ICARDA RESEARCH HIGHLIGHTS 1981

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A Brief Profile of ICARDA

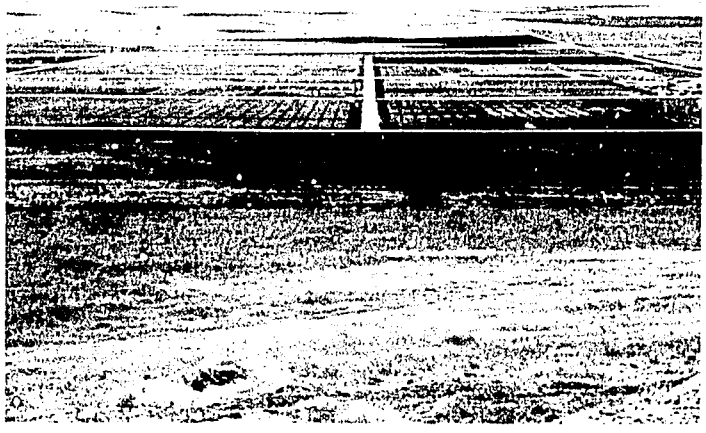
Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is one of the newest links in a world-wide network to improve and increase food production. The Center's principal geographic area of concern involves 22 countries of the Near East and North Africa with a population of more than 300 million people. It extends from Morocco in the west to Pakistan in the east and from Turkey in the north to Sudan in the south. Regardless of mineral wealth in a few countries in this region, it continues to face major food shortages and in an accelerating manner. Indeed this region claims the highest per capita food imports in the world.

ICARDA serves as a regional research and training center, in cooperation with other international centers, for the improvement of bread wheat, durum wheat, triticale, chickpeas, pasture and forage crops, and farming systems. Also, it has been designated as a world center for barley, lentils, and faba beans.

The Center is governed by an international Board of Trustees and organized into five main operational programs: Farming Systems, Cereal Crops Improvement, Food Legumes Improvement, Forage and Pasture Crop Improvement, and Training and Communications. They work in close collaboration with the national programs of the region.

Principal financing of ICARDA is arranged by the Consultative Group on International Agricultural Research (CGIAR). Support for ICARDA's core programs in research and training in 1981 was provided by the Arab Fund, Australia, Belgium, Canada, Denmark, Ford Foundation, Germany, IDA/IBRD, IDRC, IFAD, Italy, Mexico, Netherlands, Norway, OPEC, Spain, Sweden, UNDP, United Kingdom, and the United States. In addition, donors provided funds to the Center for specific research or training programs.

Headquarters for the Center and its principal research station is located at Tel Hadya, Syria, about 30 km south of Aleppo on the Damascus-Aleppo highway. Land for the site—948 hectares—was granted to ICARDA by the Government of the Syrian Arab Republic. There is another principal station (totalling 50 hectares) in Lebanon.



A portion of ICARDA's 948-hectare Experiment Station at Tel Hadya near Aleppo, Syria. The Center's headquarters is also located here.

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Covers: List of countries in the ICARDA region and names of international, regional, and national donors.

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Foreword

Over the first five years of its life, ICARDA has grown to become a recognized international research center in this region with remarkable achievements despite the varying degrees of inherent tensions. This publication briefly describes a few out of many of the Center's research achievements especially obtained in 1981.

During this year, increased attention was given to research that would help resource-poor farmers in the drier rainfed areas which are more economically disadvantaged and have benefited less from research in the past. The potential for improvement in those areas, as shown in some of the articles that follow, is as great or greater than in areas with better rainfall.

Our principal research work is conducted at ICARDA's headquarters and large experiment station at Tel Hadya, Syria, plus a sub-station at Lattakia, Syria. We conduct research also in Lebanon (Terbol and Kfardane) which constitute ICARDA's other principal station. But by no means do we limit our activities to these locations. Collaborative research exists at numerous locations at the national programs in the region, on many farmers' fields, at universities, and with other international centers.

Two of the older centers have posted scientists at ICARDA to assist with research in our joint fields of interest. ICRISAT (India) has two scientists with us who are members of our food legume team, and a CIMMYT (Mexico) scientist works on the improvement of bread wheat at Tel Hadya.

A major change in 1981 was the decision by our Board of Trustees in April to move the main ICARDA office from Lebanon (Beirut) to Syria. Now, most of the scientists and support personnel, as well as the administrators, are centered at Tel Hadya. This significant move from city to site has improved the efficiency of the Center and reduced expenses. Other financial economies in operation are being made by ICARDA because of mounting costs due to inflation and other factors.

Our offices and laboratory operations at Tel Hadya are in pre-fabricated or temporary buildings until more permanent structures can be built. We are making good progress in our efforts to raise money for this purpose. For example, the OPEC Fund for International Development has made a grant of 3,165,000 U.S. dollars to build the first permanent ICARDA laboratories, and we express our deep appreciation to Dr. Ibrahim Shehata, the Fund's Director General, and the Board of Directors for this generous donation. Similarly, the International Fund for Agricultural Development (IFAD) pledged a grant of 3,500,000 U.S. dollars for constructing the permanent training, communications, and computer buildings. We also express deep gratitude to President Abdelmuhsin M. Al-Sudeary and the governing body of IFAD for this generous support.

The research accomplishments reported here—and indeed all the work of ICARDA—would not have been possible without the support given by the Consultative Group for International Agricultural Research (CGIAR) from the many international, regional, and national donors. At the close of 1981, our donors have generously supported ICARDA over the past five years with some $50 million.

For additional information about ICARDA, please do not hesitate to write. A fuller account of our work will be available in ICARDA's 1981 Annual Report.

Mohamed A. Nour, Director General

Potential of Barley Yields in the Dry Areas

Research on barley by ICARDA in five different rainfall zones in Syria's Aleppo Province shows the potential for large productivity increases in this important dual-purpose crop. It is used principally as a major animal feed in the form of forage grain and serves as a source of agricultural stability in Middle East and North Africa areas characterized by low and variable rainfall. Before starting their experimental work, ICARDA's scientists regularly and frequently visited several villages in the province, each in a different agro-climatic zone, to get a better understanding of the different farming systems used by farmers.

In Stage I of the Farming Systems research—diagnosing problems and constraints—they collected data on how farmers grew barley and what problems they faced in improving yields.

Among their survey findings were:

- Barley increases in economic importance in low compared with high rainfall zones while family income decreases.
- The size of farms and barley plots is larger in drier areas and mechanization of barley production has been achieved to some degree. However, very few fields are planted with a combine drill and the seed rate appears to be rather high.
- Farmers make very little use of chemical inputs such as nitrogen, phosphorus, and herbicides, and they have not adopted new varieties of barley.
- Barley is grazed by animals as fodder and/or left to produce grain. In the drier villages, animal numbers per family increase and the family income derived from sheep production becomes more important compared with villages in higher rainfall zones. The livestock component, along with barley production, adds stability to the family income stream.

Those findings guided the development of priorities for Stage II, which involves research to find solutions to these problems or con-

Researchers interviewed farmers to diagnose barley production constraints.

The potential for increased barley grain yields in the drier areas is very large.

straints. Four sub-sites (each of 10 hectares) in different rainfall zones were used for this research, plus one at Tel Hayda—ICARDA's principal research station. Average annual rainfall at each site: Jinderess, 530 mm; Kafr Antoon, 450 mm; Tel Hadya, 350 mm; Brida, 250 mm and Khanasser, 200 mm. The trials were set up by multi-disciplinary teams involving scientists from disciplines such as agronomy, plant physiology, soil moisture and nutrients, livestock, agro-climatology, and economics.

Results of agronomic research, for example, during the past two growing seasons (1979/80 and 1980/81) have clearly defined the gap in various zones between potential barley yields and the yields farmers are now getting. The potential increase in grain production is very large in the drier areas—an incredible 254% in zone 4 (Table 1). In the higher rainfall zone 1, the potential increase is 30%. Part of the large gap in the drier areas may be due to economic conditions and cannot be closed.

However, at Brida, for example, an economic analysis has shown that 60 kg/ha of phosphate is profitable (Table 2). Revenue increased by 832 Syrian liras as a result of phosphate application—a benefit-cost ratio of two and a half liras for every lira of increased cost.

Rainfall zone	Yields farmers' fields (kg/ha)	Yields ICARDA trials (kg/ha)	Potential increase %
1	3150	4100	30
2	1211	3610	198
3	1106	2400	117
4	674	1710	254

Table 1. Barley yields on farmers' fields in Aleppo Province, Syria, compared with ICARDA trials (1980/81).

	No P_2O_5		60 kg/ha P_2O_5	
INCOME				
Grain yield	tons 1.47		tons 2.40	
Grain revenue	882	SL	1440	SL
Straw yield	tons 2.34		tons 5.34	
Straw revenue	468	SL	1068	SL
TOTAL REVENUE	1350	SL	2508	SL
EXPENSES				
Fertilizer				
P_2O_5 x price	—		130	SL
Labor for application	—		10	SL
Credit	—		13	SL
Harvesting				
Labor, equipment, transport, bags, etc.	—		173	SL
TOTAL CHANGE IN EXPENSE	0		326	SL
NET BENEFIT	1350	SL	2182	SL

SL = Syrian lira; Cost of P_2O_5 = 2.17 SL per kg; Price of barley grain = 0.70 SL per kg; Price of barley straw = 0.20 SL per kg; Labor for broadcasting = 10.00 SL per 120 kg of TSP fertilizer; both trials received 60 kg of N at a seed rate of 90 kg with Beecher barley.

Table 2. Partial budget for phosphate application on barley in ICARDA trials at Brida, Syria, with rainfall of 292 mm in 1980/81. (Figures per ha.)

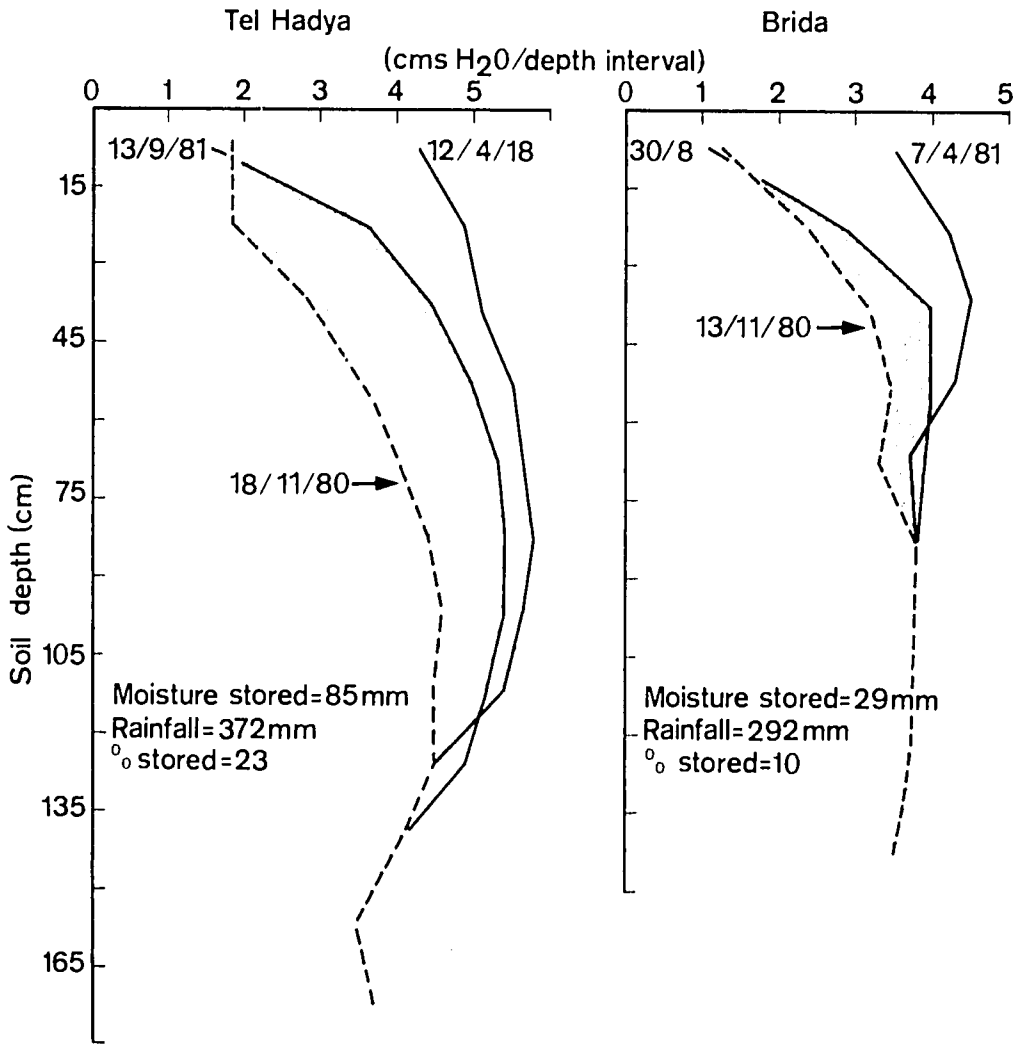
Measuring water-use efficiency for grain production in a barley field.

As part of the research work, scientists determined soil moisture recharge and discharge patterns and estimated crop water-use efficiencies. At Tel Hadya they found that a summer fallow left a substantial amount of residual available moisture (Figure 1). However, at Brida—a drier site—fallowing increased the soil moisture storage by a much smaller amount. (The contrasting patterns are shown in Figure 1.) At both of these sites, fertilizers increased the water-use efficiency for barley grain production.

These ICARDA trial results on the use of phosphate and Beecher barley in dry areas are being tested on farmers' fields (Stage III), and the control of these tests is shared by both the farmers and the scientists. The latter

know that experimental results must go through this important testing stage before farmers can be encouraged to adopt recommended changes. Their objective is to test new technologies in environments as close as possible to reality, and they have decided that phosphate and/or variety may be the easiest changes for the farmers to make.

Figure 1. Moisture loss under fallow during summer months at two sites in Aleppo Province, Syria (1981).



Yield Gains in Barley from Selection

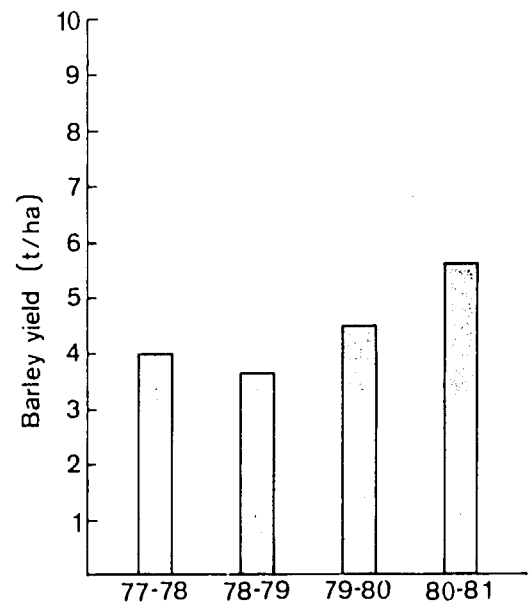
Barley covers about 10 million hectares in the Middle East, West Asia, and North Africa where its rapid growth and superior water-use efficiency make it a most dependable crop. Moreover, it is well suited for grazing in marginal areas where sheep are an important component of the farming system. ICARDA's work during the initial stages on the development of improved barley varieties for use in lower rainfall areas was aimed at increasing the genetic diversity through introductions, collections, and intercrossing of the introduced germplasm to cultivars widely adapted to the region.

Selection was done for types and traits associated with increased water-use efficiency, appropriate maturity duration, disease and lodging resistance, and high yields. The evolution in yield levels among the 10 highest entries in the Advanced Yield Trials at ICARDA's main experiment station at Tel Hadya, Syria, showed a steady increase over the 1978/79 to 1980/81 seasons (Figure 2).

The increase occurred in spite of strong variations in climatic conditions of the previous four growing seasons which, based on rainfall only, can be characterized as average, dry, rainy, and above average. Distribution was also different. Al-

Barley yield levels showed a steady increase in Advanced Yield Trials over the past two years.

Figure 2. Evolution in mean yield level among the 10 highest yielding barley entries in Advanced Yield Trials during four growing seasons at Tel Hadya, Syria, and Kfardan, Lebanon.



Dual-purpose barley varieties have been developed because many farmers use the crop for grazing early in the season as shown here and for grain later in the same season.

though the yield increases were due partly to environmental effects at Tel Hadya because the first two seasons had lower rainfall, a strong genetic improvement was clear.

Progress from selection is not confined to the testing sites of ICARDA but is quickly transmitted to many countries of West Asia and North Africa. There has been a substantial improvement in the yield levels of the lines selected by the national programs in the region and used as national checks in the Regional Barley Yield Trials (Table 3).

Because barley is used by many farmers for grazing and grain in the same season, they need genotypes suitable for both purposes. This crop is often the only green matter that can be grazed during the winter months. After grazing, it is left for grain. In drier years in some areas, the crop is grazed continuously with no grain harvested. ICARDA scientists are developing dual-purpose barley genotypes and assessing the effect of different intensities of grazing at various growth stages. The relationship between dry matter at grazing and grain yield produced with and without grazing was used to separate forage, grain, and dual-purpose types and to characterize potential dual-purpose genotypes for their grain and forage potential (Table 4).

Entry and mean yield (kg/ha)	Season			
	77/78	78/79	79/80	80/81
Highest yielding line	3356	3378	4155	4931
Poorest yielding line	2554	1951	3267	3337
National program check	3117	2719	3414	4521

Table 3. Mean yield of lines in the Regional Barley Yield Trials over a four-year period (1977/78-1980/81).

Class	Mean yield ungrazed (kg/ha)	Mean yield grazed (kg/ha)	Dry matter produced (kg/ha)
Grain types	5362	3100	4391
Dual-purpose types	5354	2141	6052
Forage types	3398	1526	6246

Table 4. Grain and forage potential of different types of barley (mean yield kg/ha).

Resistance to Major Diseases of Barley and Wheat

Upgrading the level of disease resistance and broadening the genetic base of available germplasm of barley and durum wheats is a major thrust of ICARDA's breeding program because this germplasm has not been as satisfactory as that for bread wheats. As a result, some countries in North Africa have shifted to growing bread wheats rather than durums. The development of genetic stocks (genotypes) of barley and wheat with different types of genes for resistance and/or gene combinations, along with germplasm characterized by resistance to different diseases, are the main methods used by ICARDA's scientists.

A few "hot spot" locations where one or more diseases are usually severe have been selected for screening genotypes developed at ICARDA. The sites and diseases covered by Key Location Disease Nurseries (KLDN) for wheat and barley are shown in Figures 3 and 4. In addition to screening ICARDA germplasm and identifying sources of resistance to different diseases, the KLDN also serve in a training role and foster relations with national program pathologists and breeders.

Crossing durum wheat. Several genetic stocks have been developed that combine disease resistance, grain quality, and adaptability to agroclimatic conditions of the region.

Breeding lines selected in these KLDN sites and international nurseries have been categorized for their resistance to specific diseases in the "hot spot" locations. Crosses with broad-based resistance to a disease or having multiple disease resistance have been identified. For example, several durum wheat crosses combine different types of resistance to yellow rust, leaf rust, and stem rust. Among them are: Cr'S'/F3Tun//AA'S'/3/Fg'S'/4/Jorro, ICD 80.807 for leaf rust; Plc'S'/Cr'S'//Mca'S'/3/D67-3/Cit71/4/Afn, ICD 80.839 for yellow rust; and Gediz//Roussia/BD1419, ICD 80.870 for stem rust.

Some of the crosses made to combine resistance to the three rusts in good agronomic types of durum wheats include: Mexi75//Cr'S'/USA.502229, ICD 80.180 and Roussia/BD1419//Cr'S'/USA.502229, ICD 80.227. The plant breeders added

Wheat Diseases								
Country	Yellow rust	Leaf rust	Stem rust	Powdery mildew	Septoria spp.	Septoria leaf blotch	Common bunt	Bacterial leaf streak
Morocco								
Tunisia								
Egypt								
Syria								
Lebanon								
Turkey								
Pakistan								
Yemen								
Ethiopia								
Kenya								

Figures 3 and 4. Key Location Disease Nursery (KLDN) sites and diseases of wheat (left) and diseases of barley (below).

Barley Diseases								
Country	Scald	Powdery mildew	Septoria spp.	Yellow rust	Leaf rust	Stem blight	Covered smut	Bacterial leaf streak
Morocco								
Tunisia								
Egypt								
Syria								
Lebanon								
Turkey								
Pakistan								
Yemen								
Ethiopia								
Kenya								

No disease pressure Disease present Disease severe

Barley lines have been developed with multiple resistance to scald (shown here), three types of rust, and powdery mildew.

Plant breeders select new high-yielding durum wheat lines tolerant to environmental stresses.

Waha—a new durum wheat line—is being multiplied for seed in Syria and Lebanon.

resistance to powdery mildew and bacterial leaf streak to rust resistance by making other crosses such as Ch67/Parana66-270, ICD 80.100.

Examples of barley lines developed with multiple resistance to the three rusts, scald, and powdery mildew are: Kervana/Masurka, ICB 77-369-5AP-OAP; Kervana/Ceres, ICB 77-371-IAP-OAP; and Gembloux 14/Beecher, ICB 77-338-2AP-OSH-OAP.

These and other new sources of resistance identified by ICARDA are made available to national programs in the region through the international nursery system.

Newly-Bred Durum Wheat Varieties

Improvement of durum wheat at ICARDA focuses on increasing yields under both low and high levels of rainfall and fertility, and, for this purpose, scientists use a bifurcated testing and selection process in the segregating population. (One set is planted under rainfed and low fertility conditions, another set of the same material on an irrigated and well fertilized field.) Yields of a majority of the breeding lines in the last stage of the selection procedure at ICARDA's research station at Tel Hadya are not only superior to the widely grown local variety, Haurani, but also to the improved check variety, Stork, under both rainfed and irrigated conditions.

The results suggest that the yield potential of the breeding material is increasing because the trials of 1980/81 identified more lines with very high yields than the trials of the year before. The bifurcated yield testing made it possible to select lines that gave large yields under both conditions.

The yield potential of the newly-bred durums is also tested on a regional scale. At all locations, the

highest yielding experimental durum line always yielded more than the national check, which is usually the best commercial variety of the country (Table 5).

Through these regional trials and observation nurseries, high-yielding durum lines can be identified with good adaptability to various environments. Two such lines—Waha and Sahl—are being considered for release in several countries in the region. Both are under seed multiplication in Syria and Lebanon. These two varieties gave superior yields not only under experimental but also under farmers' conditions (Figure 5).

ICARDA is also screening a large and diverse germplasm collection looking for genotypes that possess tolerance to different stresses prevalent in the region. Plant breeders are crossing such lines with higher yielding, agronomically superior genotypes that have been found to adapt well in the region. The early generation material coming from these crosses appears promising and may make varieties to provide increased yields and a more stable durum wheat production in the region.

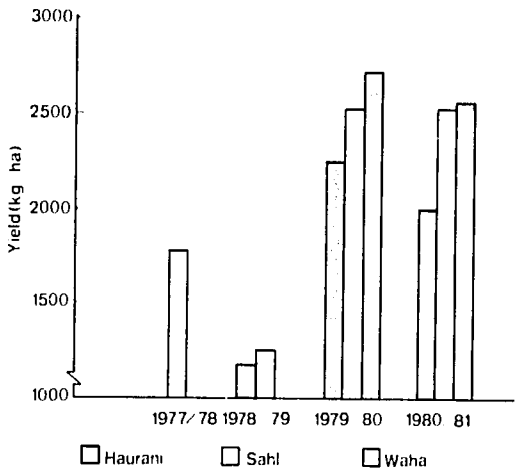


Figure 5. Yields of two new durum wheat varieties compared with the widely grown local cultivar Haurani in field verification trials under medium fertility and rainfall (250-350 mm) conditions in Syria.

Table 5. Relative yield of the highest yielding durum entry in the Regional Wheat Yield Trial (RWYT) and Rainfed Wheat Yield Trial (RfWYT) as a percentage of the local check variety in a few durum growing countries.

	Country	Greece	Cyprus	Lebanon	Syria		Jordan	Tunisia
	Location	Thessaloniki	Laxia	Tel-Amara	Tel Hadya Rainfed	Tel Hadya Irrigated	Rabba	Beja
RWYT	1977-78	103	173	125	—	158	—	—
	1978-79	145	163	122	130	193	163	166
	1979-80	92	120	—	114	110	111	109
	1980-81	109	—	129	113	171	—	112
RfWYT	1977-78	210	196	115	171	—	132	—
	1978-79	134	135	78	106	126	118	116
	1979-80	112	112	—	119	133	—	114
	1980-81	112	154	169	114	117	115	109

Performance of Wheat and Barley Varieties in Syria

Two major bread wheat varieties currently grown by farmers in Syria—Mexipak and Florence Aurore—have become highly susceptible to yellow rust and septoria leaf blotch. Similarly, existing durum wheat varieties—Haurani, Hamari, Senator Capelli, Jori 69, and Gezira 17—have become susceptible to certain diseases, as have the barley varieties Arabic Abied and Arabic Aswad (Table 6).

Realizing the need for new varieties with greater disease resistance, higher yields, and superior grain quality, a collaborative project between the Ministry of Agriculture and ICARDA was initiated in 1977. Based on field verification trials in more than 100 locations during the past four years (1977-1981), new lines/varieties have been identified which perform consistently better than the check varieties. They are scheduled for large-scale multiplication, further testing, and possible release to farmers in 1983.

The bread wheat variety S311-Norteno performed consistently better than the widely grown Mexipak (Table 7) and appears to be its best replacement in the higher yield regions. It has a 13.8% protein content and good "khobz" (Arabic bread) making quality.

Blodan was tested in the regional trials as HD2172—a line from the Indian national program. Based on its performance, it was included in the on-farm-verification trials in Syria. In the irrigated and high rainfall areas, its yield was much higher than the

Table 6. Reaction of new and check varieties of wheat and barley to diseases.

Variety	Character	Yellow rust	Leaf rust	Stem rust	Powdery mildew	Bact. blight	Bunt	Septoria	Scald*	Net* blotch	Covered smut
Bread wheat											
S311-Norteno		R	R	R	R	—	R	MR			
Blodan		R	R	R	R	—	S	R			
Mexipak (check)		VS	S	R	R	—	R	VS			
Durum wheat											
Sahl		R	R	R	R	—	R	—			
Waha		R	R	R	R	—	R	—			
Gezira-17 (check)		R	R	S	VS	VS	R	VS			
Jori-C69 (check)		S	S	S	—	—	R	S			
Haurani (check)		S	S	VS	—	—	R	S			
Barley											
Beecher		R	MS	R	R				R	R	R
Badia		R	R	R	R				R	R	—
Arabic Abied (check)		R	S	R	S				S	S	S

*Diseases of barley only.
—Not known.

R Resistant. S Susceptible.
MR Moderately resistant. VS Very susceptible.

Syrian farmers see the performance of new wheat and barley varieties at field trials conducted throughout the country in cooperation with the Ministry of Agriculture.

check variety, Mexipak—5242 kg/ha and 3123 kg/ha compared with 3896 kg/ha and 2629 kg/ha, respectively. Because of its acceptable level of disease resistance and high yield potential, it is being multiplied for possible release to farmers.

Yield records for Sahl—a spring type Algerian durum wheat selection—showed that it was superior to all

A small baker tries out a new wheat variety for its Arabic bread-making quality.

Wheats developed at ICARDA are tested for nutritional quality and various consumer uses.

Table 7. Characteristics and average yields of new and check varieties of bread wheat, durum wheat, and barley.

Variety	Character	Plant Height (cm)	Maturity	Protein (%)	1000 kernel weight (gm)	Yield (kg ha)			
						Irrigated	Zone A	Zone B	Zone C
Bread wheat									
S311-Norteno		90	M*	13.8	37	4289	2874	2583	—
Blodan		75	M	11.5	46	5242	3132	—	—
Mexipak (check)		80	M	11.29	38	3896	2629	2450	—
Durum wheat									
Sahl		100	ME	12.3	44.53	5304	3391	2564	—
Waha		90	ME	15.1	48.53	4992	3119	2632	—
Gezira-17 (check)		95	L	10	47.18	4650	3139	—	—
Jori-C 69 (check)		90	ME	11.8	49.3	—	2371	—	—
Haurani (check)		115	ME	12.5	42.5	—	—	2123	—
Barley									
Beecher		120	M	10.96	42.86	—	—	3072	—
Badia		120	M	11.2	45.77	—	—	—	2336
Arabic Abid (check)		85	M	12.24	42.98	—	—	3034	2288

*M Medium maturity; L Late; ME Medium early.

three checks under low and high rainfall conditions (Table 7). Furthermore it is resistant to major diseases and has medium to early maturity with long heads and a large grain of amber color (Table 6). Waha—another spring type variety with a protein content of 15.1%—is medium early in maturity and has a high yield potential under favorable conditions.

Barley in Syria is primarily grown in two zones with an annual rainfall below 250 mm and between 250-350 mm. The new identified varieties/lines—Beecher and Badia—are more suitable than the check varieties, not only in grain yielding ability but in higher dry matter which is extremely important to farmers in these zones (Table 7).

Resistance of varieties to diseases often breaks down after a few years, and they need to be replaced. Even the varieties described here may become susceptible later, which makes it necessary to continuously test newer lines with different resistance genes and adaptability.

Badia—a new barley—performed well in the low rainfall areas.

Nitrogen Use Efficiency in Cereal Genotypes

Cereal varieties that yield well under low fertility conditions can be especially useful in areas where fertilizers are currently unavailable, too costly, or involve a high degree of risk. The cost factor for artificial fertilizers will become more important as finite natural resources of phosphate are depleted and if prices of fossil fuels for nitrogen (N) fertilizer manufacture increase in the future.

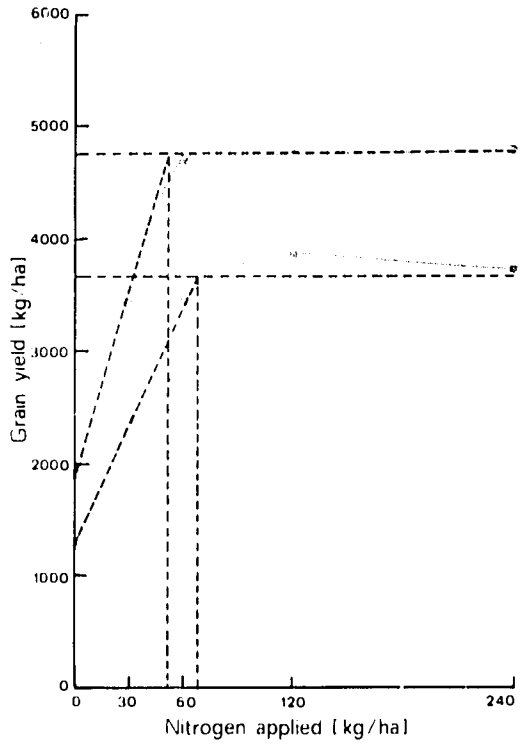
Farmers faced with low fertility conditions (as well as those who have high fertility soils) can benefit from an improvement in the yield of grain produced per unit of fertilizer applied or taken up by the crop. If this increased efficiency of fertilizer use is accompanied by better yields, current shortages of grains in many areas could be eased.

Data from 1980/81 experiments at ICARDA indicate that yield increases from efficient varieties could be as high as 25% under low soil N conditions and that cost reductions of up to 40% for N fertilizer could be realized under high fertility conditions.

During the past two years, ICARDA scientists have been conducting research to characterize the nitrogen responses of a small number of cereal genotypes. As a first step, they determined if significant differences existed among the genotypes currently used in their breeding programs and a few of the varieties

Scientists have found that cereal varieties differ in nitrogen uptake from the soil and in utilization within the plant.

commonly planted in the region. Examples of the differences found in barley and durum wheat varieties in the 1980/81 season are shown in Figures 6 and 7. These results were obtained under relatively low soil N



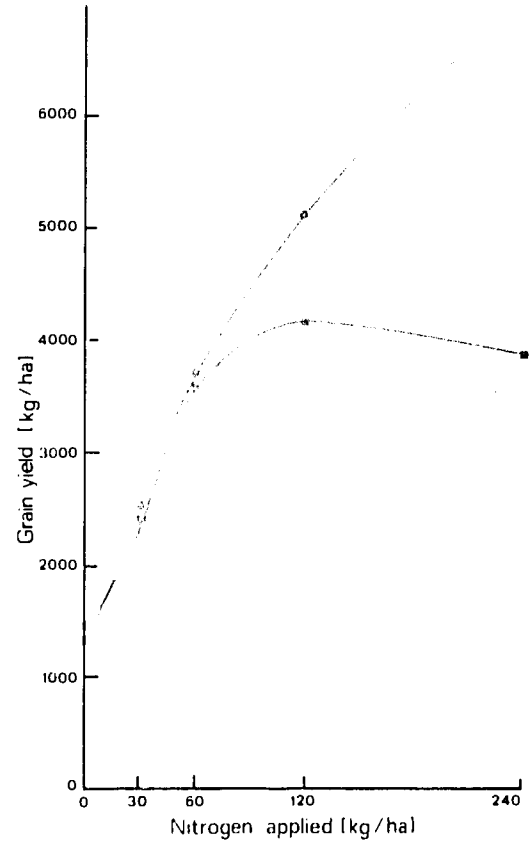


Figure 6 (left). Contrasting nitrogen response of two barley varieties showing differences in maximum response level and rate of yield increase per unit of applied nitrogen.
Figure 7 (right). Contrasting nitrogen responses of two durum wheat varieties showing differences in yield response at higher levels of applied N (1980/81).

Variety	Maximum N response level (kg/ha)	Maximum grain yield (kg/ha)	Grain yield/N applied (kg/kg)
Martin	50	4800	58
Beecher	60	4200	47
R.T.Ramage 11-13	70	4100	45
C-63	90	4800	33
Roho	70	3600	32
Esp./1808-4L	90	4500	31

340 mm rainfall + about 80 mm irrigation; method of estimating maximum yield (A) and N response level (B) is shown in Figure 6.

Table 8. Maximum N response level, maximum grain, and net "economic" efficiency of several barley varieties as estimated from their yield response to applied N (1980/81 season).*

conditions following removal of an unfertilized and irrigated maize crop in each case. (All other variables were kept non-limiting insofar as possible under field conditions, and soil tests were taken before each experiment.)

The differences in N response implied that differences in economic optimum fertilizer rates between varieties would also be found, but the research results with several barley varieties showed that N-responsiveness and net "economic" efficiency (yield per unit of N applied) were not necessarily related to yielding ability (Table 8). (Net efficiency is the additional yield per unit of additional N taken up or applied.)

A group of 45 genotypes scheduled to be used in the durum wheat breeding program at ICARDA were also tested at a wide range of nitrogen rates during the 1980/81 season. Some of the contrasting responses are shown in Table 9. These results indicate that varieties which have a high yield when no N fertilizer is applied have a low efficiency of conversion of applied fertilizer to grain and a higher N requirement for maximum yield, and vice versa. The observed differences in N responses could be due to differences in efficiency of uptake of applied nutrients (N uptake/N applied) or to differences in efficiency of utilization of N within the plant (grain produced/N uptake).

Variety	Yield with zero N applied (kg/ha)	Maximum yield (kg/ha)	N rate at max. yield (kg/ha)	Net grain yield/N applied (kg/kg)
Cando	4500	7250	85	32
Bittern 'S'	4000	8500	180	25
Faisca	4500	7250	225	12
D-Dwarf S15-Cr'S'	2500	7250	65	73
Oviachic/Amarelejo	3500	7750	70	61
Timgad 73	3000	6250	55	59

Table 9. Selected yield response characteristics of durum wheat to N fertilizer at Tel Hadya, Syria (1980/81).

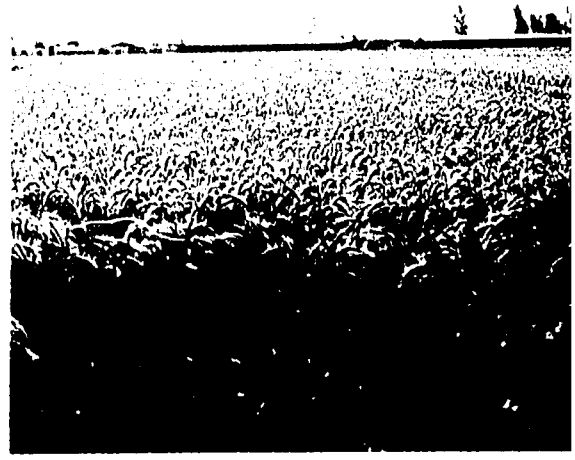
Crossing triticale. It can be grown in areas where other cereals do poorly because of environmental stresses.

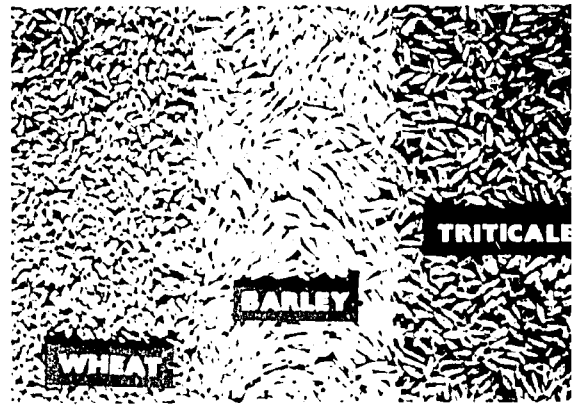
High-Yielding Triticale for Harsh Environments

Triticale—a man-made cereal created by crossing wheat *(Triticum)* and rye *(Secale)*—has the potential to help reduce the large imports of cereal grains by countries in the Middle East and North Africa which now total about 15 million tons per year. This crop can be grown by farmers with less risk in areas where other cereals do poorly because of environmental stresses such as drought, frost, and adverse soil conditions. In general, it is more tolerant than wheat to aluminum toxicity and alkaline soils in which iron and zinc are not available to the plants.

ICARDA's plant breeders are working with national scientists in Syria, Morocco, Jordan, Lebanon, Tunisia, Cyprus, and Pakistan to develop triticale cultivars that can cope with the region's erratic and often harsh environments. They have identified several cultivars—including IC-DZS and IC-CPPB—which proved to have superior performance in 1981 in Syria, Lebanon, and Jordan. These disease resistant cultivars out-performed the best high-yielding wheat varieties (Figure 8). The yield increase of the triticale cultivars over Sahl (a durum wheat variety) ranged from 18% to 38% and 9% to 27% over S311-Norteno (a bread wheat variety).

In addition to yield improvement, progress has also been made to achieve better milling and baking qualities, including a whiter color for triticale grain. Most older varieties have a grey color which is not desirable in the ICARDA region for bread making. The newly developed triticale cultivars have a hectoliter weight close to that of wheat—a range from 76 to 80 compared with 80 for durum and bread wheats. (Hectoliter weight is an index of the yield of flour that can be obtained from the grain.) Another value of the new triticale cultivars is a high protein content—14.5% to 15% compared with wheat's 11%-12%.





A large test field of triticale on a poultry farm in Morocco (top photo). The cereals program is improving grain characteristics such as plumpness, hardness, and color (lower photo) for better acceptance by farmers and consumers.

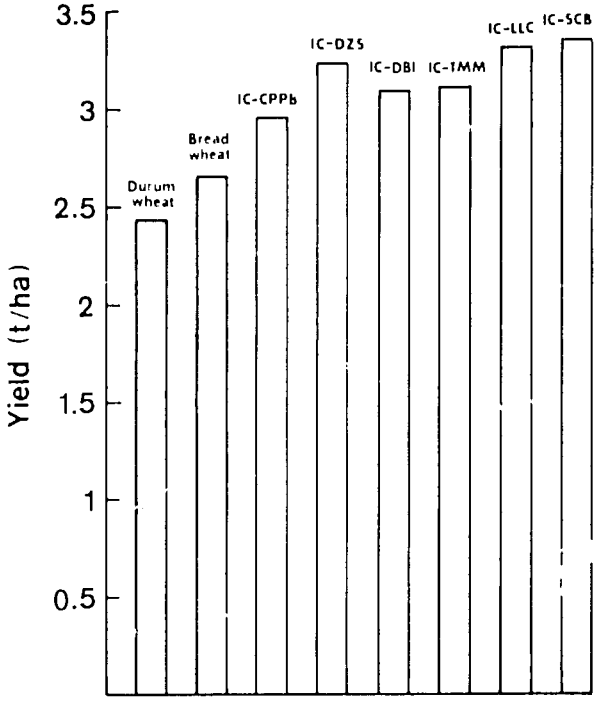


Figure 8. Triticale yields under rainfed conditions at Tel Hadya, Syria, compared with durum and bread wheats (1981).

Cereals for Diverse Climatic Conditions in High Elevation Areas

Vast mountainous and sub-mountainous areas with an elevation of 1000-3000 meters and severe winters and hot summers spread across southwest Asia from Turkey, Iraq, Iran, Afghanistan, and Pakistan and extend toward northern parts of India and Nepal. In addition, the North African countries of Tunisia, Algeria, and Morocco have extensive areas with similar agro-climatic conditions. In these areas, with an estimated population of 109 million, agriculture has been traditionally neglected, except in Turkey. In general, they have received little input of research and agricultural technology.

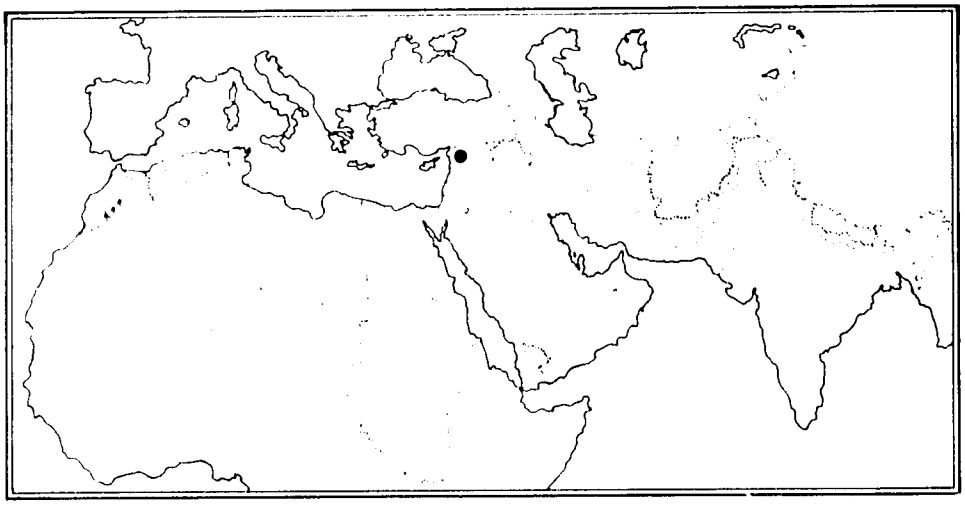
Furthermore, the technologies developed for lowland agriculture in various ecological zones of the region are not applicable to the dryland farming communities of medium to high elevation areas.

Wheat yields are low, averaging about 650 kg/ha. Lack of water, weed control, suitable varieties, and production inputs (such as fertilizer), as well as plant diseases and excessive heat and cold, all contribute to low yields. These high plateaus have low rainfall, cold winter temperatures, a rapid rise in temperature during the spring, and shallow soils. But the evidence in Turkey shows that yields can be increased substantially by developing suitable varieties coupled with improved production practices.

A modest cereal research program for these areas was initiated with a multi-location testing approach to find suitable genotypes for variable climatic conditions. Part of the research on all four winter cereals—breadwheat, durum, barley, and triticale—is being conducted at ICARDA's main Experiment Station at Tel Hadya, Syria, where the low temperature and climatic conditions facilitate the crossing of winter x winter and spring x winter types originating from the high elevations of several different countries.

ICARDA is involved in improving wheat and barley varieties and cultural practices for increasing production in the mountainous regions.

Out of USDA's large world durum collection, 1966 lines and/or varieties with acceptable winter hardiness and disease tolerance were selected for further screening at Ankara, Turkey,



High elevation areas ▾ National/ICARDA testing sites in Morocco ● Testing site in Syria
Testing sites in Pakistan

Figure 9. High elevation areas and cereal testing sites in West Asia and North Africa.

and some of these were employed in the crossing program to generate better germplasm. Similarly, 186 lines of breadwheat and 32 durums were selected out of 2000 lines/varieties from the high elevation of the region after testing them at five locations in Turkey.

During the 1980/81 season, only 15 lines were retained out of the 186 lines selected earlier. A strong selection pressure was exercised to cut the increasing number of genotypes to be repeated next year. Out of another set of 3300 durum and breadwheat lines, only 130 have been retained for further testing and evaluation.

To further enrich and widen the genetic base, 100 lines/varieties of barley, 28 of breadwheat, and 1170 of durum were obtained from the high elevation areas of the region and other countries of the world growing winter habit cereals. These were evaluated and used in cereal improvement work during 1980/81.

For evaluation and testing under diverse climatic conditions, the research material from F_1 to yield trials of breadwheat, durums, barley, and triticales were planted at three high elevation sites in Pakistan—Quetta (1675 meters), Pishin (1700 meters), and KanMehterzai (2500 meters). Also, the material was planted in Morocco in the high Atlas mountains, (mainly at Annaceur and Oulmes) and a small amount at Sarghaya in Syria (Figure 9). A set of all the material has been planted at Tel Hadya for seed increase purposes and for developing the basic material through several types of crosses.

In cooperation with national program scientists in Pakistan, a number of agronomic trials are under way to develop a package of production technology for different high elevation situations. They involve varieties (genotypes), method and time of sowing, seed rate, fertilizer use, weed control, irrigation, grazing, and grain production.

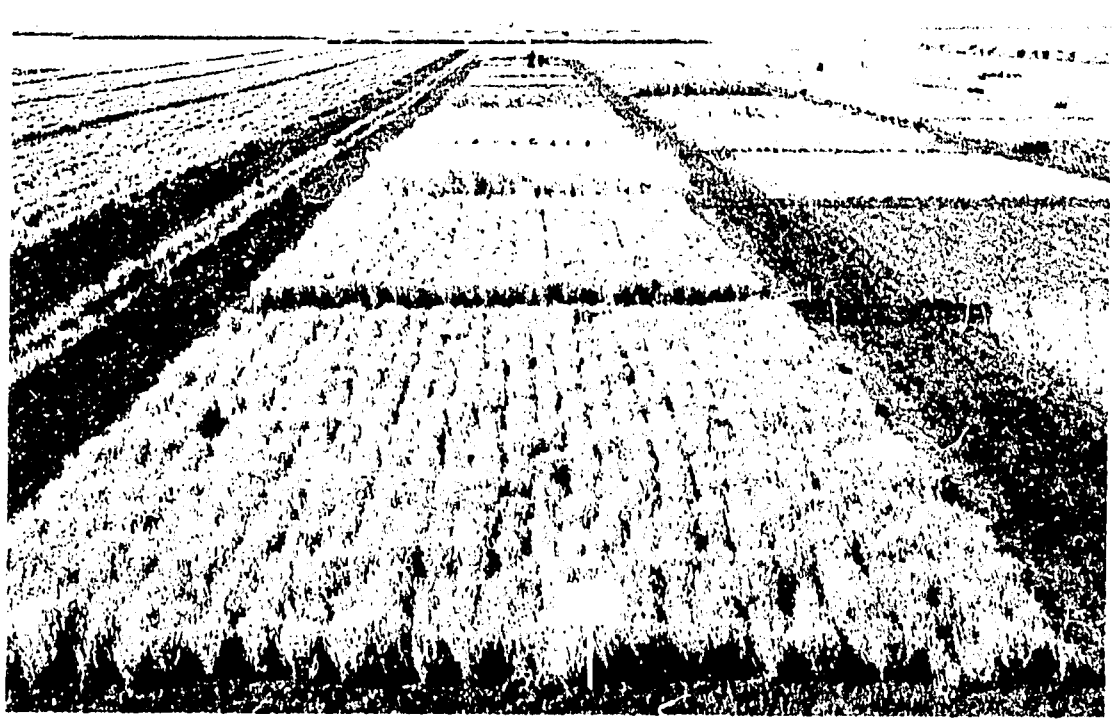
Role of Legumes in Rainfed Crop Rotations

Besides being a source of high quality protein, food legumes are also valued for their role in maintaining soil fertility. Because they are able to fix atmospheric nitrogen symbiotically by virtue of their association with bacteria of the genus *Rhizobia*, legumes not only meet most of their needs but may even enrich the soil by leaving nitrogen-rich crop residues. Although information exists on this kind of effect for several legumes in environments with an assured moisture supply, little is known about their effect on subsequent cereals in rainfed farming systems in the dry areas of North Africa and West Asia.

In parts of West Asia, there exists a belief that wheat following a lentil crop yields less than that following fallow. Therefore, a three-course rotation—fallow/wheat/lentil—is practiced in several areas where annual precipitation is less than 350 mm.

Experiments were started in the 1977/78 season at ICARDA's site in Tel Hadya to evaluate the effect of a preceding lentil crop on the yield of a subsequent crop of wheat in a two-course rotation. The results in the 1978/79 season showed that if the

Rotational trials showed that a well managed crop of lentils leave a beneficial residual effect for subsequent cereal crops.



preceding lentil crop was adequately fertilized with phosphate fertilizer on the phosphate-poor soil of Tel Hadya, the yield of subsequent wheat was as large as that following fallow and significantly higher than that following wheat (Table 10). The seasonal precipitation was 336 mm in 1977 78 and 246 mm in 1978/79.

To confirm those results, another experiment was conducted during 1979/80 in which the effect of fallow and fertilized crops of wheat, lentil for grain, lentil for hay, and faba beans for grain was evaluated on the productivity of wheat in the subsequent season (1980/81) with no nitrogen application and 60 kg N per ha. The moisture supply for this two-course rotation was more favorable than for the previous one. (Annual precipitation was 423 mm in 1979/80 and 345 mm in 1980/81). The results, however, were again similar to the first experiment (Figure 10). Wheat following the lentil crop or faba beans yielded as well as that following fallow and significantly outyielded the wheat following wheat.

Since the relative response of the residual wheat crop to application of fertilizer nitrogen in 1980/81 was smaller in a legume/wheat sequence than that in wheat/wheat and fallow/wheat sequences, it is clear that a part of this beneficial residual effect of legumes was due to an improved nitrogen supply for the residual crop of wheat. Well managed crops of legumes, such as lentils and faba beans, leave a definite beneficial residual effect for subsequent cereal crops in a rainfed two-course rotation and therefore can replace fallow if rainfall is not much below 300 mm.

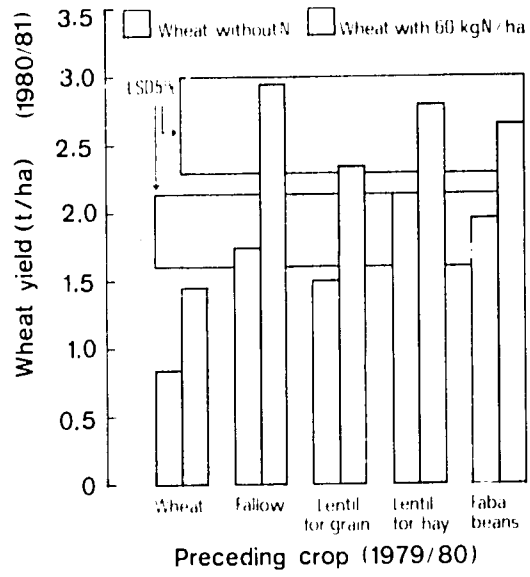


Figure 10. Effect of the preceding season's cropping treatment on the yield of wheat at two rates of nitrogen (N) application in 1980/81.

Cropping treatment in 1977/78	Wheat yield in 1978/79* (kg/ha)
Lentil with no fertilizer	528
Lentil with 50 kg P_2O_5 per ha	832
Cultivated fallow	847
Wheat with 60 kg N + 60 kg P_2O_5 per ha	487
L.S.D. (5%)	215

Wheat in 1978 79 did not receive fertilizer.

Table 10. Effect of cropping treatments in 1977/78 on the yield of wheat in 1978/79 in a two-course rotation under rainfed conditions at Tel Hadya, Syria.

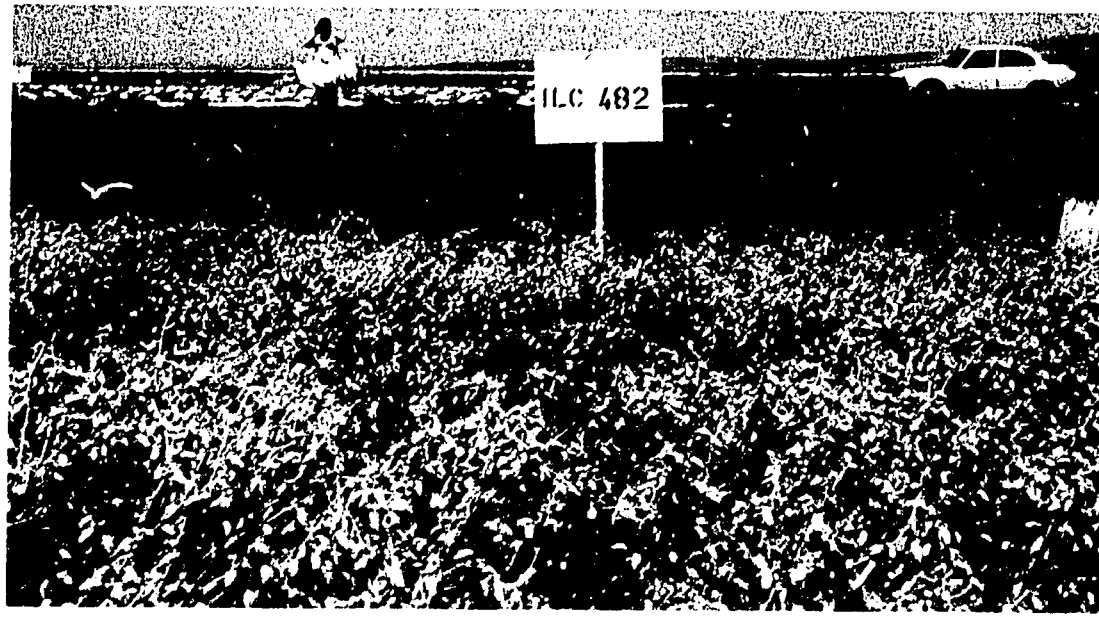
Benefits of Winter Planting of Chickpeas

Most of the chickpeas *(Cier arietinum L.)* are planted during the spring in the Mediterranean region on residual moisture which usually results in low yields, but experiment station and on-farm trials show that yields can be increased substantially if the crop is sown in the winter with cultivars resistant to Ascochyta blight and tolerant of cold. The increased yields are due to better water use, a longer growing period, better inoculation, and fewer pests.

Furthermore, winter sowing should allow a chickpea crop to be grown in drier areas than has been possible in the past. It requires, however, an additional weeding and an Ascochyta blight-resistant and cold-tolerant cultivar. Otherwise, the disease or frost can wipe out the crop. Selected winter-sown chickpea lines have survived sub-zero temperatures recorded in several countries in the region, indicating that this species has adequate cold tolerance.

In detailed crop physiological and soil moisture studies by ICARDA scientists, ILC 482—a high yielding and Ascochyta blight-resistant chickpea cultivar—was planted under optimal agronomic practices in mid-November and early March at three locations in Northern Syria. Each location has different long-term

The Ascochyta blight resistant chickpea variety—ILC 482—when sown in the winter (foreground) produced more than twice the local variety planted in the spring (background).



averages of seasonal precipitation—Jinderess (476 mm), Tel Hadya (335 mm) and Brida (278 mm).

Winter-sown crops achieved higher water-use efficiencies than spring-sown crops at all three sites. In addition, water-use efficiency decreased from the wettest to the driest site as a result of reduced canopy development at the drier sites. This permitted greater moisture loss by evaporation.

The depth of soil moisture extraction also differed between the sites. Only soil depth intervals which become recharged by the current season's rainfall will contain moisture available for uptake by the chickpea crop. At the two driest sites—Tel Hadya and Brida—the recharge front did not extend beyond 90 and 75 cm, respectively, greatly restricting the rooting depth compared with that at Jinderess. Where root development was not restricted, the winter-sown crop developed a deeper rooting system than the spring-sown crop.

A deferred date of maturity is another important factor contributing to the increased moisture stress experienced by spring-sown crops compared with winter-sown. It is approximately 15 days later. This exposes the spring-sown crops to more extreme levels of evaporative demand and heat stress during their

Country	1979/80		1980/81	
	Location mean	Best entry	Location mean	Best entry
Lebanon—Terbol	2959	3672	1864	2654
—A.U.B.	—	—	807	1226
Syria—Tel Hadya	873	1894	2137	3118
—Gelline	1605	2163	—	—
—Jinderess	—	—	2913	4011
—Lattakia	2040	2964	2826	4257
Jordan—Univ.	1328	1440	1731	2154
Iraq—Arbil	—	—	752	1012
Turkey—Diyarbakir	3030	3662	—	—
Greece—Larissa	2139	2646	3359	4070
Algeria—Khroub	2928	4286	—	—
Morocco—Douyet	3132	3917	—	—

Table 11. Location mean of winter sown chickpea entries and yield of the best entry (kg/ha) in the Chickpea International Yield Trial (Winter 1979/80 and 1980/81).

Early-maturity chickpeas (right) can make the difference between crop success and failure in marginal areas.

reproductive phase. Heat and evaporation factors increase very rapidly in the April-June period under Northern Syrian conditions. Thus, an advantage of earlier maturity by as much as two weeks can make the difference between crop success and failure in more marginal productive areas such as Brida, where spring-sown chickpeas are not generally grown.

In the on-farm trials conducted during the 1979/80 and 1980/81 seasons by the Syrian Ministry of Agricultur and Agrarian Reform and ICARDA/ICRISAT, the variety ILC 482 —when sown during the winter— produced more than twice the local variety sown during the spring. On-farm trials are being repeated for the third season and ILC 482 will be considered for release by the Syrian Government by the end of the 1981/82 season. Also, on-farm trials of these Ascochyta blight-resistant chickpeas are underway in Lebanon, Jordan, Morocco, and Tunisia in cooperation with national program scientists.

The Chickpea International Yield Trial (Winter) was initiated during 1979/80, and the results for that season and 1980/81 are summarized in Table 11. The location means in Lebanon, Turkey, Algeria, and Morocco were approximately 3 t/ha, but in several areas the highest yielding entry frequently produced more than 4 t/ha. In Syria, ILC 482 gave the overall highest yield during both growing seasons (Table 12).

Year	Winter		Spring	
	ILC 482	Syrian Local	ILC	Syrian Local
1979/80	1839*	988	—	973
1980/81	1724**	479	983	798
Mean	1782	734	983	886

*Average of 18 locations.
**Average of 21 locations.

Table 12. Mean performance (kg/ha) of the chickpea cultivar ILC 482 and a Syrian local land race during winter and spring on farmers' fields and at experiment stations in Syria.

Chickpea Lines Resistant to Ascochyta Blight

Because blight caused by *Ascochyta rabiei* is the principal disease of chickpeas in the Mediterranean region and parts of the Indian sub-continent and has become an even greater danger with the introduction of winter sowing of the crop, ICARDA/ICRISAT scientists have intensified their search for genetic control. As a result, even better resistant lines than the recently introduced ILC 482 are on the way. Other control methods such as fungicide sprays have proven ineffective and uneconomic.

A reliable technique for a large-scale field screening of germplasm and segregating material was not available in the past, but a simple and effective screening technique has now been developed. It involves sowing of spreader rows at frequent intervals, uniform spread of disease plant debris collected from the previous season, creating high humidity with irrigation as necessary, and, if needed, supplementing the inoculum with a spore suspension spray prepared from the infected plants. This method has been used at ICARDA and is being followed by several national programs.

A total of 3367 kabuli and 6005 desi germplasm lines have been screened, and from them 18 kabuli and 131 desi lines have been identified as resistant (Table 13). Kabuli lines found resistant to Ascochyta blight originated in the U.S.S.R., Turkey, and Afghanistan and desis in Iran, India, Turkey, Pakistan, and the U.S.S.R.

Resistant chickpea lines identified

Table 13. Summary of the screening of chickpea kabuli and desi germplasm lines for resistance to Ascochyta blight at ICARDA's Experiment Station at Tel Hadya, Syria.

Disease rating	Kabuli		Desi	
	No. of entries	% of total entries	No. of entries	% of total entries
1	0	0.00	0	0.00
2	0	0.00	13	0.22
3	18	0.63	118	1.97
4	4	0.12	524	8.72
5	43	1.28	253	4.21
6	17	0.53	76	1.27
7	859	25.50	246	4.10
8	14	0.42	20	0.33
9	2412	71.63	4755	79.18
Total	3367	100.00	6005	100.00

1 = Highly resistant; 5 = Tolerant; 9 = Highly susceptible.

Close-up of Ascochyta blight damage to chickpea plant and pods.

A new line of chickpea—ILC 72—has proven to be Ascochyta blight resistant in six countries in the ICARDA region. The susceptible line on the left has been wiped out by the disease.

at ICARDA have been shared with other countries since 1978/79 through a Chickpea International Ascochyta Blight Nursery distribution. Results from Lebanon, Syria, Jordan, Turkey, Algeria, and Pakistan indicated that a number of lines were resistant in each of these countries. Six of the lines—ILC 72, ILC 191, ILC 196, ILC 2380, ILC 2956, and ILC 3279—were resistant across the locations and the years. This indicates that they possess stable resistance. These sources of resistance have been useful in breeding programs in many countries. Multi-locational testing has also provided information on the variability of the pathogen.

During the 1980/81 season, ICARDA/ICRISAT scientists evaluated 2467 F_3 to F_6 progenies and 115 F_2 populations. More than 7000 individual plants from F_2-F_5 generations resistant to Ascochyta blight and judged agronomically promising were selected during the 1980/81 season and advanced in the off-season nursery at Terbol, Lebanon. The advanced breeding lines were evaluated in the initial yield trial, and the performances of the 10 best ones are shown in Table 14. Many lines produced over 3 t/ha and were resistant to Ascochyta blight.

Table 14. Performance of the best 10 bulked chickpea progenies at Tel Hadya, Syria, during the 1980/81 winter season.

Pedigree	Yield (kg/ha)	% increase over ILC 482	Disease reaction*	
			Veg.	Pod
ILC 51xILC 200	3600	93	3	2
ILC 618xILC 194	3293	66	3	3
ILC 523xILC 183	3333	86	3	2
ILC 1929xILC 200	3328	7	3	3
ILC 1929xILC 200	4848	30	5	5
ILC 72xILC 897	3471	100	3	3
ILC 72xILC 897	3977	17	3	3
ILC 72xILC 897	3502	38	3	3
ILC 201xILC 571	3302	31	3	3
ILC 202xILC 893	3373	23	3	3
Average	3603	40		

Disease reaction: 1 free; 9 killed.

Resistance to Major Faba Bean Diseases

Although fewer faba beans *(Vicia faba)* are produced throughout the world than dry peas and chickpeas, they have the highest production of the pulses in the ICARDA region, accounting for 10% to 15% of the total global output. Scientists in the national programs in this region report that chocolate spot, Ascochyta blight, and rust are the three most destructive faba bean diseases causing serious production losses in many areas.

Their control by chemical means—although possible—is expensive and often out of reach of poor farmers. Therefore, ICARDA has given a high priority to the development of genotypes tolerant or resistant to these diseases. The screening and identification of resistant lines and/or populations has been undertaken at ICARDA's sub-site at Lattakia, Syria on the Mediterranean coast (Table 15). Environmental conditions are ideal there for natural disease development.

Materials tested for chocolate spot resistance included bean pure line (BPL) world accessions, F_2 segregating populations, and advanced lines. Of 526 BPL accessions, 14 were rated resistant and 148 moderately resistant. Approximately 50 F_2 individual disease-free plants were se-

Crosses among resistant and resistant x susceptible faba beans are made to develop genetic stocks and cultivars with broad-spectrum resistance to major diseases.

Table 15. Faba bean lines or populations possessing resistance to three major diseases.

Diseases	Causal agent	Resistant lines and their country of origin
Chocolate spot	*Botrytis fabae*	BPL 112 (U.K.), 438 (Lebanon), 938* (Columbia)
Ascochyta blight	*Ascochyta fabae*	ILB 37 (Iraq), Sel.80 Latk. for 14435-3 (Lebanon), 14422-2 (Lebanon), 14986-3 (Greece), 14998-1 (U.K.).
Rust	*Uromgces fabae*	Sel.80 Latk. for 15563-1, -2, -3, -4** (All trace back to Manitoba, Canada.)

*Resistant in Egypt, Syria, and U.K.
**Also resistant to Ascochyta blight.

Faba beans on the left are resistant to Ascochyta blight, those on the right susceptible.

lected and will be evaluated as F_3 progeny rows in 1982. In replicated trials, BPL 112 (U.K.), BPL 438 (Lebanon), and BPL 938 (Columbia) were rated consistently resistant. BPL 938 —originally identified as being resistant by the national program in Egypt —has also shown a good level of resistance in the United Kingdom.

Out of more than 500 BPL accessions, 49 showed good promise and 8 of them were rated highly resistant to Ascochyta blight. Over 1000 F_2 individual resistant and moderately resistant plants have been selected for progeny row evaluation in 1982. The lines ILB 37 (Iraq), Sel.80 Latk. 14435-3 (Lebanon), 14422-2 (Lebanon), 14986-3 (Greece), and 14998-1 (U.K.), showed a high level of resistance across all replications.

The lines Sel.80 Ltak. 15563-1, -2, -3, -4—originally identified as being resistant to rust in Manitoba, Canada —were also found to be resistant in Syria.

Seeds of all promising resistant lines that have been identified for the three diseases are being increased to allow more multi-location tests. Studies on the biology and epidemiology of the diseases are also being undertaken. This will help in formulating the correct strategy for breeding for disease resistance. Crosses among resistant and resistant x susceptible genotypes are being made to develop genetic stocks and cultivars with broad-spectrum stable resistance for each disease. They can then be used by the national programs to counter their disease problems.

A farmer and a national Egyptian researcher inspect a faba bean on-farm trial in which the farmer is closely involved.

An Economic Analysis of Faba Bean On-Farm Trials in Sudan and Egypt

The methodology of on-farm trial research, with full farmer participation, was new to many national scientists in Sudan and Egypt when a unique and specially designed ICARDA/IFAD Nile Valley Project was started in 1979 with the objective of helping to unravel faba bean production constraints and increase the yields of this staple food. But they now speak with confidence about the practicality and costs of recommended technology compared with current farming practices.

This project is unique because it places the responsibility for leadership, coordination, and actual execution of the work with the national scientists, and it involves the farmer himself in the research process. ICARDA plays a catalytic and research back-up role.

Accompanying the agronomic on-farm trials from the beginning were economic surveys. In Sudan, for example, an analysis of the 1980/81 data evaluated eight different treatment combinations in the trials at Zeidab and Aliab (Table 16). The yield response of each is shown in Figure

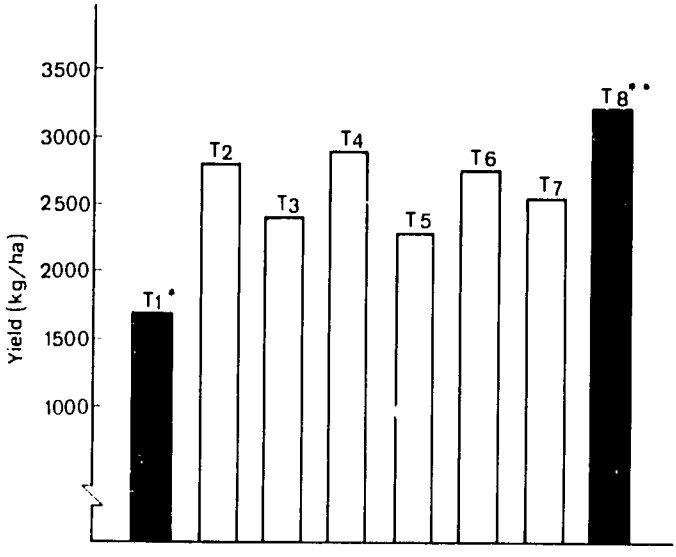
11. The economists also measured the benefits gained and costs incurred from each combination tested in the trials. Then the best alternative treatment in terms of highest income, greatest net return, and least operating capital was determined. The highest benefit cost ratio was treatment No. 5 for the farmer with scarce operating capital, but treatment No. 8 was the best choice for the farmer with sufficient operating capital because of its higher net benefit (Table 17).

Differences in the economic rankings of treatment packages were also noted in the analysis of the 1980/81 Egyptian on-farm trials. For example, trials in Kafr El Sheikh Province in the Nile delta and Minya Province in

Table 16. Treatment combinations for faba bean on-farm trials in Sudan (1980/81).

Treatment	Planting date	Variety	Irrigation	Weed control	Planting method	Pest control
1	F	F	F	F	F	F
2	R	R	R	R	R	F
3	R	R	R	R	F	F
4	R	R	R	F	R	F
5	R	R	F	R	R	F
6	R	F	R	R	R	F
7	F	R	R	R	R	F
8	R	R	R	R	R	R

R = Recommended practice; F = Farmers' practice.



*All tested factors at farmers' level
**All tested factors at recommended level

Figure 11. Yield response of faba beans to eight different treatment combinations in Sudan (1980/81).

Middle Egypt showed significant increases in average net benefits due to the use of rhizobial inoculation. In contrast, however, trial results in two other areas gave indications of lower net benefits with inoculation than without.

The different economic rankings of treatment packages from sample area to sample area affirm the wisdom of testing agronomic recommendations at several sites throughout the faba bean growing regions. It also casts some doubt on the possibility of aiming for technological packages that will apply in different environments. In the future, demonstration trials will be based on findings of the on-farm trials and analysis of costs and benefits from the farmers' viewpoint.

Economists interview a Sudanese farmer to gather data for an economic analysis of faba bean production practices.

Table 17. Economic analysis of eight different treatments in faba bean on-farm trials at two schemes in Sudan (1980/81).

		T1	T2	T3	T4	T5	T6	T7	T8
Yield	(kg ha)	1750	2755	2403	2867	2262	2685	2485	3070
Gross benefit	(SL ha)*	487	766	668	797	629	746	691	853
Variable costs	(SL ha)	119	160	175	137	125	160	160	174
Net benefit	(SL ha)	368	606	493	660	504	586	531	679
Increase in variable cost over T1 (farmers' practice)	(SL ha)	—	41	56	18	6	41	41	55
Increase in net benefit over T1	(SL ha)	—	238	125	292	136	218	163	311
Benefit cost ratio		—	5.8	2.2	15.5	22.7	5.3	3.9	5.6

*SL Sudanese pound.

Orobanche Control in Lentils

Parasitic weeds of the genus *Orobanche* are a major constraint of lentil production in parts of West Asia and North Africa. Once an area is heavily infected with its seed, which can remain viable in the soil for up to 10 years, chemical treatment and crop husbandry cannot control the infestation and yields will be drastically reduced. Tolerant cultivars have been found in other legumes but until recently were unknown in lentils. They present the best means of *Orobanche* control.

During the 1979/80 season, 1000 accessions of germplasm were screened for their reaction to *Orobanche crenata* at Tel Hadya in heavily infested soil. Highly significant differences appeared in the susceptibility to the weed with 62 accessions having a maximum of only two emerged inflorescences of *Orobanche* per m^2.

In the following season (1980/81), the most resistant entries were planted again in infested soil. Genotypes ILL 3047 and 3112 from India were the most resistant with an average of only 1.8 and 2.2 inflorescences of *Orobanche* per m^2 compared with 16.8 inflorescences/m^2 on the best local check (Table 18). These Indian genotypes are now being used as sources of genes for reduced susceptibility to *Orobanche* infestation.

Lentil lines resistant to *Orobanche*—a major parasitic weed that can destroy the crop—have been identified.

One inflorescence of *Orobanche* can produce in excess of 100,000 wind and soil borne seeds.

Accession number	Number of inflorescences/m^2
ILL 3047	1.8
ILL 3112	2.2
ILL 4400 (Syr. Local L.)	19.8
ILL 4401 (Syr. Local S.)	16.8
L.S.D. 5%	*7.2*

Table 18. Average number of inflorescences of *Orobanche crenata* per m^2 on selected lentil accessions in the 1980/81 season.

Mechanized Harvesting for Lentils

Lentils are harvested by hand in the Middle East where the high cost of harvest labor is driving some farmers out of the production of this crop. Rocky and uneven soil surfaces planted with short, lodging varieties have been the main obstacles to direct introduction of harvesting technology, but, because of the value attached to lentil straw as a livestock feed, economic methods of harvesting both grain and straw must be found.

During the 1981 season, six different methods of harvesting were tested on contrasting cultivars and different management practices at Tel Hadya: hand harvesting, use of scythe, tractor-mounted side mower and bean blades, and both forage and combine harvesters. The bean blade—now being used in farmer managed trials—was the most promising method and gave a high yield of both straw and grain. The cutter-bar methods were most effective only on unlodged tall cultivars grown on rolled land with no surface stones.

A lentil puller to pull the broadcast crop is also being developed at ICARDA with support from West Germany (GTZ). A prototype is scheduled for trials during the next harvest.

A companion approach to mechanized harvesting methods is the development of lentil varieties that are taller and less prone to lodging than the existing land races. Therefore, ICARDA initiated a selection program for tall, erect types. Sources of increased height have been found in certain germplasm, but, because of their late maturity, they are being recombined with earlier maturity selections. The mean plant height of bulk segregating populations in the F_2 generation of crosses of this type was 35cm compared with 31cm for ILL 4400 (Syrian local).

Meanwhile, selection within germplasm accessions has resulted in some tall, erect material that can be harvested mechanically, including 78S 26002 (ILL 8) from Jordan. This selection consistently yielded more than the best local check in two locations in Syria and two in Lebanon in the 1980/81 season (Table 20). Also, it has more resistance to lodging than the local checks.

Lentil Selections	Plant height	Lodging score*	Grain yield in Syria (kg/ha)	Grain yield in Lebanon (kg/ha)
78 S 26002 (ILL 8)	35	2.2	1589	884
Lebanese local (ILL 3499)	39	4.1	964	744
Syrian local (ILL 4401)	35	3.9	1248	861

Scale: 1 unlodged; 5 all plants lodged.

Table 19. Mean values of plant height, lodging score, and grain yield of lentil selections over two locations each in Lebanon and Syria.

Costly hand harvesting of lentils is driving some Middle East farmers out of producing this crop.

Testing a prototype of a small lentil-puller machine on a broadcast crop—one of the alternatives to hand harvesting.

Sheep graze annual grasses and perennials for forage productivity and regrowth studies.

Perennial Forage Crops for Marginal Lands

Perennial forage legumes and grasses, many of which are native in the ICARDA region, offer a possibility for the revegetation of the marginal and non-arable lands in areas with annual rainfall higher than 350 mm. After the arid and semi-arid rangelands, they are the major non-utilized land resources in the Middle East and North Africa. It is estimated that 300 million hectares could be revegetated, and, if this were accomplished, three principal benefits would result: (1) production of additional sources of animal feed to integrate forage production from fallow land; (2) prevention of further erosion and desertification; and (3) less grazing pressure on arid and semi-arid rangelands, which is the main cause of their deterioration.

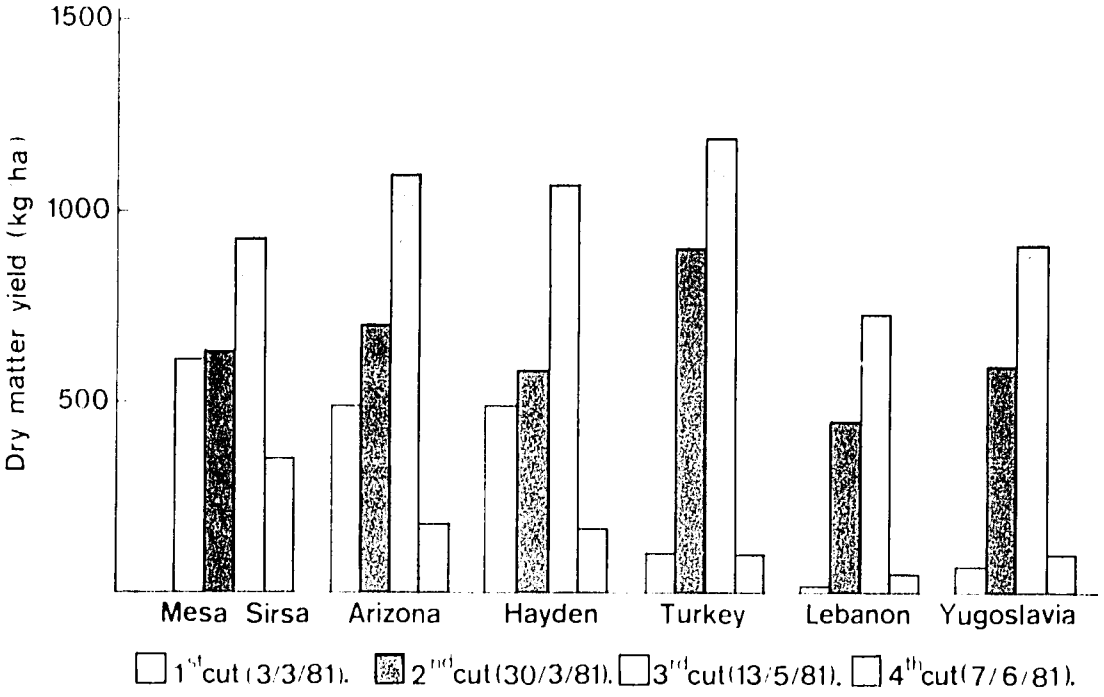
In the first stage of ICARDA's research on perennial forage crops, scientists are evaluating the adaptation of existing varieties and ecotypes collected in the region. Alfalfa *(Medicago sativa)* is being investigated for its potential under rainfed conditions, and the evaluation of 22

varieties and ecotypes in the second year after establishment has shown two basic patterns of dry matter distribution (Figure 12). Some varieties (Mesa Sirsa, Arizona, and Hayden) have a very early regrowth after winter, as shown by the dry matter yield at the first cut, and may therefore produce a forage supply at a time when other animal feeds are scarce. Varieties with this type of growth are expected to be less cold-tolerant and therefore can be grown in marginal soils of the coastal area with relatively mild winters.

Other varieties, such as the ecotypes from Turkey, Lebanon, and Yugoslavia, are typically winter dormant as shown by the very low yield at the

Winter active and winter dormant alfalfa in January. The former (foreground) has higher first-cut yields, but the latter (background) is expected to be much more cold tolerant for high plateau areas.

Figure 12. Dry yield matter (kg ha) of three alfalfa varieties and ecotypes from three countries under rainfed conditions in 1981. (Sowing date: Nov. 1979)



first cut (Figure 12). Varieties or ecotypes with this type of growth are expected to be much more cold-tolerant and adapted to high plateau areas in Morocco, Turkey, and Pakistan, which have cold winters.

All varieties have a high degree of summer dormancy, but the date at which a cultivar becomes dormant varies as shown by the dry matter yield at the fourth cut (Figure 12).

Adaptation of perennial, as well as annual reseeding grasses, has also been investigated. Annual reseeding grasses were included because these species actually behave as perennials due to their profuse seed shattering.

Trials established in November 1980 were grazed five times at about three-week intervals starting in mid-March 1981. The total dry matter yield of the best four annuals compared with the best four perennials is shown in Table 20. As expected, perennial grasses in the establishment year had a lower production than the annuals. Also, the dry matter yield distribution was different with the establishment of the annuals being much faster than that of the perennials (Figure 13). A rapid establishment is important, especially on marginal lands where grazing may be difficult to control. Therefore, the potential of mixtures of annuals and perennial species to combine rapid establishment and persistence is being investigated.

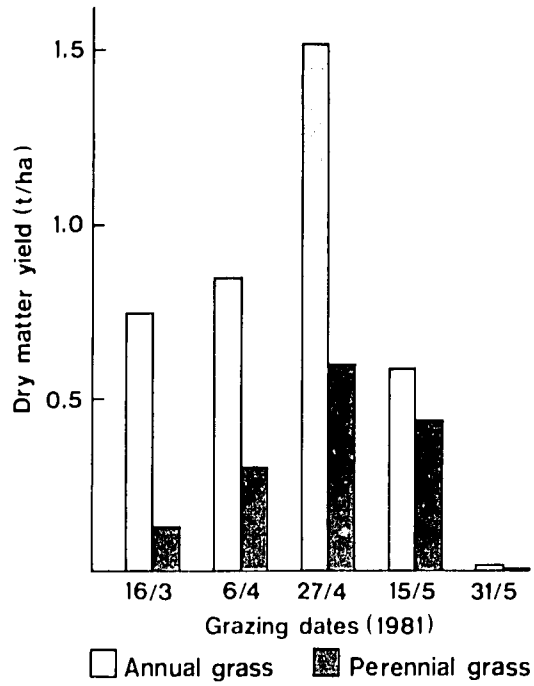


Figure 13. Dry matter yields (t/ha) in the establishment year of an annual grass (*Lolium rigidum* cv.Merredin) and of a perennial (*Phalaris aquatica* cv.Sirosa).

Species	Varieties or country of origin	Dry matter yield (t/ha)
Annuals		
Lolium rigidum	Merredin	3.9
Lolium rigidum	Wimmera	3.5
Lolium multiflorum	Combita	3.3
Phalaris canariensis	Iraq	3.2
Perennials		
Phalaris aquatica	Sirosa	1.5
Festuca arundinacea	Demeter	1.3
Phalaris aquatica	Seedmaster	1.3
Phalaris aquatica	Sirocco	1.2

Table 20. Total dry matter yield (t/ha in five grazings) of four annual and four perennial forage grasses.

Use of Fallow Land for Quality Hay Production

Over the years in the countries of the Middle East and North Africa, 70% to 80% of the feed required for animals was provided by natural range lands, but during the past two decades many changes have occurred to alter their traditional and efficient use. Plowing of good grazing lands for arable cropping, wood cutting and uprooting of shrubs for domestic use, over stocking with livestock, and intentional and accidental burning of natural vegetation have resulted in the degredation of natural range lands and deprived livestock of a valuable source of feed.

At present, the shortage of feed is especially acute in the late summer and early winter months and many farmers have to purchase supplemental feeds at high prices.

Under those constraints, the annual growth rate in livestock production—estimated at 1% to 2% in most countries of the region—is not sufficient to meet rising demands for meat and milk. Accordingly, prices are increasing and consumption is declining in rural communities.

One remedy to the feed shortage would be for farmers to engage in intensive forage production on available arable land, as well as on marginal and steppe lands. Farmers grow winter cereals in a two-year rotation (cereal/fallow). They crop about 50% of the arable land annually, leaving the rest in fallow—more than 35 million hectares. The main advantages claimed for the fallow in such a rotation are weed control, improved soil fertility, and moisture concentration carried over to the succeeding cereal season.

Vetch has been identified as one of the suitable components in a productive forage mixture for hay production.

However, recent ICARDA studies in Syria have indicated that when there is less than 300 mm of rain a farmer-managed fallow does not conserve moisture. Similar studies in the Gezira area of Iraq have shown very

little moisture conservation from fallow. On the other hand, properly managed forage crops (including legumes) can adequately serve the purposes of weed control and a build-up of soil fertility.

Large areas of existing fallow land could be used for forage crops and managed for maximum production of good quality hay. Species of legumes (such as vetch and forage peas) and forage cereals (barley, triticale, and oats) have been identified by ICARDA scientists as suitable components of a productive forage mixture for hay production. Dry matter yields of up to 10 t/ha were obtained from some of these mixtures in 1981 (Table 21).

The scientists are also examining the use of planted forages for grazing early in the season (Jan.-Feb.) to be followed by a final hay harvest at the end of the season. Promising forage lines with regrowth characteristics following early grazing have been identified and are being studied to determine the best management to maximize yields of both green forage and hay production.

To check the performance and suitability of different forage crops identified at ICARDA's main experiment station at Tel Hadya, Syria, off-site testing is carried out each year in collaboration with national programs under different agro-climatic zones in the region. This includes growing and managing annual forages on farmers' fields, demonstrating their use by grazing animals, and monitoring soil nutrition and subsequent effects on following crops.

A planting of an oat and vetch mixture on this land instead of leaving it fallow provides grazing for sheep and a later hay crop to ease feed shortages.

Barley Acc. No.	Yield (kg/ha)	Triticale Acc. No.	Yield (kg/ha)
50	7995	332	8725
52	9133	314	10225
4	10112	739	7997
9	9132	246	7649
71	9350	686	8310
46	9427	724	7378
157	6395	310	9070
146	7859	287	8364
49	10784	665	6352
143	9890	680	6839

Table 21. Dry matter yields in 1981 of selected lines of forage barley and triticale in mixtures with legumes (vetch or pea).

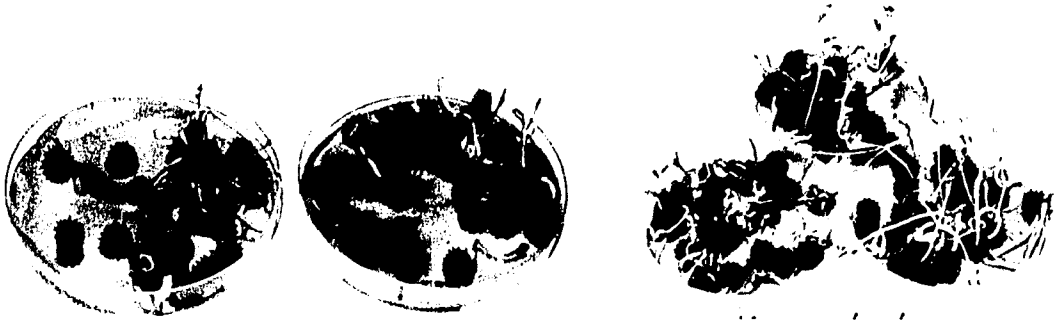
Relationship of Hardseed and Softseed Medics to Forage Production

Many annual species of the genus *Medicago* (often referred to as medics), exhibit a characteristic feature of regeneration from seeds once they are sown or established in pastures. Some have a high percentage of seeds which absorb water, germinate readily, and regrow or regenerate vigorously from one year to the next. Others have a high percentage of hardseeds which do not absorb water readily and grow only after being in the soil for about a year. When hardseed medics are planted for the first time, the seeds must be sacrificed to break the seed coat before sowing in order to get good establishment in the fields.

Annual medics with a high percentage of soft seeds are ideally suited for the revegetation and rehabilitation of marginal or non-arable lands on hill slopes, stony areas, and foothill sites. Many countries in the ICARDA region have extensive areas of these types of marginal lands. For example, Syria alone has about 3.2 million hectares of marginal lands in relatively high rainfall zones. These lands, which are subject to intense erosion, can be improved and used productively.

Medics with a high percentage of hard seed are selected especially for use in an annual rotation scheme with cereals. Medic pastures are planted during the first cropping year (Year I); seeds produced remain in the soil after shallow cultivation during the second cropping year (Year II) when the same land is planted to a cereal crop. At the beginning of the third cropping year (Year III), the medic seeds produced in Year I will germinate to produce a productive pasture.

Germination of hardseed medics (left) and softseed medics (right). The former are selected especially for use in an annual forage rotation with cereals, the latter for revegetation of marginal lands.



An ideal medic cultivar for annual rotation with a cereal should have no more than 30% permeable seeds at the time of sowing of the cereal crop in the beginning of Year II. About 70% should be hardseed and thus available for regeneration in Year III following the cereal crop. From 35 to 40 million hectares of cropping land in countries of the Middle East and North Africa are left fallowed or uncropped for one year following the cereal harvest. It is on these fallow lands that the medic cereal rotation has enormous potential to be developed into a highly profitable cropping system.

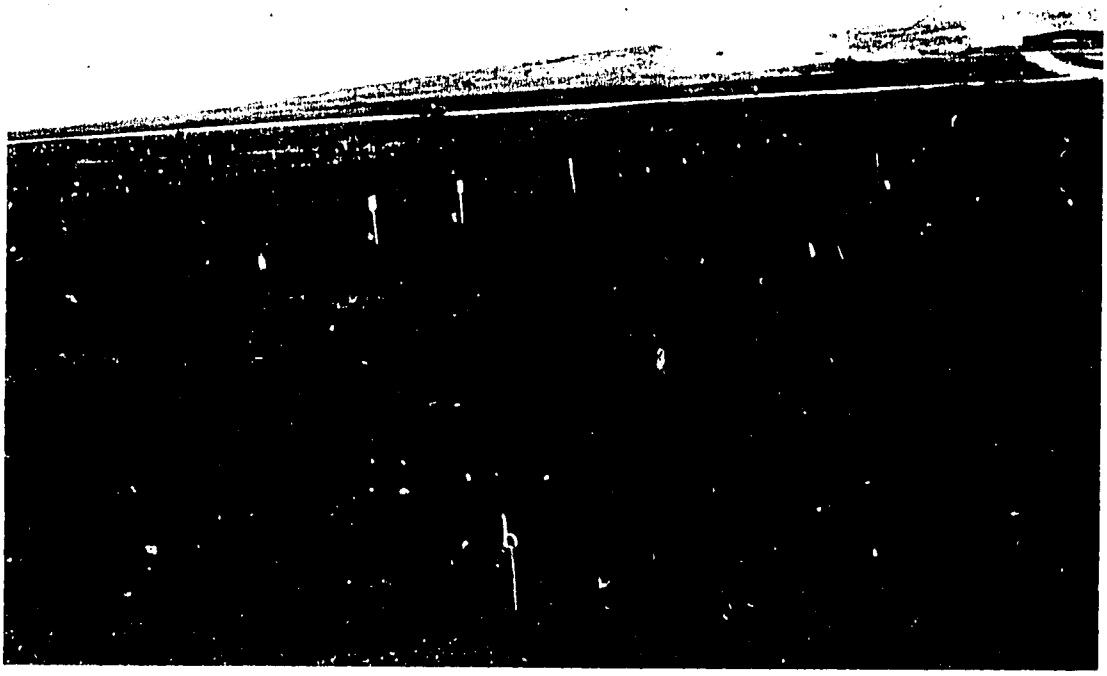
Thirty-two different species of medics—all of which are indigenous in Middle East and North African countries—have been screened by ICARDA for adaptibility and forage production potential. Five native species—*Medicago regidula*, *M.aculeata*, *M.noeana*, *M. rotata*, and *M.turbinata*—appear to have good potential as judged by their performance in small plots. Selections of these five species have been identified for further appraisal in larger plots. *M.regidula* and *M.aculeata* are now being tested under grazing pressure by sheep, and it is expected that selections of these two species will be released as cultivars in the near future.

Small plot evaluation indicates that satisfactory dry matter production and seed yield can be obtained with these two species (Table 22) and that medic pasture production in uncropped fallow lands and on barren, unproductive marginal areas could increase agricultural productivity significantly in many countries in the region.

Hardseededness is not a constraint for the development of *M.aculeata* and *M.regidula* based on seed permeability studies. The latter cultivar has better hardseed characteristics than the cultivar Cyprus which was developed in Australia and is closer to what can be considered an ideal cultivar (Figure 14). It has a higher percentage of permeable seeds (about 13%) at the time of sowing for the cereal crop in November. *Medicago aculeata* has more soft seeds (Figure 14) and a potential for permanent pasture establishment on marginal lands subject to erosion.

Table 22. Dry matter yield and seed yield of eight selected lines of *Medicago regidula* and *M.aculeata* from microplot trials at Tel Hadya, Syria (1980/81).

Species	Number of lines	Dry matter yield (kg/ha)		Seed yield (kg/ha)	
		Mean	Range	Mean	Range
M.regidula	8	8227	7215-10993	939	645-1151
M.aculeata	8	7194	3026-9826	957	597-1140



Many species of medics are evaluated in these test plots to determine their forage production potential.

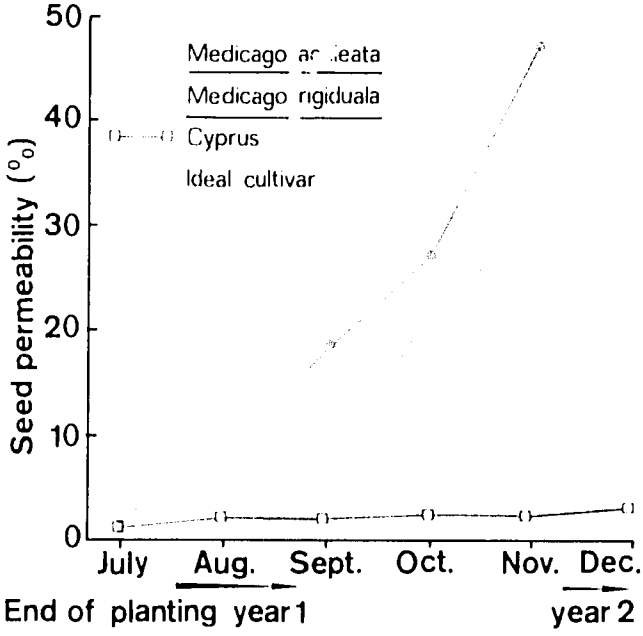
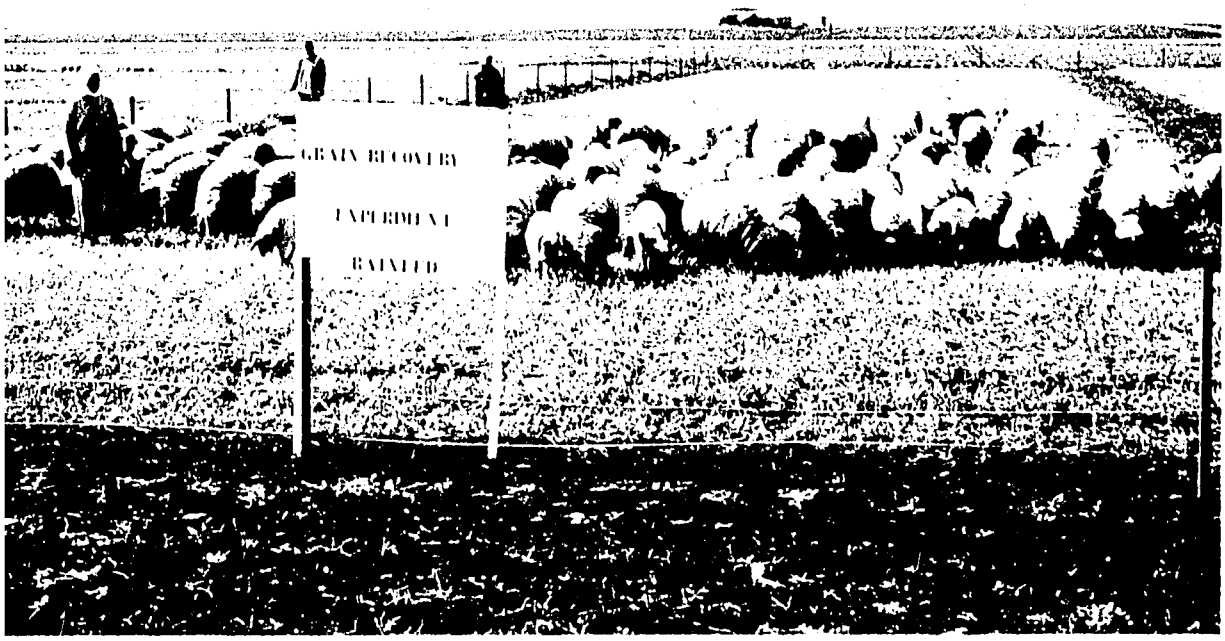


Figure 14. Relationship between seed permeability and time of year for the medics *M.aculeata*, *M.rigidula*, Cyprus, and an ideal cultivar.



Barley for grazing and its recovery for grain production receives special research attention.

Supplementary Feeds and Forage Crops in Sheep-Based Farm Systems

Sheep producers in Syria started to use supplementary feeds over two decades ago following a series of drought years that substantially reduced the national flock. Since then they have become increasingly dependent on them. The degree of dependency on barley, cereal straw, sugar beet pulp, and other supplements from November until March was clearly shown in a three-year survey conducted in regions of Aleppo Province receiving an average annual rainfall below 250 mm (Table 23). The survey was completed in September 1981.

Barley grain and cereal straw together covered between 60% and 110% of the estimated metabolizable energy requirements of the sheep. In a parallel study in six wetter villages in Aleppo Province, those two feedstuffs represented 34% to 65% and 3% to 40% of the consumed metabolizable energy, respectively.

The role of barley for grazing further emphasizes the importance of this multi-purpose crop in sheep-based farm systems. Depending on the state of the crop, rainfall, and

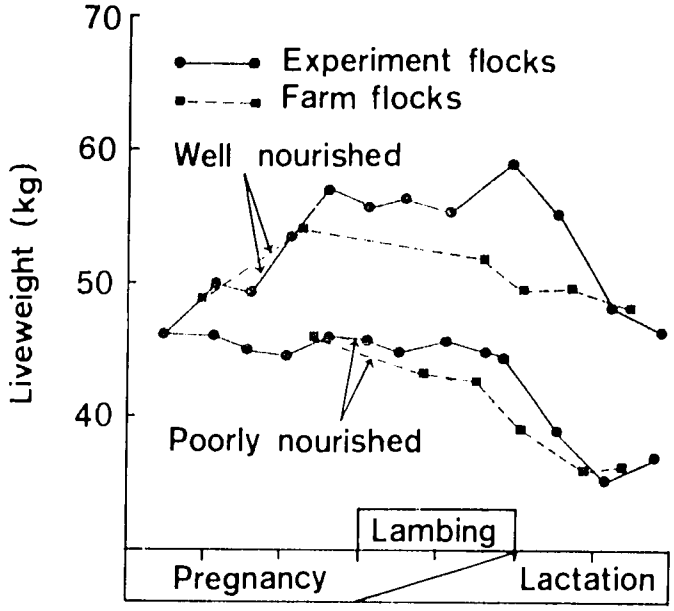


Figure 15. Liveweight pattern of well and poorly nourished ewes.

input-output cost relationships, farmers may decide to graze barley as a green fodder crop, or, if the yield is too poor to cover harvest costs as in a dry year, it will be grazed *in situ*. Therefore, the crop introduces stability into the system by providing an alternative feed supply in years of scarce natural grazing.

Table 23. Intake of supplementary feed by steppe sheep relative to estimated energy requirements.

	Year of Survey		
	78/79	79/80	80/81
Percentage of energy requirements from:			
—Barley grain	35	21	57
—Cereal straw	76	37	25
—Sugar beet pulp	—	22	31
—Others	52	18	31
TOTAL	163*	98	144*

*Energy from supplements apparently exceeds requirements.

Availability of straw from barley grown in the marginal area between the steppe and cropped areas, plus the ability to move water to sheep, have made it possible for steppe-based flocks to stay in the steppe throughout the summer. This new practice reduces the need for sheep to be moved to higher rainfall areas in the summer to graze crop residues. Thus, the traditional interdependency between the two areas is diminishing.

ICARDA scientists are measuring sheep productivity under field conditions, and results are compared with those generated from the experimental flocks at Tel Hadya. This will make it possible for them to define a "yield gap" in terms of actual and potential animal production. Preliminary results taken from two farm flocks (Figure 15) indicate that fluctuations in

This experimental flock of sheep at one of ICARDA's Unit Farms provides a framework for studying economic returns of improved vs. traditional animal husbandry practices.

body weight of ewes are less than might be expected. Furthermore, because of the high levels of supplementary feeding during lactation, the fall in liveweight of well nourished ewes after lambing is considerably less than the experimental flock at Tel Hadya (Figure 15).

The rationale of farmers who feed a high level of supplements during lactation, but less during pregnancy, will be investigated by comparing the growth performance of the lambs from farm flocks and the Tel Hadya flocks.

Tel Hadya's two Unit Farms, each supporting an experimental flock, provide a framework for studying the economic returns of applying improved crop and livestock husbandry compared with traditional practices. The two levels of husbandry permit an analysis of input/output relationships in both physical and economic terms.

The addition in 1981 of a third or sacrifice flock—which is exposed to poor husbandry—has strengthened the research framework. This low-input flock has a liveweight pattern closely similar to a poorly nourished farm flock (See Figure 15). It provides the base-line data for comparing the physical and economic response of the sheep to higher levels of husbandry inputs. Scientists consider that the transferability of their findings to the farm situation has been strengthened by the introduction of the sacrifice flock.

Correct nutrition of breeding ewes at specific phases of the reproductive cycle (mating, late pregnancy,

and early lactation) is essential to maximize reproductive rate and milk and lamb production. It has become clear after two lambing seasons at Tel Hadya that over 100 live births per 100 ewes mated can be achieved from the local Awassi breed if correct husbandry is followed. This compares with 80 to 90 live births per 100 ewes mated in village flocks. Also significant is the reduction in the spread of the lambing season in experimental flocks compared with farm flocks. This reduction simplifies the management of the sheep flock.

The Unit Farms provide a base for studying the effect on sheep production of introducing annual forages into the crop rotation. On shallow or stony soils, these forages, such as vetch, can replace a fallow in the barley-fallow rotation and therefore do not require extra land. The forage provides spring grazing for fattening lambs which might otherwise be sent to the steppe for two to three months. This helps reduce the grazing pressure on the steppe in the spring and provides an extra source of income to the farmer who fattens his lambs on forages.

Results from the Unit Farms show that over 200 kg liveweight gain per hectare can be achieved from forage vetch (Table 24). This finding has important implications since there are vast areas of fallow in the ICARDA region.

Forages can be grown and conserved as hay for winter feeding to reduce dependency on other feedstuffs, such as barley grain and cottonseed cake, which may have limited availability. This aspect is also incorporated into the Unit Farm concept. A 2.5 ha field of forage, which replaces lentils on the low-input Unit Farm, provides 4000 to 8000 kg of hay. This is sufficient for 30 to 50 ewes offered 1 kg/ha daily from November to March—about 150 days—and would probably cover the maintenance energy requirements of a 45 kg ewe and leave enough energy to synthesize about 350 g of milk. A further 560 g of hay or 460 g of barley grain would cover the energy requirements for 1 kg of milk production. This example illustrates the ability of a farm to supply all the energy—and perhaps the protein needs—for an increased number of sheep. The next step will be to determine whether this extra animal production compensates for the lost revenue from lentil production.

	1980		1981	
	Marginal land	Vetch	Marginal land	Vetch
No. of lambs	30	30	25	24
Initial liveweight (kg)	24.8	27.2	26.8	28.8
Final liveweight (kg)	29.6	34.1	38.0	43.3
Duration (days)	28	28	60	60
Average daily gain (g)	171	246	186	242
Liveweight gain (kg/ha)	—	138	—	232

Table 24. Performance of lambs grazing marginal land or forage vetch at Tel Hadya, Syria.

Study on Credit and Interest Rates for Sheep Producers

Should the smaller and poorer sheep producers in Syria be given preferential treatment in the form of lower interest rates on loans for feed purchases? A key factor in a recent large World Bank loan to Syria is a credit program that seeks to assure sufficient quantities and timely availability of feeds, particularly for these producers. To gather information on the best way to determine interest rates and obtain a better understanding of the very important sheep livestock sector in the Syrian economy, a team from the Ministry of Agriculture and Agrarian Reform and ICARDA has completed a study of credit sources and a survey of 130 members of range and sheep cooperatives and 98 members of sheep fattening cooperatives.

The team's main conclusion after the study was completed: A single interest rate should be charged to all sheep producers and other measures used to equalize incomes. It would be extremely difficult and administratively very expensive to devise a workable scheme to allocate credit for feed purchases at two different rates in order to give preferential treatment to poorer producers having an annual income of less than

A range cooperative sheep herd being given supplemental feed on the steppe in late winter in Syria.

Range sheep move down from the steppe in June to graze grain stubble after the harvest.

3,500 Syrian lira. Furthermore, feed prices are subsidized to such an extent that two different interest rates in the 5½ to 7½% range as proposed would play no role in allocating scarce credit and/or scarce feed.

Sheep production is interwoven with the rest of the agricultural sector since the animals migrate into and out of the steppe, depending on grazing, crops, and crop residues. They are given supplemental feed only when other alternatives have been exhausted. Sheep numbers in Syria—more than 8 million head—account for about 80% of the total animal population (excluding poultry), and the value of sheep production is approximately one-fourth of the total agricultural production of the country. A half million farm-based families raise sheep to supplement their income, and an estimated 35,000 bedouin families depend largely on sheep raising for their living.

Results of the survey showed that among the two types of sheep cooperatives and their members a wide variability exists in sheep numbers, production practices, animal productivity, and family income. For example, average ownership of animals in some sheep and range cooperatives was as low as 20 and as high as 700 in others.

Similarly, the sheep fattening cooperatives were characterized by tremendous variations in the number of members per cooperative, size of fattening batches per cooperative and per member, the number of members using financing, and other factors. Credit obtained outside government channels frequently took the form of share arrangements where the financier participated in the profits or losses. Some loans were available and forward contracting was common.

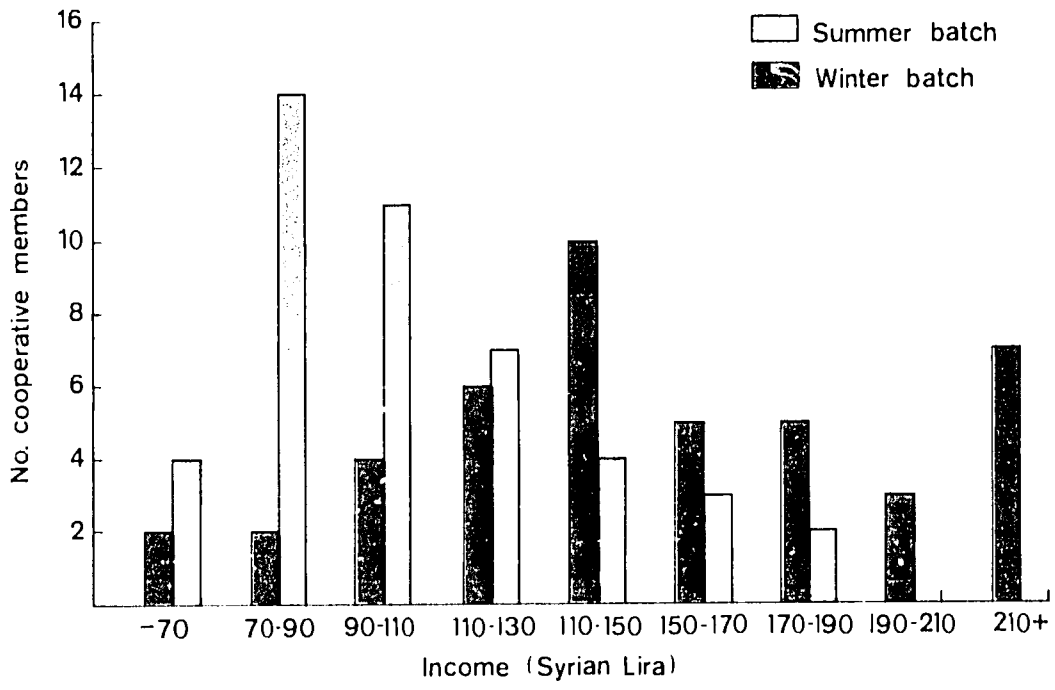
Some cooperative members made a profit and others lost money in the

fattening operation. Gross income per sheep varied widely (Figure 16), and data on feed conversion ratios showed the need for improvements in this area which could directly and significantly affect profitability (Table 25). Even in the summer, a 1:8 conversion ratio as shown in the table should be unacceptable and points up the need for a major effort in animal nutrition in fattening operations.

	Winter batch	Summer batch
	Quantity (kg)	Quantity (kg)
Barley	**97.84**	**81.52**
Cottonseed cake	19.09	18.05
Wheat	12.59	9.05
Vetch	11.48	10.38
Wheat bran	12.45	11.09
Sub-total	153.45	130.09
Legume straw	20.75	16.22
Cottonseed hull	16.16	14.06
Fish oil	3.57	.78
Salt	.57	.59
TOTAL	194.50	161.74
Weight gain	16.80	15.56
Conversion ratio (concentrate)	**1:9.13**	**1:8.36**

Table 25. Feed consumption and conversion ratios per head of sheep in fattening operations.

Figure 16. Gross income (Syrian lira) per sheep fattened in winter and summer batches.



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(September 1982)
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