development of high disease pressure. This has been done using germplasm collected from the region and other areas of faba bean cultivation. Early work was done in the open field which resulted in outcrossing of the resistant sources and variability in resistance scores in following years. ICARDA scientists developed procedures to screen and select previously identified resistant sources so as to produce uniformly resistant pure lines.

The system now used provides for planting germplasm for selecting resistance sources and previously developed sources of resistance in insect-proof, mesh-covered cages where inoculation is done and mist irrigation systems used to maintain high humidity to favor development of high disease pressure. Four years of progeny selection under this system has resulted in a fairly large number of uniform sources of resistance to the three diseases: 44 for chocolate spot, 25 for ascochyta blight, and 30 for rust. Future requests from national programs for disease resistance sources will be met from these.

Inheritance of resistance will be studied with crosses made in 1986 using several of the chocolate spot uniformly resistant lines and attention given to ascochyta blight and rust resistance inheritance in subsequent years.



The destructive chocolate spot disease on faba bean leaves. Several faba bean lines resistant to this disease have been identified.

Mist irrigation used on faba beans in insect-proof, mesh-covered cages to maintain high humidity which favors development of high disease pressure for selecting resistant sources to chocolate spot and rust.

Horizontal and Vertical Resistance in Faba Beans to Chocolate Spot Disease

Chocolate spot caused by *Botrytis fabae* can inflict large losses in faba bean production if extended periods of wet and cool weather conditions prevail. Because chemical control is beyond the reach of poor farmers and cultural practices are only partially effective against the disease, scientists consider host plant resistance as the most practical and least expensive method of control.

Several faba bean lines with resistance to chocolate spot have been identified by ICARDA scientists in a local mass screening program at the Center's Lattakia subsite near the Syrian northern coast. However, in recent multi-location testing, a few lines seemed resistant at all locations, whereas others seemed resistant at some but susceptible at other locations (Table 12). Because these findings indicated possible physiological specialization in the pathogen, ICARDA's scientists began to differentiate lines with horizontal from those with vertical resistance and also to study the race situation in the pathogen.

In a collaborative study with scientists in Syria, Egypt, England, and the Netherlands, lines BPL 710, 1179-1, and 1196 were resistant across all these locations, whereas BPL 1763, BPL 1821, and ILB 1814 were resistant in Egypt only and susceptible in the remaining countries

(Table 12). When these six lines were exposed separately to different isolates of the pathogen, BPL 710, 1179-1, and 1196 with a location non-specific-resistance were consistently rated resistant to all isolates and therefore revealed no significant differential interaction.

But lines BPL 1763, BPL 1821, and ILB 1814 with a location-specific resistance revealed consistently significant differential interaction with different isolates of the pathogen (Table 13). Therefore, lines in the first group carry genes for a broad-based-horizontal resistance, whereas those in the second group carry genes for a narrow-based-vertical resistance.

Based on their virulence on lines BPL 1763, BPL 1821, and ILB 1814, different isolates were classified into four distinct races (Table 13). The resistant reaction on BPL 1763, BPL 1821, and ILB 1814 in Egypt and their susceptibility in Syria, England, and the Netherlands indicated that races 1, 2, 3, and 4 are apparently more common in Syria and Northern Europe than in Egypt.

An in-depth survey is now being conducted in Egypt. If races 1, 2, 3, and 4 are not present there, then genes for vertical resistance in BPL 1763, BPL 1821, and ILB 1814 can also be used along with genes for horizontal resistance in BPL 810, 1179-1, and 1196. A survey in Syria indicated that races 1, 2, 3, and 4 are common in the Tartous, Akkar, Tel Kalakh, and Homs areas but not in Lattakia.

Line	Disease reaction*			
	Syria	Egypt	England	Netherlands
BPL 1763	S	R	S	S
BPL 1821	S	R	S	S
ILB 1814	S	R	S	S

R=Resistant, S=Susceptible.

Table 12. Faba bean reaction to chocolate spot disease at different locations.

Line	Disease reaction*			
	Race 1	Race 2	Race 3	Race 4
BPL 1763	R	R	R	S
BPL 1821	R	S	S	R
ILB 1814	S	R	S	S

R=Resistant, S=Susceptible.

Table 13. Chocolate spot reaction on six faba bean lines to four races of Botrytis fabae *at Lattakia, Syria.*

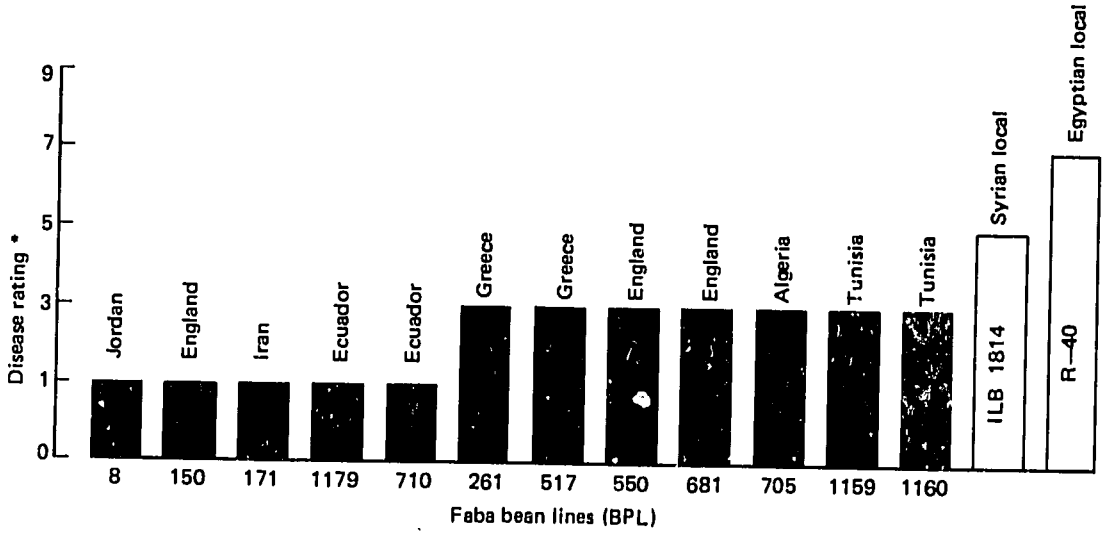
Results of Screening Faba Bean Lines for Resistance to Rust and Rust-Chocolate Spot Complex

Through screening and international testing of recently developed faba bean lines, scientists have detected useful sources of resistance to rust and its complex pathological interaction with chocolate spot disease. Of the several hundred germplasm lines tested at ICARDA's sub-site at Lattakia, Syria, 45 were rated resistant to rust and the few most resistant selections (Figure 12) were also rated resistant to rust in Egypt and Canada.

Furthermore, three selections – BPL 261, 710, and 1179 developed for resistance to rust and chocolate spot in Syria – proved to be resistant to both diseases in preliminary tests in Egypt, and BPL 1179 showed resistance to the most virulant isolates of the rust pathogen in Canada. Materials such as BPL 1179, with its broad-based simultaneous resistance to both diseases, should contribute significantly to the stabilization of faba bean yields because such multi-location and multiple disease resistant sources have been lacking in the past.

Seeds from these sources have been increased, inbred lines developed, and seeds

Figure 12. Representative rust resistant faba bean lines selected at ICARDA's sub-site in Lattakia, Syria. The lines originated from the countries listed in the graph.



*Rating: 1 = highly resistant, 3 = resistant, 9 = highly susceptible

Right, one of the rust-resistant faba bean selections made at ICARDA's sub-site in Lattakia, Syria compared with a local susceptible cultivar, left.

provided by ICARDA to several national programs and institutions around the world. Several crosses have been made to incorporate genes from ICARDA's materials into well adapted local cultivars. At present, F_5 and F_6 progenies are being tested for yield and disease resistance at different locations, particularly in Egypt and North Africa where the combined effects of rust and chocolate spot have been a major limiting factor in faba bean production. When rust acts simultaneously with chocolate spot, losses may go up to 50%.

Mechanized Harvesting of Lentils

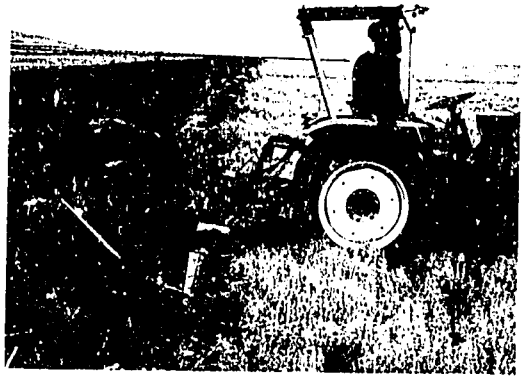
Because of the decline in lentil production areas in the Middle East due mainly to increased labor costs for hand harvesting compared with world lentil prices, the development and testing of simple and inexpensive tractor-drawn harvesting implements have been intensified at ICARDA.

In field trials during the 1984/85 season, hand harvesting of lentils was compared with two mechanical systems – a reciprocating double-knife cutter bar and horizontal angled blades. Two cultivars (a landrace vs. a lodging-resistant selection) were used along with four sowing methods to determine the minimum changes needed in existing practices for machine harvesting.

Mechanization resulted in sizeable losses of both seed and straw compared with hand harvesting. But there were major interactions of harvest method with both the sowing method and cultivar selection which emphasized the need for an integrated approach to mechanization embracing the type of cultivar and crop management in addition to machinery development (Table 14).

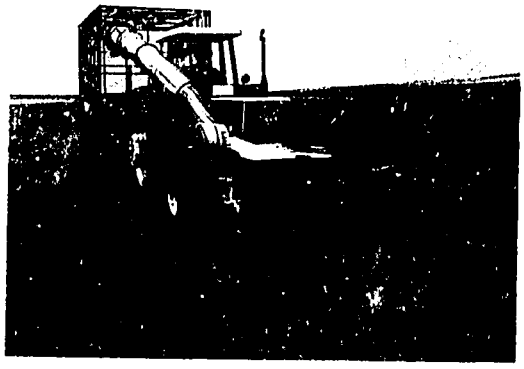
The angled blade harvesting system worked best under traditional crop management – broadcasting lentil seed on ridges. Under this system, the value of the seed and straw was 4209 Syrian lira per hectare compared with 4363 Syrian lira for the hand-harvested crop. The type of cultivar did not affect these results.

Only minor seed losses occurred with



Cutter bar ready to cut lentils.

Horizontal angled blades.



Tractor-driven lentil puller.

Traditional hand harvesting.

Sowing method	Hand harvest		Cutter bar		Angled blades	
	Seed	Straw	Seed	Straw	Seed	Straw
Broadcast	1152	2896	951	1094	732	3531
Broadcast + bar	1479	2976	1075	1617	829	3262
Drilled	1618	3294	1071	1600	616	2142
Drilled + bar	1479	2929	1092	1780	633	2348
Mean	1432	3024	1047	1523	703	2820

LSD (5%). Harvest method: seed 91 kg/ha; straw 399 kg/ha.
LSD (5%). Harvest × sowing methods: seed 183 kg/ha, straw 799 kg/ha.

Table 14. Lentil seed and straw yields (kg/ha) from different sowing and harvesting methods.

the use of the reciprocating cutter bar, but the loss of straw was high - 62% on a broadcast and ridged crop. When the ridges were flattened with a heavy bar or the lentil crop was drilled, the loss dropped to 43%. Therefore, the cutter bar will probably be practical only when straw prices are low. With hand harvesting, the improved cultivar had only a slight advantage over the landrace, but a major advantage (39%) with cutter bar harvesting because of less lodging. Clearly, the cutter bar performance was maximized with a flat soil surface and a non-lodging cultivar.

The two mechanized harvesting systems are being refined under support from IDRC and will be tested on farmers' fields during 1986. Also, experiments will continue with more complex equipment which offers both harvesting and collection of the crop in one step. They include the tractor-driven lentil puller (GTZ sponsored) and the standard combine with reciprocating blades and a straw and chaff collector.

Protein Heritability of Food Legume Lines

Not only do scientists give a high priority to the development of better yielding chickpea and faba bean lines but also to the improvement of the protein content of the seed. As part of their research program, large numbers of advanced lines of both crops have been grown at different locations over two seasons in an effort to determine the heritability of protein content in the seed. Also, world collections of kabuli chickpeas and faba beans have been screened for protein content using the rapid near-infrared technique (Table 15).

Food legumes play an important role as protein supplements to the predominant cereal diets of the Middle East and North Africa. The kabuli-type chickpea is one of the lowest of the food legumes in protein content and faba beans one of the highest.

	Protein content (%)	
	Chickpeas	Faba beans
Low	17.6	18.6
Mean	22.1	28.4
CV	6.4	8.5

Table 15. Protein content of world collections of kabuli chickpeas and faba beans.

Variability between seasons appeared to exert more influence on protein content than the growing location. The average coefficient of correlation between all lines was 0.37 for both chickpeas and faba beans. Low correlations indicated that heritability of protein was likely to be low when all lines were considered, but further investigation of the individual data revealed that several genotypes retained higher or lower protein content with low coefficients of variability across all combinations of planting. This type of information, readily available when all data are computerized, indicates to the plant breeders the feasibility of selecting parents for the improvement of protein content. Typical data are shown in Table 16.

Determining the protein content of world collections of kabuli chickpeas and faba beans using the rapid near-infrared technique in ICARDA's quality laboratory. The protein content of chickpeas in the collections ranged from 17.6 to 27.3% and faba beans from 18.6 to 37.8%.

Kabuli chickpeas			Faba beans		
Lines	Mean protein* (%)	CV** (%)	Lines	Mean protein (%)	CV (%)
ILC 2539	25.6	3.9	BPL 505	34.1	2.2
ILC 1784	25.0	2.6	BPL 400	34.1	3.9
ILC 3069	24.6	3.8	BPL 494	33.6	5.2
ILC 2761	20.7	5.2	BPL 369	23.9	9.1
ILC 929	20.0	6.2	BPL 907	24.8	5.0

**Total N × 6.25, dry basis.*
***CV = Coefficient of variability.*

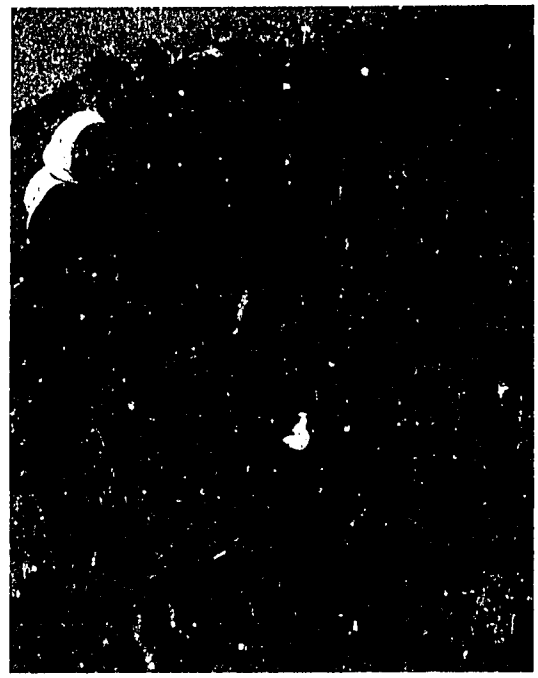
Table 16. Kabuli chickpea and faba bean lines with stable protein content.

Quality of Food Legume Straw for Livestock Feed

Net returns to farmers from lentil residues from threshing (straw, pod walls, leaves, and roots) may equal or exceed that from seed in dry seasons in Syria, Jordan, and other countries of the Middle East because of their use as a feed for sheep.

Also, in the Indian subcontinent livestock feed includes lentil straw and chickpea residues, and in Egypt and Sudan faba bean crop residues are used not only for animal feed but for fuel and brick making. In Egypt there is a cash market for faba straw which contributes 9 14% of the crop's revenue.

Because of the importance of food legume residues as forages, laboratory tests have been made at ICARDA to determine their quality. The nutritive values of lentil, chickpea, and faba bean straw from the Center's principal experiment station in Syria are shown in Table 17. The overall mean for the digestibility of lentil straw



Lentil residues from threshing are saved for feeding sheep. In dry seasons, their value sometimes equals or exceeds that from lentil seed.

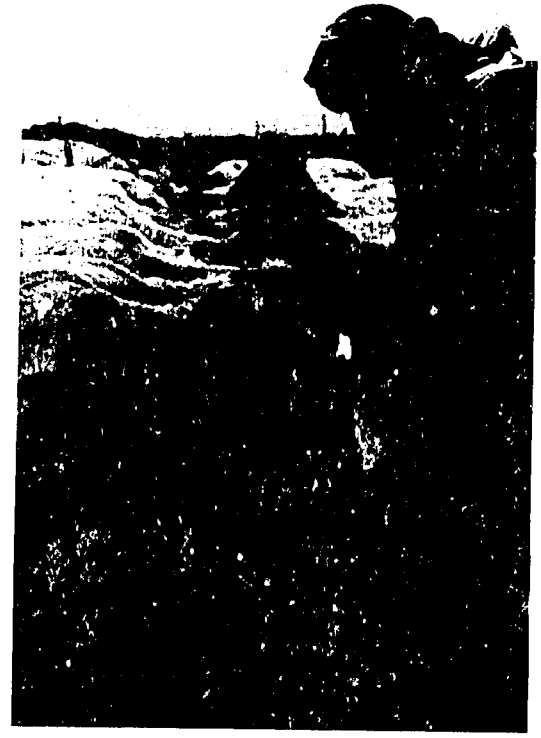
	Lentil		Chickpea 1983		Faba bean
	1982	1983	Winter	Spring	1983
Digestibility*	60.0(1.98)	39.0(2.06)	40.4(0.51)	42.5(0.35)	44.6(0.64)
Crude protein (%)	6.7(0.51)	6.4(0.65)	3.8(0.08)	4.7(0.15)	5.0(0.13)
Neutral detergent fibre (%)	60.0(1.61)	64.0(3.13)	60.9(0.55)	57.2(0.25)	65.7(0.80)
Ash (%)	9.1(0.65)	6.5(0.45)	10.6(0.24)	10.8(0.19)	8.3(0.22)

**g digestible organic matter per 100 g dry matter.*

Table 17. Nutritive values of lentil, chickpea, and faba bean straw (mean and standard error).

was 49.5 g digestable organic matter per 100 g dry matter, but this resulted from the seasonal means of 60.0 and 39.0 g/100g. The crude protein value of lentil straw was higher than that of either faba bean or chickpea straw.

The influence of year and time of planting is greater on straw quality than the effects of genotype in lentils and chickpeas, respectively. In lentils, scientists found no consistency over years in the straw quality of particular genotypes in digestibility, crude protein, and neutral detergent fibre content. The results for both chickpeas and lentils suggest that in contrast to cereals the prospects for selection for straw quality using laboratory evaluation are limited. However, the profound effects of agronomic factors such as date of sowing on straw quality indicate that the effects of other factors should be determined to see if residue quality can be altered through crop management.



Feeding chopped and ground lentil straw to sheep. Laboratory tests have shown that its nutritive value as a livestock feed is superior to that of faba bean or chickpea straw.

International Food Legume Testing Program:

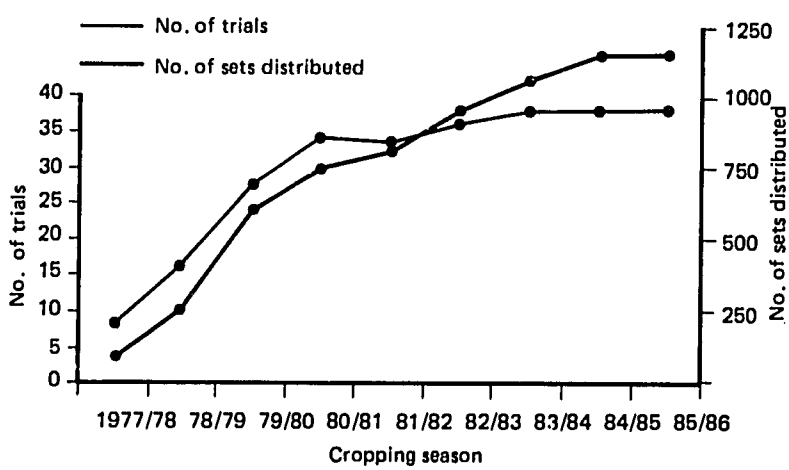
Requests of national cooperators for ICARDA's food legume breeding materials for international testing exceed the supply, but the Center was able to provide 38 trials and more than 1100 sets of these to 54 countries for the 1985/86 cropping season (Figure 13). When the Center's International Testing Program started in 1977/78, food legume breeding materials were distributed to cooperators in 11 countries

Agronomic trials in the International Testing Program have clearly demonstrated that planting done early in the winter season increases lentil, chickpea, and faba bean seed yields, and weed control trials have shown that weedicides can be effective.

Disease nurseries play a significant role in identification of sources of resistance to major diseases of food legumes.

Breeding nurseries, including F_3 segregating populations, advanced generation observation nurseries, and yield trials, are being used extensively by the national programs in several ways. The F_3 populations serve them with the base materials from which selections can be made under varying environmental conditions and the genotypes responsive to specific environments selected. Many national programs are using the F_3 populations for development of superior progenies and now have materials in the final evaluation stages.

Yield nurseries are of more immediate use to identify superior food legume lines for release as cultivars or for breeding programs. Some countries, including Syria, Cyprus, Ethiopia, and Spain, have identified superior genotypes from yield trials and nurseries, tested them in national trials, and then released them for general cultivation. In other countries, including Algeria, Egypt, Jordan,

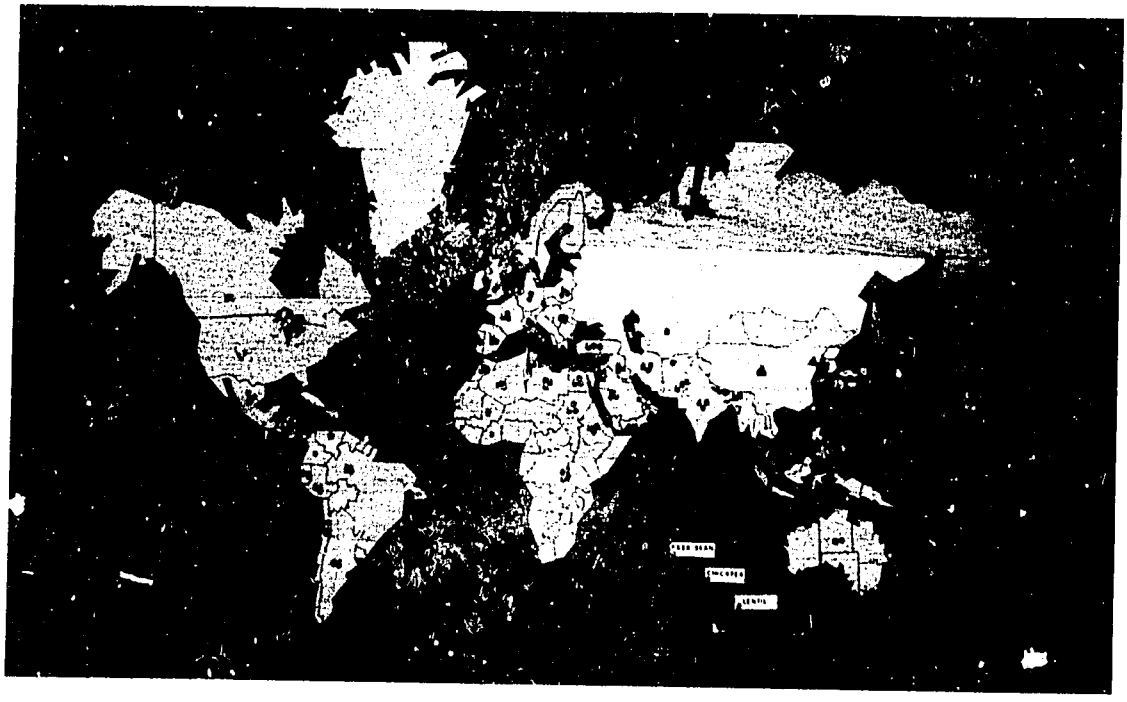


Vehicle for Disseminating Improved Germplasm

Morocco, Pakistan, Tunisia, Turkey, and Yemen, the identified lines are in the final evaluation stages for release to farmers.

Although only limited amounts of materials have been supplied so far by national programs to the international nurseries, more is expected to come from them as their breeding programs become stronger. Then ICARDA scientists will be able to shift their research emphasis to concentrate more on the segregating materials rather than on finished products.

Packing food legume germplasm to be sent to countries for international trials.



Fifty-four countries have received food legume breeding materials from ICARDA for international trials.

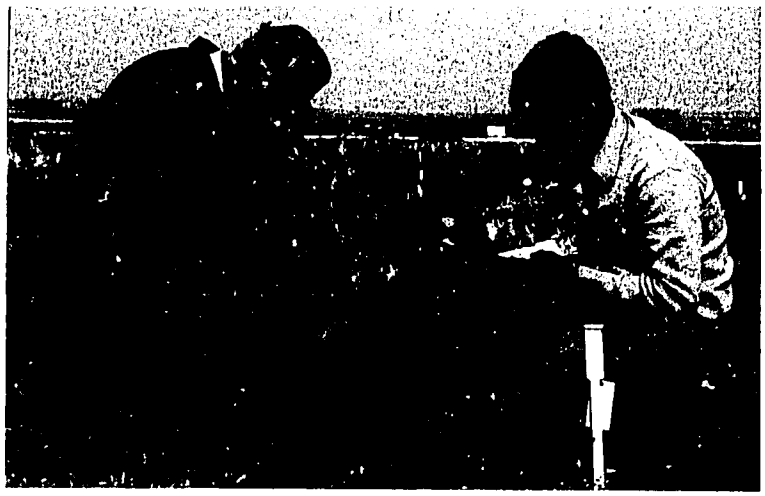
Screening Vetches and Forage Peas for Resistance to Nematodes

Nematodes can cause serious infections on the roots of forage legumes: vetches are attacked by the root-knot nematode (*Meloidogyne artiella*) and forage peas by the cyst nematode (*Heterodera rossi*), and, since both nematodes can attack cereals, use of a legume/cereal rotation is a poor form of cultural control and may even result in a build up of the diseases.

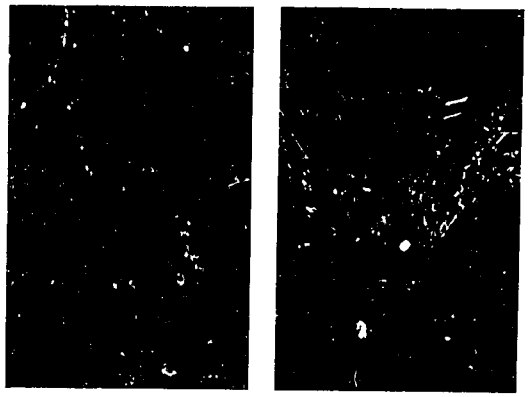
Because of the high incidence of root-knot and cyst nematodes during the past three years, ICARDA scientists started a screening program for resistance: 100 strains of forage peas and 81 of vetch (including common vetch and woollypod vetch) were examined for cyst and root knot nematodes in 1984/85 in a heavily infested field at Tel Hadya. The material included all that which had previously been evaluated in other microplot trials, advanced yield trials, and at multi-locations.

The populations of nematodes were monitored by taking soil samples before planting and during growth of the crops. Observations were made after seed germination and continued throughout the growing season. Random samples of plants were taken to isolate the nematodes and to determine the degree of root infestation. Root symptoms were diagnosed as root-knots or root galls, excessive root branching, and injured root-tips. The reaction of each strain against nematode invasion was estimated according to a severity scale (Figure 14).

Results confirmed that vetches are severely attacked by root-knot nematodes



Examining vetch plants in the field for root-knot nematode. Scientists are working on selection for host plant tolerance to the parasite.



Left, close-up of root-knot nematode attachments on vetch roots; right, a tolerant and a susceptible plant.

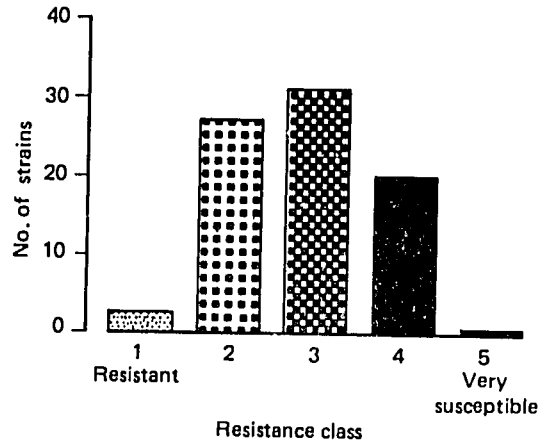


Figure 14. Variability in resistance to root-knot nematode among 81 strains of vetch based on resistance-susceptible scores.

and peas by cyst nematodes. Only six strains of common vetch were attacked by both nematodes.

Three vetches, including a line of woollypod vetch, were resistant to root-knot nematode, 27 moderately resistant and the remaining 51 moderately susceptible or susceptible (Figure 14). Those with low scores (1 and 2) were selected for further screening. The high resistance of woollypod vetch to root-knot nematode increases its value: it also showed resistance to attack by the plant parasite *Orobanche* sp., and resistance to frost. The local common vetch was moderately susceptible to root-knot nematode.

Field screening of forage peas did not reveal any strains highly resistant to cyst nematode, but some were scored resistant or moderately resistant. In these tests, resistance in forage peas was characterized by a small number of plants having roots with a few galls, the rest none. These strains have been retained and will be tested under artificial infestation in a greenhouse.

Impact of Forage Mixtures on Barley Grain Yield

When forage mixtures are produced in a rotation with grain crops, what is their impact on grain yield? To find out, ICARDA scientists conducted experiments on the effect of varying seed ratios of legume-cereal forage mixtures on grain yield in the following cereal year and also assessed the need for nitrogen fertilization by the grain crop following these mixtures.

In the 1983/84 season, six forage mixtures were established consisting of vetch or peas, each of which was grown with barley, triticale, or oats. Each mixture was sown at three alternative seed rates (120, 160, 200 kg/ha) and five legume-cereal seed ratios were used (0:100, 33:66, 50:50, 66:33, 100:0). Seed rates were laid out as main plots and seed ratios as sub-plots with the treatments being replicated three times. The plots were harvested for hay in April 1984.

Barley was grown for grain in the 1984/85 season on the plots previously used for forage mixtures. These plots were cultivated in November and sown to Badia barley on December 4, 1984, at a rate of 100 kg/ha and fertilizer with 40 kg P_2O_5/ha. Nitrogen fertilizer rates of 0, 20 and 40 kg N/ha were applied as main plot treatments in place of the seed rate treatments of the original experiment since the latter gave no significant differences in forage yield. Nitrogen was applied by hand (broadcast), one half of the total amount at time of sowing and the other half two months later. Barley was harvested on June 9, 1985.

The effect of seed ratio and nitrogen fertilizer on grain yield is shown in Table 18. There were only small differences among cereal species in their effect on subsequent grain yield, so the results for them are combined. Barley yield increased with an increased nitrogen rate at all seed ratios for both vetch-cereal and pea-cereal. Both 20 and 40 kg N/ha gave a significantly higher average yield than the control, but there were no significant differences between them.

Grain yield was highest after the pure legumes (100:0), lowest after pure cereal (0:100), and increased with increasing proportion of legume in the previous year. There were no significant differences between grain yields after pure vetch and the 66:33 vetch-cereal mixture or between yield after pure pea and the 50:50 pea-cereal mixture.

The high grain yield of barley when grown after pure legume or after a forage mixture containing a high legume proportion could be due to the biological nitrogen fixed by the legume which was then utilized by the subsequent barley grain crop. Also, the control of cereal root disease may be effective when legumes are included in the rotation with cereal crops.

The two greener strips show the effect of the previous season's planting of a pure legume on a very early growth of barley.

Table 18. Yield of barley grain (kg/ha) as affected by nitrogen rate and the seed ratio (%) of the preceding vetch-cereal or pea-cereal forage crop.

Nitrogen rate (kg/ha)	Seed ratio					
	0:100	33:66	50:50	66:33	100:0	Mean
			Vetch-cereal			
0	1581	1920	2098	2069	2195	1972
20	2488	2584	2521	2538	2979	2622
40	2726	3021	2947	3496	3398	3117
Mean	2265	2508	2522	2701	2857	
			Pea-cereal			
0	1658	1849	1966	2074	2511	2011
20	2469	2750	2995	2488	2849	2710
40	2941	2876	3354	2983	3285	3087
Mean	2350	2491	2771	2515	2881	

	Vetch-cereal	*Pea-cereal*
LSD (P=0.05) for nitrogen rates	*620*	*422*
LSD (P=0.05) for seed ratio	*287*	*338*
LSD (P=0.05) for seed ratio within nitrogen rates	*NS*	*NS*

Intensifying Sheep Production Using Forage Crops

Introducing forage crops could make a substantial contribution toward removing seasonal feed deficits that occur in small ruminant systems of North Africa and West Asia. Moreover, they could intensify sheep production by increasing both the stocking rate of sheep and the output of sheep products per hectare.

These forage crops can be planted on abundant fallow land in areas where barley-fallow rotations predominate or be incorporated into three-year rotations in higher rainfall areas. Their impact on sheep carrying capacity, production, and profitability of scientist-managed farms was tested for six years at Tel Hadya.

Scientists compared four crop rotations: barley-fallow with barley-vetch on shallow soil and wheat-lentil-melon with wheat-vetch-melon on deep soil. The vetch was either grazed in the spring or conserved as hay and fed in the winter. Three experimental sheep flocks were subjected to a low, medium, or high nutritional regime, and each had access to 10 hectares of native pasture. A linear programming model was developed to integrate the results and find combinations of feed and pastures which maximized farm profits for various combinations of crop rotations and nutritional regimes.

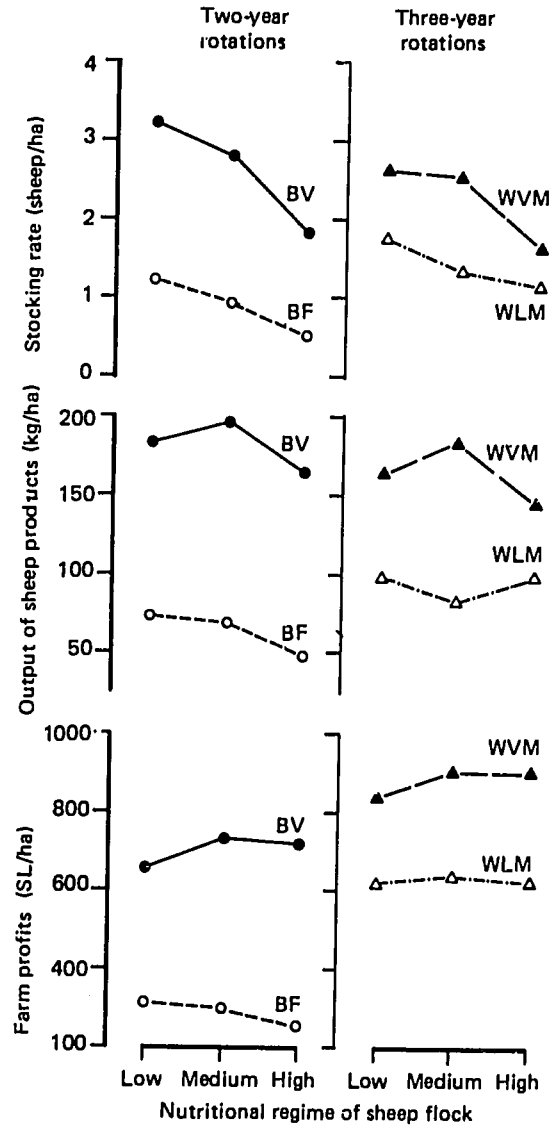
Replacing fallow land in a two-year rotation increased the stocking rate of the flock subjected to the medium nutritional regime from one to three sheep per hectare (Figure 15). The sum of the saleable meat, milk, and wool increased from SL75 (Syrian Lira) per hectare to SL200 and profits from SL300 to SL740 per hectare. Substituting vetch for lentils in the three-

Forage crops conserved as hay and fed in the winter can make a substantial contribution toward removing seasonal feed deficits in North Africa and West Asia.

year rotation also helped increase stocking rate, output of sheep products, and farm profits. Maximum profits were higher for the three-year rotation than for the two-year rotation, even when vetch was included in the latter.

As the nutritional regime improved, stocking rate decreased for both rotations. But the associated decrease in output of sheep products was smaller because the better nourished animals were more productive. Profits were fairly similar across the three nutritional regimes.

Self-sufficiency of livestock products is a high priority in North Africa and West Asia, and this project showed how growing forage crops on fallow land could double output of sheep products in a barley-based farming system.



BV=barley-vetch; BF=barley-fallow;
WVM=wheat-vetch-melon; WLM=wheat-lentil-melon

Figure 15. Stocking rate, output of sheep products, and farm profits in Syrian Lira (SL) of two-year and three-year rotations; sheep flocks on different nutritional regimes: low, medium, and high. (Assumes free access to one hectare of native pasture for each hectare of farmland.)

Milk yield measurements were taken regularly for each sheep flock in the on-farm grazing trials.

Measuring Sheep Productivity in On-farm Grazing Trials

Farmers in northwest Syria participated in a collaborative forage and pasture grazing project during 1984/85 with ICARDA and the Ministry of Agriculture and Agrarian Reform (MAAR). Based on preliminary results of the on-farm trials, they have expressed enthusiasm for continuing their participation next season in this research process – an essential step in the testing of new farming practices.

These on-farm grazing trials were conducted near Breda (275 mm average rainfall) and at Tah (350 mm). Common vetch (*Vicia sativa*) and chickling (*Lathyrus sativus*) were sown on eight farms at Breda. The sheep flock at each farm was divided

	Vetch	Chickling	Common land	SE of difference
Milk yield (g)	543	526	542	44.2
Liveweight change (g)	262	234	204	

Table 19. Daily milk yield and daily liveweight changes of ewes grazing vetch, chickling, and common land.

into groups to graze the two forage crops and common land (the control). Regular measurements were taken of milk yield and liveweight changes of the ewes and responses of cooperating farmers recorded in personal interviews.

Annual medics were planted on six farms at Tah and the productivity of ewes grazing the pasture was measured. Also, an additional farm already growing medics was monitored. Results of each trial were compared with the productivity of a traditionally managed flock.

Milk production of the ewes grazing vetch, chickling, and common land was similar, but daily liveweight gains were better for vetch and chickling (Table 19). A comparison of the milk production from annual forages and medic pasture showed that animals on pasture produced four times more milk per hectare (Table 20). Much of this difference is due to the longer grazing season on medic and to the greater yield from pasture at Tah which receives more rainfall than Breda. A milk yield of 1470 kg/ha exceeds the value of a normal 2000 kg/ha wheat crop in the area. These are striking results, especially in an area with severe shortages of high quality feed for sheep.

One of the farmers near Breda, Syria who is cooperating with ICARDA and the Ministry of Agriculture and Agrarian Reform in a forage and pasture grazing project. His sheep in this pasture are grazing vetch.

	Annual forages	Medic pasture*
Stocking rate (sheep/ha)	20	20
[redacted]		
Liveweight gain (kg/ha)	91	—
Duration of grazing (days)	31	130
Grazing days (per ha)	630	100-900**

**Second year pasture.*
***Establishment year.*

Table 20. Productivity of annual forages and medic pasture.

Relationship between Lambing Rate and Weight of Ewes at Mating Time

Surveys in Aleppo Province in Syria revealed that a large proportion of the sheep flocks failed to reach the potential lambing rate of the Awassi breed: only 86% of the ewes in the average farm flock produced lambs. Why? In a series of experiments over four years (1982–85), ICARDA livestock scientists found that ewes weighing at least 48 kg at mating time usually lambed, but lighter ewes showed increasing infertility as liveweight at mating decreased (Figure 16). These results largely explain the reason for the poor fertility in farm flocks.

Three experimental sheep flocks were subjected to a low (L), medium (M), or high (H) nutritional regime in winter. In the spring, all flocks grazed natural pastures and in summer and autumn the L flock grazed poor natural pasture and the M and H flocks cereal stubbles. The H flock also received supplementary feed. The liveweights of the ewes in the L, M, and H flocks were about 41, 43, and 50 kg, respectively, during autumn when mating took place.

Scientists are now investigating cheap and simple ways of supplementing the poor quality straw diet which is the traditional sheep feed after the cereal harvest in summer. Offering supplements of cottonseed meal or mixed grazing of cereal and medic residues enable ewes to maintain or gain liveweight during the mating season. The next step in this research is to test these practices on farm flocks.

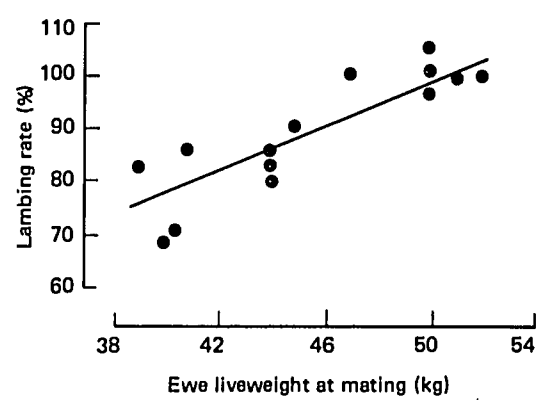


Figure 16. Relationship between lambing rate and ewe liveweight at mating.

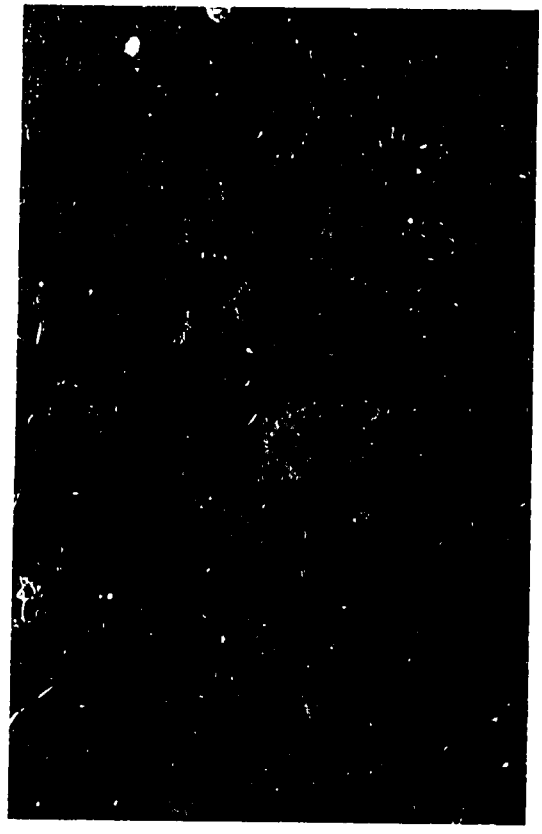
Adaptation of *Medicago rigidula* to Pasture/Cereal Rotations

The concept of using pastures to replace fallows is based on experience in southern Australia where fallows have been replaced by self-regenerating pastures whose roles are to provide livestock with year-round grazing, replenish soil fertility, and provide a disease-controlling break between cereal crops. Success of the system depends on using pasture species with the ability to produce enough dormant seed for the population to survive a year in which no seed is set.

Three years of research at ICARDA has shown that *Medicago rigidula* can regenerate naturally and form productive pasture in rotation with wheat. The experiments included 25 promising medic strains: 23 entries of *M. rigidula* and one each of *M. rotata* and *M. noeana*. Selections of *M. rigidula* originated from Turkey, Syria, Algeria, Libya, Jordan, and Lebanon; the latter two entries from Turkey.

Eighty-seven percent of the more than 600 kg/ha of seed produced in 1982/83 remained in the soil in April 1985 as a long-term seed reserve. Most of the seed had been buried by the shallow cultivation used to sow the wheat crop: only 9% of the seed remained on the surface. Figure 17 shows how the initial seed sown in 1982/83 rose and fell during the pasture and cereal phases of the rotation, the final yield of seed at the end of the third year being 700 kg/ha; an average of 15% of the seed population germinated in the second and third years, although the actual amount which germinated in the third year depended on which of the entries was measured, the highest seedling population representing 167 kg/ha and the lowest only 25 kg/ha.

Pasture yield in the year after wheat (1984/85) depended on the population of



*Regenerating medic pasture plants (*M. rigidula*) with the stubble from the previous wheat crop still visible.*

seedlings and was largely independent of other attributes of the entries. Unfortunately, examination of the interrelationships between herbage yield in 1984/85 and various measurements in 1982/83 (such as seed size, hardness of seed, seed yield, maturity time, and herbage yield) did not reveal anything which could successfully predict either herbage yield in 1984/85 or seedling numbers. This means that there is no short cut to selecting medics adapted to a pasture/cereal rotation: they must be subjected to the system in which they will finally be used.

As a result of this experiment, several selections of *M. rigidula* are now being included in grazing experiments and on-farm trials. In the near future, it is expected that cultivars adapted to pasture/cereal rotations in Syria will be released.

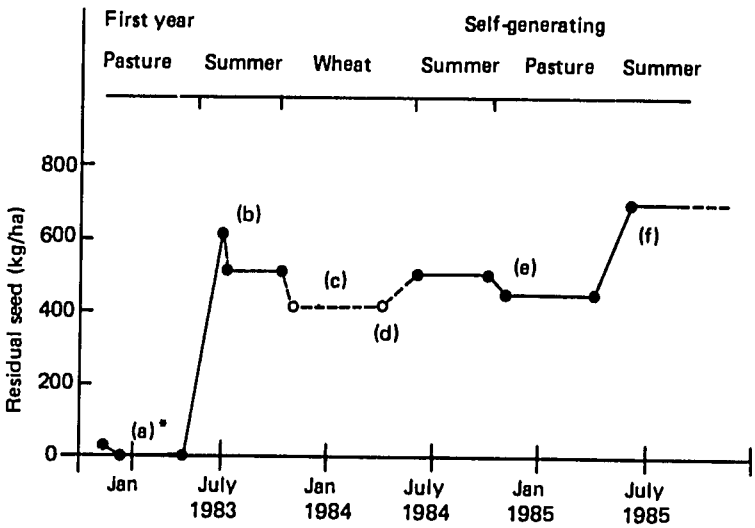


Figure 17. Changes in seed population over three years in a medic/cereal rotation where M. rigidula *was the most important medic.*

* (a) weight of seed originally sown; (b) yield of seed at end of first year (the fall caused by the sample harvested); the fall at (c) amount germinated in the year of crop; increase at (d) amount set under the crop; the fall at (e) amount germinated to form pasture in the third year; increase at (f) amount of seed set in third year; dashed lines and open circles in second year are estimates based on level of seed dormancy et point (c).

Frost Tolerance in Annual Medics

Although medic cultivars originating in Australia have grown well in some parts of North Africa, they often fail in the highlands and in West Asia. Frosty periods of more than one-week duration kill the seedlings, especially species such as *Medicago truncatula* and *M. littoralis* which normally grow in plains near the Mediterranean Sea. If these important species are to succeed in the cold areas, they must have greater frost tolerance than the Australian-developed cultivars.

Heavy frosts in December 1984 and in late February and early March 1985 presented ICARDA scientists with the opportunity to study frost tolerance of Australian and native medic species at the Center's principal experiment station at Tel Hadya, Syria: on 46 days the minimum air temperature fell below 0°C. Frost periods of this intensity are experienced at Tel Hadya only every 5 to 7 years. Many experiments were affected: one where native and introduced medics were being compared, a second where a large number of medics collected in Syria were being evaluated, and a third where three medics were sown at several densities.

In the first experiment, the Australian cultivars were Robinson snail medic (*M. scutellata*), Cyprus and Jemalong barrel medic (*M. truncatula*), and Circle Valley burr medic (*M. polymorpha*); local medics were two promising selections of *M. rigidula* and one of *M. rotata*. The number of seedlings of each species were counted soon after germination: after the late winter frosts, surviving seedlings were re-

The Australian cultivar Circle Valley (left) with frost damage at Tel Hadya compared with the frost tolerant native medic species M. rigidula *(right).*

counted and the percentage of the original population which survived was calculated. Results are shown in Table 21.

The difference between the two groups – introduced and local – is striking: seedling survival of even the best introduced species was only 21%, and these seedlings were badly damaged; in contrast, all of the

Species and genotype	No. of Seedlings (per m²)	Survival (%)
M. scutellata cv. Robinson	232	5
M. truncatula cv. Cyprus	536	7
cv. Jemalong	432	14
M. polymorpha cv. Circle Valley	856	21
M. rotata sel. 2123	1144	90

Table 21. Establishment and survival after severe frosts of seedlings of seven accessions (five species) of medic, including four Australian cultivars.

local species had 90% or more survival and the survivors were hardly affected by the frosts.

Information on the geographic origin of frost tolerance was obtained from an experiment in which annual legumes (including medics) were collected from 95 sites throughout western Syria, including the mild coastal plain (where frosts are rare), the coastal mountain ranges, and the cereal belt to the east of the ranges. Seeds were collected in summer and planted after the first autumn rains at Tel Hadya. As in the first experiment, survival of seedlings was recorded after the last winter frosts. Results are shown in Figure 18.

Frost resistance proved to be an excellent example of the benefits of choosing medics from among native populations, frost resistance of a strain being strongly related to the likelihood of frosts being experienced in their native habitat. Certain species within the populations showed a high degree of frost tolerance regardless of where they were collected (*M. rigidula* and *M. minima*, for example) while others showed strong ecotypic differentation for frost resistance (*M. scutellata*, *M. turbinata*, and *M. orbicularis*). In other words, genotypes collected at cold sites were more likely to be frost tolerant than those collected from mild sites.

Frost tolerance was affected by environment as well as inheritance. Plots of a susceptible cultivar of *M. polymorpha* (*Circle Valley*) were sown at 11 rates of seeding in an experiment designed to compare its growth with *M. rigidula* and *M. rotata*. As expected, Circle Valley was severely affected by the frosts, but much more so at a high than at a low seed rate. While more leaf was lost at high rates compared with low, the effect was most noticeable in terms of seedling death: nearly 80% of seedlings died at high compared with less than 5% at low seed rate. Neither leaf area nor seedling death of *M. rigidula* and *M. rotata* were severely affected by frost.

These experiments showed that the frost tolerance of the ICARDA medics were far superior to the commercially available Australian cultivars and will form a firm foundation for the use of annual medics in large parts of West Asia and the highlands of North Africa which frequently experience severe frosts.

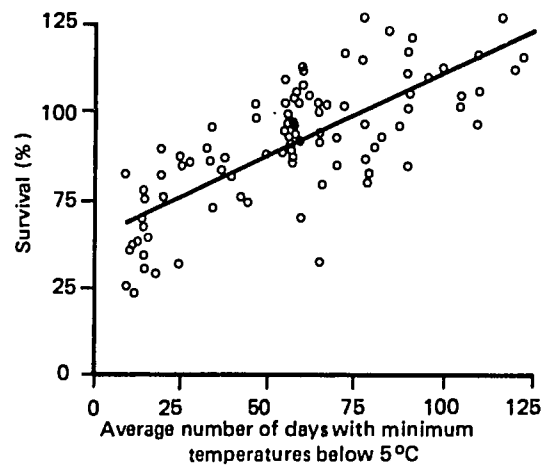


Figure 18. Relationship between frost survival and the average number of days below 5°C at 95 sites in western Syria from which annual legumes were collected.

Response of Marginal Land to Phosphate

Improvement in marginal land, characterized by stony and shallow soils, low pasture productivity, and over-grazing by sheep and other animals, is important for village economies in many parts of the ICARDA region. For example, in western Syria it makes up about 30% of the total surface and up to 60% of the land of some villages. By its nature, this land is not arable: if it were, farmers would sow it with barley or some other crop.

Three possibilities exist for improving marginal land productivity: (1) change grazing management so that grazing pressure is eased during the critical period of seed set; (2) sow improved pasture species; and (3) apply suitable fertilizer. The latter two approaches require favorable climatic conditions and proper grazing management.

Fertilizer application is being tested by ICARDA in a long-term experiment involving three aspects of marginal land development: (1) effect of phosphorus application on the botanical composition of grazed pastures with particular reference to its effect on legume content and hence its responsiveness to phosphorus; (2) economic results of phosphorus application in terms of animal productivity; and (3) effect of the animal stocking rate and its interaction with phosphorus application on the stability of the marginal land ecosystem.

The experiment consists of three rates of superphosphate (0, 25 and 60 kg P_2O_5/ha equivalent to 0, 10, 24 kg P/ha) and two rates of stocking: low (1.2 ha/sheep) and high (0.6 ha/sheep). The total area for the experiment: approximately 83 hectares. In the 1984/85 season, the animals were excluded from the experiment while waiting for the completion of plot fencing; therefore, the research was restricted to the effect of phosphate application on natural vegetation.

Fertilizer (triple superphosphate) was broadcast by hand in November 1984 following soil sampling for chemical analysis. The herbage was sampled on six occasions at monthly interval from December to May. At each sampling date, 10 samples were collected from each plot. These were separated in the laboratory into legumes, grasses, and other species. The roots were separated and discarded and the shoot portion of each category was dried (70°C) and weighed. Legume seed yield was measured in June on quadrat samples (50 × 50 cm), where all vegetation and the top one cm of soil were taken. Seeds were separated from the soil and vegetation of each sample bulked, counted, and weighed.

Phosphorus application resulted in a total yield increase of the pasture, but the most significant increase was recorded in the legume component. The slope of the regression lines for the 25 and 60 kg/ha rates were significantly greater than that of the control (Figure 19). A significant improvement in total herbage yield (legume + grass) as the result of fertilizer was recorded at the March sampling (100 days after fertilizer application), and this continued through the rest of the growing season.

The most important effect of the fertilizer, however, is shown in Table 22, where legume seed yield on marginal land was

increased by 27% and 61% over the control as the result of applying 25 and 60 kg P_2O_5/ha, respectively. This is expected to reflect favorably on legume growth, forage quality, and, more importantly, on the sheep-carrying capacity of the pasture in the coming season.

Table 22. Effect of superphosphate fertilizer rates on yield and seed number of legume species on marginal land in 1985.

Fertilizer rate (kg/ha)	Seed yield* (kg/ha)	Seed number/ m^2*
0	28.6	2072
25	36.6	3114
60	46.1	3995
LSD (P=0.05)	11.7	825

**Each value is an average of 180 quadrat samples.*

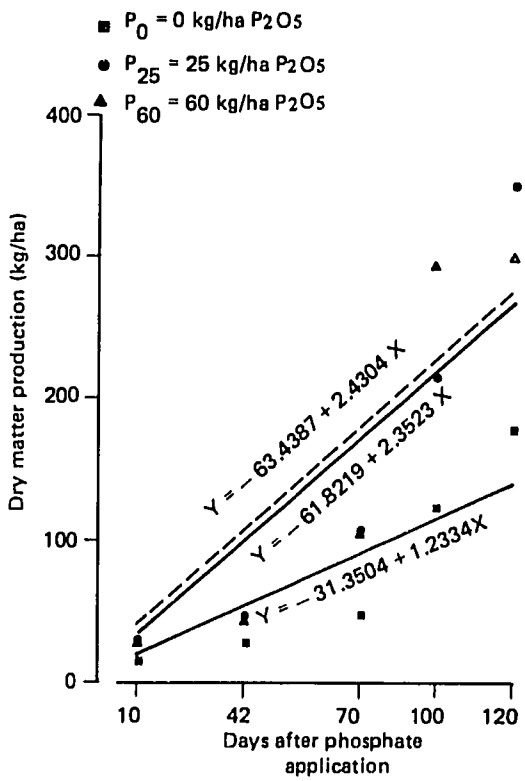


Figure 19. Dry matter production of legumes as influenced by phosphate fertilizer in the 1984/85 season.

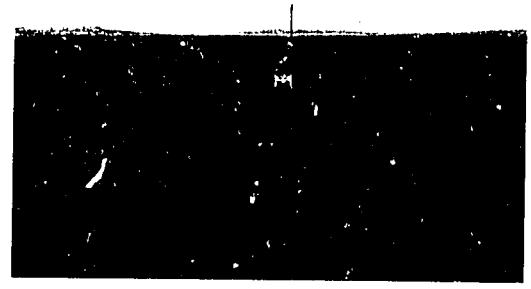
Fertilizer Use on Barley: Results of On-farm Trials and Farmers' Responses

A collaborative project of on-farm trials to assess the biological and economic effects of fertilizer use on barley, which is grown primarily as a feed for sheep, has been initiated between the Syrian Soils Directorate and ICARDA. During the first year of this project, trials with a local variety (Arabi Aswad) and different rates of nitrogen and phosphate fertilizers were conducted in four provinces of northern Syria in areas where a barley/livestock system predominates.

Barley yields in these areas normally receiving less than 350 mm of annual rainfall average less than 1 t/ha. Soils were sampled prior to sowing, on-site rainfall recorded weekly, various plant and soil samples taken during the growth period, and the harvested crop assessed for total biomass and grain yield. In addition, the agronomic practices, economic and social circumstances, and farmers' reactions to the trials were monitored in twice-yearly interviews to determine the potential for fertilizer adoption in a system which uses very little at the present time even though the soils are deficient, particularly in phosphorus.

In the 11 trials harvested in 1985, mean yields ranged from 0.87 t/ha grain and 1.36 t/ha straw to 3.33 tons of grain and 3.90 tons of straw per hectare. Phosphate fertilizer significantly increased straw production at 10 sites, grain at seven, nitrogen fertilizer straw at eight, and grain at seven. In nearly every case, most of the increase came from the first two fertilizer increments: up to 60 kg P_2O_5 and 40 kg N/ha.

The magnitude of the response reflected the low amounts of rainfall and phosphorus and mineral nitrogen available in the soil at planting time (Table 23). Responses to P fertilizer were strongest



Fertilizer use on barley advances crop maturity and helps avoid moisture stresses at the end of the season. On-farm trials (center) are ready to be harvested while surrounding farmers' crops are still developing.

where soil available phosphate was below 3 ppm and responses to N fertilizer occurred wherever initial soil mineral N was less than 11 ppm.

Responses to rainfall reflected distribution, as well as total amount, and there were interactions with the fertilizer regime. Response surfaces fitted to grain and straw yields of the six "high rainfall" sites – seasonal total >250 mm and/or rainfall from 1 February >100 mm – involved a linear response to applied nitrogen much

stronger than that to phosphate, but at "low rainfall" sites it was the phosphate response that was the stronger.

Another interesting aspect of fertilizer use on barley is the reduced variability (measured by the standard deviation) of yields in some treatments averaged over different sites. This indicates that certain fertilizer treatments offer increased yields and reduced or same levels of variability as the no fertilizer treatment. If variability is an indicator of risk, such alternatives should prove to be quite attractive to farmers.

The values for total dry matter and grain yields obtained from an analysis of co-variance of the pooled data were used to evaluate the economic feasibility of fertilizer application for each zone. Government prices were used for barley and farm gate costs for fertilizers; a straw value 35% that of grain on a weight basis was assumed. Under these assumptions, fertilizer application consistently gave increased gross revenues higher than the increased costs. Thus, in both zones 2 and 3 substantial increases in net revenues were achieved with fertilizer use. These preliminary results seem to confirm that fertilizer can profitably be used to increase barley production in drier areas.

Social and economic research at the farm level had these objectives: evaluate farmers' reaction to the trials and their understanding and evaluation of them through the season; determine the problems related to fertilizer acquisition and application; and understand farmers' practices, costs, and resources in order to study the economic and social feasibility of fertilizer use.

Thirty-seven farmers were monitored through the 1984/85 season with two visits and the largest barley plot was selected on

Table 23. Rainfall, soil conditions, and barley response to fertilizer at eleven sites in Syria (1984/85).

Site	Seasonal rainfall (mm)	0-40 cm Soil content at planting time		Mean fertilizer effects on grain yield/t/ha			
				P_2O_5, kg/ha		N, kg/ha	
		Olsen-P	Mineral-N	0	60	0	40
Ibtin	260	3.6	9.1	2.34	2.31	2.02	2.38
Mariamine	294	8.3	6.2	1.66	1.89	1.29	2.14
Hobar	268	4.2	6.7	2.35	2.65	2.29	2.60
Breda	268	2.1	8.4	1.78	2.53	2.01	2.55
Jifr Mansour	246	3.4	11.8	1.38	1.63	1.59	1.49
Grerifeh	232	1.8	4.9	0.69	0.93	0.70	0.98
Maar Shahour	323	1.7	8.2	1.01	1.33	1.01	1.42
Skiro	208	2.8	20.5	0.66	1.64	1.40	1.39
Khashouka	279	3.1	7.5	2.29	2.40	1.74	2.78
Jesaah	398	3.5	16.9	2.92	3.56	3.22	3.46
Maboujeh	220	3.9	10.9	1.98	2.46	2.14	2.59
Mean				1.73	2.12	1.76	2.16

each farm to obtain the technical information. Although this was not a random sample, these results are striking: Substantial yield gaps exist in both zones 2 and 3 between farmers' yields and the on-farm trial plots; in terms of the economically optimal yields, it appears that farmers' yields can be increased by 1630 kg/ha (168%) in zone 2 and 1376 kg/ha (211%) in zone 3; 919 kg/ha of this potential increase in zone 2 and 900 kg/ha in zone 3 is directly attributable to fertilizer use (Figure 20); even if some of this increase is to be discounted due to researcher management of the trials, the potential is still substantial.

Farmers' reaction to the trials was positive: 55% of those monitored applied fertilizer compared with only 11% before the trials and another 35% would have liked to do so but faced various technical and financial problems.

These are preliminary and tentative results from the first year of these trials, but the project will continue over several seasons. The results are expected to influence fertilizer policies in Syria and illustrate the agricultural potential of the dry areas.

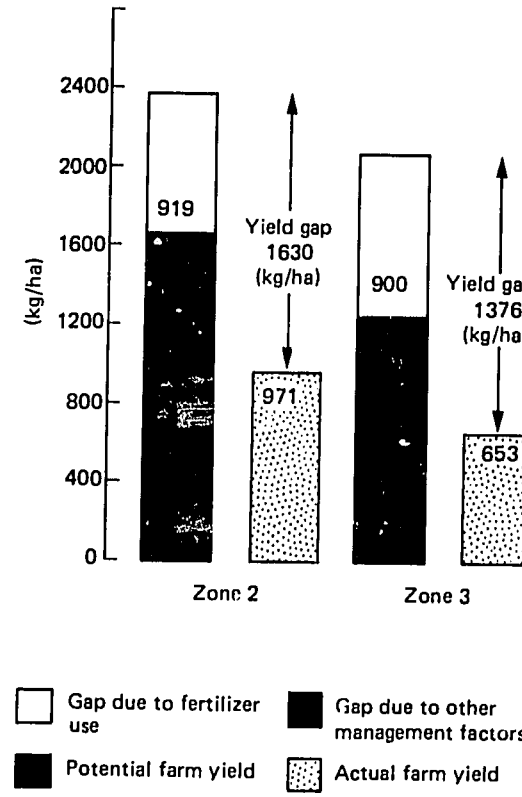


Figure 20. Gaps in barley grain yields: on-farm trials in northern Syria (1985).

Banding Superphosphates: Its Effect on Efficiency and Use by Wheat Crops

Although several countries within the ICARDA region (e.g., Morocco, Tunisia, and Syria) have large deposits of rock phosphate and are both exporters and users, soil analyses have shown that phosphate deficiency is common in the widespread calcareous soils of the area. The application of phosphate fertilizers can result in substantial increases in wheat yields, but specific management techniques are required to efficiently use them because of their gradual chemical transformation into unavailable forms and limited mobility in those soils.

Most farmers who use phosphate broadcast it prior to seeding sometimes several months before. But research at two Syrian locations (Tel Hadya and Breda) show that banding superphosphate fertilizer at the time of sowing seed promotes early vigorous growth from improved contact between roots and fertilizer, which, in turn, is closely associated with final yield potential of the wheat crop (Figure 21). This method was superior to broadcasting at two rates of P_2O_5 application: 80 kg/ha and 120 kg/ha.

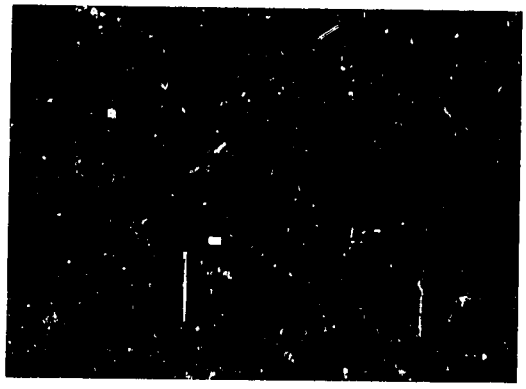
Another part of the continuing research on soil/fertilizer interaction involved a study to determine the "life" of banded phosphate fertilizer in the soil: How long can it last in available form to plants? By putting carefully weighed amounts of triple superphosphate in cylinders buried in the soil, it was possible for the researchers to follow the change in chemical forms of phosphates and determine the time needed for the availability of fertilizer to be halved due to fixation ("the half-life of fertilizer").

Rate kg/ha P_2O_5	Half life* (months after application)			Time to reach equilibrium** (months after application)		
	Jindiress	Tel Hadya	Breda	Jindiress	Tel Hadya	Breda
40	4.8	10.9	15.2	19	39	53
80	5.9	8.3	10.2	32	39	45
120	5.9	10.3	10.1	32	54	51

**Time taken for the availability of the fertilizer to be halved due to fixation.*
***Time taken for the availability of the fertilizer added to reach zero value.*

Table 24. The half life and time to reach equilibrium of banded phosphate fertilizer as affected by location and rate of application.

Carefully weighed amounts of triple superphosphate in cylinders buried in the soil make it possible for researchers to determine the "life" of the fertilizer.



Researchers found that faster rates or fixation are associated with higher levels of application: the rates of fixation were faster at Jindiress (mean half-life 5.5 months) than at either Tel Hadya or Breda (mean half-life, 9.8 and 11.8 months). An approximate calculation of residual phosphate remaining in available forms with time can also be estimated (Table 24).

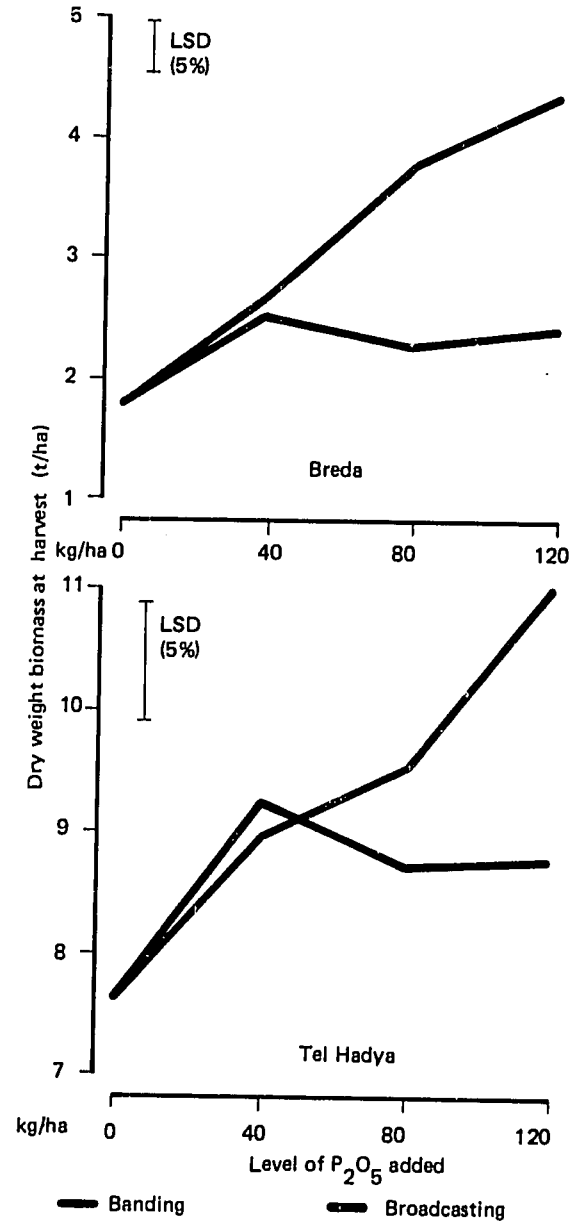


Figure 21. Effect of rate and placement of phosphate added to soils on dry weight biomass of a wheat crop at harvest at Breda and Tel Hadya, Syria.

Survey of Wheat Farmers and On-farm Trials in Northwest Syria

A survey of current practices of farmers producing rainfed wheat in northwest Syria has been completed to help guide ICARDA's farming systems research effort and to assess how this research can most usefully complement that of the national program. Also, parallel on-farm trials focused on the effects of fertilizer and herbicides on wheat production.

An increasing demand for wheat in Syria and other countries of the ICARDA region emphasizes the need for greater yields on farmers' fields. One of the encouraging facts found in the survey was this: some farmers have adopted new technologies to increase wheat production and others are ready to do so. On the average, they expect to harvest about 2 t/ha - one ton in a bad year and three in a good year. Most of their wheat is mechanically harvested - only 18% by hand, usually in stony or inaccessible fields.

The 63 farmers in the survey used a range of methods and intensity in the cultivation of their soils, and tillage absorbed 22% of the pre-harvest costs of wheat production (Figure 22). The mean number of cultivations was 2.4 but ranged from 1 to 7. Most of the farmers were familiar with fertilizers and adjusted rates according to several factors, including: soil type - more phosphate and nitrogen on better soils, less on poorer ones; more nitrogen following irrigated summer crops regardless of soil type.

Most of the wheat grown by the farmers in the survey was durum, and approximately half of them found no problem with the variety they planted. However, others reported some problems such as disease, low drought tolerance, and poor seed quality (not pure seed). When asked what they would like to see in a new variety, 87% said higher yields; other characteristics: resistance to shattering and lodging, drought tolerance, and food quality.

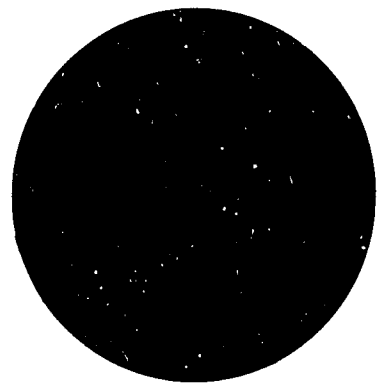
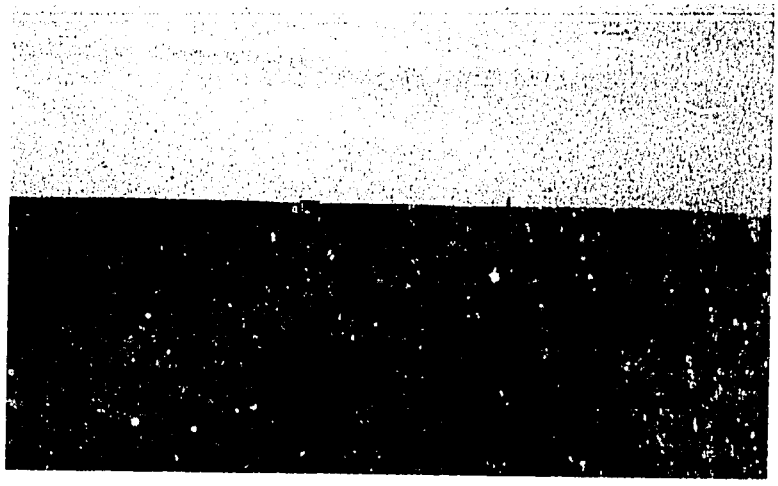


Figure 22. Distribution of pre-harvest costs for wheat.

More than half of the farmers had moderate or severe levels of weed infestation in uncontrolled areas of their wheat crops. Those with heavy infestations used less fertilizer and more tillage to try to reduce weeds. Most of the farmers reported that they applied herbicides in years of heavy infestation, but a sizable minority rely on hand weeding. They said their need for livestock feed was an important factor for



Weed control in wheat (green plots) vs. no control (yellow plots). Weed control allows the fertilizer to be used by the crop instead of the weeds.

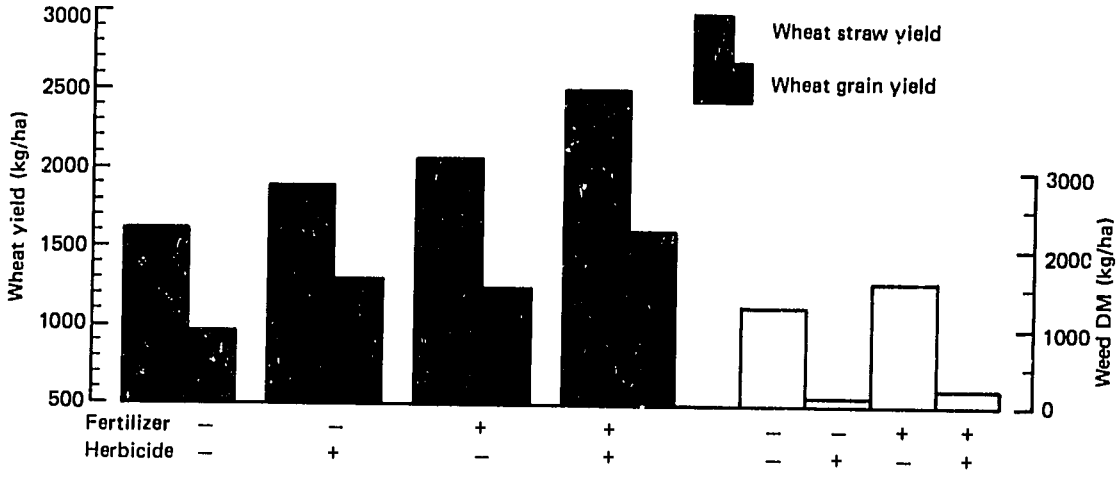


Figure 23. Effect of fertilizer and herbicide on wheat production in eight severely weed-infested farmers' fields.

this practice; 21% used no weed control.

An analysis of 18 on-farm trials in the same wheat producing area showed that farmers can achieve economical grain yield increases by using a combination of herbicide and fertilizer, especially on severely weed-infested fields.

Four treatment combinations of weed control and fertilizer were superimposed on wheat crops managed by the farmer

according to his own tillage and planting methods: broadcasting seed and fertilizer over ridged land and splitting the ridges to cover them. Eight farmers' fields were under severe weed infestation and the other 10 moderately so. On the latter, a significant response was recorded in grain and straw yield to fertilizer both with and without weed control. However, herbicide produced significant responses only in the presence of fertilizer which stimulated weed growth as indicated by a significant fertilizers × weed control interaction.

At the severe weed infestation sites, farming systems researchers found a significant response to both weed control and fertilizers, but again a significant interaction indicated that the highest yields resulted when both were used together (Figure 23).

The largest increase in net income occurred where both treatments were applied together: the use of fertilizer without weed control barely paid for itself and weed control alone was profitable on severely infested fields but not on those where weed infestation was less.

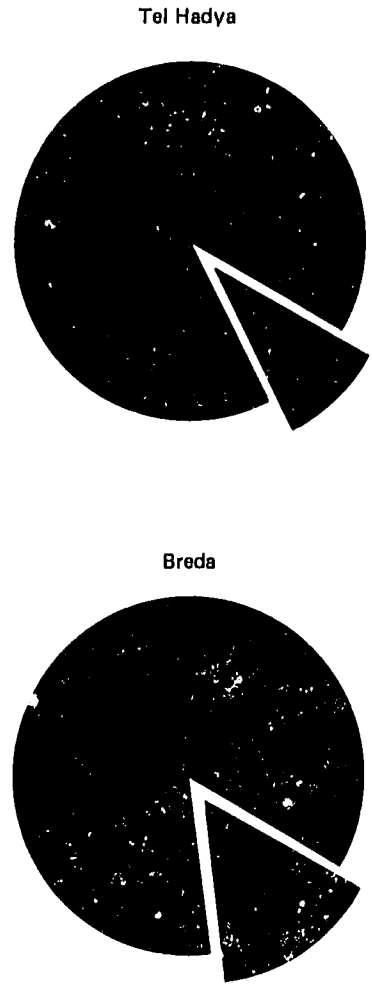


Figure 24. Nitrogen recovery from urea fertilizer in trials at Tel Hadya and Breda, Syria in 1984/85.

Nitrogen Recovery by Wheat and Ammonia Loss by Volatilization from Urea Fertilizer

Soils of the arid zones in the ICARDA region are poor in available nitrogen, and the application of nitrogen fertilizers is a major factor in increasing crop production under rainfed agriculture. Urea is the major nitrogen fertilizer used in several countries of the region because of its solubility in soil water, a cheaper price compared with other N sources, and its high concentration in available nitrogen. Some countries have been reluctant to use it because of an assumption that there is a significant loss by volatilization to the air in the form of ammonia when the urea is topdressed on calcareous soils.

Field trials were conducted in 1983/84 and 1984/85 at Tel Hadya and Breda, Syria to study the effect of various levels of urea on yields of wheat, nitrogen recovery by plants, and N residual in the soil. In selected treatments, microplots were fertilized with 15N-labelled fertilizers. Figure 24 shows the nitrogen recovery and losses from ordinary urea applied (drilled) at a rate of 40 kg N/ha at both experimental sites.

Loss of nitrogen, primarily due to ammonia volatilization, ranged from 10–15% for both seasons and locations. Nitrogen losses were relatively small in both seasons because of soil and climatic conditions. The major factor explaining the small losses was probably the high cation exchange capacity of the heavy-textured soils: the clay surfaces retained most of the ammonia (NH_4+) derived from the hydrolysis of urea.

Soil temperature may also affect ammonia volatilization. Increasing soil temperature increases the rate of hydrolysis of urea and the rate of reaction leading to ammonia volatilization. But the average temperature during February in northwest Syria is usually low, and consequently soil temperature did not show its effect except on urea applied in late February and early March. Most of the losses of nitrogen occurred during the first three weeks following the application of the fertilizer in early February.

The general conclusion of this research: urea appears to be a rather efficient and cheap source of nitrogen fertilizer for winter cereals grown on the calcareous heavy-textured soils in northwest Syria; losses of nitrogen applied at planting are expected to be small (5–10%) as are the losses when nitrogen is applied as a topdressing in early February (10–20%).

Identifying "Best Bet" Wheat Cultivars in a Variable Climate through Computer Simulations

Another year's experience with the computer model SIMTAG (SIMulation of Triticum Aestimum Genotypes) has given further evidence of its value in predicting how climate variability over the years affects wheat yields in Syria. This variability also influences selection of new varieties. (See 1984 *Research Highlights*.)

An example of the variability of seasonal rainfall and wheat yields for Muslimieh in northern Syria is shown in Table 25. While the ratio of rainfall between wettest and driest seasons is about 1:3, the ratio of wheat yields between best and worst years is more than 1:15. These large differences from year to year make it difficult to decide which combination of characters is likely to make a variety the most successful in the long run, since qualities which make a variety outperform others in one year may be the cause of a poor performance the next.

At Muslimieh, the variety Novi Sad would have outyielded Sonalika in 14 seasons out of the last 25, but for four of the last six SIMTAG predicts that the reverse would have been true. Therefore, a six-year-long experimental program would not have been enough to ensure correct interpretation, unless supported by simulations of the effect of climatic variability on the crop performance over a much longer period.

Rainfall	Rainfall (mm)	Grain yield* (kg/ha)
Maximum per season	589	5870
Minimum per season	165	360
Average	352	2570

* *Variety Novi Sad, as predicted by SIMTAG.*

Table 25. Variability of rainfall and wheat yields 1960/61 to 1984/85) for Muslimieh in northern Syria.

Such simulations were carried out by ICARDA scientists for a number of stations from different parts of the wheat growing areas of Syria, contrasting spring wheat varieties with many different combinations of genetic traits. SIMTAG allows the scientists to create hypothetical varieties with various combinations of phenotypic characters. This opportunity, if used judiciously, can help explore and identify desirable characteristics in germplasm collections for field testing in the search for wheat lines with large and stable yields.

Some of the results of this research are illustrated for three locations in Figure 25. "Earlybig", one of the compared hypothetical varieties, matures early and has relatively few but big kernels and a high kernel filling rate. The other one, "Late-small", is late maturing with potentially many but small kernels and a lower kernel filling rate. Both were "grown" in the same, good soil (a Luvisol). Two of the sites

– Muslimieh and Kamishly – have a similar temperature regime, but Kamishly has an average rainfall of 440 mm compared with 352 mm for Muslimieh over 25 seasons. Sweida with almost the same average rainfall (357 mm) as Muslimieh has a cooler climate: it lies 997 m above sea-level compared with about 450 m for the other sites.

The curves in Figure 25 are cumulative probability distribution functions of simulated grain yield. They can be interpreted as reflecting the relative ability of the crop to cope with environmental risk. The variety whose curve lies predominantly on the right represents the option with least risk and therefore is the "best bet" variety if minimum risk in a variable climate is the first priority. At Muslimieh, the variety "Earlybig" is therefore the better choice because it can be expected to outyield "Latesmall" in two seasons out of three. At Kamishly and Sweida, however, "Latesmall" outperforms "Earlybig" in most seasons.

The detailed day-to-day account of water balance and crop development which SIMTAG provides also explains how these predicted yields come about. Under optimal growth conditions, short season cultivars (such as "Earlybig") yield less than later ones. However, drought in the terminal growth stage – a frequent problem in the areas under consideration – affects late cultivars more than early ones.

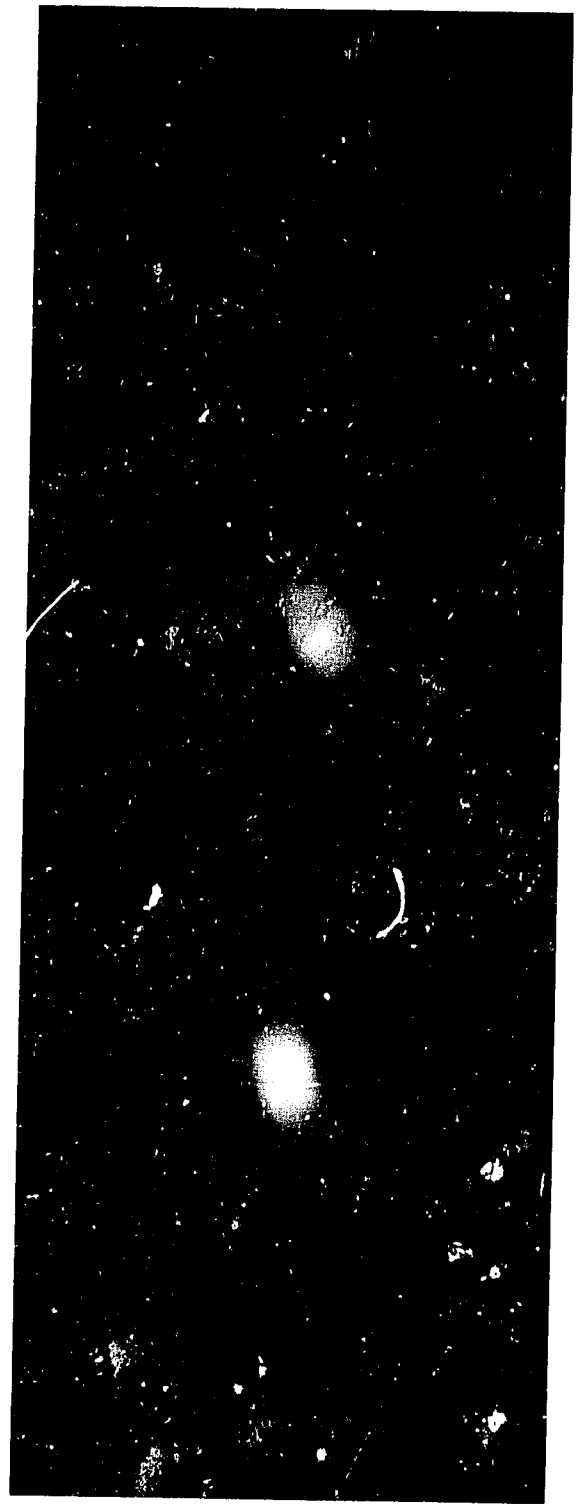


Figure 25. Cumulative probability of simulated grain yields for two hypothetical wheat varieties with different characteristics. The lines reflect the relative ability of the crop to cope with climatic risk. (See text.)

Under these conditions, early cultivars have a yield advantage.

Terminal drought is likely to affect yields at Muslimieh more frequently than at Kamishly because higher rainfall totals coincide with longer seasons, better rainfall distribution, and more available moisture at the end of the season. At Sweida, too, stress at critical periods at the end of the season affects yield less frequently than at Muslimieh, although rainfall totals are similar. This is due to the high altitude of Sweida. There cooler temperatures reduce evaporative demand, resulting in a better profile water recharge during the winter which alleviates moisture stress at the end of the season.

The relative superiority of "Latesmall" over "Earlybig" at the two sites, therefore, has different reasons: at Kamishly it is due to higher rainfall but at Sweida to lower evaporative demand. A combination of comparatively low rainfall and high evaporative demand at Muslimieh make "Earlysmall" the "best bet" for most reasons.

Climatic data for the SIMTAG analysis were supplied by the Syrian Meteorological Service.

Relationship of Fertilizer Application to Protein Content of Wheat and Barley Crops

Not only does nitrogen and phosphate fertilization affect wheat and barley yields but also the protein content of the grain and the straw of both crops – an important consideration in countries where the diets of people and animals are deficient in protein.

In trials at three experimental sites in northern Syria (Breda, Tel Hadya, and Jindiress), the application of nitrogen fertilizers to durum wheat (Sham 1) led to a significant increase in the protein content of grain (24–51%) and straw (31–65%). As shown in Figure 26, the highest protein content of wheat grain was achieved with 90 kg/N/ha.

Similarly, the average total protein content in grain and straw of Arabi Abiad barley grown in 11 trials on farmers' fields significantly increased with the application of nitrogen and phosphate fertilizers, especially when added together.

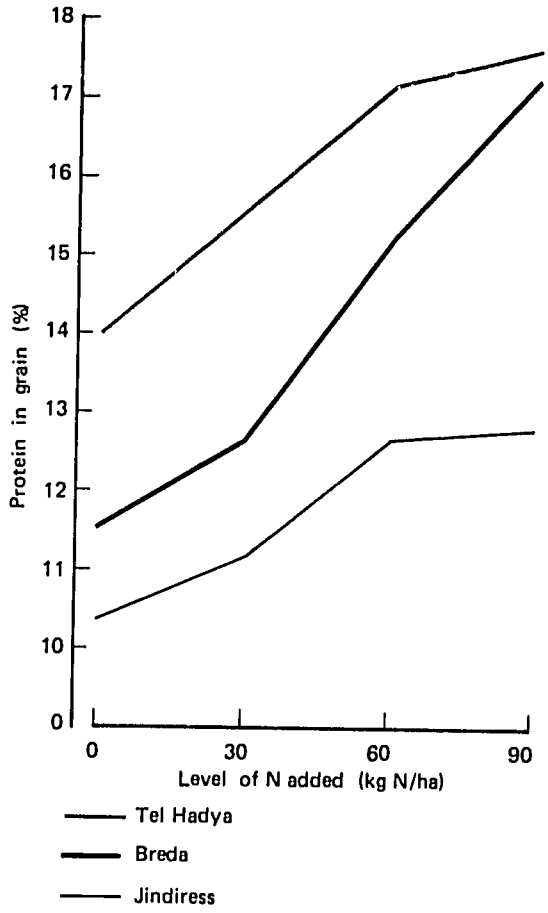


Figure 26. Effect of level of nitrogen fertilizers applied to wheat in three experimental sites in Syria on protein content of the grain.

Performance of a New Single-pass Crop Planter

Farmers growing wheat and barley in Syria and some other areas in the region usually follow a procedure that requires four passes over their land at planting time. But the Farming Systems Program has developed a simple single-pass planter that can work directly into moist or dry uncultivated soil and in a single operation open ridges, place the fertilizer, drop the seed, and cover both with soil.

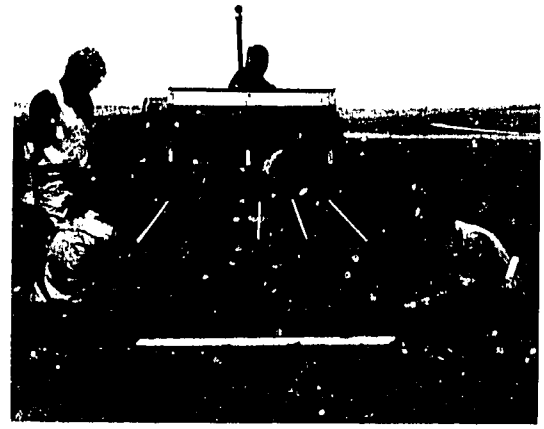
This planter incorporates the commonly used "duckfoot" cultivator, locally made driving wheels for depth control, two boxes (one for seed and the other for fertilizer with rate controls), and a fixed heavy bar (tabban). Barley sown with a prototype was compared with barley hand sown or drilled, with and without phosphate fertilizer, at Breda in northwest Syria. Initial yield results and an economic evaluation summary are presented in Table 26.

Phosphate gave significant yield increases of barley in all sowing methods. Without fertilizer, grain and straw yields were low and no significant differences could be found between sowing methods. In fertilized plots, however, both drill seeding and the single-pass planter significantly outyielded hand broadcasting.

Economic evaluation of the planter depends on several cost estimates based on custom farming charges in 1985. Hand harvest is assumed in each case to simplify valuation of straw yields; with combine harvest the values of both collected straw and stubble grazing would have to be calculated.

Total costs for barley crops sown without fertilizer by hand broadcasting and by the single-pass planter were similar, as were costs with the two seeding methods when fertilizer was applied. The significant yield increase obtained by the planter when phosphate was applied is reflected by a considerable increase in net revenue. Highest net revenues were calculated for drill seeding with fertilizer. Good placement of the fertilizer appears to be responsible for the excellent economic results obtained with sowing by drill or by the single-pass planter. The high marginal rates of return calculated for the planter and the drill without fertilizer are based on yield increases which are not significant at the 5% level.

An element of timeliness another advantage of the single-pass planter cannot be evaluated by a simple cost/benefit calculation. The seedbed preparation required by the drill and the extra operations needed for hand sowing all take time and



Instead of a farmer's traditional four passes over the land, this prototype single-pass planter can open ridges, place the fertilizer, drop the seed, and cover both with soil in one operation. It is usable for cereals, lentils, or chickpeas.

Sowing method:	Drill		Hand broadcast		Single-pass planter	
Fertilizer (60kg P_2O_5/ha)	+ P	No P	+ P	No P	+ P	No P
Grain yield (kg/ha)	1774	1034	1392	798	1674	1012
Straw yield (kg/ha)	1922	844	1374	726	1580	876
Grain value (SL* 1.43/kg)	2537	1479	1991	1141	2394	1447
Straw value (SL 0.54/kg)	1038	456	742	392	835	473
Total crop value (SL/ha)	3575	1935	2733	1533	3229	1920
Total costs (SL/ha) (Seed, fertilizer, seeding, cultivation, harvesting)	1149	727	1057	672	1064	667
Crop value minus costs (SL/ha)	2426	1208	1676	861	2165	1253

**SL: Syrian Lira.*

Table 26. Summary of an economic comparison of the single-pass planter with hand broadcast and drill seeding of Ababi Abiad barley (1985).

often cannot be completed on the same day. By temporarily bolting the "single-pass" boxes and drive wheels to the cultivator used for other jobs during the year, the farmer may gain more control over his sowing operations than has been possible before.

With minor modifications, the single-pass planter can also be used for sowing lentils and chickpeas and will be tested for this purpose during 1986.

Annual Legumes for Harvest: On-farm Research

The primary activity of rural people in the dry cultivated areas of Syria, as in similar areas of West Asia and North Africa, is barley production integrated with raising sheep. Farmers follow either the predominant crop rotation of cereal/fallow or a secondary practice of continuous cereal cultivation. Total agricultural output of both systems can be improved by using alternative crop rotations: legume crops which replace fallow will be a source of food or feed at little cost to the subsequent cereal crop. Alternatively, legumes act as a break-crop in place of continuous cereal cultivation, prevent build up of soil diseases and contributing to soil fertility.

But even with these advantages can legumes be grown economically under harsh conditions? To test the feasibility of growing these crops for harvest, on-farm trials in fields of diverse quality were selected in three villages in the 250-350 mm rainfall zone in Syria. Two replicates were planted at ICARDA's principal station at Tel Hadya for comparison. In addition, grazing trials were conducted on eight farms to evaluate an alternative use of the crops.

Previous research has shown that legume yields are often improved by the use of phosphate fertilizer. Also, the damage to root nodules by sitona weevil larvae, which substantially affects nitrogen fixation and grain yields, can be controlled with Carbofuran. These treatments were

included in a simple design with the three legume species most common in dry areas of Syria: vetch, lathyrus, and lentil (*Vicia sativa*, *Lathyrus sativus*, and *Lens culinaris*).

In addition, the trial was designed to compare barley-legume rotations with the most common local rotations: barley-fallow, unfertilized continuous barley, and fertilized continuous barley. Thus, plots of fallow land, barley, and barley with nitrogen were also treated with phosphate and Carbofuran. (All plots will be planted with barley next season to determine residual effects of crops and treatments.)

The three legumes showed different patterns of growth. At the grazing stage, vetch was clearly more productive than lathyrus and lentils. However, by the end of the season lathyrus had nearly caught up with vetch in total biological yield and far exceeded vetch in seed production. Lentil growth was similar to lathyrus at the grazing stage but late growth of lentils was slower than lathyrus.

The species exhibited significant differences in biological nitrogen fixation and sitona weevil damage: lathyrus was superior to vetch and lentils in nitrogen fixation irrespective of treatment, and, although lathyrus produced more seed with a high nitrogen content, it was not at the expense of soil nitrogen; lathyrus was relatively

Nodule damage decreased and biological nitrogen fixation increased with Carbofuran in all species. As expected, the effect on lathyrus was small, but total biological yields of lentil were increased by 14% and vetch by 21%. Phosphate fertilizer increased mean legume yields by 20%, with no significant differences among species.

These on-farm trials suggest three ways in which legume cultivation can be made more productive in dry areas: species selection, insect control, and use of phosphate. In addition, the alternative of grazing the crops instead of harvesting them is being considered: it avoids the high cost of a manual harvest.

A farmer [illegible]son turns irrigation water into a wheat field. Supplemental irrigation greatly increased wheat yields on this farm and others in two agroclimatic zones in Syria compared with yields under rainfed agriculture.

Impact and Potential of Supplemental Irrigation within Rainfed Areas

A recent study of two farming areas in Syria's Aleppo Province shows supplemental irrigation provides conditions for using improved crop varieties and more fertilizer which result in higher and more reliable yields. The areas were selected for study if they were located in agroclimatic zones 1 and 2 with an agronomic potential for development from a socio-economic perspective.

One study area, Tel Dhaman sub-district in agroclimatic zone 2, has 81,000 ha of rainfed and 7,000 ha of irrigated cultivated land with an average farm size of 20 ha under supplemental irrigation and 30 ha in rainfed farming. The other area, Mare'a sub-district in agroclimatic zones 1 and 2, has 14,870 ha in rainfed farming and 2,830 ha

under irrigation with tube wells as the principal source. Landholdings are small and generally fragmented with an average farm size of 5 ha under irrigation and 9 ha for rainfed farming.

Although surface irrigation is the main method of applying water to crops, sprinklers – a more efficient means – were introduced a few years ago and are used on about 10% of the total irrigated area.

Wheat is the number one crop to receive supplemental irrigation in both subdistricts. Barley is irrigated from the Kwiak River in Tel Dhaman where two irrigations per season are available, and in Mare'a some barley fields may be irrigated during exceptionally dry seasons.

Rainfed crops are sown a month earlier than crops for supplemental irrigation in Tel Dhaman. Wheat is planted in December for rainfed farming and in January with supplemental irrigation. Farmers plant barley during November under rainfed farming and in December when they use supplemental irrigation. Since most of the cultivated area in Mare'a is located in zone 1, no difference in sowing dates exists between cereals with supplemental irrigation and rainfed farming. Wheat is sown in November and December, barley a few days earlier.

Supplemental irrigation greatly increased wheat and barley yields compared with those under rainfed agriculture (Table 27). For example, improved varieties of wheat produced an average of 5 t/ha with supplemental irrigation compared with 2 t/ha in zone 1 and 1.5 t/ha in zone 2 with rainfed farming. Rainfed crops matured and were harvested 10 to 20 days before crops grown with supplemental irrigation. Harvesting costs were higher for cereals grown with supplemental irrigation because the net cost of harvesting cereals with combines is based on level of yield: the cost ranges from 5 to 12% of the total harvest.

Livestock is an integral part of rainfed farming in Tel Dhaman. Limited numbers of dairy cattle are integrated exclusively with supplemental irrigation. In general, the role of livestock is important in rainfed farming systems but not in Mare'a where land is too valuable for livestock grazing.

For rainfed agriculture in Tel Dhaman, 90% of the total farm labor requirement is provided by family labor. In Mare'a, 70% of the farmers rely on family labor for

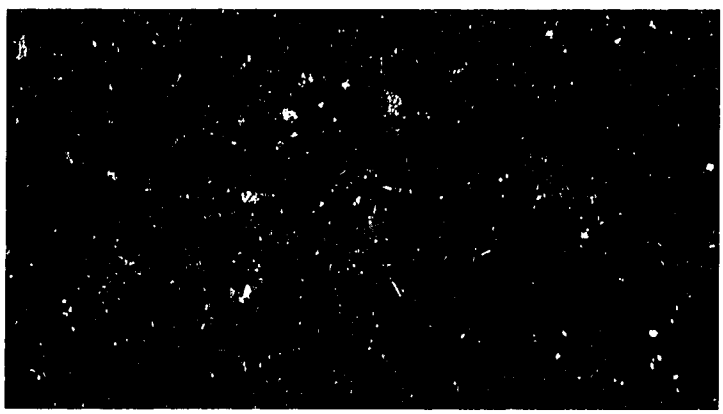


Table 27. Average crop yields for wheat and barley under supplemental irrigation and rainfed farming in two areas in Aleppo Province, Syria.

rainfed farming operations and 30% on hired labor. For supplemental irrigation, labor force percentages are the same as in Tel Dhaman (10% of the total farm labor requirement is provided by the family, 20% by sharecroppers, and 70% by hired labor). The tradition of free labor from relatives and neighbors is no longer practiced.

A labor shortage usually exists at peak demand periods: harvesting winter and summer crops, seeding, fertilizer application, and weeding of summer crops. Daily wages of hired labor have doubled and even tripled during the past five years.

In Tel Dhaman, 60% of the total migration from rainfed areas is permanent with farmers migrating to neighboring cities or abroad. Temporary migration occurs during the off-season when labor is not needed for rainfed farming with many farmers migrating to areas under irrigated agriculture for employment. Farmers from Mare'a do not migrate permanently, either from rainfed or from irrigated farms. About 35% of the farmers from rainfed farming migrate temporarily to Aleppo during off-season periods and return when their labor is needed.

Net income/ha with supplemental irrigation in Tel Dhaman is five to six times that of rainfed agriculture and in Mare'a about 10 times. With supplemental irrigation, nearly all households in Tel Dhaman and more than 70% of those in Mare'a receive their total earnings from the farm. Under rainfed farming, only 30% of the households in Tel Dhaman and less than 50% in Mare'a can rely on their farms for their total income. Income differences between the two farming systems are reflected in the diverse social status and life styles of the two groups. An increased quantity and quality of food, improved housing, and other luxuries are observed where supplemental irrigation farming exists.

Because of the importance of supplemental irrigation and water management, the Farming Systems Program has also initiated on-farm research, partly in collaboration with the Ministry of Agriculture and Agrarian Reform (MAAR), to develop improved practices and techniques appropriate to farming conditions in different areas.

A New Development at ICARDA: Virology Research

Increased awareness of crop losses induced by viruses on cereal and food legume crops led to the establishment of a new virology laboratory at the Center in 1985. It has been given four assignments: (1) study the incidence of virus diseases on food legumes, cereals, and pasture and forage crops in the region; (2) develop methods of screening germplasm for resistance to viruses; (3) develop methods of control (or prevention) based on ecological and epidemiological studies; and (4) establish methods for seed testing for virus infection.

Staff members of the laboratory got underway with assignment number one early in the year by conducting a survey to identify viruses infecting cereals and food legumes in Syria, Lebanon, Tunisia, and Morocco. Samples were collected during the spring growing season and laboratory tests made to validate field observations and to further characterize the viruses.

Bean leaf roll virus (BLRV) was found to be the most prevalent virus on faba beans in all countries surveyed based on visual observation in the field. The identity of this virus was confirmed serologically; it reacted strongly with BLRV antisera obtained from the Netherlands. When faba bean samples collected from farmers' fields were tested by serology for the presence of a number of viruses, these four were found in addition to BLRV: broad bean mottle virus (BBMV), broad bean stain virus (BBSV), bean yellow mosaic virus (BYMV), and pea seed-borne mosaic virus (PSbMV). They were identified based on serology, reaction on indicator plants, and electron microscopy.

The frequency of their occurrence varied among countries (Table 28); it was evident that in a country such as Syria, where a relatively large number of samples were tested, BYMV was the most frequently detected virus after BLRV. Control measures to minimize the effect of BLRV and BYMV on faba bean yield will

Country	Number of samples tested	Number of faba bean samples containing:			
		BBMV*	BBSV*	BYMV*	PSbMV*
Syria	145	6	36	67	33
Lebanon	44	0	6	4	1
Tunis	17	9	4	0	0
Morocco	7	1	0	1	0

**BBMV = broad bean mottle virus; BBSV = broad bean stain virus; BYMV = bean yellow mosaic virus; PSbMV = pea seed-borne mosaic virus.*

Table 28. Viruses identified in faba bean samples collected from Syria, Lebanon, Tunis, and Morocco during the spring of 1985.

be investigated. Meanwhile, in-depth evaluation of faba bean germplasm for resistance or tolerance to these two viruses is underway.

Barley yellow dwarf virus (BYDV) – the number one virus problem on cereals worldwide – was detected in samples from all the countries surveyed. Two different strains were found with the PAV strain more frequent than the F (Table 29). Resistance to BYDV is being sought in ICARDA's germplasm collection. A total of 1400 entries of bread and durum wheat and barley are being carefully screened using artificial inoculation with two species of aphids to identify tolerant or resistant plants.

Virus research at ICARDA was initiated as a special project supported by the Netherlands Government. The investigations are conducted in close collaboration with the Institute of Plant Protection (IPO) at Wageningen in the Netherlands and the Lebanese National Council for Scientific Research and the Faculty of Agricultural and Food Sciences at the American University in Beirut. Tests which cannot be done at the ICARDA laboratory because of limited facilities are conducted at Wageningen and/or Beirut.

Identifying different plant viruses through serological testing in the new virology laboratory.

Country	Number of samples tested	Number of samples giving positive reaction with antisera to: F strain (Europe)	PAV strain (USA)
Syria	55	10	28
Lebanon	23	3	8
Morocco	19	10	13
Tunis	21	12	11
Sudan	4	0	3
Ethiopia	6	0	6
Total	128	35	69

Table 29. Detection of barley yellow dwarf virus (BYDV) types using different antisera in cereal (wheat and barley) samples collected from plants showing BYDV-like symptoms from different countries in the ICARDA region during the growing season of 1984/85.

Update on Training

With rising frequency and consistent with long-range plans, ICARDA co-laborated with national agencies in conducting more training programs locally instead of scheduling most of the courses at the Center's headquarters. For example, in-country short-course enrollments for 1985 were 35% larger than those at headquarters.

The total number of participants in all ICARDA training activities reached 215 – a striking contrast to the first year (1978) total enrollment of 26 (Figure 27).

From 1978 through 1985, training participants came from 40 countries. Both formal and informal reports from many of them and their administrators provide evidence that the training helped them to gain new knowledge, technical skills, and professional confidence.

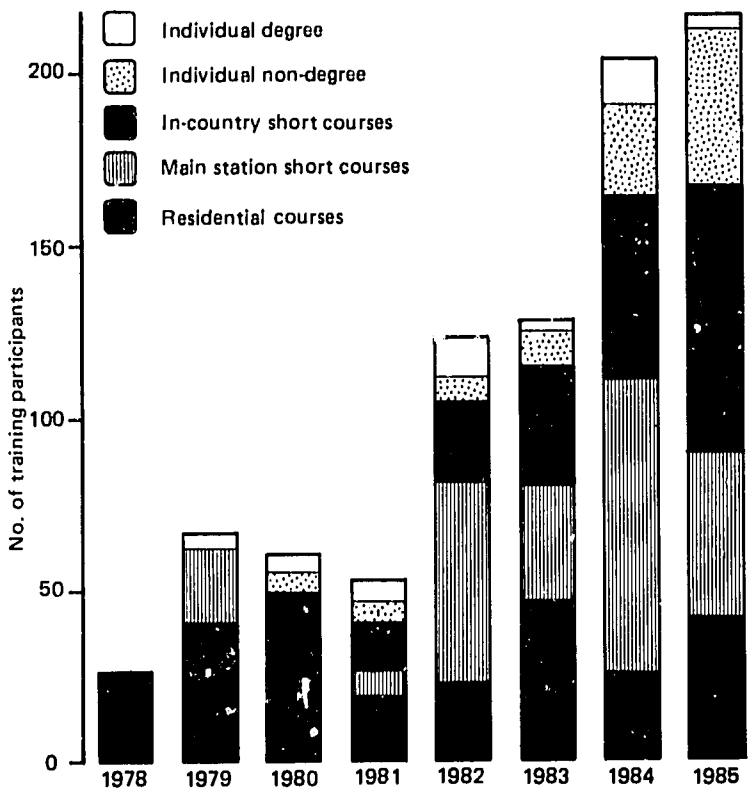


Figure 27. Growth of ICARDA's training program since its beginning.

ICARDA Donors
(Currency: US $ (×000)

Core Operations (1985)
Unrestricted and Capital

Australia	422
Canada	662
China	50
Denmark	97
Ford Foundation	175
Germany	668
IBRD (World Bank)	5,250
Italy	348
The Netherlands	343
Norway	283
Saudi Arabia	600
Spain	100
Sweden	364
United Kingdom	622
USAID	5,300

Restricted and Capital

Arab Fund	343
France	127
IDRC	
— Food Legumes (N. Africa)	132
— Farming Systems (Tunisia)	117
IFAD	
— Buildings	500
Italy	
— Building (GRU)	313
— Forage	240
— Durum Wheat	174
OPEC	
— Barley Improvement	162
— Buildings	596
UNDP	
— SWAN	200
USAID	
— Barley Diseases	160

Special Projects (1985)

BMZ/The Netherlands	
— Seed Production Organization	91
Ford Foundation	
— Farming Systems	75
— Factor Constraints	125
IDRC-Manitoba	
— Faba Bean Pathology	105
— Lentil Harvest Mechanization	50
— Lentil Haploid Culture	24
— Arabic Dimension Services	20
— Faba Bean Insect Pollination	13
— Survey of Forages	10
IFAD	
— Nile Valley Special Project	1,000
OPEC	
— Improved Wheat Technology/ Sudan	49
USAID/AZRI	
— Baluchistan – Pakistan	492
— Cereals/Jordan	45

IDRC: International Development Research Centre, Canada
IFAD: International Fund for Agricultural Development
UNDP: United Nations Development Programme
USAID: United States Agency for International Development

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