FARM RESOURCE MANAGEMENT PROGRAM

Annual Report for 1991

ICARDA

Established in 1977, the International Center for Agricultural Research in the Dry Areas (ICARDA) is governed by an independent Board of Trustees. Based at Aleppo, Syria, it is one of 16 centers supported by the Consultative Group on International Agricultural Research (CGIAR), which is an international group of representatives of donor agencies, eminent agricultural scientists, and institutional administrators from developed and developing countries who guide and support its work.

The CGIAR seeks to enhance and sustain food production and, at the same time, improve socioeconomic conditions of people, through strengthening national research systems in developing countries.

ICARDA focuses its research efforts on areas with a dry summer and where precipitation in winter ranges from 200 to 600 mm. The Center has a world responsibility for the improvement of barley, lentil, and faba bean, and a regional responsibility—in West Asia and North Africa—for the improvement of wheat, chickpea, and pasture and forage crops and the associated farming systems.

Much of ICARDA's research is carried out on a 948-hectare farm at its headquarters at Tel Hadya, about 35 km southwest of Aleppo. ICARDA also manages other sites where it tests material under a variety of agroecological conditions in Syria and Lebanon. However, the full scope of ICARDA's activities can be appreciated only when account is taken of the cooperative research carried out with many countries in West Asia and North Africa.

The results of research are transferred through ICARDA's cooperation with national and regional research institutions, with universities and ministries of agriculture, and through the technical assistance and training that the Center provides. A range of training programs are offered extending from residential courses for groups to advanced research opportunities for individuals. These efforts are supported by seminars, publications, and by specialized information services.

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ernational Center for Agricultural Research in the Dry Areas
P.O. Box 5466, Aleppo, Syria

This report was written and compiled by program scientists and represents a working document of ICARDA. Its primary objective is to communicate the season's research results quickly to fellow scientists, particularly those within West Asia and North Africa, with whom ICARDA has close collaboration. Due to the tight production deadlines, editing of the report was kept to a minimum.

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1. INTRODUCTION

1.1 Content of this Report

It is now several years since this Program's name was changed from Farming Systems to Farm Resource Management. That name change implied no major switch of interests and responsibilities, rather an extension of them more explicitly towards the long-term care of the natural resource base of agriculture, particularly soil and water, within the continuing context of farming systems and small-farmer agriculture. Such research is the essential core of any program aimed at the achievement of dependable, long-term agricultural production, or sustainability, and will remain so long after that particular vogue word has been superseded.

Nevertheless, new work explicitly focused on resource management for sustainability has been slow to take off in the Program -- we still await an appointment to the crucial post of specialist in soil conservation and land management -- and slower still to filter through to the reporting stage. However, there are, we believe, signs of real progress this year. We report here initial results from work directed towards the protection of soil in dry areas: studies of wind erosion and of techniques -- shrub windbreaks and tillage and stubble management -- with potential to prevent it.

Erosion of soil probably poses the greatest long-term threat to sustainability, but for maintaining current national production levels greater urgency attaches to water. For this resource, FRMP efforts have for a number of years been directed towards efficiency of use, specifically through the supplemental irrigation of basically rained crops; but a chapter in this report summarizing detailed socioeconomic studies of supplemental irrigation raises questions about the sustainability of the small aquifers upon which much of it is based. Meanwhile, we are initiating a new program of research, demonstration and training in water harvesting, aimed at concentrating and conserving water for agriculture in areas of low and erratic rainfall.

None of these technical initiatives will bear much fruit at the farm level unless they provide techniques, practicable, profitable and acceptable to the land user. This is where the greatest challenge lies, to apply the farming systems approach, especially as it pertains to small farmer and herdsman, with the development of simple but effective measures to conserve the resource base -- land user and researcher recognizing a common goal. The small Dryland Resource Management Project, which coordinates six national program case studies of the small farmer/resource management interface, is seen as pioneering this philosophy. We aim to build up such work on a longer-term basis as a major focus of Program activities, with coordinated inputs from both social and technical scientists.

Activities of this sort require additional support. On the one hand, they need extra financing: joint scientist-farmer participation in the research and development of resource management activities, like soil conservation and water harvesting, is not achieved on small research plots on or even near research stations, and ICARDA itself will accomplish little unless national program scientists and extension specialist are also involved. It is hoped to develop appropriate projects. On the other hand, they need data-base support, to allow site- and year-specific results to be evaluated in their environmental context. In this regard, the Program has gained strength in the field of agroecological characterization during the year, and one outcome already in this report is a preliminary reappraisal of how crop scientists view climate in Syria. A clearer picture of what crops (and varieties) are grown where and why is long overdue in ICARDA.

Other activities with a major bearing on sustainability, like efficient fertilizer use, nitrogen cycling and crop rotation studies, are also summarized in this report, as are studies of the adoption and impact of wheat and chickpea technology. Reporting is organized according to three projects within which FRMP research is nominally organized: the Management of Soil, Water and Nutrients (Chapter 3); Agroecological Characterization for Resource Management (Chapter 4); and the Adoption and Impact of New Technology (Chapter 5). However, as has been said before, boundaries between these projects are diffuse, and -- necessarily -- many activities straddle two project areas or pass from one to the other. This is in keeping with the broad farming systems and resource management philosophies still evolving within the Program.

1.2 Staff Changes

The Program has experienced another year at well below its full complement of scientists, but there are signs now that the tide is turning. Mike Jones was appointed Program Leader, after a period in an acting capacity, following the departure of Peter Cooper in 1990; but this leaves an Agronomist position vacant. Bakheit Said has moved out of FRMP to a temporary position in the Outreach program, leaving the Training Scientist position vacant; and Abdullah Matar has retired as Soil Chemist but, happily, has remained with us in a consultant role until the new appointee arrives in 1992.

On the credit side, we have welcomed the arrival of Theib Oweis and Graham Walker. Dr Oweis, from the University of Jordan, is our new Water Management Specialist and covers the very broad responsibility of supplemental irrigation and water harvesting. Dr

Walker, previously with the Canadian Wheat Board, is an agroclimatologist (with soils and crops background) and fills our new P-level Agroclimatologist position. In addition, the arrivals of three economists of different backgrounds and a visiting oilseed crops specialist are confidently expected during 1992; and there are hopes, too, that a soil conservation/land management specialist and a new training scientist will also soon be appointed.

Meanwhile, the regional staff has been strengthened by Elianor Nasseh (soils laboratory) and Abdul Baset Khatib (wheat-based systems agronomy team), both appointed after long service as daily-paid staff.

1.3 The Weather in Syria during the 1990/91 Season

In contrast to the two previous cropping seasons, which were dry, 1990/91 had a total seasonal rainfall only just below the long-term average. The early part of the season was fairly dry over wide parts of northern Syria, and much of the rain fell in the spring. Except during May, temperature during the growing period were close to the long-term average, with fewer cold spells affecting plant growth and many fewer frost days than during the previous winter. The 35 frost days recorded at Tel Hadya in 1990/91 represent exactly the average for the site. Because of this, and because there was more rainfall, distributed such that crops could make more efficient use of it, yields were generally up from the low levels of the two previous years.

The first significant rains fell during the last decade of October and the first decade of November. Some more rain followed during the first decade of December; but in the barley-growing areas, represented by the stations of Bouider, Ghrerife and Breda, rainfall up to the end of December was insufficient to allow emergence. Germination occurred, however, so that when the rain finally returned during the first week of January, the crops emerged rapidly.

In the wheat-growing areas, represented by Tel Hadya at the dry end of the range and by Jindiress at the wetter end, the picture was more complex. In the drier areas, rainfall in late October and early November provided enough moisture to enable some of the early planted wheat crops to emerge. But then followed three weeks without any rain, and December rainfall was sparse. As a result, these early crops suffered from severe moisture stress which reduced their yield potential unless they were irrigated. As in the barley area, at Tel Hadya plentiful rainfall started only at the beginning of January.

In the wetter wheat growing areas, however, rainfall was heavy during the third decade of October (at Jindiress 48.5 mm fell on 24 October) and sufficient to sustain growth during November and December. The growing season at Jindiress started, therefore, ten weeks earlier than at the other sites. At Tel Hadya, these ten extra weeks of growth could be gained through supplemental irrigation, turning the "false start" into a real one.

While January rainfall was ample, the February total stayed below the long-term average, especially in the barley-growing areas. There was, however, enough moisture left in the soil to prevent undue stress to crops. From March to May, the rainfall was above average, although the May rainfall was of little benefit to crops. The soil profile started to dry out from the second decade of April onwards.

While the season so far had been neither unduly warm nor cool, May was exceptionally cold. It was the coldest May recorded at

Jindiress since the ICARDA station was set up there. Even more remarkable, the -0.1°C measured at Bouider on 10 May constitutes the first sub-zero temperature ever observed at an ICARDA station in Syria in May. Another unusual event was the hailstorm on 21 May at Tel Hadya, which caused very serious damage to those cereal crops which had not yet been harvested.

Table 1.1 Monthly precipitation (mm) for the 1990/91 season

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	TOTAL
Jindiress													
1990/91 season	3.2	61.0	38.4	32.9	70.3	50.5	70.6	82.7	28.4	0.0	0.0	0.0	438.0
Long term average (31s.)	1.4	31.4	55.1	92.0	84.1	73.9	65.9	43.7	19.3	2.3	0.3	0.8	470.2
% of long term average	228	194	70	36	84	68	107	189	147	0	0	0	93
Tel Hadya													
1909/91 season	1.6	7.8	19.0	21.7	71.9	35.0	73.3	38.7	21.1	0.0	0.0	0.0	290.1
Long term average (13s.)	0.5	24.5	48.5	53.8	61.0	50.2	43.8	28.4	14.2	3.0	0.0	0.1	328.0
% of long term average	320	32	39	40	118	70	167	136	149	0	n/a	0	88
Breda													
1990/91 season	0.0	4.4	26.2	12.4	50.9	20.6	60.0	35.2	31.6	0.0	0.0	0.0	241.3
Long term average (33s.)	1.2	16.9	30.8	53.3	48.7	38.3	34.4	31.4	16.1	1.5	0.1	0.0	272.7
% of long term average	0	26	85	23	105	54	174	112	196	0	0	n/a	88
Bouider													
1990/91 season	0.0	4.4	15.8	21.4	52.0	18.8	61.8	22.6	16.6	0.0	0.0	0.0	213.4
Long term average (18s.)	0.1	14.7	23.0	35.0	37.6	33.9	29.6	17.5	9.4	0.7	0.1	0.0	201.6
% of long term average	0	30	69	61	138	55	209	129	177	0	0	n/a	106
Ghrerife													
1990/91 season	0.0	4.2	22.8	18.8	57.8	16.4	68.4	23.2	20.2	0.0	0.0	0.0	231.8
Long term average (6s.)	0.0	38.6	23.8	38.5	44.0	35.4	38.0	13.3	12.1	0.6	0.0	0.0	244.3
% of long term average	n/a	11	96	49	131	46	180	174	167	0	n/a	n/a	95
Terbol													
1990/91 season	0.0	8.0	47.8	42.6	128.8	80.0	121.8	44.6	57.8	0.0	0.0	0.0	531.4
Long term average (9s.)	0.0	23.9	62.4	77.9	91.2	97.4	95.6	26.2	13.4	0.6	0.3	0.0	488.9
% of long term average	n/a	33	77	55	141	82	127	170	431	0	0	n/a	109

Table 1.2 Monthly air temperature (°C) for the 1990/91 season

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
Jindiress												
Mean max.	32.4	28.4	21.1	15.0	11.3	11.9	17.7	22.6	23.4	32.9	33.3	33.9
Mean min.	17.6	14.6	8.5	3.8	1.9	2.2	7.2	9.4	8.7	16.6	21.9	22.5
Average	25.0	21.5	14.8	9.4	6.7	7.1	12.4	16.0	16.1	24.8	27.7	28.2
Abs. max.	36.7	36.6	28.6	21.1	16.8	18.6	26.3	29.6	29.2	38.5	37.2	38.0
Abs. min.	11.1	8.4	0.2	-4.4	-5.3	-4.8	-2.0	4.6	3.8	5.1	16.7	18.3
Tel Hadya												
Mean max.	34.0	29.4	22.1	15.3	11.2	13.3	18.1	23.8	27.9	35.3	35.3	36.6
Mean min.	16.9	12.8	7.2	2.6	0.9	1.6	6.3	8.2	12.1	17.1	21.1	21.8
Average	25.5	21.1	14.7	9.0	6.1	7.5	12.2	16.0	20.0	26.2	28.3	29.3
Abs. max.	37.8	35.1	29.4	19.8	18.2	18.3	27.8	31.3	33.3	41.5	39.7	39.8
Abs. min.	10.3	5.1	-0.4	-5.5	-5.5	-6.4	-4.6	2.9	6.7	8.4	16.6	17.0
Breda												
Mean max.	33.9	28.7	21.4	14.5	10.1	12.7	17.8	23.8	25.7	34.9	35.8	37.0
Mean min.	15.7	12.5	7.6	2.1	1.1	1.7	6.9	8.5	10.2	16.9	21.4	21.2
Average	24.8	20.6	14.5	8.3	5.6	7.2	12.3	16.1	17.9	25.9	28.6	29.1
Abs. max.	38.0	34.9	28.5	19.1	16.8	17.2	27.1	33.0	32.0	41.5	39.9	41.0
Abs. min.	10.0	6.7	0.1	-6.9	-4.2	-4.6	-5.7	3.2	3.9	7.0	17.7	17.6
Bouider												
Mean max.	33.4	28.4	21.1	14.0	10.5	13.0	18.5	26.1	26.1	35.3	36.0	36.1
Mean min.	12.7	9.7	4.9	0.7	0.9	1.3	6.5	9.4	9.0	14.0	16.3	16.2
Average	23.1	19.1	13.0	7.3	5.7	7.1	12.5	17.8	17.5	24.7	26.1	26.2
Abs. max.	37.4	33.9	28.3	19.6	17.8	19.1	28.3	36.9	35.0	41.6	40.0	40.2
Abs. min.	8.1	5.0	-1.4	-5.5	-4.5	-5.0	-4.4	3.2	-0.1	4.3	9.8	11.0
Ghrerife												
Mean max.	34.1	29.3	21.5	14.9	11.1	13.4	18.4	24.6	25.9	35.8	35.3	35.1
Mean min.	17.7	14.7	8.5	3.5	2.5	3.3	8.2	11.4	11.5	18.4	20.2	19.3
Average	25.9	22.0	15.0	9.2	6.8	8.4	13.3	17.8	18.7	27.1	27.8	27.2
Abs. max.	37.6	35.0	28.2	19.4	17.0	18.7	27.2	35.0	32.9	41.9	40.2	38.8
Abs. min.	13.8	9.7	1.0	-4.1	-2.2	-3.4	-1.9	6.5	3.9	8.6	14.0	15.6
Terbol												
Mean max.	31.0	27.0	21.9	16.3	11.3	12.6	17.2	22.3	24.3	31.5	31.7	32.3
Mean min.	10.0	7.8	4.8	2.1	-0.4	0.8	4.0	5.8	7.7	9.4	11.2	12.1
Average	20.5	17.4	13.4	9.2	5.5	6.7	10.6	14.1	16.0	20.4	21.4	22.2
Abs. max.	35.0	32.5	28.0	26.5	16.0	19.0	30.0	31.0	31.0	38.5	37.0	37.0
Abs. min.	5.5	2.5	-2.0	-4.0	-6.0	-4.0	-3.0	-1.0	1.0	2.0	6.5	8.0

Table 1.3 Frost events during the 1990/91 season

	NOV	DEC	JAN	FEB	MAR	APR	MAY	SEASON
Jindiress								
No. of frost days	-	8	6	9	2	-	-	25
Abs. min. (°C)	-	-4.4	-5.3	-4.8	-2.0	-	-	-5.3
Tel Hadya								
No. of frost days	1	9	13	9	3	-	-	35
Abs. min. (°C)	-0.4	-5.5	-5.5	-6.4	-4.6	-	-	-6.4
Breda								
No. of frost days	-	10	14	9	2	-	-	35
Abs. min. (°C)	-	-6.9	-4.2	-4.6	-5.7	-	-	-6.9
Bouider								
No. of frost days	2	14	14	12	2	-	1	45
Abs. min. (°C)	-1.4	-5.5	-4.5	-5.0	-4.4	-	-0.1	-5.5
Ghrerife								
No. of frost days	-	9	9	9	1	-	-	27
Abs. min. (°C)	-	-4.1	-2.2	-3.4	-1.9	-	-	-4.1
Terbol								
No. of frost days	2	10	21	15	7	2	-	57
Abs. min. (°C)	-2.0	-4.0	-6.0	-4.0	-3.0	-1.0	-	-6.0

Table 1.4 Frost events at 5 cm above the ground during the 1990/91 season

	NOV	DEC	JAN	FEB	MAR	APR	MAY	SEASON
Tel Hadya								
Frost days	2	11	14	14	4	-	-	45
Abs. min.	-1.6	-7.1	-8.0	-8.5	-6.6	-	-	-8.5

2. EXECUTIVE SUMMARY

2.1 Project 1. Management of Soil, Water and Nutrients

Soil Conservation (section 3.1)

A major area of concern within the Program's farm resource mandate is soil management and conservation. The present report gives the first results from three recently initiated studies: on wind erosion, on the intercropping of barley rotations with atriplex hedges, and on tillage and barley stubble management.

Serendipity provided our new wind erosion project with an excellent test site at Tel Hadya in 1991. Vacuum seed harvesting of a medicago field destroyed the soil structure and thereby simulated the conditions that arise frequently in barley fields through the trampling of animals which graze the stubble. Such grazing and trampling usually occur through the months of May to September. Analyses of wind data from ICARDA sites in NW Syria show that the erosive power of the wind is largely concentrated in the middle of that period, June to August.

To monitor the erosion we used dust samplers, constructed at ICARDA according to a Texas design. Each sampler traps airborne dust at five heights above the ground, 5, 10, 20, 50 and 100 cm, and from the weights collected one may calculate the amount of material passing the sampler during the period of measurement. In early September, we placed three samplers at approximately 100 m intervals in the ex-medicago field along the line of the predominant wind direction. During one week, the wind was strong enough at times to cause the soil to blow, and large increases were observed, from one end of the field to the other, in the amount of airborne material collected.

Experience elsewhere indicates that wind needs a 200 m fetch over a specific surface to achieve about 90% of its bearing capacity. Thus the third (downwind) sampler gave a good measure of total soil loss due to wind. For the particular week in September this was about 2 t over a field width of 100 m. As no sampling had been possible before September, we had no dust data from the windiest season. However, from a detailed knowledge of the wind speeds both during the September sampling period and from the time of medic seed harvest, July 11, onwards until September, we could make some tentative extrapolations. The soil surface remained unchanged during this time (no tillage, no rain), so that wind speed was the only major factor involved. We calculate that the minimum amount of material moved off the 100 m field width during this time was 60 t, which represents a surface lowering of approximately 3 mm.

Atriplex species, drought-resistant fodder shrubs, planted to improve degraded dry rangeland (steppe) also control wind erosion; but extensive stands of shrubs may be less attractive to rangeland users than the quicker returns possible from ploughing and planting to barley; and wind erosion is a problem also of broad expanses of dry arable land already planted every year to barley. One possible remedy, for both situations, is to grow barley in strips between atriplex hedges planted transerve to the prevailing wind. To investigate this, an observation was started within existing atriplex plantations at the Syrian Steppe and Range Directorate's station at Mragha and a new trial initiated early in 1991 at our own site at Ghrerife.

In that trial, young atriplex bushes were planted in rows to produce two replicates of a partial factorial combination of four hedge designs and three widths of arable alleyway between; and barley was sown to initiate two arable rotations, barley-barley and barley-vetch. The main objectives are to monitor any crop-shrub interactions and to measure productivity (of crop, fodder and total value) per unit area. The first observation has been that the atriplex bushes grew much more rapidly where a little phosphate fertilizer was supplied at planting time.

On dry barley land, the risk of wind erosion might be much reduced if stubbles were not subject to intensive grazing during the long, windy summer; further, the retention of stubble and the delay or avoidance of tillage might also improve soil water relations for the succeeding crop. To quantify these effects -- and to set a value on them vis-a-vis the current value to farmers of stubble grazing -- a tillage and barley residue management trial was initiated at Breda in the 1989/90 season. The first meaningful results, i.e. from the second cropping season, 1990/91, showed a significant difference, as yet unexplained, between normal tillage and zero tillage (with direct drilling). Barley in zero-till land produced less dry matter but equalled or exceeded the grain yields of the barley on tilled land, through an appreciably larger harvest index.

Water Management (section 3.2)

Water is increasingly becoming the most critical resource in WANA agriculture. With little or no further expansion possible in the area of dryland cropping, water is seen by many as the key to production increases from more intensive, irrigated systems. But in most areas, water supplies are also under serious pressure. Such water as there is, in a generally dry region, must be used efficiently.

The main FRMP focus in water research has previously been on supplemental irrigation -- applying small amounts of water to increase and stabilize the yields of basically rainfed crops. Under new direction, this work will continue; but an effort will be made to give equal weight to water harvesting. The present report reviews briefly the present situation in both fields of work.

Phosphate Studies (section 3.3)

The availability to crops of added fertilizer phosphate declines more or less rapidly in most WANA soils. An ability to predict the time course of this decline in particular soils would facilitate a more efficient scheduling of fertilizer use. This requires a better understanding of the chemical processes involved and the soil factors influencing them.

Results of recent laboratory studies, collaborative with the University of Córdoba, suggest that the soil properties influencing the course of declining availability differ according to whether the rates of phosphate addition are high or low. At relatively low concentrations of phosphate in the soil solution, arising from low rates of addition, loss of availability seems to stem mainly from sorption processes controlled by iron oxide surfaces.

At high rates of addition, the soil solution becomes highly supersaturated with respect to the more insoluble calcium phosphate compounds. Sorption on iron oxide surfaces may also occur, but precipitation as calcium phosphate becomes the dominant process. However, since this precipitation appears to proceed from an initial adsorption of phosphate and crystal nucleation on calcium carbonate surfaces, the amount and reactivity of calcium carbonate in the system is a major influence.

The ultimate practical aim of this work is to optimize the size and timing of the phosphate addition from a knowledge of certain key properties of the soil concerned. These would appear to include the amount and reactivity of constituent iron oxides as well as calcium carbonate.

Soil and Crop Nitrogen (section 3.4)

The interactions between nitrogen supply (from soil and fertilizer) and water supply (from rainfall and supplemental irrigation) on the quantity and quality of cereal crops were discussed in last year's report. Three more sets of results amplify the story this year.

A major concern is the efficiency of use of nitrogen fertilizer on wheat. But what exactly is meant by efficiency? Increasing the nitrogen supply increases grain yield up to the point at which water is limiting. Beyond that, additional nitrogen tends to improve grain protein content and, possibly, other parameters of quality. For thirty wheat genotypes grown under rainfed conditions at two sites for two years, fertilizer utilization efficiency (kg grain/kg fertilizer N) was negatively and significantly correlated with grain protein %. However, some genotypes clearly had greater utilization efficiencies than others at the same level of grain protein content. Such genotypic difference might be utilized to produce cultivars able to achieve adequate grain quality under specific environmental conditions -- rainfed v. irrigated cropping, high v. low input environment.

That grain quality may easily be sub-optimal was demonstrated by the results of trials over two sites and seasons with four durum cultivars under supplemental irrigation. For the purposes of international trade, wheat grain should contain at least 12.5% protein. In these trials, this standard was not reached in 1989/90 at the highest rates of supplemental irrigation even with 100 kg fertilizer-N/ha; nor at a moderate rate of irrigation with 50 kg N/ha. However, in 1990/91, 50 kg N/ha was adequate to ensure the standard was achieved at all rates of supplemental irrigation, demonstrating the importance of site and seasonal effects. In this case, it seems likely that a greater initial soil content of mineral-N in 1990/91 was a major factor in the difference between seasons. Differences between cultivars were also evident; but, in general, it must be concluded that although quality is partly genetically controlled, it is also greatly influenced by weather, management and fertilizer use.

To return to fertilizer efficiency: results from 70 fertilizer trials on rainfed wheat showed -- as did those from 75 barley trials reported last year -- that as rainfall increased, grain and straw yields significantly increased but their percentage N contents significantly decreased. This decrease was particularly marked in the straw. Recovery of fertilizer-N in the grain, estimated as the difference in total grain content between crops receiving 0, 40, 80 and 120 kg fertilizer N/ha (at uniform rates of fertilizer P), was significantly related to seasonal rainfall and rate of application:

$$\text{Recovery ratio} = 0.28196 + 0.002715Q - 0.000002Q^2 - 0.001783N \quad (R^2 = 0.46^{**})$$

where Q is the total seasonal rainfall (mm) and N the fertilizer rate, kg N/ha.

Efficiency of fertilizer use (that is, N recovered in the grain) increased with increasing rainfall up to a maximum at around 680 mm and then decreased. It was also lower at higher rates of application.

Rotations (section 3.5)

Rotation trials focus on sequences of crops and their associated management, on the comparative productivity (biological and economic) of such sequences, and on the long-term trends in that productivity and in the condition of the soil supporting it. In the present report we summarize results from two barley rotation trials, at Tel Hadya and Breda, and give details of certain treatment changes recently made in those trials.

Changing treatments in rotation trials is controversial. Arguments favoring the replacement of outmoded and less effective treatments may be countered by arguments for continuity to ensure that long-term trends are unequivocally identified. The barley rotation trials at Tel Hadya and Breda previously compared six two-year sequences of barley with fallow, with barley and with four legume-based forages -- common vetch and chickling, each grown both pure and mixed with barley -- in partial factorial combination with six fertilizer treatments. Eight years' data have shown consistently that rotations involving legume/barley mixtures are slightly less productive than those with pure legumes. So, one of the mixtures has been replaced with the promising narbon vetch (Vicia narbonensis) grown pure; the other with common vetch, to be harvested by simulated green grazing -- in contrast to the mature harvest in other legume treatments. Other work has suggested that different modes of harvesting forage legumes alter the dynamics of soil water and nitrogen, with effects on the following cereal crop and overall rotational output.

Three of the previous fertilizer treatments compared different timings within the rotation of P-fertilization, but differences were small. So, the P timing has been standardized, and the comparison is now between different rates of N-fertilizer to the barley crop -- to investigate the interaction with previous crop. Altogether, ten of the original 22 treatments remain unchanged and allow the long-term comparisons of the basic rotations to continue, while the amended treatments bring in a new series of comparisons of both short-term and long-term interest.

Results from 1989/90 and 1990/91 (respectively, very dry and moderately dry seasons) support those reported previously. Rotations involving legumes (barley-vetch, barley-chickling) continued to outyield barley-only rotations (barley-fallow, barley-barley) in both total dry matter production and total crop N output. Mean ratios (%) of the former relative to the latter were:

		Total dry matter	Total crop N
1989/90	Tel Hadya	111	205
	Breda	81	115
1990/91	Tel Hadya	125	180
	Breda	123	189

Only in respect of total dry matter at Breda under extremely dry conditions did the barley-legume rotations fail to better the barley-only rotations; and, as previously, the presence of legumes increased rotational nitrogen yield -- that is, protein production -- by up to a factor of two.

Narbon vetch, in its first season, 1990/91, produced 20-25% more dry matter than common vetch and chickling, and crop N yield was similar or greater. Our main interest, however, lies in total rotational production, legume and barley, and first indications of that will not be available until after the 1991/92 harvest.

Soils were sampled from analysis from both these trials at the start of the 1990/91 season, eight years after they were initiated. Differences were found in organic carbon and total nitrogen contents, but with little consistent treatment pattern across the two sites. Differences in available P contents due to fertilizer were clear, however, with current values: from annual phosphate, 11.5-13 ppm; biannual phosphate, 5.5-6.5 ppm; zero-fertilizer control, 3 ppm.

2.2 Project 2. Agroecological Characterization for Resource Management

Agroecological Characterization: Preliminary Climatic Analysis for Syria (section 4.1)

Crop adaptation in Syria is strongly linked to the precipitation regime. This is represented in the precipitation-based agricultural stability zone system for the country, widely used by researchers and agricultural planners. However, between different parts of the country, but within the same stability zone, other aspects of the climate (e.g. temperature) may vary. If so, this would have implications for landrace, crop, or cultivar adaptation to different geographical areas.

To assess this possibility, a range of weather variables was examined for nine widely distributed government meteorological stations in three regions -- southwest, northwest, and northeast -- using data mainly from the period 1960-87. These weather variables consisted of seasonal precipitation amount, precipitation distribution through the growing season, winter thermal time, and frost occurrence. Data from three ICARDA meteorological stations were also used in some analyses.

The principal results are that, within a stability (precipitation) zone:

i) year-to-year variation in total precipitation is greatest in the northeast;

ii) the northeast receives, on average, greater than 50% of seasonal (Oct-May) precipitation after January 31, while on average in the northwest 50% is reached before January 31;

iii) the probability of significant late season (April-May) rainfall is substantially higher in the northeast than southwest, with the northwest intermediate;

iv) accumulation of winter (December-March) thermal time (important for crop development) is faster in the southwest than for areas of similar altitude in the north; and

v) frost probability is lowest in the southwest.

An important additional result is that, throughout northern Syria, there is a strong negative correlation between precipitation and frost frequency (and a positive correlation between precipitation and winter thermal time). Altogether, the implications are:

a) the earlier end to the wet season in the south may mean greater crop vulnerability to terminal drought (though this is at least partially compensated by faster phenological development);

b) the common assertion that frost risk is higher in north-eastern than in northwestern Syria is explained by the negative correlation between frost and precipitation, in conjunction with a greater land area having low rainfall in the northeast;

c) the predominance in northern Syria of wheat (a relatively long-season crop) in the wetter areas and barley (a relatively short-season crop) in drier areas is commonly attributed to rainfall, but this could also be explained by the higher rates of winter thermal time accumulation in wetter areas;

d) the predominance of wheat in the northeast may be related to the greater probability of late-season rain there (early-maturing barley being less able to capitalize on late rains); and

e) the prevailing concept for chickpea distribution, i.e. adaptation to a specific rainfall band (stability zone 1b), is not substantiated. (In fact, chickpea in the south, the major growing region, is predominantly in zone 2.) Climatically, chickpea distribution throughout Syria is more satisfactorily explained by acknowledging its thermal requirement (and/or cold temperature avoidance) as well as moisture needs. In addition, farmer preference for chickpeas over lentils in southern Syria may be a simple hedging strategy, because the moisture picture is better-known at chickpea seeding time. This advises caution in the application of simple zoning systems to crop distribution.

Estimating the Frequency Distribution of Farmers' Crop Yields (section 4.2)

In the diagnosis of constraints within farming systems, there is a need to quantify the uncertainty of crop yield at the farm level; but long time series of crop production statistics are rarely available at the level of disaggregation that is necessary. Estimates have to be made by other methods. As part of the agroecological characterization project in Morocco, a statistical method previously proposed by März was applied and adapted to estimate crop yields over time from data collected in interviews with farmers in a region of dryland farming (Doukkala-Abda-Chaouia). Farmers were asked individually to provide, first, estimates of the numbers of 'good', 'normal' and 'poor' seasons (per ten years) based on their long-term experience; then, the yields of wheat and other crops they associated with each type of season. These data were then used to generate 100-year runs of yield data.

The method has undoubted limitations. It does not allow for any carryover effect from one year to the next, as when water stored in the soil in a wet year is available to crops in the following year. It shows a positive correlation between yields of different crops at any one site, although -- through differences in the timing of crops and their individual susceptibilities to weather and disease events -- this will not always be the case. What the method does appear to provide, however, is a reasonably objective estimate of yield variability at the farm level (dependent only on the accuracy of farmers' recall).

Validation is not possible without many years of yield records from farms in the target area. Such data are rarely available. However, a small collaborative project is being developed with ICRISAT to follow up on long-running yield records from village level studies in India. These will be compared with results from a set of brief surveys and analyses using the methods described here.

Dryland Resource Management and the Improvement of Rainfed Agriculture in the Drier Areas of West Asia and North Africa (section 4.3)

Most problems of resource management are really problems of the land users, as resource managers, and the constraints under which they operate: poverty, adverse socioeconomic structures, lack of access to technical advice, etc. The Dryland Resource Management Project comprises a group of national case studies, which focus on just these issues. Each case study, conducted by a multidisciplinary team of national scientists, assesses an existing dry-area system of agricultural production and its impact on the natural resource base. The aim is to work with the land users to formulate recommendations for improvement. Details of studies in southern Jordan and southern Tunisia were given in last year's report. This year we summarize case studies being conducted in four other countries.

Libya. Scientists from the Agricultural Research Center in Tripoli are comparing different modes of land use employed over the last 15-20 years in a selected area of the Geffara plain, about 40 km south of Tripoli, in respect of their productivity, their effect on the soil and range vegetation, and their organizational structure and management. From analyses and surveys and from the experience and opinions of land users, the most appropriate strategies for future research and development will be determined.

Lebanon. Scientists from the American University of Beirut are studying a village on the eastern slopes of Mount Lebanon. They will document historical development and changes in the village and assess their effects on the resource base and resource management strategies. Biological, physical and socioeconomic determinants of these changes will be examined with a view to identifying possible improvements that can be made in current resource management.

Pakistan. Scientists from the Arid Zone Research Institute (AZRI), at Quetta, Balochistan are focussing on water harvesting. They will compare AZRI's water harvesting techniques with existing farmer practices in the Quetta area, and they will determine to what extent crop production is increased and production risks decreased in a water-harvesting system. The adoption potential of such techniques by farmers in highland Balochistan will be assessed.

Yemen. Scientists from the Agricultural Research and Extension Authority and from the University of Sana'a are studying the factors underlying the deterioration of the traditional system of water management in a mountainous area northwest of Sana'a. Terraces on upper slopes are breaking down and no longer control the water running from the catchment of uncultivated mountain rangeland above them, resulting in floods in the wadis below and serious erosion of agricultural land downstream.

Cukurova University/ICARDA Collaborative Project: Development of Small-Scale Farmers of Taurus Mountains of Turkey (section 4.4)

In 1990, Cukurova University (Adana, Turkey) and ICARDA, utilizing

Italian funds supplied through ICARDA's Highland Regional Program, began a project to identify constraints to agricultural productivity in villages in the Taurus mountains. Scientists from FRMP and PFLP fulfill a planning and advisory role.

Agriculture in the Taurus mountains is limited by the topography. Crops, wheat, mainly for subsistence, and barley for feed, are grown on small sloping fields with stony soils; but for many farmers the main enterprise is rearing animals, mainly goats. Project work by Cukurova scientists in the first year has been largely diagnostic, and sixty-three farmers were selected from eight representative villages for a fairly detailed survey, socioeconomic and technical.

Farm economies are, to an appreciable degree, subsistence-oriented, but cash income is obtained from the sale of animals and animal products (particularly cheese) and fruit (apples, grapes). Bee-keeping is a highly profitable activity for a small number of individuals, with potential for expansion and improvement. Income is also obtained from off-farm work as migratory labor and in local forestry activities, but the survey shows a large number of 'unused days'; and farm incomes are lower than those in many other parts of Turkey.

Potential areas for future research and technology transfer include improved crop production practices, in particular soil conservation, the appropriate use of fertilizers and the introduction of more locally adapted cultivars. Feed supply is a constraint to animal production. Mountain pastures, which still provide a major proportion of that feed, are under heavy grazing pressure; and it appears logical to promote the greater use of supplementary feeds and the cultivation of forage legumes on land currently fallowed. Some of these technical activities will be started in the second year of the project.

2.3 Project 3. Adoption and Impact of Technology

Impact of Modern Wheat Technology in Syria. Part One: the Adoption of New Technologies (section 5.1)

In partnership with the socioeconomic section of Directorate of Scientific Agricultural Research, social scientists in FRMP initiated a multi-year study on the adoption and impact of modern wheat production technology in Syria. The first year objectives were to develop baseline measures of use and adoption of technology by wheat producers in Syria and to describe present levels of adoption by environmental and farm system characteristics. The specific technologies covered were mechanization, irrigation, varieties, chemical fertilizers, herbicides, and insecticides.

An initial survey was conducted in 9 provinces representing some 91% of total national wheat area. The results tend to confirm published national statistics and recent trends. Syrian wheat production is over 90% mechanized, and some 35% of the wheat area surveyed was under either supplemental or full irrigation. Modern high-yielding varieties (HYVs) account for 87% of the area planted and are grown by 86% of the farmers surveyed. Chemical fertilizers, herbicides, and insecticides were used by 95%, 54% and 13% of wheat producers surveyed, respectively.

Adoption patterns reflect the success of government policy to introduce modern technology in wheat production. For example, the uptake curve of high-yielding varieties among farmers closely follows the historical release of new varieties and increasing amounts of seed available through the General Organization for Seed

Multiplication (GOSM). Since over 80% of farmers list government institutions as a primary seed source, varieties actually grown conform closely to government targeting. From an initial 5% in the early 1970s, the proportion of farmers growing HYVs more than doubled in each succeeding 5-year interval. Interestingly, the varietal replacement rate is low. By and large, farmers continue to grow the same varieties that they originally first adopted. Among those who first adopted HYVs before 1976, for example, varieties released after 1976 constituted only one-third of their area and their varieties grown in 1991. Replacement rates were over half this modest figure for later adopters.

Durum wheat HYVs are significantly more important in area than bread wheat; the ratio is 70:30. The most important HYV durum variety is Cham 1 (released in 1983) with 38% of the HYV durum area and 29% of farmers growing HYV durum wheat. Mexipak (released 1971) covers 54% of the HYV bread wheat area and 63% of farmers growing HYV bread wheat. Haurani, a durum, is the chief local variety (92% of local variety area).

Impact Assessment of Supplemental Irrigation on the Productivity, Stability and Sustainability of Rainfed Wheat-Based Farming Systems in Syria (section 5.2)

Farm Resource Management Program has now been conducting technical research on supplemental irrigation (SI) for about five years, in the form both of on-station trials and demonstration trials on farmers' fields. Parallel with this work has been a continuing study of the social and economic dimensions of SI: what the farmers are doing; how their systems and evolving and why; the implications for production levels, the stability of production and sustainability.

Much of this work is summarized in the present report. Data from farm and village surveys in northeast and northwest Syria, along with all available experimental results from trials and demonstrations and much secondary data, have been used to quantify crop production in situations with and without supplemental irrigation. Whole-farm budget models have been used to process values of physical productivity into estimates of economic productivity and thereby to compare four levels, or development stages, of SI enterprises. The stages, which tend to be sequential in any one enterprise, are marked by an increasing intensity of cropping; and cropping intensity — in turn, determined by the nature of the water resource and the available managerial skills -- is seen as the principal factor influencing the productivity and efficiency of the SI system.

The main focus is on wheat, but other crops have to be considered when evaluating the whole-farm situation; and the cropping pattern changes as the cropping intensity increases -- barley and legumes are replaced by higher-value summer crops and vegetables, although the proportion under wheat tends to remain static.

The quantitative effect of SI on wheat yields, and its margin of advantage over rainfed cropping in both physical and economic, vary greatly from year to year according to the background rainfall, but the following wheat grain-yield figures (taken from the village survey) indicate the approximate degree of difference:

Rainfed		Supplemental irrigation	
Yield range (t/ha)	% of farmers	Yield range (t/ha)	% of farmers
1.0 - 1.5	52	< 3.0	20
1.6 - 2.0	36	1.0 - 4.0	68
2.1 - 2.5	12	> 4.0	12

Calculations suggest that, relative to rainfed cropping, SI increases the net revenue from wheat: in a wet season by 30%; in an average season by 58%; and in a dry season, it makes the difference between a negative and positive net revenue. Three-season average values for profit per hectare are 6230 and 3580 SL/ha, respectively, for the with and without SI situations.

The effect on yield stability is no less important. One conclusion from this work is that, while SI cannot eliminate all influence of weather (mainly rainfall) on wheat yields, it can reduce spatial and temporal variability to a minimum. The farm survey data showed a reduction in the coefficient of variation of wheat yields from 86% for rainfed crops to 41% for SI crops.

On the question of sustainability, it is suggested that, in general, a farming system is more or less sustainable according to its reliance on "internal" and "external" resources. For systems based on supplemental irrigation, much depends on the source of water. Water pumped from an underlying aquifer may be considered an internal resource; but, if the level of that aquifer is falling, there may be no long-term sustainability.

Economic Analysis of Chickpea Production in Aleppo and Hassakeh Provinces of Syria (section 5.3)

Last year we reported results of a survey in Syria to assess the performance of winter-sown chickpeas under farmers' conditions and to hear farmers' views of their potential for adoption and positive impact. This year we summarize a thesis-related comparison, made concurrently, of actual on-farm costs and gross margins of winter and spring chickpea in Hassakeh and Aleppo provinces. These are the first such comparisons to be based on a large sample of ordinary farmers operating under commercial conditions; previous budget data on winter chickpea derived from a small number of farmers participating in on-farm trials.

Average yields of winter chickpea were 78% and 64% higher than those of spring chickpea in Hassakeh and Aleppo, respectively. Economic analysis shows that in Aleppo province the cost of grain production was 24.9 SL/kg for spring chickpea and 18.6 SL/kg for winter chickpea, while in Hassakeh it was 15.8 SL/kg and 13.5 SL/g, respectively. Further, when we compare gross margins, those for winter chickpea were 102% and 23% higher than those for spring chickpea in Hassakeh and Aleppo provinces, respectively.

Altogether, this research shows that the yields and gross margin of winter chickpea are higher than those of spring chickpea in both provinces. However, this fact is not known by most of the farmers. Some efficient extension work is necessary. Moreover, government should take steps to provide winter chickpea seeds and herbicides and a more efficient marketing organization.

2.4 Training and Agrotechnology Transfer

See Chapter 6 of this report.

3. PROJECT 1. MANAGEMENT OF SOIL, WATER AND NUTRIENTS

Introduction

This project has as its long-term goal the development of productive and sustainable agricultural systems which optimize the efficiency of use and which conserve the basic and vital resources of soil, water and crop nutrients. We seek to attain this goal through the following medium-term objectives:

- To develop an understanding of physical, chemical, biological and environmental principles which underlie and control the productivity and sustainability of agricultural systems and hence develop strategies for the efficient management of soil, water and nutrients.
- To provide data for the development and/or refinement of methods for the extrapolation of research findings in space and time. [Linked to Project 2.]
- To provide socioeconomic evaluation of problems of farming systems and of the adaptability of research results to strategies for resource management at the farm level. [Linked to Project 3.]

3.1 Soil Conservation

In implementing its resource management mandate, FRMP has expanded its activities in the broad field of soil management and conservation. Here we give first reports of three recently initiated studies: the testing and utilization of techniques for wind erosion measurement; an agronomic investigation of atriplex hedges intercropped with barley rotations; and a tillage and stubble management trial at Breda.

3.1.1 Wind Erosion Studies

K.B. Timmerman

3.1.1.1 Introduction

The aim of this study is to investigate soil erosion by wind and the conditions under which it takes place. Information about the magnitude of erosion losses and the relative importance of contributing factors would greatly assist the development of strategies to prevent or reduce them.

Wind erosion depends on the interaction between wind speed and soil resistance to movement. Erosion occurs when the wind speed exceeds a threshold above which the power of the wind to move soil particles is greater than the resistance of the particles to movement. This threshold speed is a function of the conditions on and near the soil surface. Altogether, we may express wind erosion in the following way:

$$E \propto F\ ((u),\ (c),\ (cr),\ (a.si),\ (a.st),\ (s.r),\ (\theta))$$

E = wind erosion
u_t = threshold wind speed
u = actual wind speed
c = surface cover
cr = surface crusting
a.si = aggregate size
a.st = aggregate stability
s.r = surface roughness
θ = moisture content

Estimated wind erosion increases rapidly with increasing wind speed in excess of the threshold value, being proportional to $(u-u_t)^3$ (Skidmore 1965).

Surface cover and vegetation are effective in reducing wind erosion damage. In Texas, covering 20% of the soil with simulated flat crop residues reduced soil losses by 57%, and a 50% soil cover reduced losses by 95% (Fryrear 1985); and fine, medium and coarse gravel spread uniformly at rates of 20, 50, and 100 tons per acre, respectively, adequately controlled erosion from a smooth, bare sandy loam where no traffic was involved (Chepil et al. 1963).

The characteristics of the surface cover, height, percentage cover and total biomass, influence wind erosion. If the soil surface is not covered by vegetation, the threshold wind speed is determined by the condition of the soil surface. Crusting is very important. Although it adversely affects other soil properties, such as aeration and water infiltration, if a crust is present no loose soil particles are available for transport, and no soil loss occurs.

In the absence of a crust, soil erodibility depends on aggregate size. Soil aggregates are held together by physical and chemical bonds. Their size depends on soil type and land-use practices, and their stability is a function of soil texture and calcium carbonate and organic matter contents. Aggregates larger than 2 mm are considered non-erodible. A higher moisture content increases the cohesive bonds within and between the loose soil particles and therefore reduces soil erodibility.

Surface roughness influences the energy distribution of the wind close to the soil surface. The greater the surface roughness, the lower are the wind speeds near the surface. Microrelief provides shelter areas in which small loose particles can be trapped.

In northwest Syria, erosive winds occur mainly during June, July and August. At this time of year, the soil is dry and the surface cover very sparse. After harvest, sheep graze cereal stubbles, so that large areas are left almost entirely bare.

Erodibility is increased as soil aggregates are pulverized by the hooves of sheep during grazing. Summer is therefore the period when wind erosion is most likely to occur.

The following report is in two parts. The first analyses available wind speed data and, making certain assumptions, assesses wind erosion risk at different sites in northwest Syria. The second presents actual soil erosion data from some of those sites during part of the 1991 summer season.

3.1.1.2 Wind Data Analyses for Northwest Syria

3.1.1.2.1 Wind Data in Northwest Syria

ICARDA maintains several weather stations in northwest Syria at which wind speed has been recorded. Data are available for the following stations (years, heights):

- Tel Hadya (36°01'N 36°56'E): (1979–1984) (2m)
  (1985–1990) (2m, 10m, max. at 10m, direction)
- Breda (35°56'N 37°10'E): (1981–1990) (2m)
- Khanasser (35°46'N 37°31'E): (1981–1986) (2m)
- Jindiress (30°24'N 36°44'E): (1981–1990) (2m)
- Bouider (35°41'N 37°10'E): (1986–1990) (2m; 2 years of wind data only)
- Ghrerife (35°50'N 37°15'E): (1986–1990) (2m)

3.1.1.2.2 Wind Speed Data at Tel Hadya

For Tel Hadya, analyses were based on 10 years' data of wind speed at 2 m and on 6 years' data of 10 m recordings of average speed, maximum speed, and direction. These are summarized in Tables 3.1.1-3.1.4.

The following can be concluded:

- Highest wind speeds occur in June, July and August. In November, December and January wind speeds are very low (Table 3.1.1).
- For 28 percent of days the average wind speed at 2 m is greater than 4 m/s (Table 3.1.2).
- For 90 percent of days the maximum wind speed at 10 m is greater than 4 m/s, and for 42 percent of days it is greater than 10 m/s (Table 3.1.2).
- Wind direction is predominantly W and NW in summer (90%), and N and NE in winter (50%) (Table 3.1.3).

Table 3.1.1. Monthly average wind speeds at 2 m (1981-1990), 10 m and maximum wind speed at 10 m (1985-1990), m/s

	2m	10m	10mx
January	2.27	2.76	6.17
February	2.61	3.50	8.76
March	2.77	3.85	9.52
April	2.68	3.42	9.00
May	3.13	4.17	10.72
June	4.65	5.87	12.90
July	5.59	6.53	12.85
August	5.25	5.83	11.73
September	3.64	4.12	9.74
October	2.40	3.02	8.02
November	1.95	2.58	6.56
December	2.12	2.62	6.40
Year	3.26	4.02	9.36

- Average daily wind speeds at 10 m greater than 4.5 m/s occur from W (Feb-Oct), NW (June-July) and E (Dec-Feb) (Table 3.1.4).
- The high wind speeds from the west and their frequent occurrence pose a major threat of wind erosion damage.

Table 3.1.2. Annual frequency percentage of daily average wind speed at 2 m, 10 m and maximum wind speed (m/s) at 10 m (Tel Hadya) (1985-1990)

	0-2	2-4	4-6	6-8	8-10	10-13	13-16	16-19	19-22	> 22
2m	32.4	40.7	18.1	8.4	1.4	-	-	-	-	-
10m	23.1	36.2	21.8	13.9	6.5	1.3	-	-	-	-
mx10	0.8	8.6	18.5	15.6	14.8	20.3	14.9	6.2	1.0	0.3

Table 3.1.3. Wind direction distribution (percentage) at Tel Hadya (10 m) (1985-1990)

	N	NE	E	SE	S	SW	W	NW
Jan	36.0	23.0	8.6	10.1	2.2	7.2	7.2	5.8
Feb	14.7	28.4	10.3	8.6	4.3	6.9	11.2	15.5
Mar	15.3	24.2	3.2	8.1	5.6	1.6	24.2	17.7
Apr	14.6	16.9	2.2	6.7	4.5	11.2	19.1	24.7
May	12.8	4.6	1.8	2.8	0.0	9.2	45.0	23.9
June	2.1	1.0	0.0	0.0	1.0	8.3	67.7	19.8
July	1.8	0.0	0.0	0.0	0.0	3.6	76.6	18.0
Aug	3.6	1.0	0.0	0.0	0.0	3.5	72.7	17.3
Sep	8.6	6.7	1.0	1.0	4.8	7.6	41.9	28.6
Oct	28.7	16.5	2.6	5.2	7.8	11.3	13.9	13.9
Nov	27.2	39.8	4.9	5.8	2.9	4.9	3.9	10.7
Dec	39.2	24.8	8.8	10.4	4.0	2.4	4.0	6.4
Year	17.1	15.6	3.6	4.9	3.1	6.6	32.3	16.9

Table 3.1.4. Monthly average wind speed (m/s) at 10 m, specified by wind direction (Tel Hadya) (1985-1990)

	N	NE	E	SE	S	SW	W	NW
Jan	2.3	3.1	4.5	1.9	-	2.9	3.1	3.5
Feb	2.7	3.2	5.0	2.4	-	3.5	5.9	3.4
Mar	3.1	3.4	-	3.6	2.4	-	5.0	3.6
Apr	2.8	3.0	-	1.7	-	2.8	6.2	3.1
May	2.7	-	-	-	-	3.8	5.7	3.8
June	-	-	-	-	-	3.3	7.0	6.0
July	-	-	-	-	-	-	7.4	5.3
Aug	-	-	-	-	-	4.0	7.3	4.1
Sep	3.1	4.1	-	-	-	4.2	6.0	3.3
Oct	2.8	2.8	-	1.8	2.3	3.4	5.4	2.5
Nov	2.1	2.6	-	1.5	-	-	-	2.0
Dec	2.4	2.7	4.6	2.3	-	-	-	3.4
Year	2.7	3.1	4.7	2.2	2.4	3.5	5.9	3.7

(Omits directions that occur on less than 5% of days)

3.1.1.2.3 Wind Speed Data at the Six ICARDA Weather Stations

Monthly and yearly average wind speeds at the height of 2 m for the six ICARDA stations are shown in Tables 3.1.5 and 3.1.6. At all stations, highest wind speeds occur in summer and lowest wind speeds in winter. The yearly average speed at 2 m is highest for Breda (3.66 m/s), but values for Tel Hadya, Khanasser and Ghrerife also exceed 3 m/s. Values for the stations with a shorter recording period have been adjusted (using a correction derived from Tel Hadya data) to allow for annual differences; so observed differences in wind speed cannot be explained by this factor.

There is no clear spatial relationship. Local differences in relief and land use may result in different levels of surface roughness and resistance against airflow. In the case of Jindiress, the weather station is located in an undulating environment; and there are high olive trees not too far away, which may reduce wind speeds. Differences in wind speed between Breda, Bouider and

Table 3.1.5. Monthly average wind speed (m/s) at 2 m for Tel Hadya, Breda, Khanasser, Jindiress, Bouider and Ghrerife

	TH	Br	Kh	Ji	Bu	Gh
Jan	2.27	2.96	2.49	2.11	1.74	2.62
Feb	2.61	3.60	2.82	2.43	2.17	3.03
Mar	2.77	3.36	2.78	2.51	2.80	3.03
Apr	2.68	2.97	2.69	2.50	2.59	2.66
May	3.13	3.59	3.17	2.74	2.88	3.00
June	4.65	4.94	4.50	3.84	3.43	3.98
July	5.59	5.60	5.00	4.57	3.27	4.17
Aug	5.25	5.02	4.59	4.36	3.29	3.73
Sep	3.64	3.67	3.45	3.10	2.28	2.84
Oct	2.40	2.88	2.09	1.98	1.67	2.56
Nov	1.95	2.56	2.19	1.82	1.49	2.27
Dec	2.12	2.82	2.40	2.06	1.51	2.35
Year	3.26	3.66	3.18	2.84	2.43	3.02

Table 3.1.6. Annual average wind speed (m/s) at 2 m for Tel Hadya, Breda, Khanasser, Jindiress and Ghrerife

	TH	Br	Kh	Ji	Gh
1980	3.49	-	-	-	-
1981	3.37	-	-	-	-
1982	3.32	3.65	3.18	3.04	-
1983	3.32	3.61	3.24	2.85	-
1984	3.28	3.83	3.38	2.92	-
1985	3.35	3.58	3.31	2.86	-
1986	3.21	3.68	-	2.87	-
1887	2.90	3.63	-	2.55	3.03
1988	3.04	3.53	-	2.63	2.88
1989	3.30	3.84	-	2.98	3.02
1990	3.29	3.70	-	2.78	3.16
av.	3.26	3.67	3.28	2.83	3.02
st.d.	0.16	0.11	0.09	0.16	0.11

Ghrerife are significant. Since the stations are quite close to each other, this is probably due to local differences in relief, surface cover and surface roughness.

Average annual wind speeds for individual stations show only small variability from year to year (Table 3.1.6). Between stations, values are well correlated for Breda, Khanasser and Ghrerife, places located close to each other. For stations that are further apart, there is no clear correlation.

3.1.1.2.4 Evaluation of Average Daily Wind Speed as a Measure of the Erosive Power on a Specific Day

Uncertainty attaches to using daily wind speed values to indicate the erosion hazard. Wind erosion occurs only when the wind speed exceeds the threshold value (for current surface conditions). If it does, then the erosion increases exponentially. On a day with an average daily wind speed below the threshold, erosion may still occur during any part of the day when the wind speed exceeds the threshold. Conversely, on a day with an average daily wind speed above the threshold, wind erosion may not occur for the entire day. The following analysis examines whether daily values of average wind speed can be used as measures of the erosive energy on specific days. The detailed wind speed data used were recorded at Mragha (35°33'N 37°40'E), where an automatic weather station was installed at a research station of the Syrian Directorate of Steppe and Range.

At Mragha, hourly averages, maximum wind speed and daily standard deviation were recorded from August 20 to November 20 1991. The average daily wind speed over the recorded period was 3.39 m/s, with a maximum value of 6.27 and a minimum of 1.57. The average maximum wind speed was 7.42 m/s, with a maximum value of 13.9 and a minimum of 2.8. Standard deviations range from 0.5 to 2.77.

Average daily wind speed could be used as an index of erosive power, if wind speed values were normally distributed over the day. This has been tested (χ^2-Test and Kolmogorov-Smirnoff Test) for hourly average wind speeds in the 93-day dataset from Mragha. Using a 10% significance level for the χ^2-test, wind speed showed a normal distribution on 87% of the days. The Kolmogorov-Smirnoff test is more sensitive than the χ^2 test to deviations in the tails of distributions where frequencies are low (Davis 1973). Using the same significance level, this test indicated that hourly wind speeds showed a normal distribution on all days.

An additional way to test the normality of the distribution is to compare the maximum wind speed recorded in the field with the maximum wind speed calculated from the average wind speed and the standard deviation. An assumption of normality underlies this calculation. Wind speed was recorded every minute of the day. Thus the maximum recorded wind speed was the highest value of 1440 samples. The chance of this measurement is 1/1440, which corresponds to a value of 3.197 in the Z-distribution. An estimation of the maximum wind speed is: average wind speed + (3.197 * standard deviation). For the 93 days, the average value of recorded maximum wind speed minus the estimated maximum wind speed is -0.19 m/s with a standard deviation of 1.0. This represents a good match between recorded and calculated maximum wind speeds, indicating that the data conform to the assumption of a normal distribution.

Regression analyses show a correlation coefficient between average daily wind speed and maximum wind speed of 0.83 and between average daily wind speed and the standard deviation of 0.78. The regression equations are:

Wind speed max. = 1.80 * wind speed av. + 1.31 (m/s)
Standard Error of Estimate: 1.35

St. Dev. = 0.40 * wind speed av. - 0.06 (m/s)
Standard Error of Estimate: 0.37

The equations may become more stable with a larger data set. They could be used where values for maximum wind speed and standard deviation are not available.

3.1.1.2.5 Calculation of Erosive Power

If wind speed is normally distributed, erosive power can be calculated from the threshold wind speed, average wind speed and standard deviation. The normal distribution allows the probability of any particular wind speed to be calculated. Values of erosive power for an individual day have been calculated for a range of net wind speeds (average wind speed minus threshold wind speed, $u-u_t$) and standard deviations (Table 3.1.7) as follows:

- The time scale for the calculations is seconds. Probabilities of the occurrence of particular values of net wind speed are calculated.
- For a large number of Z-values the net wind speed is calculated and raised to the third power. For each value, the contribution to total erosive power is obtained by multiplying by the probability of occurrence.
- The total amount of erosive power is the sum of all the subtotals.

Table 3.1.7 shows that, even with an average daily wind speed 2 m/s lower than the threshold value, there is some erosive power. When the daily mean windspeed is low, the amount of erosive power depends mainly on the standard deviation; for higher mean daily wind speeds the standard deviation is less important. Taking the cube

Table 3.1.7. Erosive power $(m/s)^3$ per day, according to net wind speed $(u-u_t)$ and standard deviation of the average wind speed on that day

Net wind speed (m/s)	Standard deviation of average daily wind speed						
	1.00	1.25	1.50	1.75	2.00	2.25	2.50
-2.0	0.01	0.03	0.11	0.30	0.65	1.21	2.06
-1.75	0.01	0.06	0.18	0.43	0.88	1.58	2.61
-1.5	0.02	0.09	0.27	0.62	1.19	2.05	3.28
-1.25	0.04	0.16	0.41	0.87	1.58	2.64	4.09
-1.0	0.08	0.26	0.61	1.20	2.09	3.36	5.08
-0.5	0.26	0.63	1.26	2.21	3.55	5.35	7.68
0	0.73	1.42	2.46	3.90	5.82	8.29	11.36
0.5	1.77	2.92	4.50	6.58	9.22	12.49	16.46
1	3.81	5.55	7.81	10.65	14.14	18.36	23.36
1.5	7.34	9.84	12.88	16.60	21.06	26.34	32.50
2.0	13.28	16.41	20.29	24.98	30.52	36.97	44.40
2.5	22.07	25.94	30.71	36.42	43.10	50.82	59.61
3.0	34.53	39.14	44.82	51.58	59.46	68.49	78.72
3.5	51.43	56.75	63.33	71.70	80.27	90.66	102.40
4.0	73.50	79.50	87.00	95.90	106.20	118.00	131.30
4.5	101.50	108.20	116.60	126.50	138.10	151.30	166.10
5.0	136.20	143.50	152.70	163.70	176.50	191.10	207.50
5.5	178.20	186.30	196.30	208.40	222.40	238.30	256.30
6.0	228.50	237.20	248.00	261.10	276.30	293.60	313.10
6.5	287.70	297.00	308.70	322.70	339.00	357.80	378.80
7.0	356.50	366.40	378.90	393.90	411.40	431.50	454.00
7.5	435.80	446.30	459.50	475.50	494.10	515.50	539.60
8.0	526.20	537.30	551.30	568.20	588.00	610.70	636.20

root of any value in Table 3.1.7 gives the net wind speed that, if blowing for 24 hours constantly, would produce an equal amount of erosive power.

The erosive power of the wind on any specific day may be calculated from the average wind speed on that day and assumed quantities for the threshold value and the standard deviation. But the calculation procedure is time consuming. Alternatively, a value for the amount of erosive power for a specific day can be read from Table 3.1.7, if data on threshold wind speed and standard deviation are available.

3.1.1.2.6 Erosivity for the Five Stations

At any particular site, the magnitude of the threshold wind speed depends on the size and density of loose soil particles and on soil surface conditions, which are partly controlled by land management. Values change over the season and are rarely precisely known. In the literature, a wide range of threshold wind speeds (m/s) are encountered:

- 4.1 (Malina 1941 in Skidmore 1965) for the transport of sand;
- 5.8 to 13.5 at a height of 30 cm, depending on the previous history of the field (Chepil 1945 in Skidmore 1965);
- 6.4 at a height of 2 m, for sandy material (De Boodt & De Vleeschauer 1981);
- 8 at a height of 6 to 8 m, for highly erodible soil (Bondy et al. 1980).

In the present calculation, the uncertainty of the threshold wind speed is dealt with by using three different values, 3, 5, and 7 m/s (at 2m height). These values are arbitrary but probably cover the values that usually apply in northwest Syria. For actual wind speed, average daily values are used, since calculation of the distribution of wind speeds over the day would have been too time consuming. The calculated erosive power levels are lower as a result, but this may compensate for the threshold wind speeds that have been chosen, which may be slightly low. These assumptions are acceptable, because the main purpose is to compare the different stations rather than to provide actual values of erosive energy. Bouider has been excluded because of its short recording period. For the other five stations, erosive power has been calculated in the following way:

- Assumed threshold wind velocities of 3,5 and 7 m/s at 2 m have been subtracted from the average daily wind speed values;
- If the subtraction is negative, the day is set to zero; if positive, the value is raised to the third power.

This provides erosive power values for every individual day. Tables 3.1.8, 3.1.9 and 3.1.10 summarize these values on a monthly basis for the three chosen threshold wind speeds.

Table 3.1.8. Average monthly erosive power $(m/s)^3$ for five stations in northwest Syria, assuming a threshold wind speed of 3 m/s

	TH	Br	Kh	Ji	Gh
Jan	28.2	246.0	38.0	21.8	95.6
Feb	68.0	577.0	134.0	57.5	140.0
Mar	47.7	260.0	42.1	20.8	100.0
Apr	41.7	61.0	28.1	12.1	20.3
May	97.4	194.8	101.0	27.3	35.2
June	572.9	662.5	301.0	190.0	163.0
July	1270.7	1296.0	520.0	458.0	228.0
Aug	978.8	682.0	313.0	298.0	123.0
Sep	224.2	163.0	95.9	73.8	15.3
Oct	32.2	116.0	16.2	6.1	47.6
Nov	5.0	144.0	21.4	7.4	21.1
Dec	44.1	473.0	45.6	27.6	80.9
Total	3411	4874	1656	1200	1070

Differences between stations in total erosive power are quite large. Because they depend on the third power of the net wind speed difference, they are much larger than the differences in average wind speed (Table 3.1.5). For the same reason, at each individual station, the total erosive power declines sharply with increasing threshold wind speed.

The erosive power is largely concentrated in June, July and August at all stations. At a threshold wind speed of 5 m/s, 90% of

Table 3.1.9. Average monthly erosive power $(m/s)^3$ for five stations in northwest Syria, assuming a threshold wind speed of 5 m/s

	TH	Br	Kh	Ji	Gh
Jan	1.3	51.6	2.3	0.7	12.6
Feb	7.1	163.0	17.4	4.8	20.8
Mar	2.4	47.8	2.4	0.2	7.9
Apr	1.0	2.8	0.2	0.0	0.1
May	6.5	24.2	6.7	0.3	0.1
June	68.4	95.8	18.9	22.5	5.5
July	217.0	254.0	42.8	46.8	15.2
Aug	151.0	90.7	12.0	20.5	8.1
Sep	22.2	18.4	2.6	5.5	0.0
Oct	2.1	15.2	0.2	0.1	1.5
Nov	0.2	39.1	0.4	0.4	0.5
Dec	6.5	139.2	1.1	1.3	10.5
Total	486	942	107	103	83

Table 3.1.10. Average monthly erosive power $(m/s)^3$ for five stations in northwest Syria, assuming a threshold wind speed of 7 m/s

	TH	Br	Kh	Ji	Gh
Jan	0.0	7.5	0.0	0.0	0.3
Feb	0.3	35.2	0.5	0.0	1.1
Mar	0.0	5.0	0.0	0.0	0.0
Apr	0.0	0.0	0.0	0.0	0.0
May	0.1	1.4	0.0	0.0	0.0
June	1.3	6.4	0.3	3.8	0.0
July	11.6	23.4	0.7	0.7	0.1
Aug	8.9	4.9	0.0	0.1	0.1
Sep	0.9	1.6	0.0	0.1	0.0
Oct	0.0	0.4	0.0	0.0	0.0
Nov	0.0	10.0	0.0	0.0	0.0
Dec	0.4	28.5	0.0	0.0	0.3
Total	23.6	124.3	1.5	4.7	1.8

the erosive power is concentrated in these months at Tel Hadya; at Jindiress, 87%; at Khanasser, 69%; and at Breda, 47%. The data of Ghrerife are less reliable because of the shorter recording period. All stations exhibit a substantial amount of erosive power in February in spite of a lower average wind speed. This is explained by the higher standard deviations in this month arising from a greater variability in wind speeds.

Values of total annual erosive power apparently vary appreciably from year to year at each station, particularly for higher threshold wind speeds (Tables 3.1.11-3.1.13). There is some correlation between the stations; 1984 and 1989 were years of high total erosive power and 1987 a year of low total erosive power. The year with the highest average wind speed was not always the year with the highest total erosive power. This is because erosive power increases exponentially with higher wind speeds. Years with higher variance in wind speed have a relatively higher total erosive power.

Table 3.1.11. Total annual erosive power $(m/s)^3$ for five stations in northwest Syria, assuming a threshold wind speed of 3 m/s

	TH	Br	Kh	Ji	Gh
1980	3639	-	-	-	-
1981	3366	-	-	-	-
1982	2891	5403	1458	1742	-
1983	3672	3781	1426	1325	-
1984	4675	6170	2440	1443	-
1985	4180	5086	1588	1190	-
1986	4057	4802	-	1064	-
1987	1623	3672	-	436	815
1988	1967	3832	-	615	952
1989	4183	7009	-	2091	1230
1990	3272	4744	-	997	1220
Av.	3411	4944	1757	1211	1054

Table 3.1.12. Total annual erosive power $(m/s)^3$ for five stations in northwest Syria, assuming a threshold wind speed of 5 m/s

	TH	Br	Kh	Ji	Gh
1980	480	-	-	-	-
1981	540	-	-	-	-
1982	339	1225	80	189	-
1983	489	607	47	112	-
1984	777	1228	188	102	-
1985	628	1241	124	74	-
1986	706	861	-	75	-
1987	148	521	-	12	38
1988	213	663	-	28	102
1989	607	1430	-	276	80
1990	419	897	-	59	98
Av.	486	964	110	93	80

Table 3.1.13. Total annual erosive power $(m/s)^3$ for five stations in northwest Syria, assuming a threshold wind speed of 7 m/s

	TH	Br	Kh	Ji	Gh
1980	11	-	-	-	-
1981	36	-	-	-	-
1982	8	220	0	3.8	-
1983	14	55	0	1.0	-
1984	41	153	1.8	0	-
1985	35	278	3.2	0.1	-
1986	60	77	-	0.6	-
1987	4	30	-	0	0.2
1988	5	70	-	0	4.9
1989	23	156	-	35.0	1.0
1990	24	113	-	0.3	1.3
Av.	24	128	1.3	4.5	1.8

3.1.1.2.7 Conclusions

Strong winds from the West in June, July and August bring the greatest threat of wind erosion in northwest Syria. Wind speed appears to be a very local and highly variable parameter. The significant differences between stations in recorded wind speed, and the lack of a clear spatial trend, make it impossible to interpolate wind speed for locations that lie between the stations.

On most days (at one station for which detailed data are available), wind speed shows a normal distribution. This is taken to justify taking average daily wind speed as a measure of erosive power. If values of the standard deviation of the wind speed and the threshold wind speed are also available, erosive energy can be accurately estimated.

Erosivity analyses show the great importance of threshold wind speed in the calculation of erosive power. This is a complicating factor in wind erosion research, because threshold wind speed is a dynamic parameter and difficult to measure in the field.

3.1.1.3 Measurement of Wind Erosion

3.1.1.3.1 Selection of Sites for Wind Erosion Measurements

Wind erosion has been measured at eight sites across four locations along a rainfall gradient, Tel Hadya, Breda, Ghrerife and Mragha (annual means: 327 mm, 262 mm, 244 mm and < 200 mm, respectively). There is also a soil gradient. At Tel Hadya, soils have vertic properties, due to the presence of smectite clay minerals. Clay and silt contents are 60 and 32%. At Breda (clay and silt contents, 40 and 42%, respectively) and Ghrerife (60 and 15%), vertic properties no longer occur. Organic matter content is less than 1% at all three locations.

At Mragha, soils have formed under completely different conditions. Gypsum content is more than 50%. The soils have a very massive structure. At the soil surface, there is an "organic crust" (OM > 4%) about 1 cm thick, which has been eroded over large areas.

At Tel Hadya wind erosion was measured at three sites, each under different utilization during the preceding cropping season: (1) bare fallow, (2) medicago seed production with vacuum seed harvesting, and (3) chickpea, harvested by combine. At Breda, two sites: (4) barley, hand harvested (plants pulled and all biomass removed), and (5) barley, harvested by combine. At Ghrerife: (6) barley and bare fallow strips between lines of Atriplex bushes; and at Mragha: (7) large field of degraded steppe, and (8) large field of 'improved' steppe (with planted Atriplex spp.).

3.1.1.3.2 Methodology

Modified BSNE-samplers, developed by the USDA at Big Spring, Texas (Fryrear 1986) to collect airborne dust under natural field conditions, and copied at the ICARDA/workshop, were used to measure wind erosion. Fryrear's composite dust sampler (Figure 3.1.1) consists of a vertical pin (1.5 m high) placed upright in the soil, on which four individual samplers are fixed. Each individual sampler has a wind vane and can rotate around its axis. The vane makes sure that the sampler is balanced and faces into the wind. The lowest sampler collects airborne material at two heights, approximately 5 and 10 cm above the soil surface. The other samplers collect material moving at heights of 20, 50 and 100 cm, respectively. Inside each sampler, level with the base of the opening, is a coarse mesh floor, through which the collected material falls into a tray. At the top, there is a fine mesh cover to allow the air flow. Each sampler can be opened, and the contents of the collection tray removed for weighing and analysis.

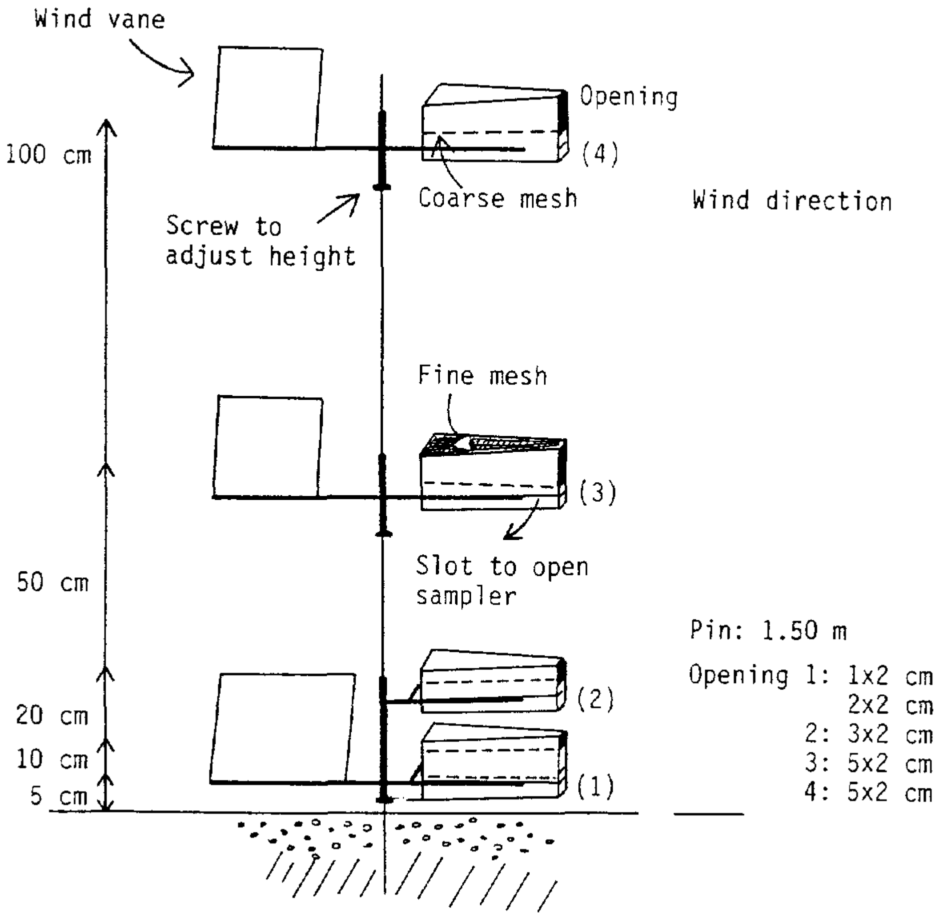

Figure 3.1.1 BSNE-dust sampler, for measuring wind erosion under natural field conditions

In each test field, three pins are installed in a line along the line of the predominant wind direction. In summer in northwest Syria, this is W and NW (90%). The first pin (west-facing side of the field) should preferably be installed near a non-erodible boundary, so that no locally eroded soil is collected. The amount of material collected here serves as a background value. The third pin should be placed at least 200 m downwind from the first pin.

The wind needs a 200 m fetch over a specific surface to reach about 90% of its bearing capacity. The second pin should be put half way between the other pins, to study the build up in the collected material.

In the wind erosion process, soil particles are transported in different modes: creep, saltation and suspension (Fryrear et al., unpublished). Creeping particles have a diameter of 1 to 2 mm. They are too large to be transported in the air and roll over the soil surface. Saltating particles have a diameter of 0.1 to 1 mm and, depending on surface roughness, particle size and distribution and wind speed, move in a series of short hops at heights generally below 1 m. Suspended particles range in diameter from < 0.001 to 0.1 mm and are subject to long-range transport.

At each pin, soil material moving in the wind is sampled at five different heights, and the total amount passing the pin is calculated by integrating the five sample values, as follows (after Fryrear et al., unpublished):

- the amounts of soil, collected at each height, are standardized to kg/m^2.
- for creep and saltation, the equation: $f = a * e^{y*B}$ is used, in which y is the height (m) above the surface and B is the slope of the creep/saltation curve. The standardized amounts of soil, collected at 5, 10 and 20 cm, are used to solve this equation, giving values, a_1 and B_1.
- for suspension, the equation: $f = a * y^{B}$ is used, in which y is the height (m) above the soil surface and B is the slope of the suspension curve. The standardized amounts of soil, collected at 20, 50 and 100 cm, are used to solve this equation, giving values a_2 and B_2.

- the height at which the two curves cross (X), considered to be the upper limit of saltation and the lower limit of suspension, is calculated.
- the amount of creep is calculated by integrating the creep/ saltation equation between heights 0 to 0.003 m, and saltation by integrating between heights 0.003 and X; and the amount of suspension is calculated by integrating the suspension equation between heights X and 1 m.
- the total amount of material passing the pin is the sum of creep, saltation and suspension.

This calculation procedure is computerized, so that only the values of the collected amounts of soil need to be entered to obtain a value for total erosion.

Other relevant measurements included: Wind speed and rainfall (all four locations) and wind direction (Tel Hadya only) (average daily wind speed values are available for Tel Hadya, Breda and Ghrerife; average hourly wind speed, maximum wind speed and standard deviation for Mragha). Aggregate size and stability. Soil surface samples were sieved by hand gently, to obtain the non-erodible-, creep-, saltation- and suspension fraction. Afterwards, the samples were sieved mechanically for 10 minutes, to study the breakdown of aggregates. Surface cover: less than 3% for all arable fields, which may be considered as effectively bare during the period of observations; but paddocks at Mragha had greater surface cover. Surface crusting and surface roughness: monitored to some extent.

3.1.1.3.3 Wind Erosion Measurements

Due to delays in the fabrication of the dust samplers, measurements were limited to the period, September 11 to November 11, 1991, which is after the end of the main erosive season. Wind speeds decreased from September onwards, and rainfall started in October.

Somewhat surprisingly, most erosion was measured at Tel Hadya, on the field previously under Medicago. The medic crop had been harvested by a vacuum seed harvester, and this operation destroyed the soil surface structure, leaving behind a highly erodible field. Aggregate size analysis showed that 67% of the soil surface material was in the saltation fraction (1-2 mm) and 6% in the suspension fraction. (Next to the medic field, a ditch was filled with eroded soil; 98.9% of this material was in the saltation fraction.)

Although measurements continued for two months, most erosion occurred during the period, September 17 to 25, when mean and maximum average daily winds speeds were highest -- 3.52 and 7.08 m/s, respectively -- and predominantly from the west. After this time wind speeds were lower, wind direction was variable, intermittent rain events occurred, and virtually no further soil loss was recorded. But during the critical week in September, over 2 t of soil were transported out of the field over a 100 m width. Figures 3.1.2 and 3.1.3 show the lateral and vertical distribution of the collected soil. Apparently, very little soil (16.2 kg/m^2) was moving at the beginning of the field (Pin 1); by half way (Pin 2) there was a significant increase (891 kg/m^2), and at the end (Pin 3) 2109 kg/m^2 was moving, presumably right off the field. Most of this soil was transported by saltation and the amount of collected material decreased sharply with height (Figure 3.1.3). This is a common feature in wind erosion and is consistent with the particle distribution found at the soil surface.

A single day can be identified as providing most of the erosion. On September 18, the average daily wind speed was 7.08 m/s and the predominant direction was west. The second highest daily

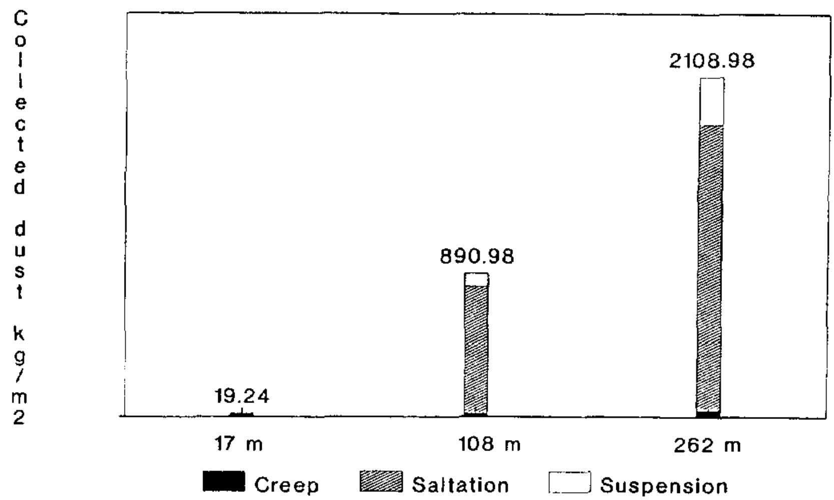

Figure 3.1.2 Lateral distribution of collected dust, medic field, September 17-25, 1991

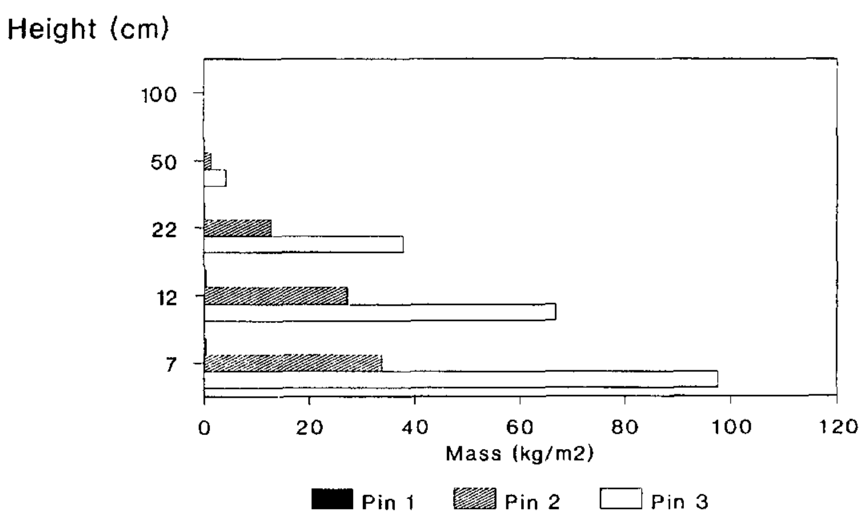

Figure 3.1.3 Vertical distribution of collected dust, medic field, September 17-25, 1991

wind speed (5.68 m/s) occurred on September 19. A wind speed higher than 5.68 m/s also occurred during another recording period, but that period produced much less soil in the samplers. Therefore most of the erosion recorded during 11-25 September seems likely to have occurred on September 18.

It is interesting to extrapolate these results to the whole period for which this vulnerable field was exposed to the wind. From July 11 to October 5, soil surface conditions must have been comparable to those pertaining on September 18. Analyses of wind speed for this period show that there were 16 days with average daily wind speeds between 7.08 and 8.08 m/s; 10 days between 8.08 and 9.08 m/s and 2 days between 9.08 and 10 m/s. If the erosion loss on each of these days was similar to that on September 18, total loss would have been over 60 tons. This corresponds to a surface lowering of approximately 3 mm. If we allow for the fact that erosion increases with wind speed and would therefore have been greater on some of the days, actual loss may well have been double that amount.

On the other two fields monitored at Tel Hadya, ex-fallow and ex-chickpeas, there was little erosion. In the main erosive period (September 11-25) there was some increase in material collected between the first and third pin, but in each case the amount collected at the end of field was less than 20 kg/m^2.

Examples of the soil surface material indicated, for the ex-fallow field, 54% in the saltation fraction and 5% in the suspension fraction; and for the ex-chickpea field, 68 and 4%. These values are higher than expected (and imply more erosion) but result from the sampling technique. The soil surface is disturbed when samples are taken, and the fragile crust breaks apart. This fragile crust provides significant resistance against wind erosion and covers fine particles that are not exposed to the wind. If a crust is present, the aggregate size analyses is useful only as a relative index. A technique to measure the erodibility of a crusted soil is not yet available.

No serious wind erosion was recorded at any of the other three sites. At Breda, there were two measuring periods before the first rain, during which the maximum daily wind speed was 5.83 m/s, appreciably less than at Tel Hadya. In neither test field was there any clear increase from one end to the other in the amount of airborne material. During the third recording period, October 1-8 (after rain), the maximum wind speed was 6.59 m/s. Approximately 40 kg/m^2 were collected at both fields, but the high percentage found in the suspension fraction is significant. Probably, this was not local erosion but dust received from the east.

At Ghrerife, the maximum daily wind speed (in the first measuring period) was 6.25 m/s. Little material was collected in the samplers. During the third recording period (October 1-8, maximum daily wind speed, 6.22 m/s, predominant direction ENE), 88 kg/m^2 was collected at the eastward pin, decreasing to 50 kg/m^2 at the westward pin, and during the fifth period (October 20-November 10, 3.84 m/s, N), 107 kg/m^2 was collected at the westward pin. These are probably not local erosion recordings, but dust received from elsewhere.

At Mragha, the maximum daily wind speed was 6.22 m/s (recorded during the period 16-22 September). Due to topography, wind speeds are probably higher in the unimproved (degraded) paddock; but little material was collected in either paddock. Most soil was collected during winds from the east, indicating dust from elsewhere.

The wind erosion action at Mragha appears to be different from that in the arable fields at the other locations. One obvious feature is the patchy removal of the protective organic crust, exposing the subsoil. Loss of this crust is serious because it contains soil nutrients and seeds. Below, the soil has a very massive structure. No soil samples have been taken for aggregate size analysis, because there are no individual aggregates. Although little dust has been collected, there is significant erosion damage near Mragha. It is not clear how this happened.

3.1.1.3.4 Conclusions

Although the recording period was short and limited to the end of the wind erosion season, the collected data are of considerable interest and, significantly for the future of this work, the methodology employed seems to perform well. In particular,

- The data of the medic field show that, in a highly erodible field, the lateral build-up of local wind erosion can be studied.
- It is possible to collect and identify very fine dust of non-local origin.
- Wind speed and direction data and information on lateral and vertical distribution of the collected material make it possible to determine the origin, local or otherwise, of the collected material

Soil management is a very critical factor. The exceptional case of the medic field has demonstrated how erosion can be accelerated perhaps one hundredfold by inappropriate management. Under normal conditions, Tel Hadya soils are not susceptible to wind erosion. The high clay content and calcium carbonate results in stable aggregates of sufficient size. In many cases, the soil surface is protected by a crust, but -- given reasonable tilth --

the absence of a crust does not greatly increase vulnerability to wind erosion. Had it been cultivated after harvest, the medic field would likely have been no more susceptible to erosion than those previously under fallow or chickpeas.

The low values recorded for soil erosion at the other sites probably reflect the timing of the measurements -- the period of strongest winds was already over -- and the relatively low erodibility of the fields used. Neither Breda nor Ghrerife arable soils lack natural structure; and the post-harvest soil surface of ICARDA-managed land, with or without crust or crop residues, will usually be sufficiently irregular to protect loose, erodible soil material from all but the strongest winds. As the Tel Hadya show, surface condition is the major factor on open land. Serious wind erosion can occur almost anywhere when the surface aggregates are pulverized, and this happens every year on farmers' stubble and fallow fields (and on grazing land) through the agency of small ruminant hooves. Such situations need to be included in future wind erosion studies, and simple preventive measures (strip tillage?) evaluated.

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3.1.2 Potential of Atriplex Hedges for Wind Erosion Control

M.J. Jones

3.1.2.1 Introduction

As mechanized tillage extends further into the flatter areas of dry rangeland and dry marginal arable, the danger of serious wind erosion intensifies. Appreciable wind erosion was observed in grazed fields of barley stubble in the Ghrerife area (barley-zone, mean annual rainfall, 250 mm approx) in 1990 and 1991. One potential solution to the problem is to plant windbreaks, but for these to be acceptable to farmers they should be productive.

Atriplex spp are drought-resistant fodder shrubs planted to improve degraded dry rangeland by government agencies in Syria and many other countries. The planting of such shrubs almost certainly controls wind erosion, but stands of shrubs may be less attractive to land users in steppe areas than the quick returns obtained from ploughing and planting to barley. One possible compromise -- applicable to both steppe and barley-zone conditions -- would be to grow the barley in arable strips between shrub hedges. The hedges, planted transverse to the prevailing wind, would provide erosion control and a grazing resource, while the greater part of the land surface could still produce barley and other feed crops.

Two activities were initiated in the 1990/91 season to follow-up on this idea: to provide experience of establishing and managing atriplex hedges; to investigate how well crops grow between those hedges; and to provide data of total productivity (crops and atriplex forage) on land effectively under mixed cropping. This appears to be a necessary preliminary to establishing demonstrations of wind erosion control by hedges, which would need to be a large-scale operation.

3.1.2.2 Observation at Mragha

The Steppe and Range Directorate of the Syrian MAAR maintains a large station in the steppe at Mragha (Aleppo province), about 30 km east of Khanasser), which has been largely planted to Atriplex spp. Some of this (mature) atriplex is in double rows with ploughed alleyways between, 10-12 meters wide. With the cooperation of the Steppe and Range Directorate Staff, short lengths of six of these alleyways were sown to barley in December 1990, to provide six replicates of two treatments: with fertilizer (20 kg N and 60 kg P_2O_5/ha) and without. Under a seasonal rainfall of 215 mm, which may be slightly above the long-term mean for this site, mean yields were:

	With fertilizer	Without fertilizer	
Grain	0.69	0.48	
Total dry matter	1.93	1.26	(t/ha)

3.1.2.3 Atriplex Trial at Ghrerife

Access to additional land adjacent to FRMP's small experimental field at Ghrerife made possible the planting of a new long-term trial (approx 4 ha) specifically to look at atriplex intercropping. In January and February 1991, around 10,000 young atriplex shrubs (Atriplex halimus) were planted out in a long sequence of rows, each approximately 60 m long, to comprise two replicates of a partial factorial combination of four hedge designs (varying number of shrub rows and inter-shrub distances) and three widths of arable alley-way. Half of each 60 m length of hedge was planted with phosphate fertilizer (about 5 g P, as single superphosphate, per shrub), half without. All bushes were watered at the time of planting and once subsequently (April). Two crop rotations will be grown on the arable areas, barley-barley and barley-vetch. In this first year, sowing was unavoidably very late, only barley was sown and the vetch plots were left fallow. The full rotations will be established in the 1991/92 season.

3.1.2.4 Comment

At least another year must elapse before this work begins to yield hard data; but, meanwhile, two observations may be recorded:

i. No interaction between mature atriplex shrubs and barley was evident on the barley grown at Mragha; crop growth and height was uniform across the width of the arable strip from one hedge to the other.
ii. Phosphate fertilizer very strongly promoted the growth rate of young atriplex shrubs at Ghrerife. Growth was very weak in the absence of fertilizer, particularly on those parts of the site that had not previously been under crop experiments. (Across the site as a whole, values of Olsen available-P

ranged from 1.8 to 5.2 ppm; mean, of 10 samples, 3.1 ppm).

3.1.3 Tillage and Barley Residue Management Trial at Breda

M.J. Jones and H. Harris

3.1.3.1 Introduction

The increasing intensity of cropping and tillage across wide open tracts of arable land in dry areas is increasing the risk of wind erosion. The areas concerned support large populations of small ruminants, and most stubble and crop residues are intensively grazed. Particularly after a poor rainfall season, flocks are herded across the same field several times during the long hot summer, until very little plant material remains and any soil-surface structure or roughness has been largely broken down. Given the value of animals and animal feed, this practice will not be readily changed; but it is still important to quantify what is happening and to establish the value (and costs) of alternative, more conservative practices, such as stubble retention.

Further, in some environments, the retention of cereal stubbles after harvest is said to reduce evaporative loss from the soil and to contribute to a better water balance of the succeeding crop. While it seems unlikely that the same will happen in the dry barley lands of Syria, it is necessary to obtain some hard data to settle the issue. It is possible, also, that retention of crop residues on the soil surface may, with time, improve the surface structure and in turn, the slow rate of infiltration into the silty, capping soil. Since small quantities of additional stored water can have a significant effect on crop production, efficiency of infiltration could be important.

For these purposes, a "tillage and barley residue management" trial was established on a 2.5 ha field at the Breda station in the

1989/90 season. The five main treatments examine the questions of: tillage v. no tillage; time of tillage; straw retention; stubble retention, in the following combinations:

	Tillage†	Tillage when	Straw*	Stubble*
1.	Yes	October	Remove	Graze
2.	Yes	October	Remove	Leave
3.	Yes	June	Remove	Graze
4.	No	-	Remove	Leave
5.	No	-	Leave	Leave

† Ducksfoot
* Straw removal and stubble grazing, soon after harvest, May/June

[The direct-drill ('zero-till') planter, necessitated by treatments 4 and 5, is used to plant the whole trial, to ensure uniform row-spacing and seed rate.]

These treatments are applied after the harvest of all barley crops in the two rotations, barley-barley (B-B) and barley-vetch (B-V). Both phases of each rotation are represented each year, and the barley crop in the first phase receives phosphate fertilizer in the seedbed. (Further, each barley plot is divided into three subplots to carry three N-fertilizer treatments, 0, 20, and 40 kg N/ha. These are applied in both phases of the B-B rotation but not to the vetch in the B-V rotation.)

All the vetch crop is harvested as hay, so there are no subsequent 'straw' or 'stubble' treatments, but the pattern of the tillage treatments is the same as that following the barley crop.

The first crops were planted in this trial in 1989/90. The 1990/91 crops were thus the first to follow the various tillage and residue management treatments. Their yield data are most easily considered in three groups: barley in B-B rotation, barley in B-V rotation, and vetch in B-V rotation.

3.1.3.2 Yields of Barley in B-B Rotation

There were three experimental factors operative: (i) P-fertilizer application -- because both rotation phases are represented and the P addition is biannual, half the plots received P in 1990/91, half did not; (ii) three rates of topdressed N-fertilizer; and (iii) the five management treatments involving tillage and the disposition of barley residues from the previous season.

The main effect of applied P was small and non-significant, but that of N was positive and highly significant in respect of grain, straw and total dry matter. However, there was also a strong NxP interaction (Table 3.1.13). Yields of grain and straw responded to N much more strongly in the presence of applied P.

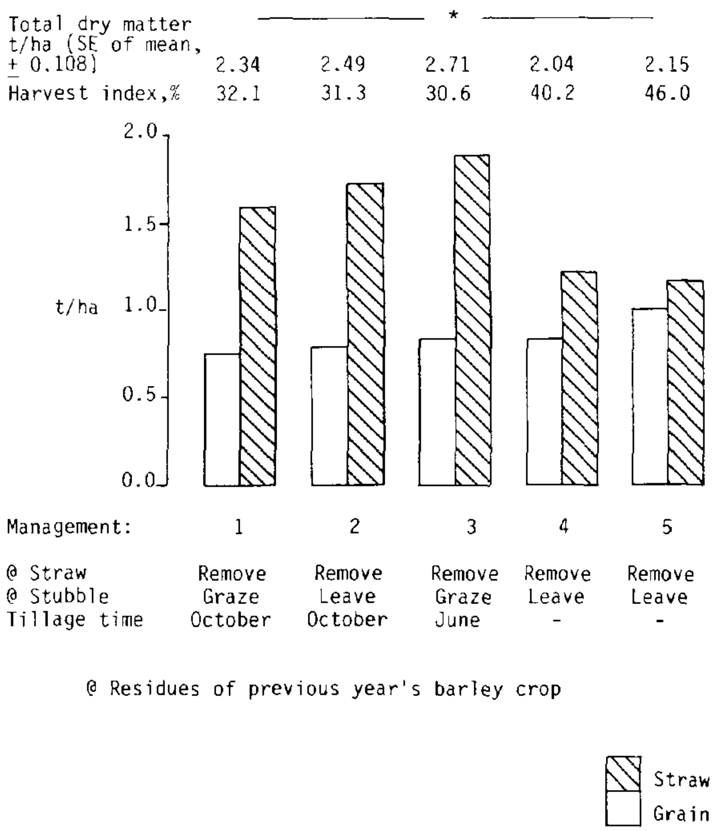
These values are means across the five management treatments; but there were also significant differences between management treatments in straw (and total dry matter) yield and significant interactions between management and N-fertilizer rate. Straw yields

Table 3.1.13. Tillage and barley residue management trial, Breda: interaction between applied fertilizer N and P on yield of barley in barley-barley rotation

N, rate kg N/ha	Grain		Straw	
	+P	O	+P	O
	***		*	
0	0.69	0.68	1.20	1.33
20	0.87	0.94	1.64	1.41
40	1.02	0.80	1.91	1.58
SE of mean	±0.034		±0.077	

CV's of subplots: grain, 12.9%; straw, 16.2%

were significantly lower in the two zero-till treatments, although grain yields were unaffected (in fact, the treatment, № 5, in which the crop had been drilled directly into the previous season's straw and stubble gave, non-significantly, the highest grain yield) (Figure 3.1.4). Responses to 40 kg N/ha (over zero-N control) ranged from only 0.32 and 0.20 t dry matter/ha in treatments 1 and 4, respectively, to 0.79, 1.09 and 1.14 t/ha in treatments 2, 3 and 5.



<u>Figure 3.1.4</u> Tillage and barley residue management trial at Breda: effect of management treatments on barley grain and straw production, 1990/91 (SE's of means: grain, 0.06 t/ha; straw, 0.09 t/ha)

3.1.3.3 Yields of Barley in B-V Rotation

Uniform P-fertilizer was applied in this phase, and the experimental factors were (i) the three rates of topdressed N-fertilizer; and (ii) the tillage component (only) of the five management treatments.

Mean yields were almost identical with those in the fertilized phase of the B-B rotation (grain, 0.86 t/ha in both cases; straw, 1.58 t/ha in B-B rotation, 1.55 t/ha in B-V rotation). However, there was no significant response to N-fertilizer; compared with those in B-B rotation, yields were slightly higher in the N_0 treatment, slightly lower in the N_{40} treatment. Responses to tillage treatment were similar to those in the B-B rotation, with significantly lower straw production (but higher harvest indices) following direct-drill (zero-till) planting (Table 3.1.14).

Table 3.1.14. Tillage and barley residue management trial, Breda: effect of management treatments on yields of barley and vetch hay in the B-V rotation

Treatment Nº:	1	2	3	4	5		
Tillage time:	October	October	June	-	-	Signif.	SE of mean
Barley, t/ha							
Grain	0.81	0.82	0.87	0.88	0.91	ns	±0.067
Straw	1.87	1.52	1.90	1.33	1.14	***	±0.064
TDM	2.68	2.34	2.77	2.21	2.05	**	±0.090
Harvest index	30.3	35.0	31.3	40.0	44.3		
Vetch hay, t/ha	1.40	1.35	1.53	1.51	1.83	*	±0.080

3.1.3.4 Yields of Vetch Hay in B-V Rotation

Vetch followed the full range of barley residue and tillage management treatments. The significant difference between these treatments that shows up in the hay yields (Table 3.1.14) arises mainly from Nº 5 (retain hay and stubble; zero tillage). This treatment yielded 0.38 t/ha (26%) more hay dry matter than the mean of the other four treatments.

3.1.3.5 Discussion

The results presented here are from one year only and must be regarded with caution. However, the main focus of the trial is on the barley residue and tillage management treatments, and it is interesting that significant differences have emerged between these treatments so soon. There were some indications that June tillage (trt. 3) had led to higher yields of barley and vetch than October tillage (trts 1 and 2), but these differences were not significant. However, between tillage (at either time) and zero-tillage, differences -- for barley straw consistently across both rotations -- were significant. It appears that barley crops in zero-till treatments produced less dry matter but equalled (or exceeded) the grain yields of the tilled treatments through a larger harvest index. For the vetch crop, the pattern of dry matter production was reversed: one (but only one) zero-till treatment significantly outyielded the rest.

No interpretation of these findings can yet be offered. Measurements of soil water are made in selected management treatments, viz nº 1, 2 and 5, at the middle level of N fertilizer application. Differences in storage between treatments where the residues are fully used or fully retained (Figure 3.1.5) were

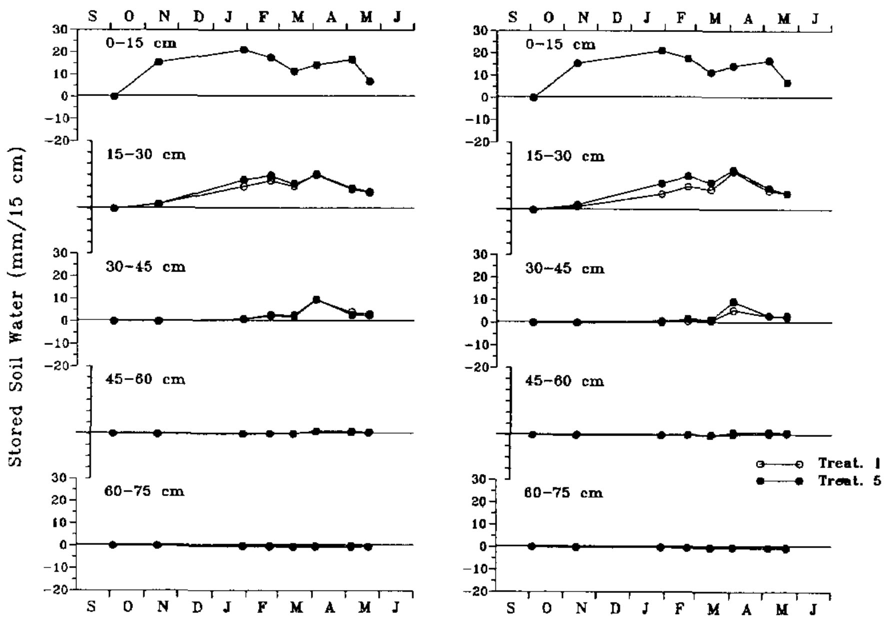


Figure 3.1.5 Soil water storage under tillage/residue treatments 1 and 5, in continuous barley (left) and vetch (right)

consistent in this first year. However, they appear to be too small to explain the differences in production noted above. It is expected that much more time will be required before significant changes occur.

3.2 Water Management

The second major resource that FRMP is concerned with is water. In the past, the main research focus has been on supplemental irrigation -- applying small amounts of water to increase and stabilize the yields of basically rainfed crops. This work will continue, but at the same time new initiatives will be undertaken in the field of water harvesting. Here we review briefly the current position in both fields.

3.2.1 Supplemental Irrigation

T. Oweis

3.2.1.1 Summary of Previous Research and Activities

Rainfall characteristics (amount, frequency and intensity) are rarely optimal for rainfed crop growth. In consequence, yields are often low, and variation between years is large. Some of the risk and variation inherent in these conditions can be alleviated by supplemental irrigation, which provides needed moisture when the weather fails.

To explore the potential of SI to improve and stabilize wheat production, a collaborative program was initiated in 1985/86 between ICARDA and the Syrian Ministry of Agriculture and Agrarian Reform (MAAR). It included diagnostic and impact surveys, basic research at Tel Hadya and MAAR stations and field demonstrations on farmers' fields.

The research looked at the effect of different rates of SI on wheat yield, varietal effects and interactions with nitrogen fertilization. In summary, the results showed:

a) At Tel Hadya, SI was needed every year, even when total rainfall reached 500 mm, but the number of irrigations and the amount required varied considerably from year to year. A total of 60 mm in one or two irrigations was sufficient in a wet year, but as much as 180 mm in 3-4 irrigations was needed in a dry year. Rainfall distribution was crucial. More than twice as much water was needed in 1985/86 as in 1986/87, although the total rainfall was the same in both years, 315 mm. When rainfall started late, SI to initiate germination showed great impact on yield.

b) Yield can be increased significantly by providing relatively small amounts of SI at critical stages of growth. The best example is the 1986/87 season (rainfall, 315 mm) when wheat grain yield was increased from 1.78 t/ha to 5.35 t/ha by just two irrigations: 20 mm to initiate germination, followed by 40 mm in the spring. However, differences are smaller when rainfall distribution is more even.

c) SI greatly improved water-use efficiency. In 1986/87, wheat production increased from 0.56 kg grain/m^3 of water under rainfed conditions to 5.95 kg/m^3 with supplemental irrigation. The economics of SI depend largely on the cost of irrigation and the price of wheat. However, under the Syrian conditions, SI economics were very favorable even when pumped groundwater was used.

d) In field demonstrations, conducted in cooperation with the Directorate of Agricultural Extension since 1988/89, the mean wheat yield for 5 sites was increased from less than 0.8 t/ha under rainfed conditions to over 4.8 t/ha with SI, with respective coefficients of variation reduced from over 100% to only 10%. Supplying 50% of the theoretical water balance at farmers' fields caused only 10% reduction in yield. But farmers showed a tendency to overirrigate. In some cases they applied more than 300% of the required amount to get yields 22% lower than those of the research trials.

3.2.1.2 Major SI Research Issues in WANA Region

The research done so far has demonstrated the technical and economical feasibility of SI. It has also laid the groundwork for further studies aimed at optimizing this practice.

Scheduling SI (when to irrigate and how much water to apply) for optimal results continues to be a high research priority. The main problem lies in the unavoidable dependence of scheduling on rainfall which is itself highly variable. It is important not only to develop optimal schedules but also to make such schedules simple and practical enough for ordinary farmers to apply. Current scheduling techniques on demonstration farms depend on the daily measurement of class A pan evaporation and rainfall. Calculations of water balance are needed before decisions on whether to irrigate and how much to apply can be taken. Evaluation of this technique in terms of farmers adaptability and acceptability are needed. Possible simplifications and/or alternative methods may then prove to be necessary. Alternative methods include the evaluation of soil moisture content and irrigating at sensitive stages of growth.

Previous research was largely on wheat, but relatively few varieties were tested. Ideally, a wide range of varieties should be tested for response to SI, including those that perform well under irrigated conditions. Screening across a range of water management alternatives should perhaps become a regular part of the varietal selection process. Other crops also have good potential under SI. Some work has been done on barley, lentil and, recently, sunflower, but these crops and chickpeas need further attention.

The profitability of SI depends strongly on the available water resource. Conventional cheap water resources are often reserved for fully irrigated agriculture. Rainfed areas usually have limited, costly and sometimes lower-quality water. Groundwater, water harvesting, springs and effluent water are the most common sources. Due to the unique water supply schedule required by SI, the development and management of these resources is different from those for full irrigation and requires more research attention.

Further, conventional irrigation systems used for full irrigation are often unsuitable for SI, both technically and economically. Permanent irrigation systems are designed to be operated continuously to justify the investment cost, but under SI the only occasional use may make such systems uneconomic. Low-cost systems with high flexibility and mobility need to be developed in parallel with optimal SI management.

All ICARDA's initial work on SI was conducted in Syria; but, more recently, collaboration has been established with Libyan scientists and a new program started in Jordan. However, a better understanding of the SI concept needs to be extended to other WANA countries, and collaborative research programs set up in areas of appropriate potential. Ultimately, those should provide enough data from different environmental conditions to enable us to assemble and verify a comprehensive SI package (model) to be used by national programs to determine optimal management strategies for their prevailing farming conditions.

3.2.2 Water Harvesting

T. Oweis

3.2.2.1 Introduction

The term "water harvesting" covers a range of activities by which rainfall runoff is collected and/or concentrated for improved cropping, livestock watering and domestic use. It has most significant application in drier areas where rain events are sporadic and unpredictable. Water harvesting has been widely practised for thousands of years for both domestic and agricultural purposes, not least in WANA countries, where evidence of many different water harvesting techniques can still be found. Indeed, some old systems are still in use. These old techniques are now receiving more world attention, as the intensifying demand for food increases the need to make better agricultural use of lower potential areas.

Depending on local conditions, water can be collected from runoff that is either natural or enhanced by various land-surface treatments. Collected water can either be stored in the soil profile for direct crop use or in reservoirs, to be used later for irrigation. Concentrating rainwater on to part of the land makes reliable agricultural production possible where it would otherwise not be, improving the efficiency of use of both water and land.

3.2.2.2 Major Issues of Water Harvesting Research in WANA Region

Some ancient water-harvesting systems still survive in certain WANA countries like Libya and Yemen. Others are variously recorded in the literature. Almost certainly, the development of modern systems could benefit from a study reviewing the experience and knowledge of indigenous, regional water-harvesting systems, past and present.

From other parts of the world, substantial research is on record concerning water-harvesting techniques, rainfall and runoff characteristics, runoff promotion and the area ratios needed between catchment and target fields; but transferability has not been tested. Such issues set the priorities for future research, which will need to be a mix of adaptive and some basic research, depending on local circumstances.

Most existing water-harvesting systems and trials show increases in crop yields; but those increases do not always meet the high expectations often placed in water-harvesting. Only "moderate" improvements in yield have disappointed some arid-land researchers. However, the point here is that water stress is not the only limitation to yield improvement. Unfavorable soil characteristics, temperatures and other factors may greatly impede response to improved moisture conditions. For example, crust formation is a major limitation both to crop germination and to the infiltration of harvested water in the Jordan steppe. Research must therefore integrate water harvesting with other factors in the farming system.

Human factors are also important. Even successful demonstrations of water-harvesting techniques do not always induce adoption by farmers. Reasons may include lack of training, ineffective extension and the fact that these techniques are strange to the area. Research needs to include studies of farmer needs and perceptions as they relate to water-harvesting.

3.2.2.3 Previous Work and Research Priorities

Although research and technology transfer programs for water-harvesting are only now being started at ICARDA base, there has already been some recent progress elsewhere in the region. Probably the most important is the collaborative development of "Kushkaba" systems with AZRI in Quetta, Pakistan. On-farm water harvesting with catchment:target area ratios of 1:1, 2:1 and 3:1 have been tested for wheat and barley production. Results from three seasons seem encouraging.

A preliminary cooperative survey with the national program, which assessed the potential for developing water harvesting systems in the northwest coastal area of Egypt, has yet to be followed up; but more recently, a program to establish a water harvesting-supplemental irrigation pilot farm has been initiated with Jordan. Potential collaboration with other WANA countries is being sought. In addition, it is planned to select a permanent site for water-harvesting research and training which might serve all WANA countries. Research will focus on testing and transferring water harvesting techniques to appropriate areas and farmers.

3.3 Phosphate Studies

Phosphate deficiency is the nutritional factor most limiting crop production over the drier parts of the WANA region. Yields can often be substantially increased by phosphate fertilization; but fertilizers are costly, and percentage utilization of the applied nutrient is low. This inefficiency is a consequence of the complex chemistry of phosphate in calcareous soils. To develop strategies to improve the efficiency of soil and fertilizer phosphate utilization, a better understanding of the predominant chemical processes is required. The following section reports studies with this aim.

3.3.1 Availability of Phosphate Applied to Calcareous Soils of West Asia and North Africa*

J. Torrent (Córdoba University), E. Afif (graduate student) and A. Matar (FRMP)

3.3.1.1 Introduction

Owing to surface adsorption and precipitation processes, not all the fertilizer phosphate applied to soils is available to plants. In calcareous soils, abundant in arid and semiarid areas, precipitation of highly insoluble Ca phosphates is supposed to be a major factor in the time-loss of P availability. In support of this contention, the fertilizer P availability index (AI), measured as the ratio of Olsen-P or labile (resin) P to applied P, applied, was found to be negatively correlated to $CaCO_3$ content for a group of 20 calcareous soils of the continental U.S. (Sharpley et al. 1984). For another group of 23 calcareous soils of several countries, Sharpley et al. (1989) defined AI as the ratio between Olsen P and applied P, and

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* This work is part of a joint project between ICARDA and Universidad de Córdoba (Spain)

found that the decrease in AI between 30 and 180 d after P application also correlated to $CaCO_3$ content. In contrast, for six calcareous soils of Lebanon, Ryan et al. (1985b) found that the AI was unrelated to total or "active" $CaCO_3$ (Drouineau 1942) content but related to the amount of Fe oxides. This possible influence of the Fe oxides on the availability of P applied to calcareous soils merits further attention; these minerals appear to be the most active P sorbents in the calcareous soils of the Mediterranean region (Solís and Torrent 1989; Peña and Torrent 1990).

The objective of this study was to investigate how P availability was related to soil composition, to time after P application, and to P application rate for a group of calcareous WANA soils. These soils ranged widely in their contents of $CaCO_3$, Fe oxides and other soil components believed to influence P availability.

The 19 samples used were collected from the surface (0-20 cm) horizons of Entisols, Inceptisols, Alfisols, Aridisols, Mollisols and Vertisols of several important agricultural areas in Jordan, Syria, Tunis and Pakistan. These samples were analyzed for particle size distribution, organic carbon and pH in water (soil:solution ratio 1:2); for cation exchange capacity (CEC), $CaCO_3$ equivalent (CCE) and "active" $CaCO_3$ equivalent (ACCE) (Drouineau 1942); and for citrate-bicarbonate-dithionite and oxalate-extractable Fe (Fe_d and Fe_o). Results are summarized in Table 3.3.1.

Phosphate sorption curves were determined by the method of Fox and Kamprath (1970) for the 0-3 mg P/l equilibrium concentration range. The sorption data were fitted to the Freundlich equation expressed as $X = Ac^b$, where X is the amount of P sorbed, c is the concentration of P in the equilibrium solution and A and b are constants. In the calculations, native sorbed P, measured by the

Table 3.3.1 Properties of selected calcareous soils of the West-Asia and North-Africa region

Soil	Clay	Organic matter	pH (water)	CEC[†]	CCE[†]	ACCE[†]	Fe_d[†]	Fe_o[†]	Olsen P	Resin P	P sorption parameters[‡] A	b
	--- g/kg ---			$cmol_c/kg$	--------- g/kg	---------			------ mg/kg ------			
Husn	590	14	8.1	61	80	33	15.9	1.7	8.2	13.0	149	0.53
Sarihe	470	14	8.3	50	200	80	10.7	1.6	5.3	11.3	169	0.49
Bichra	720	11	8.1	75	110	43	12.7	1.9	3.4	6.8	186	0.49
Birg-el-Amri	320	12	8.4	27	80	40	10.0	1.0	9.7	18.1	102	0.41
Haouaria	380	11	8.3	22	30	15	21.3	2.2	5.0	6.8	152	0.46
Pakistan	130	5	8.9	10	250	33	6.2	0.7	7.1	24.3	55	0.41
Ezraa	630	14	8.2	69	130	48	16.2	1.6	6.4	12.5	167	0.52
Breda	260	10	8.4	32	330	83	13.4	1.8	2.7	12.2	127	0.47
Tel Hadya	550	7	8.2	61	230	61	20.8	2.1	3.0	8.3	161	0.47
Jindiress	700	14	8.1	69	190	86	15.0	1.7	2.4	5.6	155	0.53
Raqqa	90	4	8.7	10	170	15	3.3	2.5	6.9	17.1	49	0.35
El Haffeh	760	16	7.8	42	20	5	53.2	4.9	3.9	6.1	578	0.41
Bassa	50	1	8.9	8	490	45	4.0	1.8	2.1	5.7	81	0.33
Tel Kallahk	270	13	6.8	45	30	5	46.2	4.7	4.3	10.2	246	0.40
Blass	470	5	8.4	53	220	50	15.4	1.8	2.3	8.8	142	0.46
Tel Zegram	420	20	8.4	23	490	148	0.4	1.3	6.3	11.7	114	0.41
El Jayed	630	53	8.0	79	170	80	3.2	2.2	6.2	16.1	148	0.52
El Josieh	380	15	8.1	25	490	150	1.7	1.6	3.4	4.9	69	0.41
El Kabir	420	22	8.1	32	490	204	5.1	2.8	3.6	6.6	104	0.3

† CEC = cation exchange capacity, CCE = $CaCO_3$ equivalent, ACCE = "active" $CaCO_3$ equivalent, Fe_d = citrate-bicarbonate-dithionite extractable Fe, Fe_o = oxalate-extractable Fe.

‡ From the Freundlich equation, $X = Ac^b$.

anion-exchange resin method of Sibbesen (1978), was included.

Three incubation experiments were carried out. In Experiment 1, phosphate (as $Ca(H_2PO_4)_2.H_2O$, MCP) was added to 100 g subsamples of soils that had been previously depleted in P by cropping them to wheat in shallow trays until Olsen P values were < 3 mg/kg. Addition rates were 20, 40, 100, 200, 300, 400 and 500 mg P/kg soil. For the 20 and 40 mg/kg rates, MCP was dissolved in the amount of water needed to bring the 100 g soil to field capacity, and, for the other addition rates, powdered MCP was thoroughly mixed with the soil before adding water to field capacity. Incubation (in pots) was carried out at 22 ± 1°C for 240 d, the soil being rewetted to field capacity every second day. Every 30 d, subsamples were taken and air dried before analysis.

In Experiments 2 and 3, subsamples of the soils previously depleted in P were treated in the following ways: (i) MCP was added to the soil at a rate of 20 mg P/kg, and the soil was incubated at field capacity for 30 d and finally dried (Experiment 2); and (ii) MCP was added to the soil at a rate of 40 mg P/kg, and the soil was placed in pots, cropped to wheat for 60 d, and, finally, separated from the roots and dried (Experiment 3). Then, for both experiments, soil samples were incubated for 90 d under five different treatments: (i) dry-stored (control); (ii), (iii), (iv), and (v) soils brought to field capacity and rewetted every 45, 22, 15, and 1 d, respectively. Treatments (i) and (v) were carried out at 22 ± 1°C under normal room conditions, and treatments (ii), (iii), and (iv) in an oven with circulating air at 27 ± 1°C and 98% relative humidity (by equilibration with a solution of 0.5 *M* NaCl).

All incubation experiments were carried out in duplicate. Incubated samples were analyzed for Olsen P, and the P content of all solutions was analyzed (Table 3.3.2).

Table 3.3.2 Changes in Olsen P values of soils pretreated in different ways[†] and incubated for 90 d under different moisture regimes

	Experiment 2					Experiment 3				
		Soil brought to field capacity every					Soil brought to field capacity every			
Soil	Soil dry	45 d	22 d	15 d	1 d	Soil dry	45 d	22 d	15 d	1 d
	mg/kg									
Husn	8.2	7.8	8.0	7.8	7.3	18.6	18.6	17.7	17.9	20.0
Sarihe	7.6	7.2	8.1	8.2	6.5	24.6	21.8	22.6	24.2	24.3
Bichra	6.1	6.1	6.2	5.9	5.5	23.6	23.0	22.2	22.2	25.0
Birg-el-Amri	10.6	9.7	8.9	8.3	8.7	18.0	18.8	16.1	16.0	18.0
Haouaria	6.7	6.2	7.0	6.7	6.4	17.5	16.4	15.8	14.7	17.2
Pakistan	10.3	9.4	9.4	9.2	8.5	16.2	17.6	15.7	14.8	17.4
Ezraa	5.7	5.8	6.7	5.9	5.2	14.9	14.4	13.7	13.8	15.2
Breda	7.5	7.2	7.5	7.3	6.7	20.4	20.4	18.3	17.2	19.9
Tel Hadya	7.7	6.4	6.7	6.2	6.9	18.0	17.2	16.1	15.8	18.0
Jindiress	6.0	5.2	6.7	5.5	5.4	21.0	20.1	18.6	18.9	21.0
Raqqa	9.1	7.4	8.3	7.9	7.1	16.5	13.5	12.3	12.7	13.7
El Haffeh	5.1	5.2	5.4	5.7	5.3	11.7	10.0	9.2	10.4	10.8
Bassa	7.2	6.1	7.2	6.6	6.2	14.0	15.3	13.9	14.4	15.2
Tel Kallahk	5.2	5.3	5.4	5.4	5.0	11.9	11.2	11.0	10.6	12.1
Blass	6.3	5.6	6.0	5.7	5.7	21.8	19.7	18.6	19.4	21.8
Tel Zegram	9.0	8.2	7.9	8.0	7.6	25.5	25.7	25.5	23.4	24.9
El Jayed	8.3	7.8	8.3	8.1	7.6	15.4	16.7	14.1	14.2	15.5
El Josieh	9.2	8.3	8.2	7.5	7.7	12.5	15.2	13.9	13.5	14.1
El Kabir	8.0	8.4	8.6	7.8	7.2	16.9	18.0	15.9	15.3	17.6

[†] Experiment 2: Soil resulting from a P-exhaustion process was fertilized with 20 mg P/kg and incubated for 30 d at field capacity before the incubation experiment;
Experiment 3 = as Experiment 2 but soil was fertilized with 40 mg P/kg and cropped to wheat for 60 d before incubation.

3.3.1.2 Phosphate Sorption Properties

The constant A of the Freundlich equation, i.e. the amount of P sorbed at an equilibrium concentration of 1 mg P/l, ranged between 49 and 578 mg P/kg soil (Table 3.3.1). The exponent of that equation ranged between 0.33 and 0.53, i.e. the curvature of the sorption curve did not differ widely between samples. From the fitted Freundlich equation, the amount of P sorbed at an equilibrium concentration of 0.2 mg P/l (P_{02}) was calculated (detailed values not shown) and taken as the index of the P sorption capacity, as this concentration represents an adequate "external" P requirement for most field crops. From the properties listed in Table 3.3.1, P_{02} was significantly correlated to Fe_d ($r = 0.86^{***}$), Fe_o ($r = 0.78^{***}$) and clay ($r = 0.48^{*}$). These results are compatible with the aforementioned dominant role of Fe oxides in the P sorption by calcareous soils of the Mediterranean region. Inasmuch as in most soils the Fe_o/Fe_d ratio (which is considered as a measure of the ratio of poorly crystalline to crystalline Fe oxides) is low (< 0.15), it is possible to conclude that the crystalline Fe oxides are the ones quantitatively important in P sorption. According to this, the relationship between P_{02} and Fe_o in these soils is not causal but the simple result of the high covariance existing between Fe_o and Fe_d ($r = 0.81^{***}$).

3.3.1.3 Availability of the P Added

The ratio between the increase in Olsen P and the P applied to the soil as MCP was chosen as the availability index (AI). The rationale for this choice lies in the known fact that Olsen P correlates well with the amount of soil P available to plants. In addition, soil test calibration for WANA is based on this soil test (Matar and Ryan 1990).

In the first incubation experiment, the absolute values and patterns of change with time and P addition level differed widely between soils, as illustrated by four soils (Figure 3.3.1). For all soils and addition levels, AI decreased with time, as is commonly observed. The rate of decrease of AI with time depended on the P addition level. At low (20 and 40 mg P/kg soil) levels, AI underwent relatively little change after 60 d, as exemplified by the soils in Figure 3.3.1. The AI 180 d after on addition of 20 mg P/kg (Table 3.3.3) ranged between 0.147 and 0.424 and was negatively

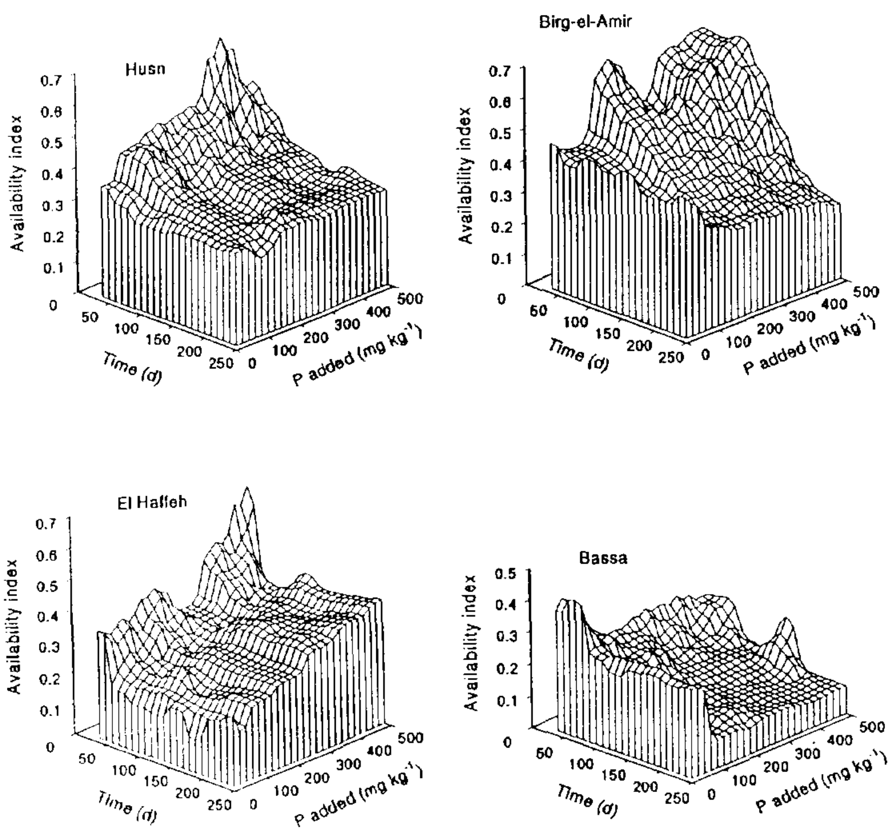

Figure 3.3.1 Smoothed block diagrams showing the availability index (ratio between the increase in Olsen P and P applied) in four soils as a function of amount of P applied and time after P application

Table 3.3.3 Selected availability indices† of applied P

	Amount of P added and time			
	20 mg/kg	500 mg/kg		
Soil	180 d	30 d	120 d	240 d
Husn	0.294	0.504	0.321	0.329
Sarihe	0.316	0.435	0.273	0.251
Bichra	0.256	0.549	0.364	0.238
Birg-el-Amri	0.403	0.717	0.501	0.237
Haouaria	0.420	0.655	0.620	0.490
Pakistan	0.424	0.496	0.269	0.141
Ezraa	0.237	0.484	0.386	0.375
Breda	0.297	0.496	0.444	0.421
Tel Hadya	0.305	0.351	0.215	0.182
Jindiress	0.282	0.375	0.296	0.249
Raqqa	0.359	0.705	0.465	0.218
El Haffeh	0.147	0.512	0.342	0.433
Bassa	0.249	0.240	0.160	0.110
Tel Kallahk	0.168	0.374	0.342	0.306
Blass	0.266	0.365	0.201	0.180
Tel Zegram	0.349	0.609	0.311	0.264
El Jayed	0.290	0.558	0.542	0.499
El Josieh	0.364	0.330	0.236	0.173
El Kabir	0.320	0.446	0.201	0.178

† Availability index = ratio between the increase in Olsen P and the amount of P applied

correlated to Fe_d and Fe_o but not to measures of $CaCO_3$ (Table 3.3.4, Figure 3.3.2). At the highest addition level (500 mg P/kg): (i) the decrease of the AI with time was markedly greater than at low addition levels (Figure 3.3.1, Table 3.3.3), and (ii) the AI was, at nearly all times, significantly (and negatively) correlated to CCE but not to other soil properties (except for organic matter at 240 d). Figure 3.3.3 shows the AI-CCE regression for 240 d of incubation.

It seems that the soil properties influencing AI differ between high and low rates of P addition. At low addition rates, AI

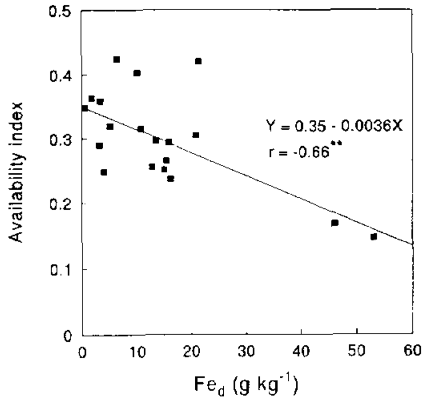

Figure 3.3.2 Availability index 180 d after application of 20 mg P/kg soil in relation to citrate-bicarbonate-dithionite extractable Fe (Fe_d)

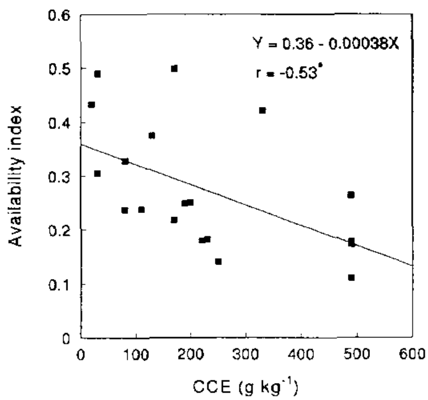

Figure 3.3.3 Availability index 240 d after application of 500 mg P/kg soil in relation to $CaCO_3$ equivalent (CCE)

was a negative function of the amount of Fe oxides. These, according to the P sorption curves, seem to dominate sorption at low (< 100 μM) concentrations of P in the soil solution. Compared with other soil components such as $CaCO_3$, Fe oxides and clay minerals (edge surfaces) have high-affinity P-adsorption sites from which phosphate is less easily removed by the bicarbonate ions of the Olsen extractant.

Table 3.3.4 Correlation coefficients between selected availability indices and soil properties.

Soil property†	Availability index for 20 mg/kg 180 d	500 mg/kg 30 d	500 mg/kg 120 d	500 mg/kg 240 d
Clay	-0.45	-0.01	0.04	0.41
Organic matter	-0.09	0.19	0.35	0.54*
pH	0.59**	0.15	-0.09	-0.38
CEC	-0.51*	-0.15	0.04	0.34
CCE	0.24	-0.41	-0.57*	-0.53*
ACCE	0.22	-0.21	-0.37	-0.27
Fe_d	-0.66**	-0.11	0.07	0.39
Fe_o	-0.69**	-0.11	0.04	0.33

† Abbreviations as in Table 3.3.1.

At high rates P addition, the soil solution becomes much more highly supersaturated with respect to insoluble Ca phosphates, and so precipitation can take place more easily than at low rates of addition. Since precipitation of Ca phosphates in calcareous systems seems to proceed from the initial phosphate adsorption and crystal nucleation on the $CaCO_3$ surfaces, the amount and reactivity of the $CaCO_3$ in the system must influence the availability of the applied P. This explains the negative correlation between AI and CCE.

The lack of correlation between AI and Fe oxides at high P addition rates does not necessarily imply that Fe oxides are not active in retaining the adsorbed P against bicarbonate extraction. It may simply result from the "dilution" of true adsorption by the quantitatively more important precipitation processes. Consequently, one would expect AI to be correlated to Fe_d only for populations of calcareous soils with high Fe_d/CCE ratios.

The present results contradict several field and laboratory studies in which linear relationships were reported between extractable P and amount of P added (i.e. AI was similar at different P addition levels). But much depends on the choice of experimental conditions in the laboratory incubation experiments. One would expect incubation data for high (10^2-10^3 mg/kg) P application levels to match field conditions, since high phosphate concentrations occur in the vicinity of granules, powder or droplets of liquid fertilizer. This conclusion may not be in toto true if high phosphate concentrations near the point of P application do not result in rapid precipitation of Ca phosphate, and phosphate can diffuse to high affinity adsorption sites within a relatively large soil volume. Then, the AI would be better predicted by an incubation at low P addition level. In long-term field studies carried out in the Breda, Tel Hadya and Jindiress soils described in this work (Matar 1990, Matar et al. 1991), the AI appeared to increase in the order Jindiress < Tel Hadya-Breda. This matches better the relative order of the AI values at low than at high addition levels (Tables 3.3.3)

In summary, this study stresses the difficulties involved in predicting the availability of fertilizer P applied to calcareous soils. The loss of availability is related to the nature of the processes of adsorption and precipitation, but the relative importance of these processes appears to be a complex function of the soil composition (in particular of the amount and reactivity of $CaCO_3$ and Fe oxides), P addition level and time after P addition.

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3.4 Soil and Crop Nitrogen

As concerns for sustainability build up, the interest in nitrogen sharpens. Fixation by legumes is a major area of interest, and the contributions legumes may make, within rotations, to subsequent crop nutrition and the longer-term nitrogen and organic matter status of the soil is covered in a later section (3.5); but where available N from soil and legume is insufficient for optimal growth, the focus is on fertilizer and its efficient use. The three short reports grouped here are concerned with nitrogen fertilizer efficiency, its interaction with the external moisture supply and its effect of cereal grain quality.

3.4.1 Responses of Wheat Genotypes to Nitrogen Fertilizer In Two Contrasting Environments

M. Pala and A. Matar (FRMP),
M. Nachit and G.O. Ferrara (CP)

3.4.1.1 Introduction

Differences between genotypes in their response to N-fertilizer may be associated with their growth characteristics as well as with environmental and management factors. Higher yield potential may in itself lead to greater response to N and greater efficiency in terms of yield per unit of applied N at all levels. However, this is not necessarily the case because of "cross-over" responses under some circumstances (Anderson 1985b).

Varietal differences in winter cereal response to applied N have been demonstrated under a wide range of conditions (Pala et al. 1978; Krentos and Orphanos 1979; Anderson 1985a). Differences have been found mainly between tall, unimproved or landrace varieties (nonresponsive) and short, improved or high-yielding varieties (responsive) and are largely attributable to the ability of dwarf or semi-dwarf varieties to utilize higher N rates under good growing conditions without lodging.

Varietal differences in response to applied N can have considerable economic significance (Anderson 1985a). Varieties yielding relatively well without fertilizer can be useful in situations where the addition of N is risky due to unreliable weather, or where resources do not allow its use. Varieties that respond strongly to applied N can be useful in more favorable environments and where resources for fertilizer and other inputs are not a constraint. However, yield response to N is of little value if it is achieved at the expense of grain quality or, in low fertility situations, at the expense of declining soil fertility. De

Wit et al. (1979) considered that a higher efficiency of N use can be achieved only by increasing the grain to straw ratio or by breeding varieties with a lower minimum N content, especially in the grain.

The present work aimed to assess various durum and bread wheat genotypes for economic efficiency in N-fertilizer use and for seed quality at different N-fertilizer rates, under different environmental conditions.

3.4.1.2 Experimental Procedure

Combinations of 25 durum wheat genotypes (different set for each year) with 4 rates of N fertilizer (0, 30, 60 and 90 kg N/ha) and of 5 bread wheat genotypes with 5 rates of N fertilizer (0, 30, 60, 90 and 120 kg N/ha) were sown in two contrasting rainfall environments in the 1989/90 and 1990/91 seasons. Genotypes were factorially arranged within the split plots of N application in 2 replicates (plot size was 1.5m X 5m).

Soil mineral-N (ammonium plus nitrate) was measured on a composite sample (0-60 cm in 20 cm increments) taken from 6 profiles within each experiment area at planting time. Initial values (0-60 cm) were 12.0 and 7.5 ppm at Tel Hadya, 6.6 and 10.0 ppm at Jindiress, for the 1989/90 and 1990/91 seasons, respectively.

3.4.1.3 Results and Discussion

1989/90 Season: The season was extremely dry at both sites with seasonal rainfall totals of 233 mm at Tel Hadya and 332 mm at Jindiress. These values are, respectively, about 100 mm and 150 mm lower than the long-term averages. The distribution of the rainfall, which is often more important than the total, was irregular, with 88% and 95% falling in the period, October to February, at Tel Hadya and Jindiress, respectively. This situation was reflected in crop performance and response to applied N.

a) Durum Wheat: Yields and yield parameters are summarized in Tables 3.4.1 and 3.4.2. In general, yields were much higher at Jindiress than at Tel Hadya, where the season was very marginal. No interactions between genotype and applied N were found at either site. All comparisons are therefore based on the mean values for genotypes and for N rates. Significant genotype differences were recorded for all the yield parameters at both sites. Om Rabi 5, DRL 13, DRL 4, DRL 15, Cham 6 (bread wheat as check) and Gezira 17 were the first six genotypes at Jindiress, and Cham 6, Gezira 17, Om Rabi 5, Om Rabi 3, DRL 15 and DRL 8 were the first six under the very dry Tel Hadya conditions. Cham 3 was unexpectedly low in yield ranking at the drier site but higher in the more favorable environment.

Grain protein percentages were lower at Jindiress (9.6 to 13.1; SE=0.3) than at Tel Hadya (13.9 to 17.0; SE=0.3). This may be attributed to a "dilution" of N in the grain where the yield was higher. Total N uptake was greater at Tel Hadya, despite low yield levels, and gave rise to higher N concentrations in grain and straw. Vitreousness is also important in marketing. However, vitreousness above 80%, as was found for most genotypes, is usually an acceptable value.

Grain yield positively and significantly responded (5% level) to applied N at Jindiress, where more favorable weather conditions prevailed, but the response was negative (10% level) under the drier Tel Hadya conditions (Table 3.4.2). However, straw yield did not respond to N significantly, although the trend was positive at both sites. Grain protein (%) responded positively to increasing rates

Table 3.4.1. Mean yield and quality parameters of durum wheat genotypes at two contrasting locations, 1989/90

Genotypes	Jindiress (332 mm rainfall)							Tel Hadya (233 mm rainfall)						
	GY	SY	TGW	PRT	SPRT	TNU	Vit.	GY	SY	TGW	PRT	SPRT	TNU	Vit.
	**	*	**	**	**	*	**	**	+	**	**	**	**	**
1. Hourani	1664	5557	35.3	11.2	2.6	56	80	550	3394	23.2	16.4	7.1	54	96
2. DRL 2	1655	5321	37.4	10.6	2.3	51	91	582	3362	25.4	15.0	8.1	59	95
3. DRL 3	1509	5612	32.7	12.0	2.5	54	95	358	3427	22.1	17.0	8.0	56	96
4. DRL 4	1751	5387	32.9	10.3	2.4	52	90	694	3863	23.5	14.7	7.6	64	96
5. DRL 5	1417	5728	36.6	11.6	2.6	53	90	514	3678	25.1	16.1	7.4	58	95
6. DRL 6	1527	5551	38.3	11.5	2.3	51	95	567	3528	26.8	15.7	7.3	56	96
7. DRL 7	1456	5258	36.6	11.1	2.5	50	95	528	3323	26.3	15.4	8.1	57	97
8. DRL 8	1551	5238	34.9	11.9	2.5	54	89	697	3400	25.0	15.9	8.1	62	96
9. DRL 9	1234	5281	35.3	13.1	2.9	53	95	435	3569	24.5	16.7	8.3	60	97
10. DRL 10	1292	5301	34.6	11.8	2.5	49	95	470	4035	22.7	16.8	7.6	63	94
11. DRL 11	1485	5066	38.1	12.6	2.4	53	97	595	3550	27.9	16.6	8.3	64	97
12. DRL 12	1646	5317	33.4	11.3	2.5	54	93	559	3762	23.3	16.3	8.2	65	96
13. DRL 13	1755	5297	38.3	10.9	2.1	52	94	696	3573	28.0	15.3	7.7	62	96
14. DRL 14	1614	5540	34.9	11.7	2.5	55	91	589	3925	26.0	16.2	7.8	65	97
15. DRL 15	1690	5027	36.7	11.3	2.4	53	90	730	3233	26.9	15.8	6.7	55	96
16. DRL 16	1508	5288	37.6	11.3	2.4	50	89	693	3778	23.8	15.6	6.9	60	95
17. DRL 17	1329	5242	33.9	12.0	2.4	48	94	692	3651	24.0	16.6	6.9	60	97
18. Om Rabi 5	1792	5393	36.2	11.1	2.4	56	81	744	3633	24.3	15.3	8.0	66	95
19. Belikh 2	1623	5647	33.6	11.0	2.2	52	89	454	3717	21.5	15.8	8.1	61	95
20. Om Rabi 3	1669	4857	35.5	10.7	2.0	47	77	721	3715	24.7	15.8	7.9	67	97
21. Cham 3	1615	5597	38.5	11.1	2.3	52	95	583	3384	26.0	16.1	7.6	58	96
22. Stork	1551	5281	35.3	11.1	1.9	49	83	550	3549	22.5	15.6	9.1	67	95
23. Gezira 17	1677	5041	33.9	10.1	2.1	49	77	827	3736	22.0	15.5	8.2	72	96
24. Nesser (BW)	1678	5283	28.8	10.0	2.0	49	54	1116	4134	21.5	13.9	8.7	84	96
25. Doc 7 (TLL)	1600	5800	34.0	9.6	1.9	45	73	556	3717	23.0	14.0	7.6	59	100
LSD (.05)	174	505	1.9	0.6	0.4	6	5	190	509	1.9	0.6	1.0	11	2.0
SE (±)	88	255	0.9	0.3	0.2	3	3	96	257	1.0	0.3	0.5	6	0.9

GY=grain, kg/ha; SY=straw, kg/ha; TGW=1000-grain weight, g; PRT=grain protein %;
SPRT=straw protein %; TNU=total N uptake, kg/ha; Vit.=vitreousness, %. * $p<0.05$; ** $p<0.01$; + $p<0.10$

Table 3.4.2. Mean yield and quality parameters of durum wheat under different nitrogen fertilization at two contrasting locations, 1989/90

N kg/ha	Grain kg/ha	Straw kg/ha	1000 gr wt. g	Grain protein %	Straw protein %	Total N uptake kg/ha	Vitreousness %
	Jindiress (332 mm rainfall)						
	*			**	*	**	**
0	1487	5074	34.9	9.6	2.0	41	77
30	1563	5338	35.1	10.6	2.2	48	86
60	1678	5533	35.7	12.3	2.5	58	93
90	1559	5480	35.7	12.5	2.8	59	94
LSD (.05)	95	NS	NS	0.2	0.4	6	3.0
SE (±)	30	196	0.6	0.1	0.1	2	0.9
	Tel Hadya (233 mm rainfall)						
	+		**	**	*		
0	774	3443	26.3	14.3	6.3	54	96
30	615	3408	24.4	15.5	7.1	56	97
60	502	3801	22.7	16.5	8.8	68	96
90	577	3769	24.1	16.7	9.1	71	95
LSD (.05)	217	NS	1.6	1.0	1.8	NS	NS
SE (±)	68	318	0.5	0.3	0.6	6	0.6

** $p<0.01$ * $p<0.05$ + $p<0.10$

of N, with higher values in the drier environment. The same was true for the protein percentages in the straw. And total N uptake increased with increasing rate of N-fertilizer. Vitreousness was unaffected by N at Tel Hadya but was very low and low, respectively, at zero and 30 kg N/ha rates at Jindiress.

b) Bread Wheat: Yield and yield parameter data are summarized in Table 3.4.3. Again, since there were no significant interactions, comparisons are made simply between genotypes and between N rates. Genotypes showed significant differences in most parameters at both sites. As with durum wheat, yield and 1000-grain weight were higher under the more favorable conditions of Jindiress. Cham 6 and Cham 4 gave most grain at both sites, irrespective of the environmental differences. That is quite promising for the adaptability of these genotypes to drier conditions.

Grain yield was decreased significantly by applied N at Tel Hadya but increased significantly (up to the rate of 60 kg N/ha) at Jindiress. Grain protein content responded positively to N at both sites; but again values were lower under higher moisture conditions, particularly where little N was applied. Grain protein contents (%) were in the ranges, 10.2 to 12.4 (SE=0.2) at Jindiress and 12.8 to 15.1 (SE=0.3) at Tel Hadya.

1990/1991 Season: The season was near the average at both sites, with rainfall of 290 mm at Tel Hadya and 438 mm at Jindiress. However, rainfall distribution was unfavorable at Tel Hadya; in particular, there was a long dry spell after the crop had emerged following 19 mm in November. To save the crop, 30 mm of additional water was applied by sprinkler. Distribution of rainfall was not a problem at Jindiress, but the crop did not use the favorable weather conditions effectively. This was probably because of preceding sunflower in the rotation or a waterlogging problem, due to the

Table 3.4.3. Mean yield and quality parameters of bread wheat genotypes and mean response to nitrogen at two contrasting locations, 1989/90

Genotypes	Jindiress (332 mm rainfall)						Tel Hadya (233 mm rainfall)					
	GY	SY	TGW	PRT	SPRT	TNU	GY	SY	TGW	PRT	SPRT	TNU
	**	**	**	**		**	**		**	**		
Cham 6	2043	5229	30.9	10.3	2.4	57	987	3433	22.6	13.3	7.7	64
Zidane 89	1451	5055	32.1	11.6	2.7	51	674	3403	24.4	14.3	7.5	57
Cham 4	1905	4998	28.4	10.2	2.6	55	989	3214	21.5	12.8	7.4	58
Tevee	1589	5008	25.7	11.6	2.6	54	598	3165	23.1	14.2	7.9	56
Hagel	1730	5572	30.3	12.4	2.4	58	677	3415	25.4	15.1	6.7	56
LSD (.05)	140	280	0.8	0.3	NS	4	177	NS	1.6	0.7	NS	NS
SE (±)	67	134	0.4	0.2	0.2	2	85	187	0.8	0.3	0.5	5
N, kg/ha												
	*	*	+	**		*	**		+	**		
0	1552	4681	28.9	9.7	1.9	41	927	3030	25.6	11.5	9.1	62
30	1819	5253	29.2	10.7	2.3	53	832	3335	23.1	13.5	7.4	61
60	1923	5472	29.5	11.3	2.8	62	740	3233	23.4	14.0	6.4	50
90	1792	5341	29.4	12.0	2.8	62	771	3415	22.8	15.0	7.1	59
120	1632	5114	30.3	12.4	2.7	57	656	3616	22.1	15.7	7.3	59
LSD (.05)	169	436	0.9	0.8	NS	13	104	NS	2.7	1.1	NS	NS
SE (±)	82	157	0.3	0.3	0.3	5	37	204	1.0	0.4	2.1	13

GY=grain, kg/ha; SY=straw, kg/ha; TGW=1000-grain weight, g; PRT=grain protein %; SPRT=straw protein %; TNU=total N uptake, kg/ha; * $p<0.05$; ** $p<0.01$; + $p<0.10$

lower infiltration rate at Jindiress. Another problem was the hot winds at the anthesis stage in mid-April, which made some of the spikelets sterile.

a) Durum Wheat: As before, there were no significant interactions between genotype and applied N. Apart from straw yield at Jindiress, all parameters showed a significant genotype effect (Table 3.4.4). Between sites, the rainfall difference had less effect on the general levels of grain and straw yield than might have been expected, perhaps because the 30 mm irrigation gave the emerged but stressed crop at Tel Hadya a substantial boost. The higher straw yield at Tel Hadya was possibly due to this additional water. The Jindiress crop was, however, weaker than that at Tel Hadya, probably due to the hot winds at anthesis. The higher 1000-grain weights at Jindiress may be explained by a better utilization of the heavier late rains at that site.

DRM 11, Gallerata, DRM 9, Om Rabi 3, Cham 3 and DRM 2 were the highest-yielding six genotypes at Jindiress, and Om Rabi 5, DRM 11, Om Rabi 3, Lahn, DRM 13 and Cham 3 at Tel Hadya -- with Om Rabi 3, Cham 3 and DRM 11 common to both sites.

The pattern of protein percentages was similar to that of the previous season ranging between 10.1 and 12.7 (SE=0.5) at Jindiress and 15.6 and 17.8 (SE=0.7) at Tel Hadya. Total N-uptake was greater at Tel Hadya, with higher N contents in grain and straw. Vitreousness was much higher under the drier environment at Tel Hadya, probably reflecting the higher accumulation of N in the grain.

Grain response to applied N was not significant at either site, but straw yield increased significantly with increasing N (Table 3.4.5). At both sites, 1000-grain weights responded

Table 3.4.4. Mean yield and quality parameters of durum wheat genotypes at two contrasting locations, 1990/91

Genotypes	Jindiress (438 mm rainfall)							Tel Hadya (290 + 30 mm rainfall)						
	GY	SY	TGW	PRT	SPRT	TNU	Vit.	GY	SY	TGW	PRT	SPRT	TNU	Vit.
	**		**	**	**	**	**	**	**	**	+	*	**	+
1. Stork (chk)	2235	3630	39.3	11.6	1.9	56	77	2079	5653	26.6	15.6	4.1	92	92
2. DRM 2	2318	4302	43.7	11.9	2.0	61	85	1888	6269	30.2	16.7	5.0	109	96
3. DRM 3	2382	3520	39.4	11.8	1.9	60	77	1979	5248	27.2	16.6	4.1	90	96
4. DRM 4	2018	3118	39.6	10.8	1.8	46	80	2001	5591	26.7	17.3	4.6	102	96
5. DRM 5	2204	3658	43.1	12.0	2.1	58	85	1838	5708	27.8	17.1	4.2	93	94
6. DRM 6	2222	4052	42.9	11.9	1.9	60	82	2072	5322	28.6	16.6	3.8	92	97
7. DRM 7	2133	3898	43.3	12.1	2.1	59	81	1868	5419	29.9	16.6	4.3	91	97
8. Awalbit-2	2134	3496	39.4	11.6	1.7	52	95	1748	5166	27.3	17.8	4.1	91	98
9. DRM 9	2355	3461	38.5	11.0	1.8	55	81	1957	4687	27.3	15.7	4.2	85	97
10. DRM 10	2235	4661	34.8	12.4	1.9	63	88	2079	6298	26.7	16.4	3.9	99	95
11. DRM 11	2621	4508	36.6	11.2	2.1	67	69	2268	5489	26.9	16.2	3.8	98	97
12. Cham 1	1958	4037	34.0	12.6	2.0	56	84	1540	4610	24.0	17.6	4.3	79	96
13. DRM 13	2197	3442	39.7	10.1	1.8	49	69	2185	5589	26.4	15.7	4.0	95	94
14. Sabil 1	2049	3361	40.7	11.8	1.5	50	84	1907	5421	26.9	17.3	3.9	91	98
15. Om Rabi 5	2122	3646	38.4	11.8	1.6	54	74	2425	5918	26.9	16.3	3.6	103	96
16. Loukos 3	2093	3306	40.5	11.4	1.6	51	79	1907	5177	28.8	16.7	4.2	90	97
17. Haurani	1812	3216	35.9	12.3	2.1	49	75	1735	5287	25.0	17.1	3.7	80	94
18. Gallerata	2358	3983	39.5	11.8	1.7	59	92	1981	5286	27.8	17.1	3.8	90	98
19. Om Rabi 3	2352	4229	38.8	11.5	1.7	59	81	2220	6558	26.8	16.6	3.4	101	98
20. Belikh	2168	3670	34.7	12.2	2.1	58	78	1829	5436	24.6	17.2	3.6	86	96
21. Cham 3	2321	4065	36.9	11.3	1.9	59	79	2154	6462	23.8	16.7	4.2	106	96
22. Lahn	1978	3976	42.8	11.1	2.2	53	76	2209	7650	29.0	17.0	4.1	118	92
23. Omtel 1	2238	4033	34.1	11.0	1.7	54	74	1858	4719	23.6	16.3	3.3	77	94
24. Gezira 17	2092	4387	33.6	11.7	2.1	58	74	1822	5942	22.5	17.2	4.5	95	96
25. Rufom 4	1823	3690	40.0	12.7	1.8	52	96	1874	6088	32.1	17.0	3.4	88	98
LSD (.05)	337	NS	2.4	1.0	0.3	11	14	335	1316	1.8	1.3	0.9	17	4
SE (±)	170	510	1.2	0.5	0.2	6	7	169	663	0.9	0.7	0.4	9	2

The parameters are the same as the footnote of Table 1. * p<0.05; ** p<0.01; + p<0.10

Table 3.4.5. Mean yield and quality parameters of durum wheat under different nitrogen fertilization at two contrasting locations, 1990/91

N kg/ha	Grain kg/ha	Straw kg/ha	1000 gr wt. g	Grain protein %	Straw protein %	Total N uptake kg/ha	Vitreousness %
	Jindiress (438 mm rainfall)						
		*	**	**	**	**	**
0	2150	3400	41.6	8.8	1.3	40	41
30	2297	3900	40.4	10.6	1.7	53	86
60	2199	3948	38.0	12.7	2.0	62	97
90	2061	4007	35.2	14.5	2.6	70	97
LSD (.05)	NS	550	1.9	0.9	0.5	9	10
SE (±)	289	209	0.6	0.3	0.1	3	3
	Tel Hadya (290 + 30 mm rainfall)						
		*	**	**	*	*	
0	2166	4807	32.3	12.5	2.5	66	94
30	2142	5764	26.8	16.6	3.6	95	97
60	1979	6226	24.9	18.2	4.5	108	97
90	1620	5763	23.7	19.7	5.5	106	96
LSD (.05)	NS	923	2.4	2.4	1.4	21	NS
SE (±)	169	290	0.8	0.8	0.4	7	1

** $p<0.01$ * $p<0.05$

negatively and significantly to N, probably because the fertilizer and sufficient winter rainfall encouraged early vegetative growth, while the grain-filling period was dry. Grain and straw protein contents (%) showed a similar pattern to that of the 1989/90 season. Vitreousness was not affected by N-rate at Tel Hadya but was reduced at low rates of N at Jindiress, as in the previous season.

b) Bread Wheat: *There were no significant genotype* differences at Jindiress, but most yield parameters at Tel Hadya showed a significant genotype difference (Table 3.4.6). Protein percentages were similar to those of the durum wheats, 10.6 and 11.1 at Jindiress, 14.0 and 15.7 at Tel Hadya.

Grain yield responded negatively and significantly to applied N at Tel Hadya, probably because of late drought. Grain protein contents (%) were again low at lower rates of applied N under the wetter conditions at Jindiress (Table 3.4.6).

3.4.1.4 Conclusion

The data show that genotypes respond differently in yield as well as in yield and quality parameters under different environmental conditions. The lack of any significant genotype x N interactions encouraged us to use agronomic efficiency (grain yield/N applied), utilization efficiency (grain yield/total N uptake) and uptake efficiency (total N uptake/N applied) as a means of comparing genotypes.

The high positive correlation (r=0.97**) between uptake and agronomic efficiency in all experiments (data are not given) suggests that agronomic efficiency is more closely associated with root and soil factors than with factors influencing N utilization within the plant (Anderson 1985b). This correlation supports the

Table 3.4.6. Mean yield and quality parameters of bread wheat genotypes and mean response to nitrogen at two contrasting locations, 1990/91

Genotypes	Jindiress (438 mm rainfall)						Tel Hadya (290 + 30 mm rainfall)					
	GY	SY	TGW	PRT	SPRT	TNU	GY	SY	TGW	PRT	SPRT	TNU
							**		**	+		**
Cham 6	2088	3872	30.9	11.0	2.0	52	2014	4712	20.0	14.9	3.8	81
Gomam	2078	3823	30.2	10.7	2.0	51	2069	4785	20.7	14.0	3.8	79
Cham 4	2104	3465	31.5	11.1	1.7	50	1931	5257	18.6	14.6	3.9	81
Baz	1676	3679	31.8	10.9	2.2	44	2359	5878	22.3	15.7	3.2	95
Zidane	1883	3145	29.7	10.6	2.2	46	1378	4789	24.4	14.2	4.3	66
LSD (.05)	NS	NS	NS	NS	NS	NS	290	NS	1.5	1.2	NS	16
SE (±)	204	464	1.2	0.4	0.5	5	139	514	0.7	0.6	0.5	8
N, kg/ha												
				+		*	**		**	**	**	*
0	1849	2761	33.2	8.2	1.4	33	2099	4572	25.6	11.2	2.1	56
30	2155	4004	31.1	10.5	1.9	52	2229	5702	23.8	13.1	3.0	78
60	1991	4219	31.2	11.6	2.1	54	1973	4944	20.5	15.3	3.7	83
90	1916	3321	30.3	10.8	1.9	45	1738	4973	18.5	16.5	5.1	91
120	1918	3678	28.1	13.1	2.7	59	1712	5231	17.7	17.3	5.2	94
LSD (.05)	NS	NS	NS	3.6	NS	15	154	NS	2.1	2.0	1.3	30
SE (±)	155	565	2.1	1.3	0.5	5	55	484	0.7	0.7	0.5	11

GY=grain, kg/ha; SY=straw, kg/ha; TGW=1000-grain weight, g; PRT=grain protein %; SPRT=straw protein %; TNU=total N uptake, kg/ha; * $p<0.05$; ** $p<0.01$; + $p<0.10$

contention of De Wit et al. (1979) that there is more scope for increasing agronomic efficiency through increasing uptake efficiency than through increasing utilization efficiency (r=-0.18 between agronomic and utilization efficiencies).

It may be inappropriate, however, to increase uptake efficiency in areas of low fertility where farmers either cannot afford N fertilizer or where it is unavailable. Varieties with high utilization efficiency may be useful in such cases, even if this is achieved at the expense of a lower grain protein percentage. For durum wheat, utilization efficiency was significantly and negatively correlated with grain protein percentage in all four experimental situations (Figure 3.4.1). (Bread wheat data were too few to show a clear trend.) These results also show that increased utilization efficiency can be achieved only at the expense of reduced grain protein content, as Anderson (1985b) also found. However, some genotypes clearly have higher utilization efficiencies than the others with the same level of grain protein content (Figure 3.4.1). They could be utilized in the crossing process to enhance N efficiency in new wheat cultivars.

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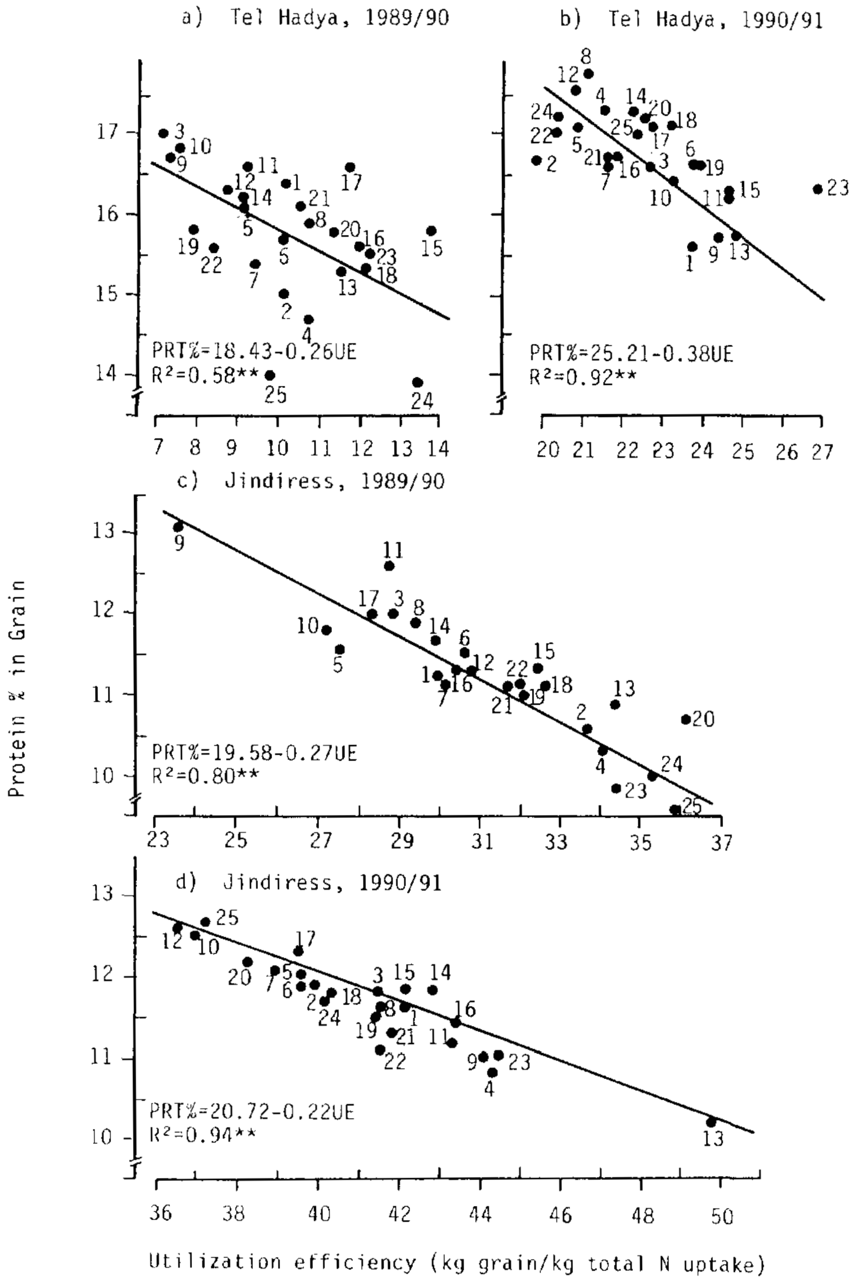

Figure 3.4.1 Relationship between percentage and utilization efficiency in durum wheat
a and c) numbers refer to genotypes in Table 3.4.1
b and d) numbers refer to genotypes in Table 3.4.4

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3.4.2 Effect of Seasonal Rainfall, Fertilization and Rotation on the Nitrogen Content and N Fertilizer Use Efficiency of Wheat

A. Matar and M. Pala

3.4.2.1 Introduction

Over the four years 1986-1990, a total of 70 successful fertilizer trials on rainfed wheat (Cham 1) were conducted jointly with the Soils Directorate in farmers' fields across NW Syria. Sites were selected every year to represent the main soil types used by farmers for wheat (chromoxererts and xerochrepts), the range of natural fertility found in these soils and the three predominant crop rotations -- wheat following lentil (W-L), chickpea (W-Ch) and summer crops (W-SC). A summary of the yield data was reported last year (FRMP 1991).

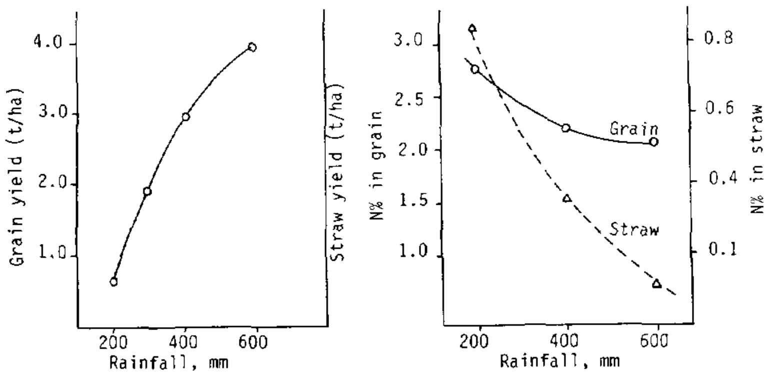
In the area of study, wheat is grown to provide grain for human consumption and straw for animal feed. Although nutritional quality is partly genetically controlled, it is also greatly influenced by weather, cultivation practices and fertilizer use. To investigate this, the N contents of the grain and straw from all 70 trials were determined, and the effects evaluated of site factors (rotation, seasonal rainfall, available N-status) and N fertilizers on N uptake, wheat quality (protein content) and N fertilizer use efficiency.

Each trial comprised two replicates of a randomized complete block design with four rates of N (0, 40, 80 and 120 kg N/ha) supplied as ammonium nitrate and four rates of P (0, 20, 40 and 80 kg P_2O_5/ha) as triple superphosphate. Samples of harvested plants were dried at 70°C, threshed, and the grain and straw separated. Nitrogen content was determined in grain samples from all treatment combinations and in straw samples from the four treatments, N_0P_0, $N_{120}P_0$, N_0P_{80} and $N_{120}P_{80}$. Ground samples were digested using concentrated H_2SO_4 and a catalyst mixture (K_2SO_4 + 1% Se), and total N analysed in the digest by distillation.

Rainfall was recorded at each site over the full cropping season (October-May). Totals varied widely according to year and site, with a mean of 363.4 mm (± 151.5 mm) and an extreme range, 153.0-907.5 mm.

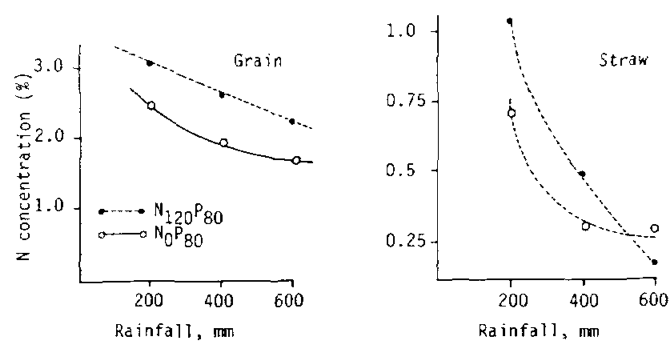
3.4.2.2 Effect of Seasonal Rainfall on Wheat N %

Low rainfall is the main factor limiting the size of rainfed wheat yields, but there tends to be an opposite effect on crop N content (%). In the present trials, while grain and straw yields decreased significantly with decreasing rainfall, the N concentration in wheat grain and straw increased significantly (Figure 3.4.2). This increase, similar to that previously reported for barley (FRMP 1991), was observed under both zero and high N fertilizer regimes (Figure 3.4.3) and within various rotations. However, N% was significantly lower in wheat grown after summer crops than after lentil or chickpea (Figure 3.4.4). This may be explained by the higher grain yields obtained after summer crops.



<u>Figure 3.4.2</u> Main effects of seasonal rainfall on yields and N% in grain and straw taken across all 70 trials

		R^2
<u>Grain</u>	Yield = - 2862 + 20.629 RN - 0.0154 RN^2	0.64**
	N% = 3.354 - 0.003263 RN + 0.000002 RN^2	0.39**
<u>Straw</u>	N% = 1.586 - 0.00426 RN + 0.000003 RN^2	0.64**



<u>Figure 3.4.3</u> Effect of seasonal rainfall on N% in grain and straw of wheat under zero and high N fertilizer regimes

<u>Grain</u>		R^2
N120P80:	N% = 3.44025 - 0.002 RN	0.29**
NOP80:	N% = 3.12994 - 0.00437 RN + 0.00000 RN^2	0.38**

<u>Straw</u>		
N120P80:	N% = 1.84151 - 0.00458 RN + 0.00000 RN^2	0.55**
NOP80:	N% = 1.40849 - 0.00427 TN + 0.00000 RN^2	0.42**

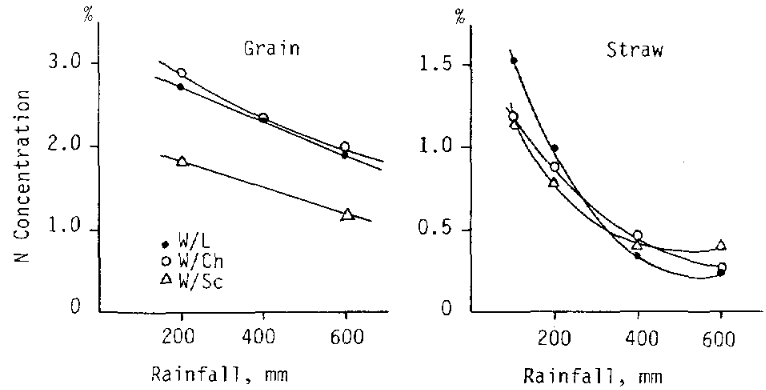


Figure 3.4.4 Effect of seasonal rainfall on the N concentration (%) in grain (GR) and straw (ST) under three different rotations [wheat-lentil (W-L), wheat-chickpea (W/Ch) and wheat-summer crop (W/Sc)]

Rotation		R^2
Wheat/lentil	N% (GR) = −0.00208 RN + 3.169	0.53**
	N% (ST) = −0.00742 RN + 0.000007 RN^2 + 2.199	0.78**
Wheat/chickpea	N% (GR) = −0.00467 RN + 0.000003 RN^2 + 3.729	0.38**
	N% (ST) = −0.0039 RN = 0.000003 RN^2 + 1.563	0.51**
Wheat/sumer crop	N% = −0.00164 RN + 2.1912	0.29**
	N% = −0.00495 RN + 0.000005 RN^2 + 1.590	0.67**

The negative effect of rainfall on wheat N% can be similarly explained by "dilution": any factor that increases yield (e.g. rainfall) without increasing N availability tends to reduce the crop N concentration by diluting the available N supply within a larger biomass. Taken across all sites, a negative relationship was observed between grain yield and grain N%, under both zero and high levels of N fertilization (Figure 3.4.5). This decrease in N% was greater in the straw component than in the grain, a reflection perhaps of more intensive translocation of N from stem and leaves to the grain when rainfall stimulates heavy grain production.

3.4.2.3 Effect of Available-N in Soils at Sowing on Wheat N%

Across all sites, values of N% for wheat grown with phosphate but

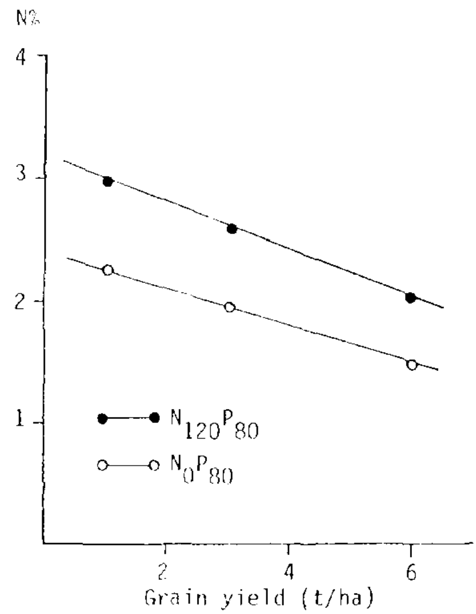


Figure 3.4.5 Grain yield - N% relationships of durum wheat (Cham 1) taken across all sites under zero and high N fertilizer regimes

		R^2
N120P80:	N% = 3.19401 - 0.00019 GY (kg/ha)	0.34**
N0P80:	N% = 2.40256 - 0.00015 GY (kg/ha)	0.20**

without nitrogen fertilization (N_0P_{80} treatment) correlated positively and significantly with the NO_3-N content of the soil plow layer (0-20 cm) at planting:

$$N\% \text{ (Grain)} = 0.04211 \, (NO_3\text{-}N_{ppm}) + 1.714 \qquad R^2 = 0.32$$

3.4.2.4 Effect of Fertilization on Yields and N% of Grain

Nitrogen fertilizer (½ at planting and ½ at tillering) significantly increased grain and straw yields (FRMP 1991). It also increased grain N%, alleviating the negative effect of high rainfall. Further, although grain yield increases from N-fertilization reached a plateau at a relatively low N rate (e.g. 40 kg N/ha), the grain N%

continued to increase up to the highest fertilizer rate (120 kg N/ha) (Figure 3.4.6). N may continue to accumulate in the grain, beyond the point at which the agronomic N requirement for maximum yield have been met. However, any deliberate increase in the rate of N intended to increase grain protein content needs to be justified in terms of an agreed quality threshold and related economic considerations.

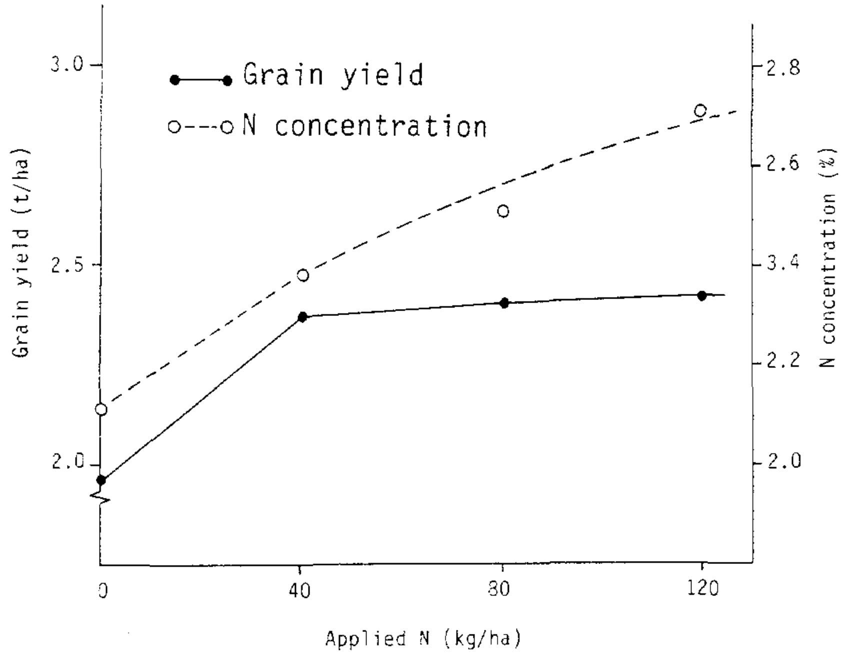


Figure 3.4.6 Main effects of rate of N fertilizer applied on the grain yield and the N% in grain of durum wheat (overall average of all 70 trials)

3.4.2.5 Nitrogen Fertilizer Efficiency

Crops never recover all the fertilizer N that is applied, but it is useful to examine the effect of site factors on nitrogen fertilizer efficiency, NFE (or fertilizer recovery percent). NFE may be measured in two ways:

a) the indirect or difference method,

b) the direct or isotope recovery method, using N^{15} labelled fertilizer (Harmsen 1986).

The indirect method is the easiest and most available to national program scientists in WANA region. It defines NFE as the ratio of the amount of N fertilizer nutrient recovered by the above-ground parts of the crop (or by the grain) to the amount of fertilizer-N applied to the soil (NF):

$$NFE = \frac{N_{120}P - N_0P}{NF}$$

Fertilizer-N recovery is estimated as the difference in N uptake between crops in plots fertilized ($N_{120}P$) and not fertilized (N_0P) with N (all else, including P-fertilizer rate, equal). The assumption is that the uptake of soil N is the same for fertilized and unfertilized plots.

Across sites and seasons, NFE for grain was found to be highly related to seasonal rainfall and the amount of N applied, but not to amounts of mineral-N or NO_3-N in the soil at planting:

$$NFE = -0.28196 + 0.002715\ Q - 0.000002\ Q^2 - 0.001783\ NF$$

($R^2 = 0.46$**)

where NF is the amount of N fertilizer applied in kg N/ha and Q is the total seasonal rainfall (mm).

Thus, 46% of NFE variability could be accounted for by variations in site rainfall and rates of N applied. The relationship of NFE to rainfall is quadratic. Efficiency of fertilizer use increased with increasing rainfall up to a maximum

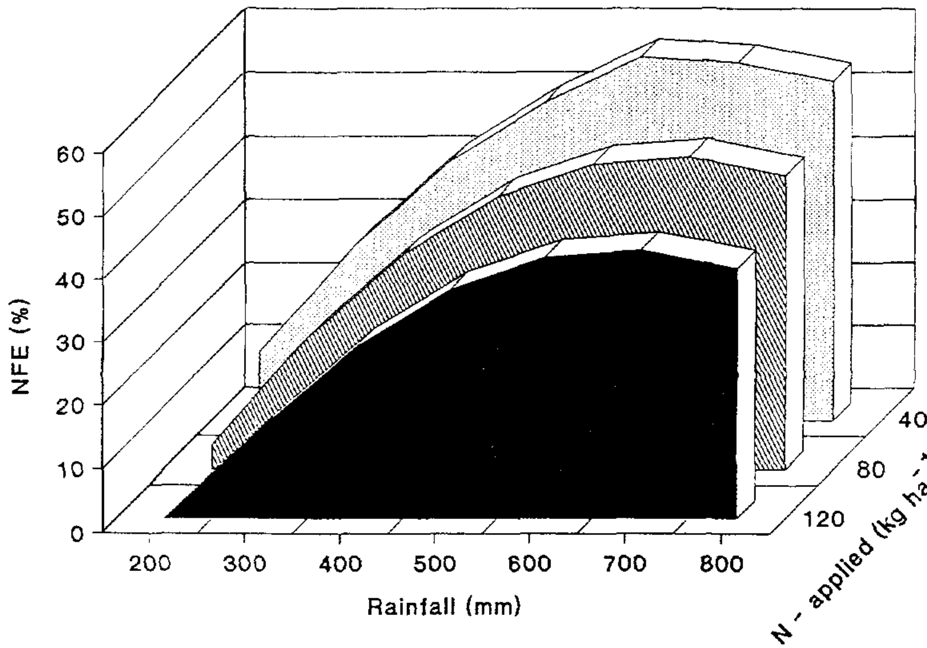


Figure 3.4.7 Nitrogen fertilizer efficiency % by grain as related to seasonal rainfall and level of N applied

and then decreased (Figure 3.4.7), perhaps as a result of leaching under high rainfall. It also decreased with increasing rates of N applied.

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3.4.3 Comparative Effects of Supplemental Irrigation and Nitrogen Fertilization on the Technical Properties of Four Local and Improved Varieties of Durum Wheat*

*A. Matar, A. Mikhail, and Z. Abbasi***

3.4.3.1 Introduction

In the 1990 FRMP Annual Report we discussed the effects of supplemental irrigation and nitrogen fertilization on the protein content of two improved varieties of wheat (Cham 1 and Cham 4) grown in the 1988/89 season. It was shown that measures to increase wheat production by supplemental irrigation can decrease crop protein content (on a % weight basis), which has implications for the nutritive value of both grain and straw. The application of N fertilizer at rates adequate to optimize grain production (½ at sowing and ½ at tillering) improved, but did not eliminate, the negative effect of irrigation on protein content. Attempts to increase wheat production through supplemental irrigation must therefore go hand in hand with N fertilizer additions which optimize yield and maintain, if not improve, its quality.

Here, we evaluate the effects of supplemental irrigation and nitrogen fertilization on the technical properties (protein % and baking quality by the Na sedimentation test) of the grain of five local and improved varieties of wheat, grown at Tel Hadya under supplemental irrigation in 1989/90 and 1990/91. (Full agronomic results will be reported later.) The trials used a split-plot design in three replicates similar to that described previously

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* This work is part of a MSc thesis, for joint cooperation of ICARDA with University of Aleppo

** Soil Chemist (ICARDA), Graduate student, and Associate Professor of Soil Science (Aleppo University)

(Matar and Perrier 1991). The main plots carried the six supplemental irrigation treatments, I0, I1, I2, I3, I4 and I5; I0 was the rainfed treatment and the others were the irrigated treatments replenishing 20, 40, 60, 80 and 100% of the water balance requirement, respectively. The sub-plots carried the 15 factorial treatments (5 varieties x 3 levels of N). The 3 rates of N were 0, 50 and 100 kg N/ha, and the five varieties tested: (local, durum W.) Haurani and Gezira 17; and (improved) Cham 1 (durum W.), Cham 3 (durum W.) and Cham 4 (bread W.).

3.4.3.2 Rainfall Conditions and N Status of Soil

Although both seasons had below-average rainfall, the distributions were quite different (Figure 3.4.8). In the first season (1989/90), the total was only 233 mm, and most of it fell between November and February; and supplemental irrigation was applied regularly from March onwards. In 1990/91, the rain was better distributed and totalled 290 mm (exclusive of 30 mm applied at seeding to all treatments). Less supplemental irrigation water was required in this second season.

The mineral-N content of the soil profile at sowing was significantly higher in the second season as compared to the first, with mean values of mineral-N in the top soil (0-15 cm) of 9.9 ppm and 4.2 ppm, respectively.

3.4.3.3 Effects on Protein %

In 1989/90, all varieties responded significantly to N fertilization, with optimal rates of 50 kg N/ha for Haurani and Cham 1 and 100 kg N/ha for Cham 3, Cham 4 and Gezira. However, in 1990/91, with an almost adequate soil content of mineral N (Matar et

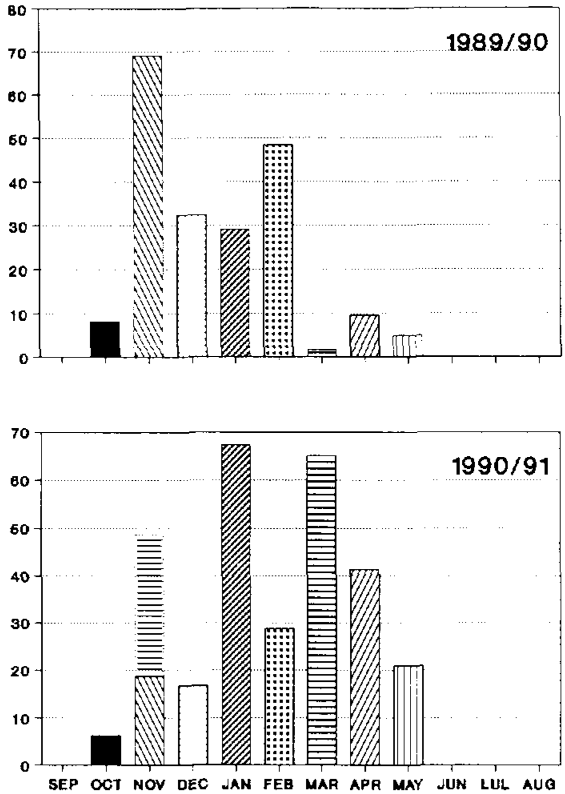

Figure 3.4.8 Rainfall distribution in both seasons at Tel Hadya

al. 1990), three varieties did not respond to applied N (Haurani, Cham 1 and Gezira), and the optimum rate for Cham 3 and Cham 4 was 50 kg N/ha.

Nevertheless, rate of applied N generally had a highly significant effect on the protein % of all 4 durum wheat varieties (Figure 3.4.9). Protein % increased, in both seasons, with increasing rates of applied N; and protein % was significantly higher in the second season. That could be explained by the higher content of available N in the soil at sowing time.

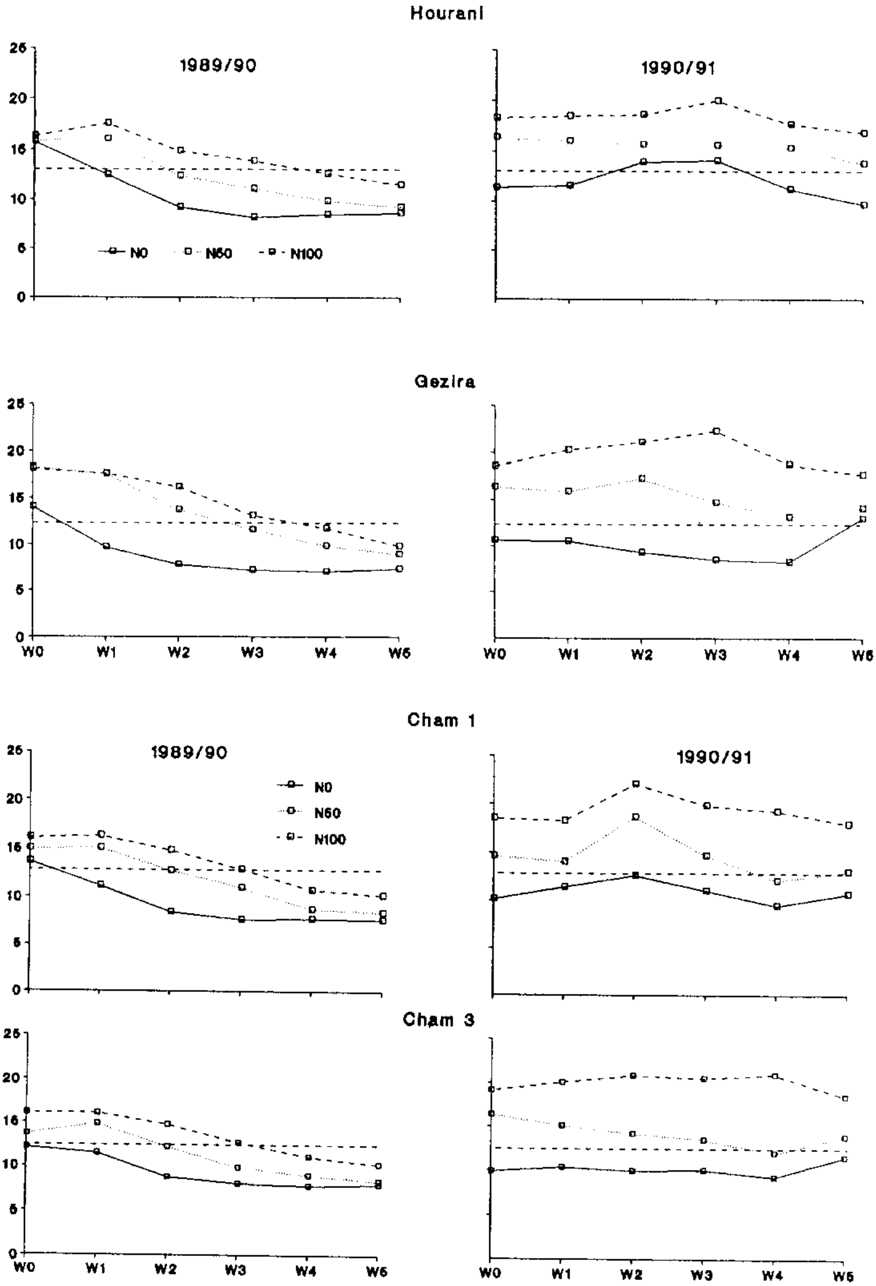

Figure 3.4.9 Relationship between levels of supplemental irrigation and N applied on the protein content % in grain of 4 varieties of durum wheat

In 1989/90, supplemental irrigation had a strong negative effect on grain protein % in all varieties at all rates of applied N, although there was no further depression beyond the I3 treatment (Figure 3.4.9). However, in 1990/91, supplemental irrigation had only a small negative effect.

For the purposes of international trade, wheat grain should contain at least 12.5% protein. In these trials, this standard was not reached in 1989/90 at the highest rates of supplemental irrigation, I4 and I5, even with a fertilizer rate of 100 kg N/ha, and was not reached with 50 kg N/ha in the I3 treatment. Yet, in 1990/91, 50 kg N/ha was adequate to ensure the standard was achieved at all rates of supplemental irrigation. Almost certainly, the initial soil content of mineral-N was a major factor behind this difference, although other seasonal effects may have been involved. However, in both seasons, differences between varieties were relatively small.

3.4.3.4 Effects on Baking Quality

The sodium dodecyl sulfate (SDS) sedimentation test measures the strength and baking potential of wheat, which depends on the degree of hydration of proteins in the wheat and on their degree of oxidation (Williams et al. 1988). The SDS test was applied to the grain from all treatments and for both seasons. The potential baking strength can be classified: > 35 good; 30 to 35 acceptable; and < 30 not acceptable.

Again, season effects were large, with SDS values markedly higher in 1990/91 than in 1989/90 -- for all varieties and almost irrespective of fertilizer and supplemental irrigation treatments (Figure 3.4.10). Applied N increased SDS values in all situations, but those increases tended to be higher in the second season. The

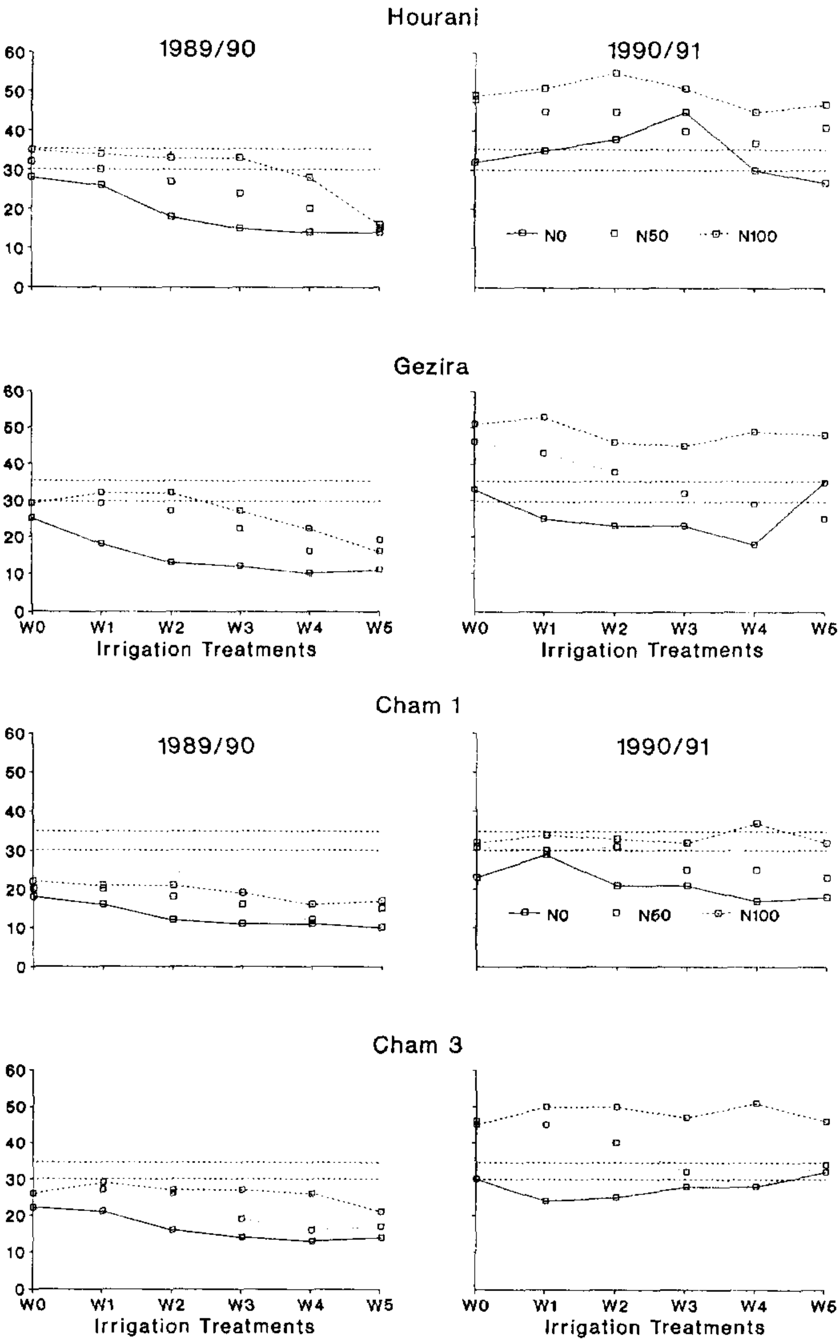

Figure 3.4.10 SDS sedimentation test for wheat grain

effect of supplemental irrigation also differed between seasons. In 1989/90, increasing the amount of water fairly generally decreased SDS values, although the severity of this decrease appeared to depend on variety x N-rate effects; but in 1990/91 there were no consistent trends.

Varietal differences were quite large. In particular, values for Cham 1 were generally lower than those for the other three varieties. The local Haurani appears to have the best baking potential, followed by Cham 3.

Although a weak positive relationship was observed between SDS test values and protein%:

$$\text{SDS test} = 1.78\ \text{Protein}\ \% + 9.63 \qquad (R^2 = 0.35)$$

the SDS sedimentation test is considered as complementary to the protein determination in assessing the technical properties of wheat. Apparently, for industrial purposes the total protein content is not adequate to assess those properties. What is interesting from the present results is that SDS test values seem to be more affected by seasonal factors -- in this case, probably, the size of the available N pool in the soil -- than are the protein % values. Further, it seems that is harder to bring the SDS values up to the international standard by N fertilization than it is the protein values.

We may conclude that, since the technical properties of wheat are strongly affected by supplemental irrigation and N fertilization as well as by initial soil fertility status, measures to increase wheat production through supplemental irrigation must be coupled with appropriate N fertilizer additions -- which optimize yield and maintain, if not improve, the quality of the grain. A greater awareness and understanding of these relationships, and how they differ between varieties, is required.

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3.5 Rotations

Growing an annual crop is not an independent event but part of a sequence. Through the medium of the soil, this year's crop is influenced by crops that preceded it and by the management and inputs those crops received, and it will itself and its management influence the performance of future crops. The soil acts as the agent of these influences, changing according to its utilization. Temporary changes, like water-storage between seasons, affect only the next crop; others, perhaps involving the build-up or decline of organic matter, structure, nutrient status, pests or pesticide residues, may be responsible for long-term productivity trends. Rotation trials are concerned not with single crops but with sequences of crops, with cooperative productivity (biological and economic) of those sequences, and with the long-term evolution of that productivity and of the underlying condition of the soil. Such studies are intrinsic to the question of agricultural sustainability.

3.5.1 Barley Rotation Trials at Tel Hadya and Breda

3.5.1.1 Introduction

The so-called 'new' rotation trials at Tel Hadya and Breda have now completed nine cropping years. Each trial comprises three replicates of both phases of an incomplete factorial combination of six two-year rotations of barley with fallow, with barley, or with a legume forage (Jones 1989). Previous reports (FRMP 1989; 1990) have summarized results up to and including the 1988/89 season -- providing comparisons of productivity (grain, total dry matter, total crop N, etc.) between rotations, between different forages and between different fertilizer regimes on both rotations and sequences of continuous barley.

In June 1990, a Program planning meeting considered the future of these trials and decided to continue them but with changes to some of the treatments. Here, we detail those changes and summarize yield data for the 1989/90 and 1990/91 seasons.

3.5.1.2 Changes in Experimental Treatments

The four forage crops in rotation with a grain barley crop were previously: two pure legumes, *Vicia sativa* (vetch) and *Lathyrus sativus* (lathyrus) and mixtures of each of those with barley. Originally, these crops were all harvested at the hay stage, but since the 1985/86 season they have been allowed to grow to maturity, with earlier cutting of small sample areas to assess hay-stage productivity. However, mature mixtures of cereal and legume are not a very practical crop, either experimentally or agriculturally; and differences in production between rotations with pure legumes and rotations with legume barley mixtures proved to be small and fairly consistent (see below). So it was decided to stop planting mixtures and replace them: in one treatment with another forage legume, Vicia narbonensis, to be harvested mature; in the other treatment with more Vicia sativa, to be harvested green to simulate a green-grazing utilization. This latter treatment is intended to provide a comparison with the mature-harvested vetch treatment, in respect of the availability of soil moisture and mineral-N to the succeeding barley crop (following the results of other crop sequence studies - FRMP 1989, pp 34-36).

The four forage rotations were also, previously, in factorial combination with four fertilizer treatments. One of these was (and remains) a zero-fertilizer control; the other three each provided biennially the same rate of N to the barley crop (20 kg N/ha at Breda; 40 kg N/ha at Tel Hadya) and also the same rate of P, 60 kg P_2O_5/ha, but supplied either all to the barley crop, all to the legume crop or half and half. However, the timing and splitting of the phosphate fertilizer made very little difference to the yield of either crop, and it was decided to drop this comparison, apply all the phosphate to the barley crop and add a comparison of N rates to barley instead.

The new treatment plan is given in Table 3.5.1. It should be noted that treatments in columns E and F and in lines I, II, III and VI remain unchanged. This means that certain comparisons, specifically (i) that within the continuous barley rotation, and (ii) that across rotations (barley-vetch, barley-lathyrus, barley-fallow and barley-barley) under fertilizer regimes III and VI can be made across the years before and after 1990.

3.5.1.3 Comparison of Rotations

Figure 3.5.1 summarizes the annual output of above-ground total dry matter and total N for the four rotations, barley-lathyrus (B-L),

Table 3.5.1. Plan of treatments employed in 'new' rotation trials at Tel Hadya and Breda, as amended in June 1990

Fert. regime N:P2O5 in phase			Rotation Phase 1 / Phase 2	A Barley Lthrus	B Barley Narbon	C Barley VS(MH)	D Barley VS(GG)	E Barley Fallow	F Barley Barley
	1	2							
I	20:60	20:60							19
II	0:0	20:60							22
III	20:60	0:0		1	2	3	4	18	20
IV	40:60	0:0		5	6	7	8		
V	0:60	0:0		9	10	11	12		
VI	0:0	0:0		13	14	15	16	17	21

(Numbers 1-22 refer to particular treatment combinations of rotation and fertilizer regimes. The N fertilizer rates indicated are those for Breda; the Tel Hadya rates are twice as large. VS=common vetch, Vicia sativa; MH=mature harvest; GG=green grazing.)

barley-vetch (B-V), barley-fallow (B-F) and barley-barley (B-B). Each value is presented on a per hectare basis and comprises the total of contributions from half a hectare of one phase of the rotation and half a hectare of the other. Values for fertilized and unfertilized conditions (+ and -, regimes III and VI) are shown side by side. It should be noted that the alternate year barley crop in the fertilized condition received 20 and 40 kg N/ha at Breda and Tel Hadya, respectively, equivalent to 10 and 20 kg N/ha across the whole rotation.

In two previously reported years, 1987/88 and 1988/89, rotations including legumes (B-L, B-V) in all cases outyielded rotations restricted to barley (B-F, B-B) both in total dry matter and total nitrogen yield (FRMP 1990, p 169). But, in 1989/90, which was a very dry year, legume growth was poor, particularly at Breda; and fertilized B-B at Tel Hadya and fertilized and unfertilized B-F and B-B at Breda outyielded the corresponding barley-legume

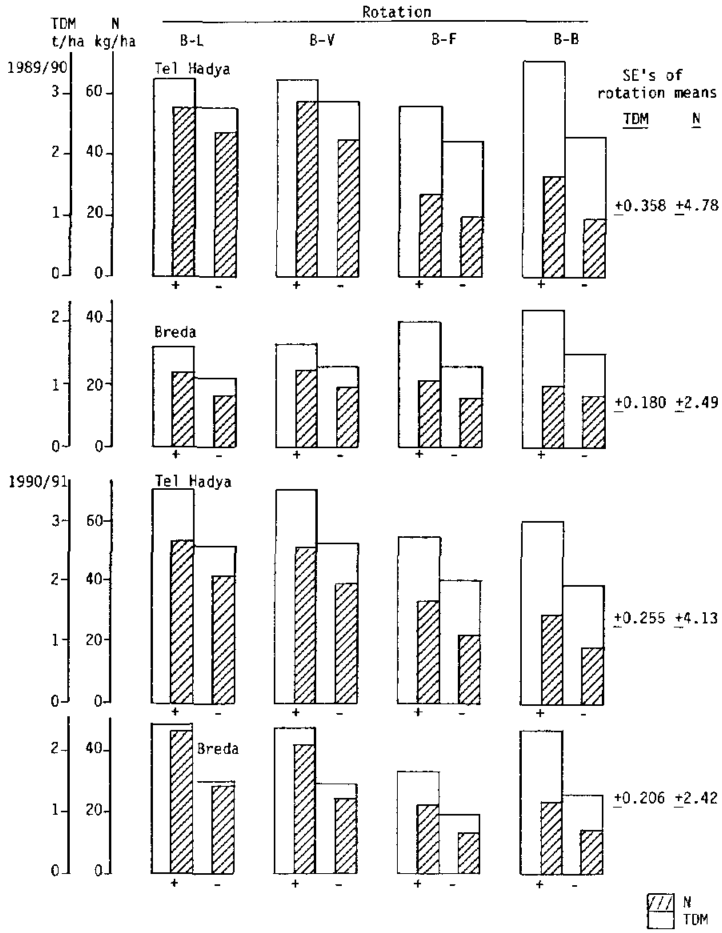

Figure 3.5.1 Comparison of four rotations at two sites over two years in respect of above-ground total dry matter and total N output from both phases of the rotation taken together

rotations in total dry matter production (though not in all cases significantly). However, in terms of crop N output, rotations including legumes were consistently superior (Table 3.5.2).

The question is often asked, how much nitrogen do legumes actually contribute. If it is offtake in the harvested crop that matters (and, after 8 or 9 years of the same rotation, the state of the soil may reasonably be assumed to be approximately stable), then these trials give us some clear answers. Over two years that were 'dry' and 'average-to-dry', the difference in net offtake of nitrogen between rotations with legumes and rotations without was about 20 kg N/ha/yr at Tel Hadya and 10 kg N/ha/yr at Breda (Table 3.5.3).

Table 3.5.2. Summarized comparisons of total dry matter and crop nitrogen outputs: barley-legume rotations (B-L, B-V) as a percentage of barley-only rotations (B-F, B-B)

		Total dry matter	Total crop N
1989/90	Tel Hadya	111	205
	Breda	81	115
1990/91	Tel Hadya	125	180
	Breda	123	189

Table 3.5.3. Yields of nitrogen (kg N/ha) in harvested crops in barley-legume (B-L, B-V) and barley-only (B-F, B-B) rotations: means over two seasons, 1989/90 and 1990/91 (with amount of fertilizer-N applied subtracted from values for fertilized rotations)

	Barley-legume rotations	Barley-only rotations
Tel Hadya:		
Fertilized	34.6	11.0
Unfertilized	43.6	20.1
Breda:		
Fertilized	24.1	12.1
Unfertilized	22.2	15.3

3.5.1.4 Rotations with Legume-Barley Mixtures

The 1989/90 season was the last in which legume/barley mixtures were grown and the last affording comparisons between rotations of barley with pure legumes and those with legume/barley mixtures. Mean values over four fertilizer regimes are given in Table 3.5.4. Many of the differences between rotations, though arithmetically small, are statistically significant. What is more important, however, is the fact that the pattern of yields conforms with that reported previously (FRMP 1990, pp 172-173): while dry matter yields of the mixed-species forage tend to outyield the pure legume forage, for the pure barley yields from the other phase it tends to be the other way round. And total crop N offtake in the harvest is higher (appreciably higher at Tel Hadya) in the pure-legume rotations. Thus the trial appears to lose little of experimental value from the deletion of the mixed-forage rotations.

Table 3.5.4. *Comparison of four barley-legume rotations in respect of rotational crop yields of dry matter and nitrogen in 1989/90*

	Total dry matter, t/ha				Crop N, kg/ha		
	Barley		Legume or				
Site/rotation	Grain	Straw	mixture	Total†	Barley	Legume	Total†
Tel Hadya:							
B-L	1.48	2.52	2.24	3.12	45.6	66.0	55.8
B-L/B	1.62	2.31	2.56	3.25	43.0	52.3	47.7
B-V	1.56	2.64	2.17	3.19	49.3	57.9	53.6
B-V/B	1.50	2.33	2.30	3.06	42.8	44.8	43.8
Breda:							
B-L	0.80	1.77	0.43	1.50	30.5	14.5	22.5
B-L/B	0.65	1.74	0.84	1.61	28.6	14.9	21.8
B-V	0.70	1.86	0.64	1.60	32.0	18.4	25.2
B-V/B	0.58	1.58	0.77	1.47	29.6	14.6	22.1

All values are means over four fertilizer regimes, three involving 60 kg P_2O_5/ha biennially, and 20 kg N/ha (Breda) and 40 kg N/ha (Tel Hadya) biannually and one zero-fertilizer control.

† Since all values are given on a per hectare basis, totals are means of respective barley-phase and legume-phase values.

3.5.1.5 Pure Legume Yields in 1990/91

It will not be possible to see the full impact of the rotations newly introduced in 1990 until the first 2-year cycle is completed with the 1992 harvest. But it is interesting to compare the performance of the newly introduced Vicia narbonensis with the two other forage legumes grown to maturity (Table 3.5.5). Narbon vetch produced 20-25% more dry matter at maturity than common vetch and lathyrus (and crop N output was comparable or higher); and differences at the hay-stage sampling were even greater. This result is in keeping with previous comparisons of forage legumes, but relative effects on subsequent crops have not previously be looked at in a rotation context. Improved legume performance, without detriment to the subsequent barley, is essential if barley-forage rotations are to become sufficiently attractive for widespread adoption by barley-zone farmers.

Table 3.5.5. Yields of three pure legumes in barley-legume rotations, 1990/91

	Mature crop				Hay crop, TDM t/ha
	Grain t/ha	Straw t/ha	TDM t/ha	Total N kg/ha	
TEL HADYA	***	***	***	*	***
Vetch	0.68	1.43	2.11	48.2	2.09
Lathyrus	0.72	1.41	2.13	54.4	1.80
Narbonensis	0.93	1.67	2.60	52.8	2.73
SE/mean	±0.032	±0.044	±0.067	±1.52	±0.064
BREDA	***	***	***	***	***
Vetch	0.50	0.88	1.38	34.1	1.25
Lathyrus	0.75	0.81	1.55	41.5	0.96
Narbonensis	0.77	1.08	1.85	45.7	1.72
SE/mean	±0.020	±0.021	±0.039	±0.96	±0.033

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3.5.2 Long-term Effects of Regular Fertilizer Use Within Different Two-year Cropping Rotations on the Phosphorus and Nitrogen Status of Soils

A. Matar, M. Jones, A. Saddiq and M. Shaheen

3.5.2.1 Introduction

Regular fertilizer application and the employment of particular crop sequences will usually build up cumulative effects on soil properties, on crop response to fertilization and on the maintenance of yield levels. Some of these will be evident within a few years, e.g. increase in soil available P from the regular use of P fertilizer (1); but others, which may ultimately have important implications for sustained and profitable crop production (FRMP 1988 and 1989 Annual Reports), may take much longer to appear.

As described in the previous section, two long-term trials (called "New Rotation") were established in 1982/83 at Breda and Tel Hadya (Jones 1989). Both trials compare three basic rotations, barley-legume (B-L), barley-fallow (B-F) and barley-barley (B-B); but the B-L rotations occur in four forms, including barley-vetch and barley-lathyrus. There is also a range of fertilizer regimes, which form an incomplete factorial design of 22 treatment combinations with the rotations. Nine of these were selected for the investigation described in this report (Table 3.5.6).

Table 3.5.6. Rotation and fertilizer treatments

Site	Fertilizer regime: $N:P_2O_5$ in Barley Phase	Fertilizer regime: $N:P_2O_5$ in Other Phase	Rotation: Barley/ Fallow (B-F)	Rotation: Barley/ Barley (B-B)	Rotation: Barley/ Vetch (B-V)	Rotation: Barley/ Lathyrus (B-L)
Breda	20:60	20:60		+		
	20:60	0:0	+	+	+	+
	0:0	0:0	+	+	+	+
Tel	40:60	40:60		+		
Hadya	40:60	0:0	+	+	+	+
	0:0	0:0	+	+	+	+

To evaluate the impact of rotation and fertilization on the N and P status of the soils, composite soil samples were taken in September 1990 before the onset of rainfall from replicates of the nine selected treatments in 20 cm increments down to 100 cm depth. Organic C and total N were analyzed in the surface soil layer (0-20 cm); available P (= $NaHCO_3$-extractable P) in the first 3 layers (0 to 60 cm); and mineral-N in the whole profile (0 to 100 cm).

3.5.2.2 Effects of Rotation and Fertilization on Soil N and C Status

More soil mineral N was found after fallow (in B-F rotation) than after barley (in B-B rotation) or vetch (in B-V rotation), with or without NP fertilization (Figure 3.5.2a,b). Differences were statistically significant except in the comparison with the B-V rotation at Tel Hadya.

At Tel Hadya, following fertilized barley in B-F rotation and annually-fertilized B-B rotation and following fallow and vetch in fertilized and unfertilized rotations, soil mineral-N contents, 7-9

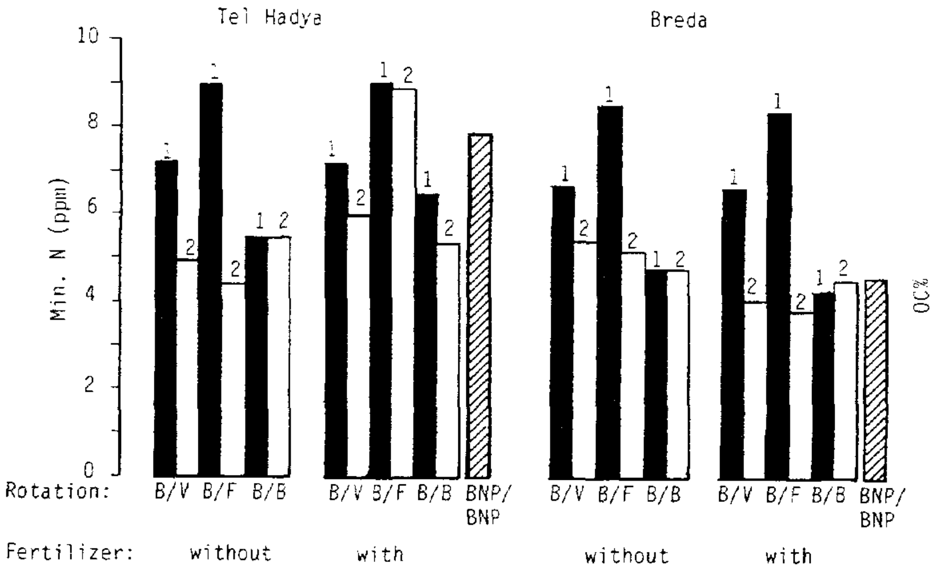


Figure 3.5.2 Mineral-N concentration in soil profile (0-100 cm) as related to rotations, fertilizer regimes and phases (Phase 1: after legumes or fallow and Phase 2: after barley)

ppm, were at an adequate level for subsequent crop production. (However, it should be remembered that this followed a dry cropping season in 1989/90.) The pattern was similar at Breda, except following barley in B-F and annually-fertilized B-B rotation.

There are no fully consistent patterns in the organic C data (Figures 3.5.3 and 3.5.4):

- Fertilizer use has not increased soil C, although one would have expected it to have promoted the return of a greater quality of crop residues. If anything, C values are slightly higher in unfertilized treatments, although this difference is significant only for the B-F rotation at Breda.

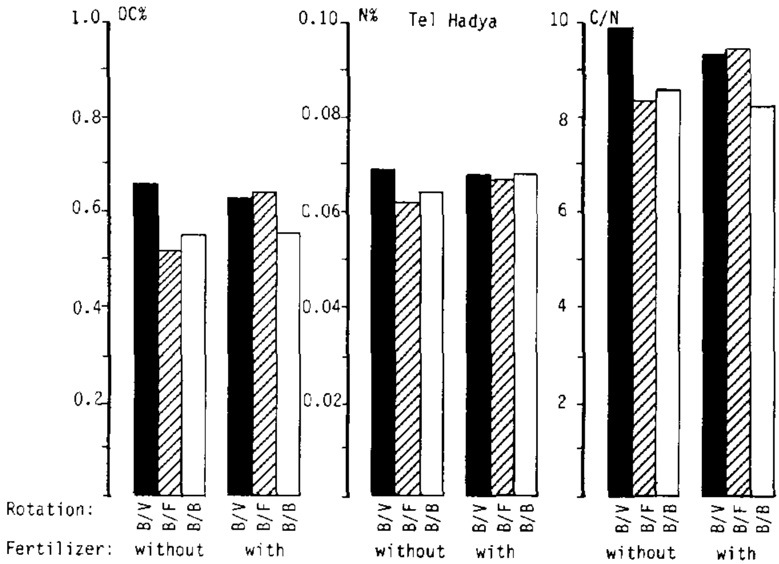


Figure 3.5.3 The mean organic carbon of both phases, N% and C/N ratio in top (0-20 cm) soils, in relation to rotation and fertilizer regimes at Tel Hadya

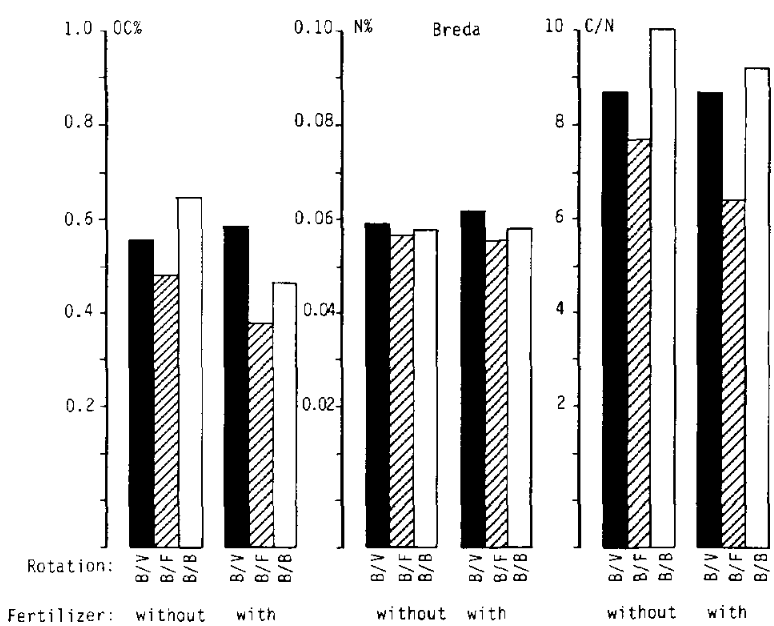


Figure 3.5.4 The main organic carbon of both phases, N% and C/N ratio in top (0-20 cm) soils, in relation to rotation and fertilizer regime at Breda

- Soil that has carried crops every year (either B-V or B-B) tends to have a higher C content than soil cropped only biannually (B-F), presumably because more residues have been returned; but the fertilized situation at Tel Hadya is anomalous.
- The B-V rotation has produced a higher soil C content than the B-B rotation, significantly so under fertilized and unfertilizer conditions at Tel Hadya and under fertilized conditions at Breda; but in this case, the unfertilized situation at Breda is anomalous. This is ironic. The unfertilized B-B soil at Breda has the highest soil C content of all treatments at both sites, but it produces one of the lowest yields of crops.

Treatment differences in soil total N are proportionately smaller than those for the organic C data. Again there was no appreciable effect of fertilizer use; but values were generally highest in B/V rotation (significantly in the unfertilized treatment at Tel Hadya and the fertilized treatment at Breda). This is some evidence of benefit from the inclusion of a legume in the rotation.

The C:N ratio is an indication of the state of the organic matter in the soil: high values imply the presence of relatively fresh, unhumified material; low values, a high degree of humification. The present values, ranging from 11 to 7 are all fairly low or very low. At Breda, their pattern can be related to treatment: moderately high values in treatments (B-V, B-B) producing crops (and therefore residues) every year, very low values where residues are returned only in alternate years (B-F); but this logic does not seem to apply to Tel Hadya. In particular, the low C:N ratios of the B-B treatment are difficult to explain.

3.5.2.3 Effect on Soil P Status

Soil available-P status was evaluated by the Olsen test ($NaHCO_3$-P extraction) and by extraction with anion exchange resin. The Olsen values, summarized in Figure 3.5.5, offer no surprises. The only factor to have any significant effect was frequency of phosphate fertilizer application. The small apparent differences between rotation (for which there appears to be no consistent pattern) may be entirely fortuitous.

It is well established that soil phosphate extracted by anion exchange resin correlates better with actual available P (= isotopic exchange P) and with total P uptake by plants than does Olsen P. By

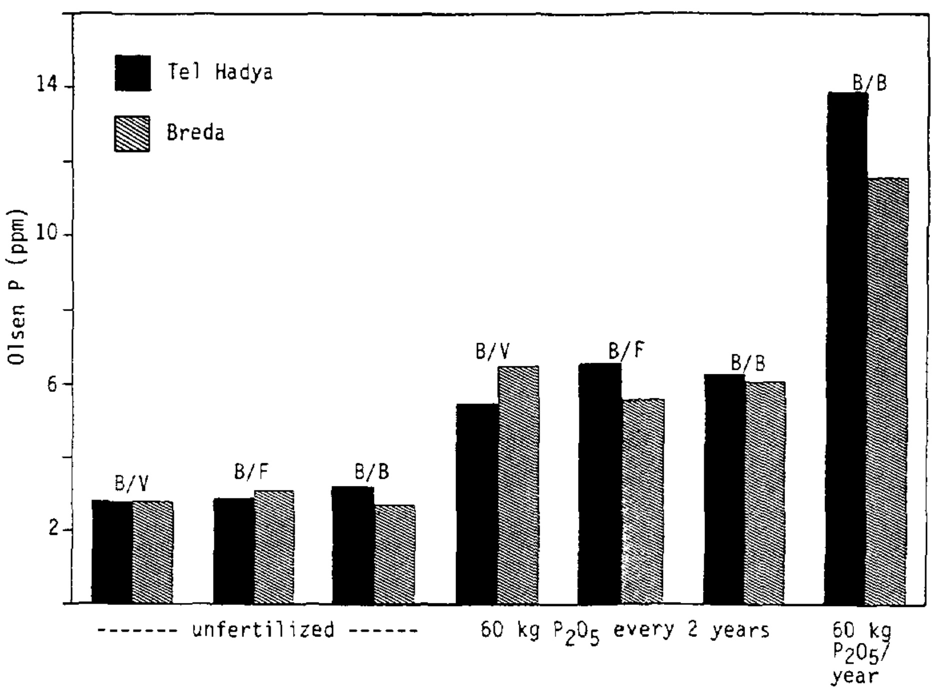
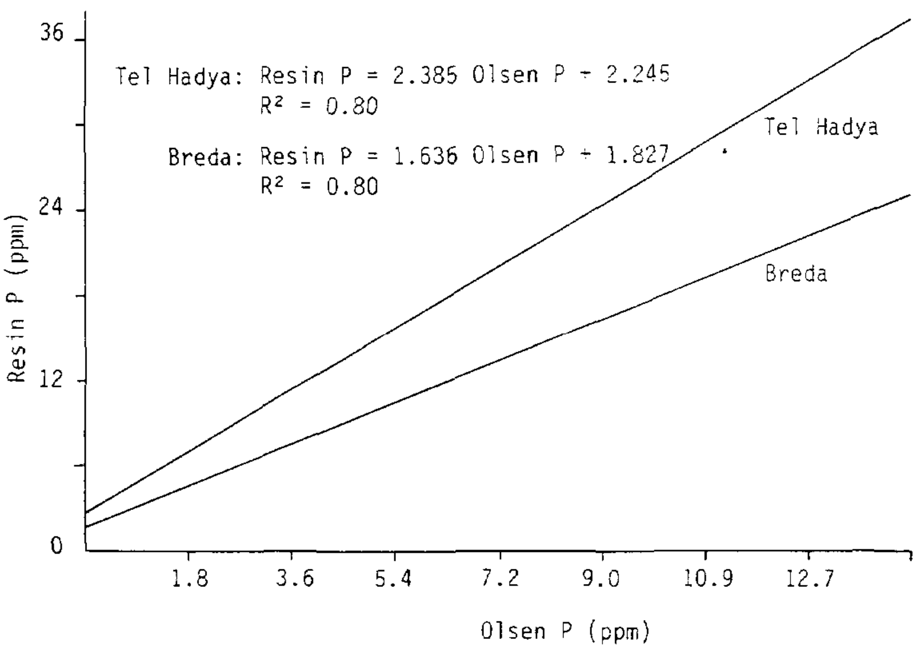


Figure 3.5.5 Effect of fertilizer regimes and rotation on top-soil available P content after 9 years in the New Rotation Trials at Breda and Tel Hadya

comparing the amounts of P extracted by the two methods, it was found that for the same value of Olsen-P the corresponding resin-P value was significantly higher (at 0.01 level) at Tel Hadya than at Breda (Figure 3.5.6). That suggests that the Olsen method underestimates soil available P status at Tel Hadya relative to Breda. This could be due to the higher buffer capacity for P at Tel Hadya (161 ml/g) and higher Fe-dithionate (2.1%) as compared with Breda (127 ml/g and 1.3%, respectively), determined in separate P-isotherm studies (E. Afif, PhD thesis).



<u>Figure 3.5.6</u> Comparison of values of available soil-P obtained by anion-exchange resin and Olsen method for soils at Tel Hadya and Breda

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4. PROJECT 2. AGROECOLOGICAL CHARACTERIZATION FOR RESOURCE MANAGEMENT

Introduction

The long-term goal in this project is to help ICARDA and national programs to solve weather-related agricultural problems and to improve the efficiency, relevance and targeting of research through the application of techniques which both characterize agro-ecological variability and predict how such variability will interact with and modify of new technology. This goal will be attained through the following medium-term objectives:

- To develop, test and make available techniques which characterize and map agroecological variability.
- To combine expressions of agroecological variability with crop models and farm models to simulate farm decision making and to identify homogeneous recommendation domains.
- To apply, in collaboration with commodity program scientists, the analysis of weather data to the definition and solution of weather-related pest problems and the better definition of experimental environments.
- To initiate the building of a selective database of weather, soil and crop production data from the WANA region.
- To develop and test, in collaboration with national scientists, models to predict crop yields from real-time weather data.

4.1 Agroecological Characterization: Preliminary Climatic Analysis for Syria

G. Walker

4.1.1 Introduction

The predominant ecological classification scheme for Syria is based on precipitation. Zones are distinguished on the basis of long-term average precipitation, plus a requirement for a minimum frequency of years exceeding the prescribed precipitation threshold for that zone. This scheme is clearly useful in explaining the distribution of natural vegetation, and for targeting crop species.

Perhaps because of the obvious importance of precipitation, the agroecological relevance of other factors has not been widely considered. For example, one might want to ask if 300 mm precipitation environments in northeastern and southwestern Syria should be considered homogeneous as regards the introduction of improved germplasm. Factors which might influence the answer to such a question include: precipitation distribution over the cropping season; the temperature regime (mean temperatures, and 'events' such as heatwaves or frost); the timing of moisture supply in relation to evaporative demand; photoperiod; regimes of humidity, solar radiation, and wind; soil properties; government policy; availability of supplemental irrigation, labor, etc.

One way to get answers to such questions is empirically -- by observing responses to introduced technology. However, this is costly if it involves multi-year, multi-site field trials. In addition, the climatic factors listed above show variability from year-to-year, so there is no guarantee that a tolerably short time-span for technology testing will be representative of the long-term climate. Efficiency in technology development, testing, and transfer is maximized when all the available information is used. The goal of this brief chapter is to demonstrate some simple climatic analyses, to draw some conclusions from them, and to draw attention to the possibilities of using such information in addressing issues of efficient agricultural technology enhancement in the WANA region.

The analyses were conducted for Syria, partly because ICARDA conducts much of its work in Syria, and partly because the data for a number of weather stations were available for 20-30 years (mostly 1960-87). The stations used are shown in Figure 4.1.1, along with the Syrian agricultural stability (ecological) zones. Station elevations are also given.

4.1.2 Analysis

4.1.2.1 Precipitation Amount

Table 4.1.1 presents October-May precipitation statistics for the nine stations. Median amounts range from 481 mm at Idleb to 267 mm at Tel Abiad. On the basis of such data, Idleb, Marret, and Kamishly would fall into zone 1b, Sweida and Hama are borderline 1b and 2, Aleppo would be in zone 2, and Hassakeh, Tel Abiad and Izra are all borderline zones 2 and 3 (mean precipitation exceeds 250 mm, but less than two-thirds of the years have more than 250 mm

Table 4.1.1 Statistics for total October to May precipitation for nine Syrian weather stations

Station	10% chance of lower precip (mm)	Median	10% chance of higher precip (mm)	Coefficient of variation (%)
Idleb	327	481	633	26
Maaret	230	392	542	29
Aleppo	200	349	437	29
Hassakeh	149	279	432	38
Kamishly	239	410	579	32
Tel Abiad	186	267	391	30
Hama	241	364	459	24
Sweida	254	356	482	26
Izra	194	283	343	30

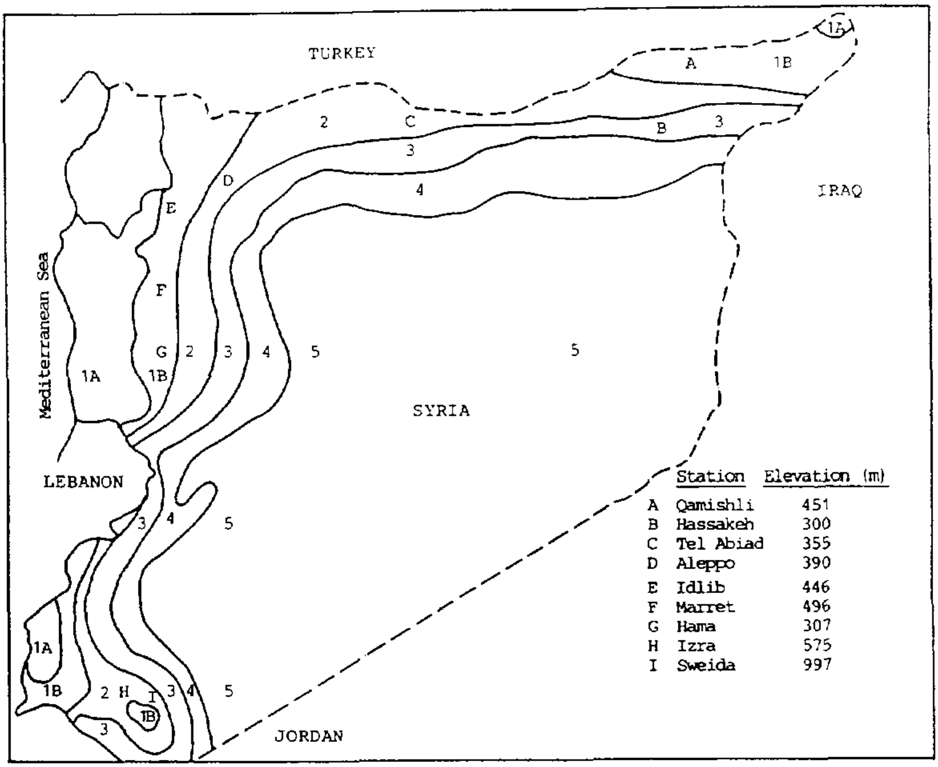

Figure 4.1.1 Agricultural stability zones in Syria

precipitation). These findings do not in every case agree with the station classifications implied by Figure 4.1.1, raising possible questions about the stability of the boundaries that separate zones.

A measure of the variability of precipitation is the coefficient of variation (CV). This is lowest for Hama, and highest for Hassakeh. The stations with highest CVs are the three in the northcentre/northeast. There is insufficient data to determine if differences in variability exist between different areas of western Syria.

4.1.2.2 Precipitation Distribution

It is often speculated that the pattern of precipitation distribution over the crop season is important in determining crop yields (i.e. yields may vary with the same amount of precipitation distributed differently over the season). However, a characterization of the statistical properties of the distribution has not been previously made. Here we address the statistics of the distribution within and among sites. The distribution could be characterized in many ways. Two approaches are used here.

The first approach is to consider that fraction of seasonal precipitation received before (or after) a certain date or growth stage. With reference to specific crops, an analysis based on growth stage would be preferable, but for more general application an analysis based on date can be used. This analysis is based on that fraction of October-May precipitation received on or before January 31 (Table 4.2.2).

Table 4.2.2 Statistics for precipitation received by January 31 at Syrian weather stations

Station	Lowest recorded (%)	Median (%)	Highest recorded (%)	Difference between 10 and 90% probabilities (%)	Std. Dev. (%)
Idleb	34	56	73	31	11.3
Maaret	33	55	79	30	12.5
Aleppo	37	56	80	30	11.6
Hassakeh	18	48	87	44	16.3
Kamishly	25	47	73	38	11.4
Tel Abiad	16	49	78	47	17.5
Hama	39	54	82	33	11.1
Sweida	23	48	73	35	12.4
Izra	18	53	78	39	15.2

First, it is clear that the range in distribution is large. In the extreme case, Hassakeh, as little as 18% or as much as 87% of the Oct-May precipitation has been received by Jan 31. Conversely, at Idleb, not less than 34% and not more than 73% of Oct-May precipitation has been received by Jan 31.

The median precipitation received by Jan 31 is close to 50% of seasonal rainfall for all sites. However, northeastern sites are all just under 50%, and northwestern sites just above, with no clear trend for the southwest. Measures of variability are shown in the last two columns. The northeast appears to be the most variable, and the northwest the least, with the southwest intermediate.

The second approach used to examine precipitation distribution is a tabulation of the month-by-month frequency of rainfall above a certain threshold. In the example shown in Table 4.1.3, a 25 mm monthly threshold was used.

Table 4.1.3 Probability of exceeding 25 mm monthly precipitation

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Idleb	100	93	97	69	23	3	0	0	3	0	70	97
Maaret	92	79	79	52	20	4	0	0	4	28	62	85
Aleppo	87	85	76	47	25	0	0	0	0	32	61	93
Hassakeh	81	65	77	65	30	0	0	0	4	13	43	70
Kamishly	93	83	86	86	38	0	0	0	0	21	67	82
Tel Abiad	86	68	75	43	22	0	0	0	0	22	35	69
Hama	100	79	79	59	7	0	0	0	4	29	63	81
Sweida	96	89	89	39	8	0	0	0	0	27	59	73
Izra	88	84	76	30	0	0	0	0	0	4	35	71

The most striking thing about these figures is the relatively high probability of receiving significant rainfall in northeastern and northcentral Syria in April and May. At both Kamishly and Hassakeh the probability of significant rain is as high in April as in February. This is not the case at other stations. In effect, for a given seasonal rainfall total, the month-by-month distribution in the northeast will be 'flatter' than elsewhere. That implies, for a given seasonal total, a somewhat lower risk for terminal drought in the northeast, but a somewhat higher midseason drought risk.

At Tel Abiad the distribution is not quite so 'flat' as in the northeast, but given that this is the driest of the nine sites, it still exhibits surprisingly high probabilities of significant rain late in the season.

The southwest is in contrast to the northeast, with virtually no prospect of significant rain in May, and much lower prospects in April than in February and March. This might in turn imply greater susceptibility to terminal drought than in the north.

4.1.2.3 Thermal Time

The ability of crops to exploit efficiently the winter peak in precipitation is influenced by the growth of the crop canopy. Winter crop growth is constrained by phenological development, which is highly sensitive to temperature. An integrative measure of the thermal regime is a growing degree-day (GDD) sum above a base temperature. In the example shown here (Table 4.1.4) GDDs are accumulated above a base temperature of 0 C for the period December 1 to March 31.

The variability in thermal time accumulation within sites is clearly substantial, implying wide year-to-year variability in rates

Table 4.1.4 Statistics for December-March growing degree day sums

Station	10% chance of lower GDD sum (deg-C days)	Median GDD sum (deg-C days)	10% chance of higher GDD sum (deg-C days)	Std. dev. (deg-C days)
Idleb	836	1037	1192	138
Maaret	726	849	1043	137
Aleppo	813	964	1131	132
Hassakeh	798	952	1164	145
Kamishly	877	1053	1211	138
Tel Abiad	749	949	1095	140
Hama	889	1084	1277	131
Sweida	856	1007	1188	127
Izra	1016	1157	1305	111

of crop development. For example, these figures suggest a range of up to a month in heading date. Among sites, variability is greatest in the northeast and least in the southwest.

The thermal time sum for Izra suggests substantially faster crop development there than at other sites. This is not surprising given the lower latitude. The other southern station, Sweida, has an elevation 500-700 m greater than elsewhere and has GDD sums similar to those further north.

4.1.2.4 Frost Events

Cold tolerance is an important aspect of crop adaptation to some Mediterranean environments. Measures that relate to the cold tolerance required include frequency, severity, and stage of growth of frost events. Statistics for two measures — number of frost days, and date of last frost -- presented in Table 4.1.5, indicate:

a high degree of year-to-year variability within sites; distinct regional tendencies; and considerable site-to-site variability within a region.

Table 4.1.5 Statistics for number of frost days during November-April for Syrian weather stations

Station	Number of days, with > = 90% probability	Number with days, with > = 50% probability	Number of days, with > = 10% probability	Standard deviation (frost-days /season
Idleb	0	5	29	11.1
Maaret	11	31	54	20.4
Aleppo	7	23	41	13.3
Hassakeh	15	39	59	16.7
Kamishly	1	16	31	13.1
Tel Abiad	22	39	63	18.5
Hama	4	17	37	12.6
Sweida	3	7	18	6.2
Izra	2	11	23	9.5

Regarding year-to-year variability, the number of frost days at a site can be very few (zero in some years at some sites) to 50 or more at some northern sites. Tel Abiad has recorded as few as 9 and as many as 84 frost days in a season. Region-to-region differences show that the southwest has lower frost probabilities than elsewhere, while the dry stations in the northeast have the greatest frost probabilities.

Regarding site-to-site differences within a region, it is somewhat surprising that, despite its 997 m station elevation, Sweida has similar frost probabilities to Izra. On the other hand, Kamishly in the far northeast has much lower probabilities than Hassakeh and Tel Abiad. That the extreme northeast of the country (corresponding to zone 1 in Figure 4.1.1) has fewer frost days than regions to the immediate south is supported by results presented in the Climatic Atlas of Syria (Climate Division 1977).

At first glance these data imply substantially greater frost risk in (most of) the north-east than the northwest. However, seasonal frost frequencies for Tel Hadya and Breda (ICARDA Meteorological Reports 1989/90) are mostly greater than those for Aleppo for the period of overlapping record (1979/80 to 1986/87). Tel Hadya and Breda in fact have frost frequencies closer to those of Hassakeh and Tel Abiad. The contrast between northeast and northwest is therefore not as large as Table 4.1.5 suggests. This is discussed further below (relation between precipitation and frost).

Probabilities for late frosts follow a similar pattern to number of frost days (Table 4.1.6). Those stations having high frost frequencies also tend to have later frosts. An exception is Sweida which, despite its relatively low frost frequency, can still record late frosts.

Table 4.1.6 Frost date at selected probabilities for Syrian weather stations

Station	50% chance of later frost	10% chance of later frost	Latest frost on record
Idleb	Feb 1	Mar 10	Mar 26
Maaret	Mar 12	Mar 29	Apr 14
Aleppo	Mar 6	Mar 28	Apr 6
Hassakeh	Mar 11	Apr 2	Apr 18
Kamishly	Feb 27	Mar 28	Apr 18
Tel Abiad	Mar 15	Apr 9	Apr 27
Hama	Feb 25	Mar 21	Mar 29
Sweida	Mar 2	Mar 27	Apr 26
Izra	Jan 28	Mar 8	Mar 27

April frosts at Tel Abiad and Hassakeh can be expected at least once in ten years, but April frost has very low probability at the other locations considered.

4.1.2.5 Relation between Frost and Precipitation

Weather variables are not mutually independent. As indicated above, the geographical distribution for frost frequency might be related to the geographical distribution of precipitation. The way to examine that is to see if a single relationship holds across the entire geographical area of interest. Here we are interested in northern Syria. We use data for available stations from Hama (latitude 35-08 N) north to Kamishly (37-03 N), including ICARDA data for Breda, Tel Hadya, and Jindiress. Results for the wettest and coldest month (January) are shown in Figure 4.1.2.

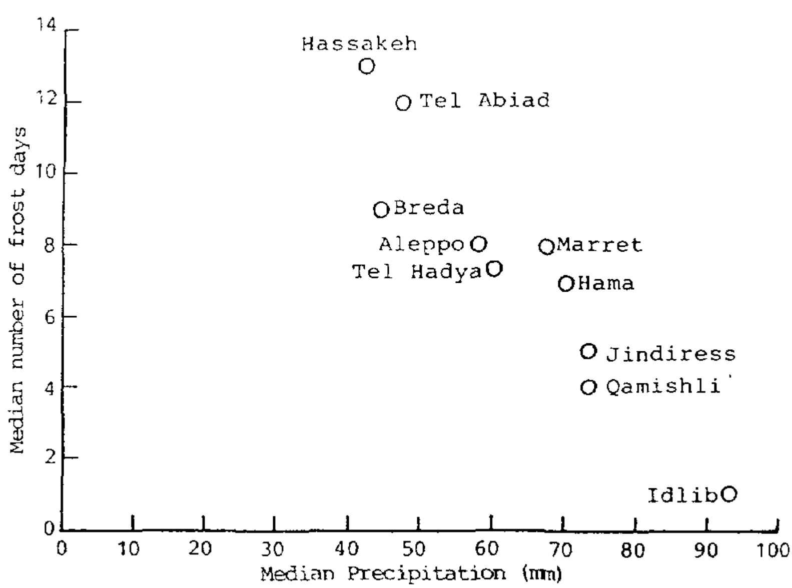

Figure 4.1.2 Median number of January frost days and median January precipitation for weather stations in northern Syria

There clearly is a negative correlation between frost days and precipitation. Furthermore, the relationship appears unaffected by the 2-degree range in latitude, or by the elevation differences among the stations. One serious consequence of such a close correlation is that it potentially confounds the attribution of crop distribution (ie. crop 'zones') to a single variable, precipitation. An example of the problems that arise is given below.

4.1.3 Discussion

It is difficult or impossible to find Syrian weather stations, in different parts of the country, having closely similar growing season precipitation totals and long periods of record. Nevertheless, it is still possible to draw conclusions regarding climatic differences that exist between geographically distinct regions that are classified in the same agricultural stability zone.

4.1.3.1 North versus South

There are clear differences between north and south. Crop areas in the south (represented by Izra) have relatively warm winters and earlier crops (heading estimated at 10-15 days earlier) and less frost risk (although, since the analysis is conducted by date rather than growth stage, the risk is not diminished quite as much as first appears).

The south also has a somewhat compressed wet season, with sharply decreasing probability of significant rain in April. However, in terms of matching 'crop evaporative demand' to water availability, earlier crop development may partially or completely compensate for the shorter wet season. Even in relatively wet years, though, terminal drought must be the norm in this region.

Although the south presents some interesting contrasts with the north, it is not very important for production of ICARDA-mandated crops on the national scale. (The exception is chickpea, for which the bulk of the national sown area is concentrated in the south.) Cereal grain production is in fact most concentrated in the northeast, and the climate regime there, and its contrast with the northwestern areas in which much ICARDA research is conducted, deserve serious attention.

4.1.3.2 Cereal Adaptation in Northern Syria

Across the north, as Figure 4.1.2 shows, frost risk increases with dryness. Thus, from northwestern to northeastern Syria, at similar precipitation levels large differences in frost regime are not evident. Differences in crop performance, or landrace distribution, occurring within a stability zone but in geographically separate areas of the north, are therefore unlikely to be related to frost.

Stations with higher frost frequencies not surprisingly have slower accumulations of thermal time over the period when frost mostly occurs (Dec-Mar) (Tables 4.1.4 and 4.1.5). Thus, the apparent adaptation of barley to relatively dry, and wheat to relatively wet, environments may be partly a consequence of the warmer winter conditions in wetter areas. The relatively long-season crop (wheat) will develop somewhat faster in the wetter than in the drier environments of northern Syria.

The precipitation regimes of northeast and northwest Syria are subtly different. At a given rainfall level, the probability of significant late season (April-May) precipitation is substantially higher in the northeast (with correspondingly lower probabilities through the mid-season).

The fact that the northeast is the principal area for wheat production in Syria may be related to the ability of the relatively long-season cereal crop (wheat) to make the best use of late rainfall. Government statistics show that dryland wheat production in Hassakeh mohafaza (northeast) far exceeds that of barley, whereas in Aleppo mohafaza (northwest) there is more barley than dryland wheat. This observation may suggest strategies for crop improvement. For example, could earliness in barley be a more desirable requirement in the northwest than the northeast?

4.1.3.3 The Case of Chickpea and Lentil

Consideration of winter temperatures may also help to explain the distribution of food legumes in Syria. Chickpea is usually (at least within ICARDA) considered to be a crop adapted to the wetter areas of the so-called 'wheat-based farming systems' of West Asia/North Africa (e.g. Cooper et al. 1988). That is, chickpea is considered to be concentrated at the wetter end of the 350-600 mm mean precipitation band (i.e. the wetter end of stability zone 1b). Lentil in this system is considered to be the predominant food legume at the drier end of zone 1b.

This rainfall-based zonation concept for food legumes in Syria does not square with the fact that the chickpea-growing area is concentrated in the south, in a lower rainfall environment. For example, in 50% of years, the southern mohafazats of Daraa and Sweida contribute at least 60% of the national chickpea area (source: government statistics up to the 1989/90 growing season). The bulk of this is in areas classified as stability zone 2 (250-350 mm mean precipitation), with a climate represented by that of Izra.

Despite the relatively low precipitation in southern Syria (compared to the northwest) lentil is clearly not the preferred food legume in the south. In 50% of years, Daraa and Sweida contribute less than 10% of the national lentil sown area. In absolute terms, the lentil area is also much smaller than that of chickpea in these mohafazats. Whether for climatic or other reasons, application of the stability zone system to explain lentil distribution does not extend to southern Syria.

Evidence from Turkey (Eser et al. 1991) suggests, in that country, that the positions of lentils and chickpea for drought tolerance are reversed. These authors regard chickpea as the more drought-tolerant food legume.

To reconcile this information in climatic terms, it is evident that the distribution of chickpea in Syria corresponds to those areas where the risk of cold damage is relatively low/heat unit accumulations are relatively high. That includes the south, and the wetter (i.e. low frost risk, higher winter GDD sum) areas of the north.

Preference of chickpea over lentil in the south, and chickpea's southern predominance in stability zone 2, are probably connected to the later planting that is possible with chickpea. Planting lentil is risky because this crop is seeded early in the wet season. Planting chickpea (usually about 2 months after lentil) entails less risk since, the statistics show, farmers adjust to dry conditions simply by not seeding.

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4.2 Estimating the Frequency Distribution of Farmers' Crop Yields

T. Nordblom[1], F. Shomo[1], H. Farihane[2], M. el Mourid[2], M. Boughlala[3], H. Harris[4]

4.2.1 Introduction

Throughout West Asia and North Africa variability in weather conditions from one cropping season to the next is reflected in crop yields which, at national levels, show coefficients of variation of about 15 to 60%. At the level of the individual farm, year-to-year variations in yield can be much greater. In the last four years at Tel Hadya, yields have varied by an order of magnitude from one season to the next, due to seasonal differences in growth conditions, particularly rainfall.

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1. Pasture, Forage and Livestock Program, ICARDA

2. INRA, CRRA, Settat, Morocco

3. MIAC, Settat, Morocco

4. Farm Resource Management Program, ICARDA

In the diagnosis of constraints within farming systems, we need to quantify the uncertainty of crop yield at the farm level. The long time-series statistics on crop production which would make this a simple matter are often not available, or not available at the level of disaggregation that is necessary. We report here on the adaptation and application of methods proposed by März (1987) to estimate the statistical parameters of crop yields over time based on data collected in interviews with experienced farmers. The aim is to estimate the frequency distributions of crop yields at selected sites with contrasting environments in the Doukkala-Abda-Chaouia dryland farming region of Morocco. The study was undertaken under the auspices of a larger project, funded by IDRC, which aims to validate methods for agroecological characterization.

4.2.2 Methods

März's (1987) methods entail the following steps: (1) each farmer is asked to provide an estimate of the numbers of 'good', 'normal' and 'poor' crop seasons he experienced in the past ten years; (2) the farmer is then asked to say what crop yields he associates with each category of season. In the single-variate case (single crop) the estimates of a number of farmers are aggregated and analyzed to produce a grand mean and measures of variance among and within farms. A random time series of yields is generated using the grand mean, the standard deviation derived from within-farm variance, and the Box-Muller approximation for normally distributed random numbers.

The multivariate (several crop) case is similarly handled but requires a vector of mean values and a variance-covariance matrix for the several crops, analogous to the single mean and standard deviation in the single-variate case. The variance-covariance matrix is decomposed by Cholesky's method (see März 1987). Random variates from Box-Muller approximations are multiplied by the decomposed matrix and the products added to the respective means. The result is a simulated random multi-crop series of any desired length having virtually the same statistical characters (means and variance-covariance) as the original data.

The multivariate procedures were implemented through an interactive BASIC program, 'MULTISIM', adapted from März's original (1987) program. A second program, STAT1[1], was developed to derive the vector of mean values and variance-covariance matrix from the farm interview data in the forms required by MULTISIM. Aside from the present application, these programs are designed to allow generation of random correlated series of price and yield variates for whole-farm analyses based on time series of prices and yields observed during long-run crop rotation trials.

4.2.3 Sites

Five sites for the study were selected to reflect known variations in climate and soils within a small geographic area forming part of the target zone of the Aridoculture Center of the Institute National de la Recherche Agronomique, Settat, Morocco. At one site, Maarif, farmers were working with two kinds of soil ('deep black' and 'shallow white'), and they were interviewed about crop rotation yields on both. Site locations and characteristics are indicated in Figure 4.2.1. The interviews were carried out in three days, 28-30 October 1991.

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1. Copies of these programs are available on request to the first author.

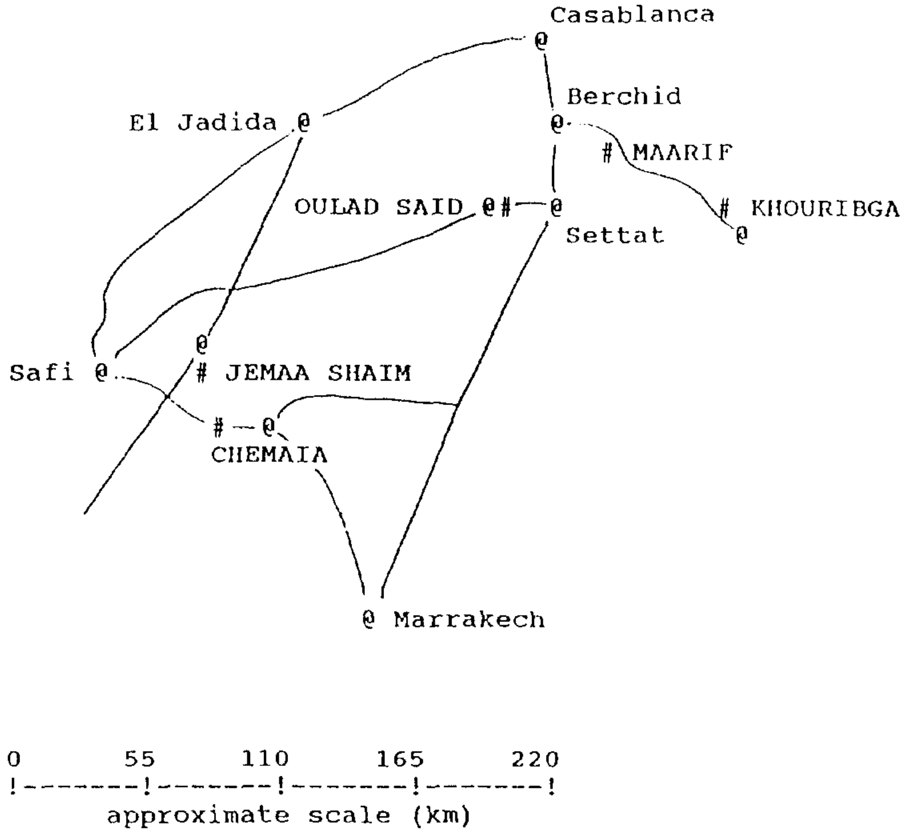


Figure 4.2.1 Yield survey sites in Morocco, 28-30 October 1991

Legend

@ = Main town locations
# = Farmer interview sites (within 1-2 km radius of point)
Details on sites selected for survey of farmers' crop yields in Chaouia and Safi provinces, Morocco

Location	Elev m	Annual Rain mm	Soil characteristics Local name	Depth cm	Stones as % of volume
Maarif (deep)	400	390	Deep, black	> 80	nil
Maarif (shallow)	400	390	Shallow, white	20-50	20-40
Jemaa Shaim	160	350	Black 'Tirs'	>100	nil
Chmaia	300	240	Red 'Hmar'	50-100	10
Khouribga	760	380	Red 'Hamri'	25-50	20
Oulad Said	300	370	Black vertisol	100	0-20

4.2.4 Selection of Farmers

März's interview method was adapted for present purposes, to allow comparisons with yields generated by a crop growth model **at specific sites** with **known soil characteristics.** Five farmers were interviewed in the close neighborhood (within 2 km) of a chosen site. Selection criteria were that all should be farming the same soils and **growing the same cultivar of wheat in rotation with the same crops.** Only older farmers (appearing over 55 years of age) were interviewed, to have the benefit of their long experience in the local environment. The idea was to remove as many sources of variation as possible, leaving year-to-year variation in weather as the main source.

The farmers were individually asked to provide estimates of the *numbers* of *'good'*, *'normal'* and *'poor'* seasons (expressed as years in 10) **based on their whole experience with that soil and those crops**, not just the past ten years. Then they were asked the levels of wheat yields they associated with each category of season and yields of the other crops associated with these wheat yields.

A set of data from 5 farmers, each farming two soil types in the same area (Maarif), is shown in Table 4.2.1. It is the practice in very poor years to graze crops which will not return sufficient grain yield to cover harvest costs. Farmers considered this as a zero crop yield, but for the purposes of this study they were asked to suggest what the yield would have been if such crops had been harvested.

4.2.5 Data Generation

The statistical parameters of these two pieces of information (i.e.,

Table 4.2.1. Yield distribution data for two soil types and rotations from five farmer interviews in the Maarif area (Chaouia Region) of Morocco. (Qx = Quintal = 100 kg)

			Deep black soil		Shallow 'White' soil	
Farmer	Year[1]	Frequency in 10 yrs	Wheat grain, Qx/ha	Pea seed, Qx/ha	Wheat grain, Qx/ha	Sheep grazing days/ha
1	Poor	5	18.9	2.5	8.6	60
	Normal	2	29.7	9.0	20.5	450
	Good	3	45.9	18.0	32.4	1620
2	Poor	5	3.0	5.0	2.0	120
	Normal	2	17.5	12.0	12.5	300
	Good	3	40.0	20.0	25.0	900
3	Poor	5	7.0	5.0	5.0	120
	Normal	3	15.0	8.0	12.0	300
	Good	2	40.0	12.0	30.0	900
4	Poor	3	8.0	8.0	4.0	120
	Normal	3	15.0	10.0	10.0	240
	Good	4	40.0	15.0	24.0	720
5	Poor	6	7.0	2.0	5.0	60
	Normal	2	17.5	10.0	10.0	300
	Good	2	40.0	15.0	25.0	720

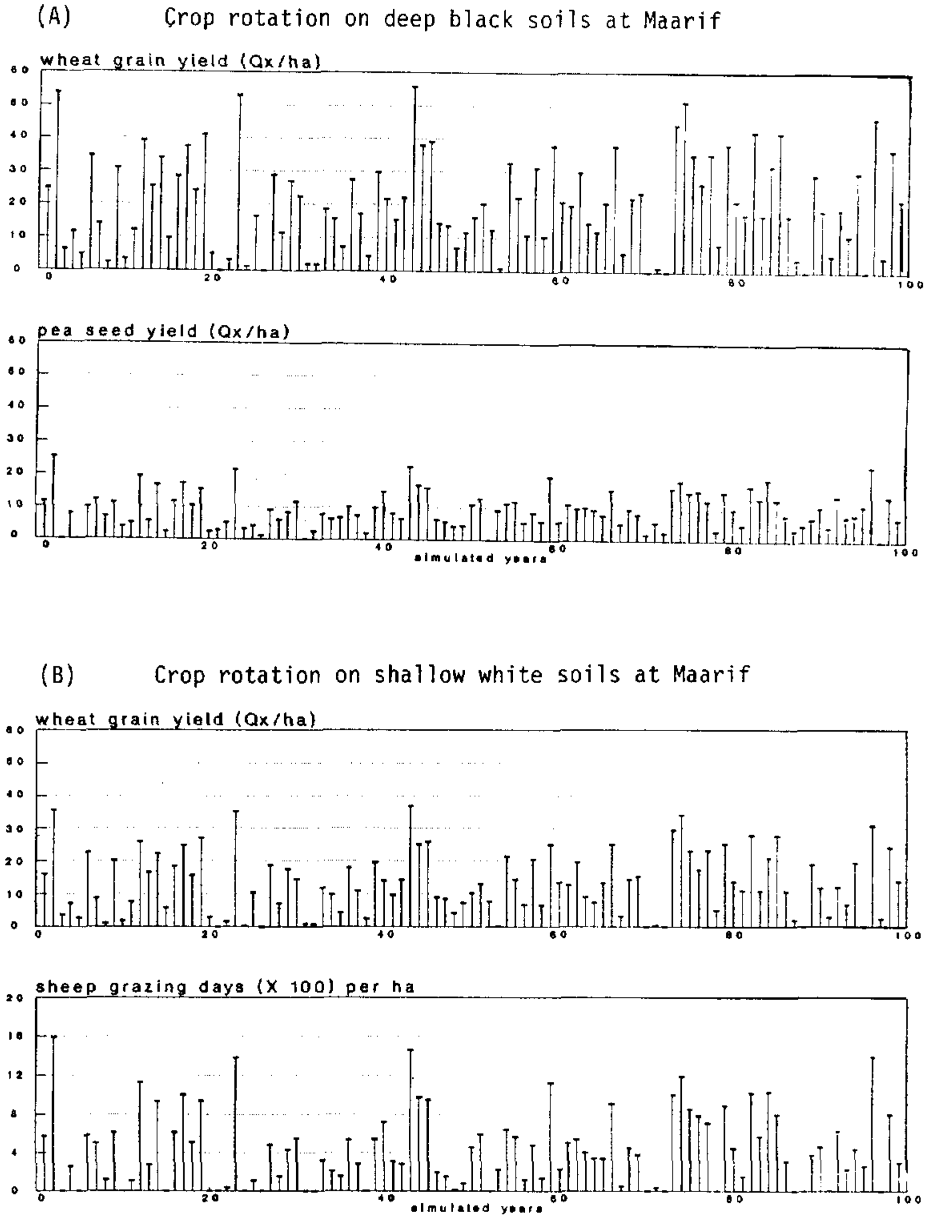
1. Each farmer was free to define these categories as he liked.

the distribution of 'year categories' and their associated yields) were used in MULTISIM to generate 100-year runs of yield data. The generated data for crops on the two soils at Maarif are plotted in Figure 4.2.2. Dramatic year-to-year variation in crop and pasture (weedy fallow) yields can be seen. It should be noted that, while these appear to mimic well the yield distribution that farmers have reported, they do not indicate an actual sequence of years, either past or future. The other feature that the method does not reflect is autocorrelation, or a 'carry-over' effect from one year to the next. This can happen, for example, when additional water stored in the soil in a wet year is available to crops in the following year. Similarities in the sequences of good or poor years for the two sets of generated data in Figure 4.2.2 resulted from giving the same 'seed numbers' to the random number generator.

Zero yields arose from two sources in the simulations: either a genuine zero was generated, or the generated value was negative and was recorded as a zero by the MULTISIM program. This truncation of the distribution at zero has the effect of increasing the mean and decreasing the variance of the generated values. The sizes of these biases were examined with some simple statistics (Tables 4.2.2 and 4.2.3). Where the CV% (coefficient of variation = 100 X standard deviation divided by the mean) of the interview data exceeded 100%, as in the case of grazing days, biases in the generated data could exceed 12%. However, for the data on crops, for which the CVs ranged from 54.8 to 81.5%, biases were reduced to 6% or less.

The degree of agreement between the original and generated data is increased as the length of the generated sequence is increased. Short runs of, say, 10 years often give summary statistics very different from those of the original data.

The yields generated for different crops at any one site are positively correlated. Implicitly we assume that weather is the main factor causing the variability in yield and that weather conditions (especially rainfall) favorable for one crop (in this case wheat) will also be favorable for the associated crops. While this is true in some degree, we recognize that it is also somewhat simplistic. Because of differences in the timing of crops, between wheat and maize for example, the relationship may be a relatively



<u>Figure 4.2.2</u> 100-year generated crop yields on two soils at Maarif, based on data from farmer interviews (Qx=Quintal=100 kg)

Table 4.2.2 Comparative statistics of original data from farmer interviews and a 100-year generated series for six soil/sites (Qx = Quintal = 100 kg)

Soil/site name	Farmer data summary: Mean Vector	Farmer data summary: Variance-covariance matrix			Summary of 100-year series: Mean Vector	Summary of 100-year series: Variance-covariance matrix		
Maarif (deep)	Qx/ha	**Wheat**	**Pea**		Qx/ha	**Wheat**	**Pea**	
Wheat	20.15	210.3	68.0		20.22	206.7	68.7	
Pea	8.85		30.7		9.20		31.3	
Maarif (shallow)		**Wheat**	**Gr.d.**[1]			**Wheat**	**Gr.d.**	
Wheat	13.00	94.4	3778.3		13.08	92.0	3513.9	
Grazing days	392.40		175386.3				154092.3	
Jemaa Shaim		**Wheat**	**Faba bean**	**Pea**		**Wheat**	**Faba bean**	**Pea**
Wheat	13.06	108.6	91.8	67.6	13.37	102.4	89.9	67.1
Faba bean	12.23		82.31	58.1	12.51		83.0	60.2
Pea	9.43			45.8	9.45			47.3
Ghamania		**Wheat**	**Barley**	**Maize**		**Wheat**	**Barley**	**Maize**
Wheat	9.59	50.2	40.9	26.1	9.74	48.6	42.5	27.3
Barley	10.37		41.6	24.2	10.52		44.9	27.2
Maize	5.69			19.5	5.72			20.7
Khouribga		**Wheat**	**Barley**	**Gr.d.**		**Wheat**	**Barley**	**Gr.d.**
Wheat	5.74	21.9	28.5	1543.1	5.89	20.5	27.7	1421.4
Barley	8.24		40.1	1760.1	8.74		40.1	1792.2
Grazing days	429.90			220010.5	441.95			171931.5
Oulad Said		**Wheat**	**Maize**			**Wheat**	**Maize**	
Wheat	15.85	75.5	50.7		15.80	76.6	51.1	
Maize	9.12		45.5		9.59		44.9	

Gr.d. = sheep grazing days per hectare

Table 4.2.3 Comparisons of summary statistics from original interview data and from 100-year generated series: the mean (Mg) and standard deviation (Sg) of a generated series expressed as ratios to those of the interview data (Mo, So); also shown is the coefficient of variation of the original interview data

Site/soil		CV %[1]	Mg/Mo	Sg/So
Maarif				
Deep	Wheat	71.96	1.003	0.991
	Pea	62.61	1.040	1.010
Maarif				
Shallow	Wheat	74.74	1.006	0.987
	Gr.d.[2]	106.73	1.107	0.937
Jemma Shaim	Wheat	79.79	1.024	0.971
	Faba bean	74.18	1.023	1.004
	Pea	71.77	1.002	1.016
Chemaia	Wheat	73.88	1.015	0.984
	Barley	62.20	1.014	1.039
	Maize	77.61	1.005	1.030
Khouribga	Wheat	81.53	1.026	0.968
	Barley	76.85	1.061	1.000
	Gr.d.	109.11	1.028	0.884
Oulad Said	Wheat	54.82	0.997	1.007
	Maize	73.96	1.052	0.990

1. CV% = 100 (So/Mo)
2. Gr.d. = sheep grazing days per hectare

loose one. Even crops that grow at the same time of the year (eg. wheat and peas) may be differentially affected by weather events such as dry spells or frosts within a growing season. Or a favorable moisture regime for one crop may induce a disease epidemic in another. We do not pretend that this method will account fully for such factors.

What the method does appear to provide is a reasonably objective estimate of yield variability at the farm level, although its 'objectivity' depends on the accuracy of farmers' recall. We see no way to validate the method critically in the absence of long-run crop yield records; that is, many years of records on crop yields for a number of farms in a target area. Such data are rarely available. A small collaborative research project is being developed with ICRISAT in India to follow up on long-running yield records from Village Level Studies there. It will comprise a set of brief surveys and analysis using the methods discussed here; results can then be compared directly with the available yield records.

4.2.6 Frequency Distributions

Cumulative frequency distribution (CDF) curves derived from the generated data are shown in Figure 4.2.3. The data (in Qx = Quintal = 100 kg) suggest that, at four of the six sites, zero yield will occur in 1 year in 10. This is perhaps an over-estimate due to the truncation of the distribution during data generation (above). If farmers consider 2.5 Qx/ha as crop failure (Section 4.2.4 and Table 4.2.1), the generated data suggest this happens about 1 or 2 years in 10 at all sites except Oulad Said. At two sites, Khouribga and Chemaia, farmers expect less than 5 Qx/ha (0.5 t) in 50% of years, and at all sites the expectation is for less than 20 Qx/ha in 50% of years. The Khouribga area is perceived as the lowest yielding environment, followed by Chemaia, Jemaa Shaim and shallow soils at Maarif, Oulad Said, and deep soils at Maarif, in that order.

The data suggest that the Jemma Shaim area and the shallow soils around Maarif provide very similar yield environments throughout the spectrum of years, although the constraints are not necessarily the same in both areas. Oulad Said appears to be

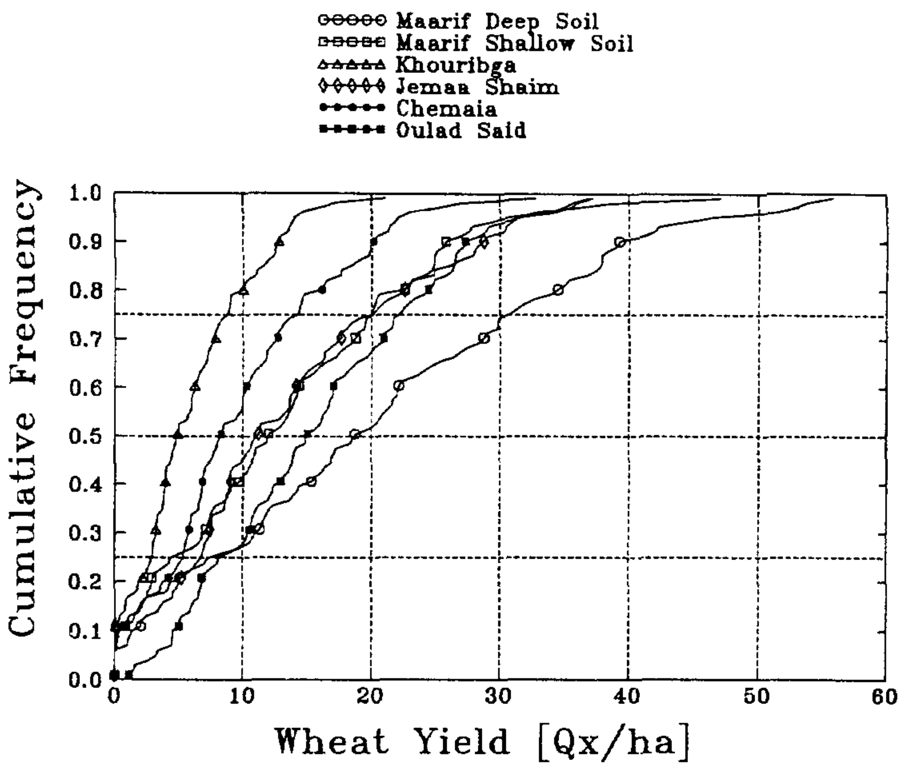


Figure 4.2.3 Cumulative frequency distributions of random wheat grain yields for six soil/sites in Morocco, generated from farmer interview data (Qx=Quintal=100 kg)

somewhat more reliable than the other sites in the poorest years (less than 1 in 10), and deep soils at Maarif seem most responsive to good years.

4.2.7 Applications of Methods

Data of this type can assist us in planning research and/or extension. Outcomes to be expected from the use of such techniques are:

- Assistance in the interpretation of existing field, and especially on-farm, research data in the context of the variability in space and time that exists in the environment.

- Better identification of sites for on-farm research to cover the spectrum of conditions in the area for which the Aridoculture Center has research responsibility.
- Help in defining where research results already exist that can be targeted to farmers through extension services.
- Assistance in the identification of areas where undefined constraints limit production, providing a form of geographic 'direction finding' for research planning.

These CDF's based on farmer interviews can be compared with others derived from dynamic crop growth simulation models, thereby providing a rapid and objective way to identify areas with large yield gaps. The growth model, already validated at two locations in Morocco, simulates a weather-governed yield potential. All existing weather records for this region of Morocco are being used, together with a spatial weather generator (Goebel 1990), to provide a weather data base to use with the simulation model. Data on the distribution of soil types are being digitized for inclusion in the database. This work is being carried out jointly with scientists from the Department of Meteorologie, Casablanca, and the Milieu Physique Section of INRA, Rabat.

It is not expected that farmers' yields will ever equal those predicted by the simulation model which was built on data from very carefully controlled small-plot experiments. However, the methods described here allow comparisons of CDF's that reflect farmers' experience with those of a theoretical potential, and with research findings. Together, the crop growth simulation model, the spatial weather generator and the CDF's from farmer interviews promise a rapid way to appraise the existence and size of yield gaps at many points across large agricultural districts.

References

Goebel, W., 1990. Spatial weather generation: examples from a case study in the Aleppo Area, NW Syria. Farm Resource Management Program, Annual Report for 1989. ICARDA-162 En. Aleppo, pp. 179-214.

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4.3 Dryland Resource Management and the Improvement of Rainfed Agriculture in the Drier Areas of West Asia and North Africa

4.3.1 Introduction

In the past, the agricultural systems that evolved in the drier areas of WANA were of low intensity and low productivity but were well adapted to an environment characterized by a fragile and limited natural resource base and uncertain and fluctuating meteorological conditions. However, today, the increasing pressures on soil, water and natural vegetation in these areas seriously threaten their potential for future productive utilization.

At present, the problems and potential of the existing systems are poorly understood. The physical limitations of the environment interact with the people, institutions and policies to determine how drylands are utilized. Degradation results from decisions made by individual land users in response to a range of perceived constraints and incentives. Understanding the rationale behind such decisions will help to identify the underlying causes. Once these have been identified, the search for solutions can begin. The individual's local knowledge, of both the environment and the factors controlling how it is utilized, are crucial in this. The people concerned must participate actively in all stages of the research and development process if practicable and acceptable improvements are to be instituted. To achieve this, a flexible, interdisciplinary approach is needed.

To this end, the Dryland Resource Management Project aims to help develop the capacity of small multidisciplinary teams of national scientists to work together to diagnose, analyze and solve agricultural and environmental problems in drier areas of WANA. Case studies in each of six countries have the objectives: (1) at specific locations, to describe and analyze current resource management practices and indigenous perceptions of options for sustainable improvements; and (2) to initiate within the national program interdisciplinary activities that address the problems of farmers and herders in drier areas.

Much of the work in 1991 was concerned with identifying, first, national teams of scientists to conduct the case studies and, then with those scientists, the study areas and problems to be tackled. Regional events delayed this process and caused the project planning workshop to be postponed from June to November. That workshop was held in Amman and was attended by representatives from all six national teams. Each team presented its proposal, and these proposals were modified and finalized during the course of subsequent discussions. They will now be implemented by each national team, and the findings reported at a second workshop scheduled for March 1993.

In last year's report we gave brief details of the proposed case studies in Jordan and Tunisia, which had already been drafted. This year we summarize the proposals for Libya, Lebanon, Pakistan and Yemen.

4.3.2 Libya Case Study

This is being conducted by scientists from the Agricultural Research Center, Tripoli. It will focus on an area of about 150,000 ha at Bir Al-Ghanem between Azizia and Yefren, in the Geffara plain, about 40 km south of Tripoli, where the average annual rainfall is about 170 mm.

Over the last 15-20 years a number of alternative modes of land use have been introduced in what were previously open rangelands in the Geffara plain. These include ley-farming/cereal projects, range improvement/grazing projects, and settlement projects often based on irrigated farming. Grazing and cereal production continue in the remaining open range. The objectives of the present study are:

1. To compare these different systems of land use in terms of:
   - their productivity;
   - their effect on the resource base (soil and range vegetation);
   - their organizational structure and management.
2. From the above analysis and surveys of the activities, objectives and opinions of land users (both individual and corporate/project land users), to determine the most appropriate strategies for future research and development in these areas.

   The main activities are:
   - to document and evaluate the previous projects and their differing modes of land use, working mainly from secondary sources;
   - to describe and quantify the current farming systems in the open range, by conducting a survey;

- to compare the different land-use systems, in terms of productivity, resource utilization and effects on the resource base;
- to determine, through discussion, land users' opinions of the various land-use systems, current problems and perceived options for improvements.

4.3.3 Lebanon Case Study

This is being conducted by scientists of the American University of Beirut. It focusses on the village of Buarij on the eastern slopes of Mount Lebanon (Bekaa). Until the first half of this century such villages subsisted on a traditional agropastoral economy based on small-scale farming and vertical transhumance; and aspects of these systems are documented by A. Fuller in her book "Buarij, Portrait of a Lebanese Muslim Village" (1961). This work will provide a valuable historical dimension to the case study. The objectives of the study are:

1. To document and assess the effect of the historical development and changes in Buarij on the resource base and resource management strategies;
2. To identify possible determinants of these changes (biological, physical, socioeconomic, etc.), with a view to showing where improvements in current resource management can be made.

It is expected that the study will produce:

a) documentation and analysis of the processes of change in Buarij and the villagers' perceptions of these changes;
b) an analysis of existing production systems and management practices;

c) an analysis of the productivity of the system;

d) identification of existing problems as perceived by the local population;

e) identification of possible alternative resource management strategies, if appropriate.

The case study will proceed in three phases. The first phase will characterize the village system, the resources available and the current management of those resources, and the changes that have occurred in the village system since Fuller's study. In addition, it will identify non-village users of the resources available to the village; and a parallel study of these users, focussing on how they interface with the village system, will be conducted.

The second phase will involve, through interviews with a sample of individual land users, a detailed diagnosis of resource management, productivity, returns to land use, and the problems faced by farmers under the existing production systems. In both phases, the present situation will be related to that reported by Fuller, in order to identify the determinants of change in the system, and the impact of these changes upon the resource base.

In the final phase, the information from the first two phases will be used to assess the possibilities for appropriate alternative resource management strategies.

4.3.4 <u>Pakistan Case Study</u>

This is being conducted by scientists from the Arid Zone Research Institute, at Quetta, Balochistan, at sites in the Quetta area.

The most limiting factor in crop production in rainfed areas of Balochistan is the low and variable rainfall. Crop production in non-irrigated areas is either totally dependent on rainfall (kushkaba) or on rainfall supplemented by run-off water collected from uncultivated land (sailaba). Farmers have long practised water harvesting under the sailaba system by constructing bunds which collect the run-off water flowing from the steep hillsides onto the level valley bottoms.

In an attempt to demonstrate the improved utilization of rainfall in the valley plains, AZRI has for the last four years been growing cereals, lentils and forage legumes under water harvesting techniques. In a variation of the traditional sailaba system, small catchment basis are constructed on the level valley floor, representing a low cost method of generating run-off and increasing crop yields.

The objectives of the case study are threefold:

1. To compare AZRI's water-harvesting techniques with the existing farmer practices.
2. To determine to what extent crop production is increased and production risks decreased under the water-harvesting system.
3. To assess the adoption potential of water-harvesting techniques by farmers in highland Balochistan.

The approach will be:

a) To utilize data from four seasons of wheat trials (1986/87 to 1989/90) and two seasons of barley trials (1988/89 and 1989/90) to develop budgets for each crop, season, location and trial, in order to determine the costs and benefits associated with the water-harvesting relative to the rainfed control.

b) To simulate crop performance over a wider range of seasons than experimental data is available for. In a situation where rainfall variability is so extremely influential on crop performance, it is necessary to incorporate the probabilities of different rainfall distributions and intensities in the economic analysis. Available daily weather data from three stations will be used in a model that represents crop yield as a function of water availability. Crop performance will be simulated for a set of weather seasons available for each site (Quetta, Loralai, and Kuzdhar), representing the central, northern and southern regions of highland Balochistan.

c) To compare the simulated distributions of yields and associated net benefits, using stochastic dominance techniques that identify the dominant (preferred) treatment in terms of risk efficiency.

d) To conduct a survey of local farmers to monitor costs and returns associated with traditional farmers' practices, and to investigate their perceptions and opinions of the water harvesting system.

4.3.5 Yemen Case Study

This will be conducted by scientists from the Agricultural Research and Extension Authority and from the University of Sana'a. Plans have not yet been finalized, but the likely study location is Kohlan Affar, northwest of Sana'a.

The study will focus on the deterioration of the traditional system of water harvesting. Two system levels can be identified. One is the farming system represented in Affar: uncultivated mountain rangeland (which constitutes the catchment), terraced upper slopes, trees on lower slopes. However, this is only one component of a larger 'water management system', by which excess water from the catchment and upper terraced slopes runs off into wadi beds, continuing down to traditional irrigation systems on the coastal Tihama plain. The collapse of terracing on the upper slopes means that runoff is increased and floods in the wadis are more intense. The wadi beds are widened by the larger floods, with the result that valuable agricultural land along the wadi banks is washed away. The primary problem for investigation is the degradation of the upper terraced slopes, although an analysis of the impact of the breakdown in this component on other components lower down the system might be included.

4.4 Cukurova University/ICARDA Collaborative Project: Development of Small-Scale Farmers of Taurus Mountains of Turkey

In 1990, Cukurova University (Adana) and ICARDA initiated a joint farming systems project, utilizing funds supplied by Italy through ICARDA's Highland Regional Program. The project aims to identify constraints to agricultural productivity in mountain villages and develop acceptable technical solutions through coordinated research studies in Karaisali and Tarsus districts. Scientists from FRMP (and PFLP) fulfill a planning and advisory role. The following summary of the first year's work of the project is taken from a report provided by Professor Onur Erkan, who leads the project.

4.4.1 Introduction

Two million people live on small farms in villages in the Taurus mountains of southern Turkey and depend largely on agriculture for a living. Rainfall is often in excess of 600 mm, but crops, mainly wheat and barley, with small areas of chickpea and sesame grown on sloping fields of usually shallow, stony soils are not always able to take full advantage of it; and for many farmers the main enterprise is livestock rearing, mainly goats. Farm incomes are lower than in many other parts of Turkey; but local agricultural problems have received little attention from research and extension organizations.

The present study uses a multidisciplinary FSR approach: to examine the existing farming system; to develop appropriate new and/or improved technology; to test that technology with the farmers; and to disseminate the findings.

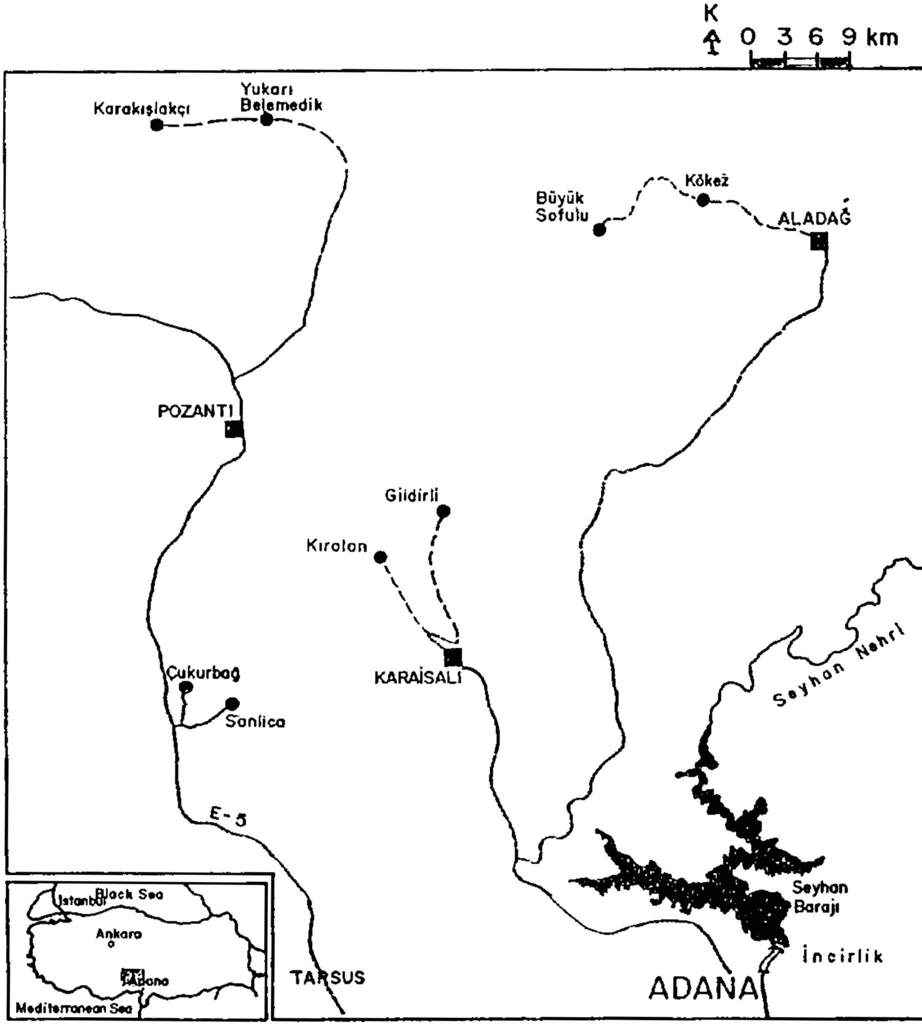
4.4.2 Economic Diagnosis

O. Erkan, V. Tansi, T. Tükel, N. Uygen, O, Biçer, O. Kaftanoglu, U. Dinç

A total of 63 representative farmers were selected from eight mountain villages (cultivable land situated above 600 m) (Figure 4.4.1). Their average holding of operated land is 40.8 da. Most such land is owned by the user; and, although most is allocated to arable crops, areas of fruit (apples, grapes) and fallow are significant (Table 4.4.1a).

The main source of agricultural labor is the farm family. The figures collected suggest that more than 50% of their labor potential is not actually used (Table 4.4.1b), although in peak seasons some labor is hired by all farm-size groups.

Greatest production value derives from livestock (includes live-weight gain, milk and honey) in small and medium-sized farms but from crops in larger farms (Table 4.4.1c). Crop totals include fruit, which -- on a proportional basis -- is of greatest importance for the smallest farms. Wheat has the highest value of the arable crops; but the value of barley is understated in the figures shown,



<u>Figure 4.4.1</u> Taurus Mountains Project area

which reflect only the marketed amounts. The greater part of the barley crop is used as animal feed, and its value is converted into livestock value.

Production costs and farm and family income are summarized in Table 4.4.2. The average farm income is $1282 and family income is $2125. Per capita values are $195 and $323, respectively (which should be compared with $1238, the per capita national income of Turkey in 1990). These figures indicate the scope for improvement the project seeks to effect.

Table 4.4.1. Taurus mountain villages: agricultural land use, labor and production values, by farm size

	Farm size groups (da)				
	1-25	26-50	51+	Mean	%
a. Land use:					
Wheat	7.9	17.9	33.2	18.5	45.4
Barley	2.5	6.0	9.3	5.7	13.9
Chickpea	0.4	4.8	7.1	3.9	9.5
Oat	0.1	0.5	0.6	0.4	1.0
Fallow	2.3	5.8	19.9	8.4	20.6
Fruit	2.0	3.1	3.9	2.9	7.2
Other	0.0	0.0	3.7	1.0	2.5
Total	**15.1**	**38.1**	**77.8**	**40.8**	
b. Labor:					
Potential: mpu*	3.14	4.67	4.47	4.08	-
days	879	1308	1252	1142	-
Days on farm	228	354	416	327	-
Days off farm	18	25	26	23	-
Days used non-agriculturally	109	184	134	144	-
Total days used	355	563	576	494	-
Days not used	524	745	676	648	-
c. Production value ($)					
Wheat	266	514	890	529	19.5
Barley	24	46	70	45	1.7
Chickpea	6	81	96	59	2.2
Oat	1	1	1	1	-
Fruit	389	246	448	350	12.9
Crop total	686	888	1505	984	36.2
Livestock	1198	1752	1204	1411	52.0
Off-farm activities	154	301	565	321	11.8
Total (gross production value)	2038	2941	3274	2716	

* Manpower unit

Table 4.4.2. Taurus mountain villages: production costs and income ($), by farm size

		Farm size groups (da)			
		1-25	26-50	51+	Mean
A. Production costs:					
Variable:	- crops	389	638	946	635
	- livestock	394	433	369	402
Fixed:	- family labor	1592	2474	2910	2284
	- depreciation	137	192	363	219
	- repair/maintain	82	84	158	103
Total		2594	3821	4746	3643
B. Income:					
Gross production value		2038	2941	3274	2716
Total variable costs		783	1071	1315	1037
Gross margin		1255	1870	1959	1679
Farm income		1016	1487	1335	1282
Off-farm income		608	1117	762	843
Family income		1624	2603	2097	2125

4.4.3 Field Crops and Grazing Land Studies

V. Tansi, T. Tükel, T. Polat and E. Haser

All villages were visited between one and three times to survey cropping practices. It was noted that all crops were rainfed. Tillage is always with a plough, which may be animal or tractor-drawn. Farmers do not try to plough on the contour, but contour-ploughing is easier with animals. Seeding is by hand-broadcasting. For wheat and barley, seeding is in October (one village, April); the commonest rotation is fallow-wheat, but wheat-wheat and legume (chickpea, phaseolus)-wheat were also recorded.

Farmers save their own seed for planting. Most wheat cultivars are old (e.g. of Mexican origin, dating from the 1960s) and more suited to lowland conditions. The common seeding rate, around 15 kg/da, is similar to that recommended for lowland conditions. Fertilizer is used but rather arbitrarily, without any soil analysis; and, although many small ruminants are kept, farm-yard manure is not used. Grain yields, harvested in July are only around 1 t/ha, partly because of low numbers and weight of seeds/ear.

For chickpeas, seeding is in March or April, at a rate of about 5 kg/da, without fertilizer or inoculation. No yield figures are yet available.

Fairly small areas of barley are grown for animal grazing or feed production. In one village, fallow growth is cut for hay for winter feeding; and some maize is also grown and cut for feed. But no other forages are grown.

Mountain pastures are under heavy grazing pressure, and productivity is going down. Nevertheless, they still provide most of the feed requirements of the villagers' livestock. For example, six villages (Çukurbag, Kiralan, Büyük Sofulu, Kökez, Yukari Belemedik, Karakislakci) have about 2742 cattle, 7542 sheep and 9804 goats. These animals subsist largely in common grazing areas located within the forest belt between 800 and 1600 m elevation. These are not officially licensed grazing lands but are the remnants of cleared forests. Some of the steepest land of this type is already protected for forest re-establishment.

At each of the six villages, forage production of the grazing lands was estimated by sampling (five randomly thrown quadrats, 0.5 x 0.5 m) and separating into three botanical components (Table 4.4.3). Total herbage varied from 0.6 to 1.8 t/ha, with grass contents, 3-51% and legume contents, 6-52%. At most sites, most material was in the category "other forbs". Protected (ungrazed) sites tended to yield more material.

Table 4.4.3. Natural pasture samples from grazing lands of six villages in Taurus mountains: dry weights and simple botanical analysis

Village		Grasses kg/da	(%)	Legumes kg/da	(%)	Other forbs kg/da	(%)	Total kg/da
Kiralan	(g)	17.9	(10)	46.5	(26)	113.4	(64)	177.8
Büyük Sofulu	(g)	14.5	(25)	12.6	(20)	34.1	(56)	61.2
Kökez	(g)	2.9	(3)	55.9	(52)	48.0	(45)	106.8
Yukari Belem	(g)	24.4	(24)	6.6	(6)	73.1	(70)	104.1
	(p)	39.0	(24)	22.9	(14)	102.4	(62)	164.3
Karakislakci	(g)	10.3	(17)	9.0	(15)	39.9	(67)	59.2
	(p)	51.6	(51)	16.6	(16)	32.9	(33)	101.1
Cukurbag	(g)	28.4	(33)	10.2	(12)	48.4	(56)	87.0

4.4.4 Plant Protection Studies

N. Uygun, M. Bicici, N. Uygur, A. Erkilic, H. Paspinar, C. Özkan, O. Boz, S. Çolak

A multidisciplinary team (entomologist, phytopathologist and weed specialist) surveyed pests, diseases and weeds by making observations in fields and orchards, by taking samples for identification where appropriate and through talking with farmers.

No serious insect pests were found in wheat, barley or chickpea, but diseases (particularly Ustilago nuda hordei, Urocystis tritici and Erysiphe graminis tritici in cereals; and Aschocyta rabiei and Fusarium spp. in chickpeas) were quite important. In apples, the most important fruit crop, Carpocapsa pomonella and Ventura inaequalis were destructive pests and diseases, respectively.

Weediness varied widely. Among cereals, Secale cereale, Bromus spp., Anthemis spp. and Galium aperine were serious crop competitors; and in chickpea, Amaranthus spp., Heliothropium spp., Centauria cyanus and Ranunculus arvensis.

Generally, it was observed that farmers' control measures are limited to the use of chemicals and take little account of pest density. They may often use the wrong pesticides or the wrong timing or the wrong applicators; and sometimes they mix two different herbicides to control grassy and broad-leaved weeds. Some weed problems are attributable to hand sowing of crops. Non-homogeneous emergence leaves empty spaces in the field, which encourage weed proliferation.

4.4.5 Livestock Studies

O. Bicer and O. Güney

Small ruminants make a major contribution to farmers' economies. Even though productivity levels are low, goats and sheep are the main source of animal protein (meat and milk), provide year-round cashflow and utilize land that has no other agricultural potential. The Kil goat (hair or black goat) is the dominant breed, but local, fat-tailed sheep (and, more recently, Awassi) are being encouraged by the Ministry of Agriculture.

A survey was conducted among selected farms to obtain basic information on their animal numbers and management problems and their perceptions about possible improvements. Although small ruminant husbandry is the principal animal production activity in each village, less than half the families are involved in it, but nearly all families keep one or two cattle (Table 4.4.4).

Table 4.4.4. Taurus mountain villages: distribution of animal production and flock sizes

Village	% of farmers in animal production		Small ruminant flock size	
	Small ruminants	Cattle	Sheep	Goats
Kokez	45	100	83	-
Büyük Sofulu	8	85	80	20
Yukari Belem	44	-	147	56
Karakislakci	10	90	47	25
Gildirli	13	-	200	-
Kiralan	33	100	-	226
Sanlica	50	75	-	-
Çukurbag	43	43	120	265

Production from the small ruminants comprises kids (and lambs) sold off-farm and milk, which is processed mainly into cheese for sale in the local market. There are appreciable limitations in reproductive performance (little or no twinning, and six-month mortality rates, 5-20%), and milk yields are low (mean total for goats, 35-50 kg); but non-commercial off-take (e.g. yoghurt) makes an important contribution to family subsistence.

Supplementary feed is used sparingly. Ewes and does are not supplemented until heavy winter conditions occur. No lamb fattening is practised; some farmers are now finishing yearlings on concentrates but at low levels. Health care is weak; although farmers are aware of parasite control and contagious diseases, they make little use of veterinary services.

4.4.6 Beekeeping Studies

O. Kaftanoglu and H. Yeninar

Beekeeping requires almost no land and little equipment, time or money; and hive products command a good price everywhere. Beekeeping is therefore an agricultural activity with great potential to increase the income of small farmers. A survey showed that there are already many hives in project villages (Table 4.4.5), and many more farmers would like to take up beekeeping.

Table 4.4.5. Taurus mountain villages: bee colonies and beekeeping potential

Village	Number of colonies	Remarks
Çukurbag	70	
Yukari Belemedik	260	Very suitable
Karakislakci	480	Great beekeeping potential; increases planned
Kiralan	160	Very suitable; but problems are lowering honey yields
Gildirli	30	
Büyük Sofulu	600	Some beekeepers have more than 150 colonies; trucks rented to practise migratory beekeeping
Kökez	250	

Problems include lack of capital to invest in more hives and improved hives; and lack of knowledge about queen management, diseases, feeds and feed hygiene, and foundation material (for comb-building). There is much scope for training and demonstration.

4.4.7 Preliminary Soil Productivity Studies

Remote-sensing techniques can be used to study land use in the project area; pictures are available. The extreme topography and steep slopes make much of the area unsuitable for agriculture.

Removal of vegetation by tillage, by grazing or by tree felling always promotes soil loss; and many farmers currently plough up and down the slope, which increases erosion.

Samples taken from farmers' fields indicated insufficient crop nutrients or an imbalance between them. Many soils were high in available-P (and would not need P fertilizer for two years) but were lacking nitrogen. Farmers know little about soil-testing, and tend to use the same fertilization technique irrespective of crop or planting season. In particular, there is no effective program of N fertilization and this reduces yields. Manure is available from the widespread keeping of animals, but it is not used by most farmers.

5. PROJECT 3. ADOPTION AND IMPACT OF TECHNOLOGY

Introduction

The long-term goal in this project is to assess factors related to the acceptability of new technologies and develop methods to predict, monitor and improve the adoption and impact of technology at the national, community and farm level. We seek to attain this goal through the following medium term objectives:

1. To help biological scientists design technologies which can be easily adopted by farmers through the collection and implementation of information on the needs and constraints of farmers.
2. To help to derive ways to introduce new practices into farming systems of the region.
3. To describe ways to estimate the impact of new technology, and to identify benefit and problems arising from new practices and their implications for technology design.
4. To assess, within the region, trends in crop production, policies affecting agriculture, labor supply and other sociological and economic factors directly affecting agriculture.

5.1 Impact of Modern Wheat Technology in Syria Part One: The Adoption of New Technologies

R. Tutwiler and A. Mazid

5.1.1 Introduction

Wheat is the most important food commodity in Syria. Until 40 years ago, production was able to expand as population expanded simply by increasing the area cultivated. Expansion of wheat area allowed

Syria to be a net exporter until the 1950s. However, in the past 30 years growth in domestic demand has far exceeded the ability to increase the area planted to wheat. Moreover, vegetables, fruits, and industrial crops, have all increased and impinged on wheat land. Consequently, Syria no longer produces a surplus of wheat, and wheat grain and flour have become the most important agricultural imports. The wheat self-sufficiency ratio fell to 72% in the 1985-89 period.

The Syrian government has invested heavily in agricultural development with the twin objectives of improving the living standards of producers and achieving self-sufficiency in those commodities which account for most of the negative trade balance. Wheat has been a consistent focus of attention. Realizing that there can be little increase in the existing arable land base, planners concentrated on improving the productivity of existing wheat land. Research was directed towards adapting modern high yielding wheat varieties (HYVs), chemical fertilizers, herbicides, and pest control measures to Syrian conditions. Extension and credit institutions were organized. Farmers were encouraged to mechanize production, and the government embarked on a number of infrastructural projects to provide irrigation facilities where technically feasible. Pump wells and other on-farm irrigation systems were developed by the government and private sector.

5.1.2 Study objectives

In 1991, the Socio-economic Section of the Directorate of Agricultural Research (DSAR) joined ICARDA's Farm Resource Management Program in a multiyear study of the adoption and impact of improved wheat production technology. The study has three objectives:

1) To develop baseline measures of use and adoption of improved wheat production technology among farmers in different agro-

ecological zones and regions.

2) To describe levels of wheat technology adoption and impact, differentiated by socio-economic characteristics of farms and by farming systems.

3) To assess reasons for adoption or non-adoption of particular technologies and factors contributing to yield gaps between technology performance on farm and results obtained in research trials.

Activities in the first year were designed to develop the initial descriptive baseline, confirm levels of adoption, and develop hypotheses to be tested in following seasons. Existing published sources were reviewed, and a primary data set was collected through a formal survey covering 9 provinces representing some 91% of the national wheat area. The results of this first year are presented here.

5.1.3 National planning

As a basis for planning agricultural production, the Syrian government in 1975 divided the country into five agricultural stability zones based essentially on rainfall patterns. Zone 1 has a mean annual rainfall over 350 mm. Zone 2 lies between the 250 mm and 350 mm isohytes and receives not less than 300 mm in two out of three years. Zone 3 has a mean greater than 250 mm and receives not less than 250 mm in half the years. Zone 4 lies between 200 and 250 mm isohytes and receives not less than 200 mm in half the years. Zone 5 lies below the 200 mm isohyte and is deemed unsuitable for rainfed agriculture. Cutting across these rainfall zones are irrigated areas of two basic types: those requiring regular applications of water (full irrigation) and those in which water is applied to complement rainfall (supplemental irrigation). In general, full irrigation is necessary for dependable wheat production in zones 4 and 5; supplemental irrigation markedly enhances productivity in the other zones. Planners recommended that wheat be grown in zones 1 and 2 and in the fully irrigated areas. However, rainfed wheat in zones 3, 4, and even 5 still constitutes about 12% of total wheat area.

Planning began by setting national production targets. Then the technical requirements for production were considered, to determine the allocation of resources across stability zones and irrigated areas needed to achieve those targets. Two production aspects were stressed. The first was the introduction of modern technology at the farm level, machinery, irrigation systems, new wheat varieties, fertilizers and other inputs. The second was the provision of economic incentives to producers. Modern inputs were made available to them through government agencies at subsidized prices. Wheat was then bought from farmers at fixed supported prices, durum wheat prices being set slightly higher than bread wheat prices. In general, because modern inputs were in short supply, priority in their provision was given first to fully irrigated areas, then to zone 1, then to zone 2. An important exception was the southern Hauran region where the local durum variety was encouraged to the exclusion of modern varieties, although other modern inputs were made available.

5.1.4 National trends

The most noticeable features in the national trends of annual wheat area and production (Figures 5.1.1 and 5.1.2) are: (1) general decline in total area, (2) increased use of HYVs instead of local varieties, (3) increase in irrigated area, and (4) large year-to-year fluctuations in total production but without a noticeable trend since 1974. Whereas irrigated yields show overall improvement, rainfed yields are less easily interpreted (Figures 5.1.3 and

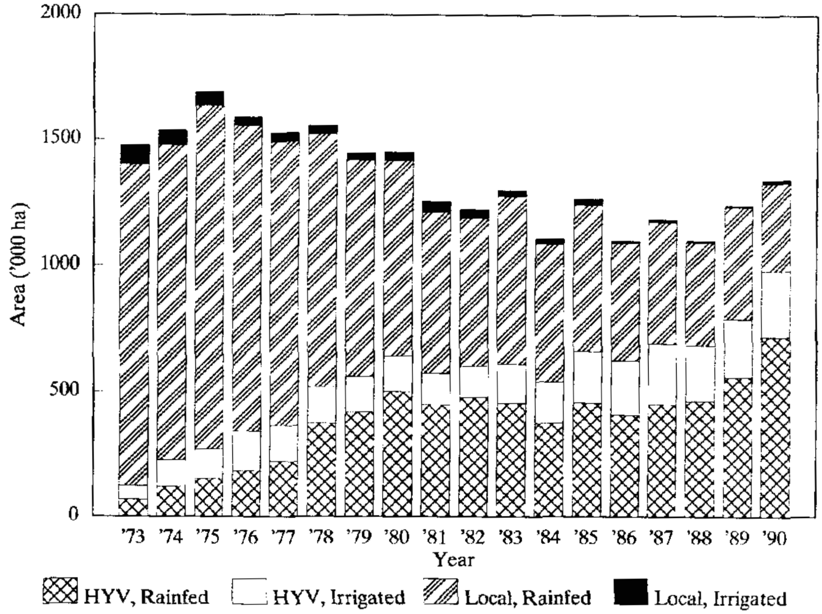


Figure 5.1.1 Trend of areas sown to wheat, Syria, 1973-1990

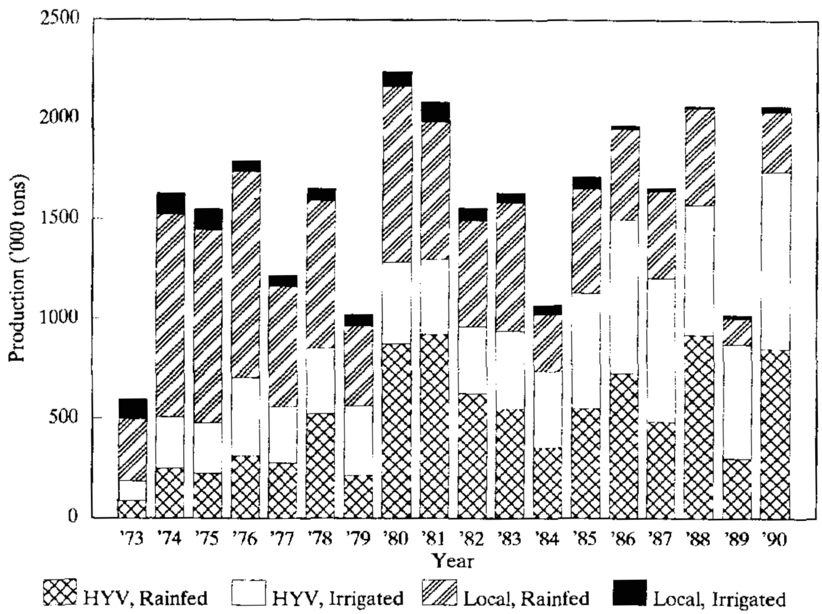
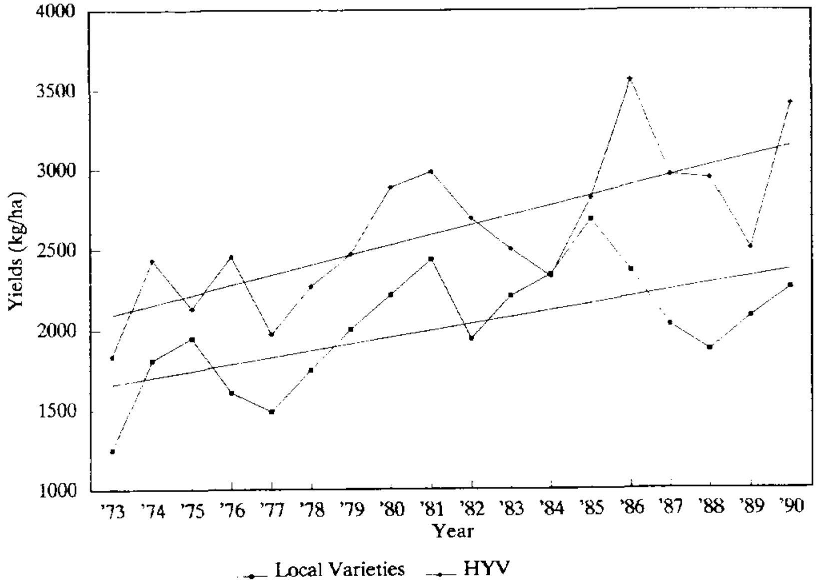
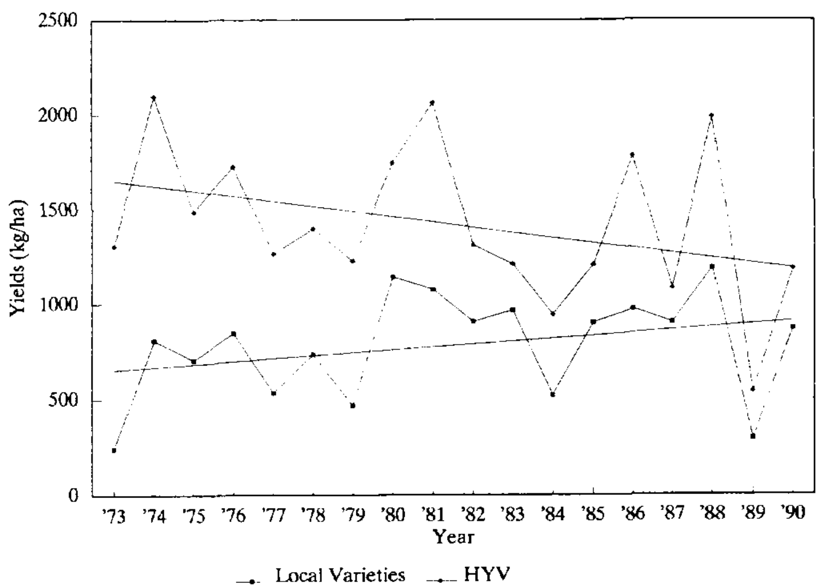


Figure 5.1.2 Trend of wheat grain production, Syria, 1973-1990



Note: Straight lines indicate linear trend.

Figure 5.1.3 Yield trends of irrigated local and HYV wheat, Syria, 1973-1990



Note: Straight lines indicate linear trend

Figure 5.1.4 Yield trends of rainfed local and HYV wheat, 1973-1990

5.1.4). Indeed, once HYV rainfed yields are adjusted for rainfall variation according to water-use efficiency indices, there is no significant trend either upwards or downwards. Nonetheless, HYV yields are almost invariably higher than local variety yields under both rainfed or irrigated conditions.

The reduction in total area and the seeming failure to improve rainfed HYV performance may be due to changes in the geographic distribution of wheat. Although a definitive statistical study remains to be done, observation and informed opinion suggest that rainfed wheat is being replaced at the wetter end of the spectrum by other, perhaps more valuable crops, while at the drier end more HYV wheat is being grown. Such shifts would encourage continued yearly fluctuations in production and yields and detract from the performance of rainfed HYV wheat. About 21% of the area planted to HYVs is currently in zones 3, 4, and 5. This constitutes some 55% of the total rainfed wheat in these zones. According to official statistics, in 1990 HYV's covered some 73% of the total area, 95% of the irrigated area, and 67% of the rainfed area.

Although HYV wheat demonstrates a definite advantage over local wheat in rainfed areas, the largest contributor to increased productivity, according to published statistics, is the combination of irrigation and high-yielding varieties. The significance of irrigation alone is indicated by the higher yields obtained from irrigated local wheat compared with rainfed HYV wheat over the past decade.

The growth of irrigation in Syria has been remarkable, more than doubling since 1973. Fully irrigated wheat area has expanded in a similar fashion, from 9% of total wheat area in 1973 to 20% at the end of the 1980s. Irrigated high-yielding varieties now provide slightly less than half of national production. Moreover, there is a noticeable trend of increasing yield in irrigated wheat but no corresponding improvement of rainfed HYV yields.

Government statistics do not differentiate between areas of full and supplemental irrigation. Riverine and canal irrigation is considered full irrigation but so also are individual, farm-based pump well systems, whether or not the farmer elects to use this resource merely as a supplement to rainfall. The statistics record the rated capacity of pump wells to fully irrigate a certain number of hectares, although in practice farmers may be using the same wells to supplementally irrigate a much larger area. Thus, the published figures underestimate the total area receiving irrigation water.

The first improved wheat varieties in Syria were Florence Aurore (a bread wheat) and Senator Capelli (a durum wheat). These were joined by Jouri 69 (durum) and Mexipak (bread), both released before 1973. At that time, high-yielding varieties accounted for about 15% of the total wheat area. Florence Aurore and Senator Capelli have since been officially reclassified as local varieties, but between 1973 and 1987 a total of nine new varieties were released (six durum and three bread wheats). To a very limited degree, the varieties were targeted to different environments: zone 1, zone 2, full irrigation in any zone, or a combination of these (see Table 5.1.1). Associated technology, such as fertilizer recommendations, are based on zones rather than varieties. Seeds are multiplied by the General Organization for Seed Multiplication (GOSM) under contract to producers and made available to farmers through governorate and local outlets. The seeds are usually treated for seed-borne diseases and pests before sale to farmers.

Government planners and executing agencies achieved notable success in having the new production technology adopted by farmers.

Mechanical tillage, planting, and harvesting; high-yielding varieties; fertilizers; and chemical weed and pest control are common. However, published statistics provide only area figures and average yields. They do not, for example, record distribution of varieties, varietal performance, or adoption rates among farmers. Nor do they address questions regarding differential adoption according to farm and farmer characteristics or adoption of multi-component "packages" of new technology. It was largely to address these gaps in our understanding of technology uptake that DSAR and ICARDA undertook the present study.

Table 5.1.1 High-yielding varieties in Syria, 1990

Name of variety	Type	Release date	Target environment	Experimental yields (average, various years)
Jouri 69	Durum	1970	Irrig.& zone 1	--
Mexipak	Bread	1971	Irrig.& zone 1&2	3.0 t/ha (rainfed)
Jezirah 17	Durm	1974	Irrig.& zone 1	4.5 t/ha (irrig.) 3.0 t/ha (rainfed
Bohouth 1	Durum	1980	Irrig.& zone 1	5.0 t/ha (irrig.)
Cham 1	Durum	1983	Irrig.& zone 1	4.5 t/ha (irrig.)
Cham 2	Bread	1983	Irrig.& zone 1	4.5 t/ha (irrig.)
Cham 4	Bread	1986	Irrig.& zone 1	5.0 t/ha (irrig.) 4.0 t/ha (rainfed)
ACSAD 65	Durum	1986	Zones 1 & 2	--
Cham 3	Durum	1987	Zone 2	--
Bohouth 4	Bread	1987	Irrig.& zone 1	3.2 t/ha (rainfed)
Bohouth 5	Durum	1987	Irrig.& zone 1	7.5 t/ha (irrig.)

Source: MAAR and ICARDA Cereals Program

5.1.5 Survey sample and general characteristics

A formal survey sample was selected on the basis of published wheat production statistics. Farmers were chosen at random within districts selected according to stability zone and contribution to national production. For purposes of characterization and tabulation, the districts were grouped into five regions: (1) West Region, (2) al-Ghab Region, (3) al-Jazirah Region, (4) al-Furat Region, and (5) Hauran Region (see Figure 5.1.5). Farmers were located in stability zones 1 and 2, except for al-Furat farmers, who rely on full irrigation from the Euphrates River.

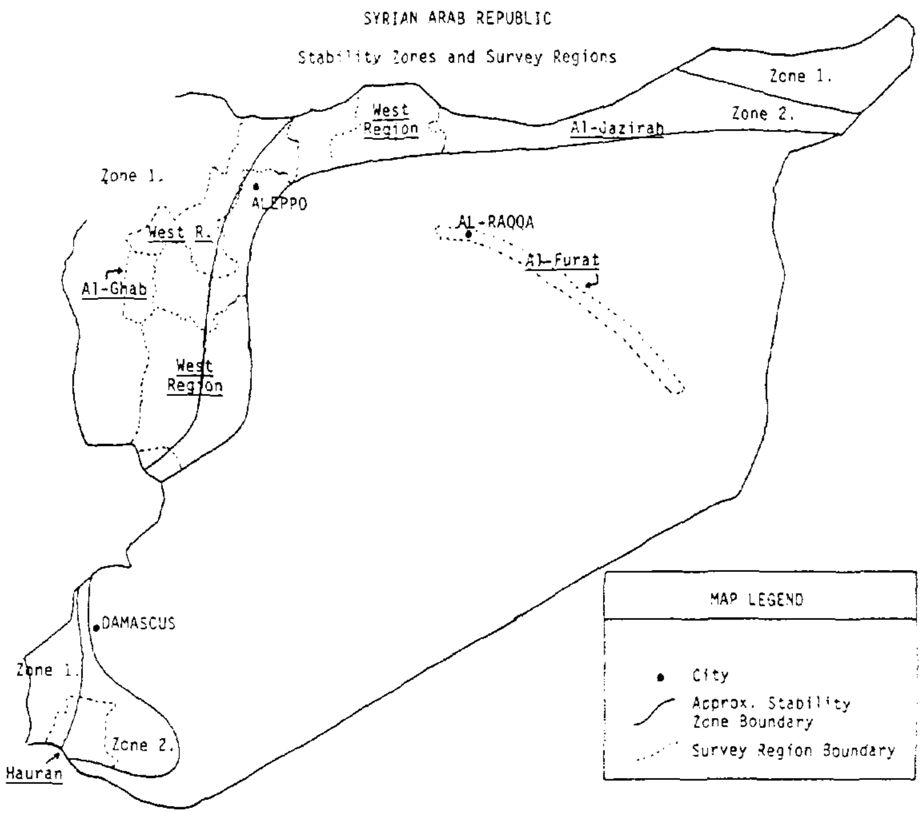


Figure 5.1.5 Stability zones and survey regions

Because no current agricultural census is available, the number of sample farmers in each region was based on practical considerations, representativeness, and relative wheat area. The wheat area cultivated by the farmers of each regional sample was roughly proportional to the total wheat area of that region, except in al-Jazirah, where the coverage in terms of area was much greater. In part, this was due to the much larger farms in al-Jazirah and, in part, to the large contribution of al-Jazirah to national production. It is recognized that this leads to a bias in farm size distribution within the total sample by overweighting the importance of the large al-Jazirah farms, but the sample was not meant to be representative of farm size per se. Rather, the purpose was to describe and characterize wheat technology adoption and impact across a range of farm types in different locations.

In general, the West region showed the expected distribution among small to medium sized farms (Table 5.1.2). Hauran farms tended to be neither very small nor very large, and al-Jazirah farms were medium to large. In al-Ghab and al-Furat most farms were small because of their recent history of agrarian reform, irrigation development, and settlement.

Some interesting comparisons emerge in the cropping systems, according to region, farm size, and source of water (Table 5.1.3). Hauran, for example, presents the clearest case of "traditional" differentiated dryland cropping, with large fallow areas and a wide range of crops. By contrast, al-Jazirah is cereal culture at its most extreme in Syria, with some 81% of the arable devoted to wheat and barley. Al-Ghab and al-Furat combine wheat with mainly industrial crops (e.g. cotton and sugar beet). The West region is as diversified as Hauran, but without much fallow. Instead, other crops (mainly market vegetables) replace fallow, and barley substitutes for forages. Higher soil moisture availability and greater incidence of supplemental irrigation in the West make possible a more intensive land use than in Hauran.

Table 5.1.2 Sample distribution: farm size by region*

Farm size	West reg.	Al-Ghab	Al-Jazirah	Al-Furat	Hauran	Row total
0-5 ha	24	15	3	10		52
	46.2	28.8	5.8	19.2		22.7
	30.0	75.0	3.4	50.0		
	10.5	6.6	1.3	4.4		
>5-10 ha	15	1	14	8	5	43
	34.9	2.3	32.6	18.6	11.6	18.8
	18.8	5.0	15.7	40.0	25.0	
	6.6	.4	6.1	3.5	2.2	
>10-20 ha	25	2	24	1	8	60
	41.7	3.3	40.0	1.7	13.3	26.2
	31.3	10.0	27.0	5.0	40.0	
	10.9	.9	1.5	.4	3.5	
>20-50 ha	13	1	31	1	6	52
	25.0	1.9	59.6	1.9	11.5	22.7
	16.3	5.0	34.8	5.0	30.0	
	5.7	.4	13.5	.4	2.6	
>50 ha	3	1	17		1	22
	13.6	4.5	77.3		4.5	9.6
	3.8	5.0	19.1		5.0	
	1.3	.4	7.4		.4	
Column	80	20	89	20	20	229
Total	34.9	8.7	38.9	8.7	8.7	100.0

* Numbers, from top to bottom, in each cell are number of farmers, row percent, column percent and percent of total.

Some 69% of the sample farmers had access to at least one source of irrigation water, such as canals, rivers, or pump wells. This figure is no doubt high for Syria as a whole but less so for farmers in the region surveyed, which includes major irrigation schemes in al-Ghab, al-Furat, and the West region. It is impossible to quantify any sample bias regarding access to irrigation, because national and district figures for numbers of farmers with irrigation water do not exist.

Table 5.1.3 Crop distribution (in % of arable land)

Farm criteria	Av. farm size, ha	Cropping intensity %	Wheat	Barley	Food legumes	Forages	Tree crops	Other crops	Fallow
West Region	14.5	93	35	13	11	1	6	27	7
Al-Ghab Region	8.5	92	52	1	0	3	0	36	8
Jazirah Region	50.9	98	57	24	3	n.s.	n.s.	14	2
Al-Furat Region	7.4	110	50	2	0	n.s.	1	45	2
Hauran Region	18.0	72	33	6	10	9	6	8	28
≤ 5 ha	3.2	99	64	1	3	1	3	27	1
> 25-10 ha	7.6	99	43	12	5	3	3	29	5
> 10-20 ha	15.6	94	44	10	9	1	5	25	6
> 20-50 ha	31.6	94	45	17	6	2	2	21	7
> 50 ha	150.0	97	56	26	3	n.s.	n.s.	11	4
With Irrigation source	22.6	97	43	23	2	n.s.	1	26	5
Without irrigation	39.1	95	62	16	8	1	2	6	5
Means of total	27.8	96	51	20	4	1	2	17	5

Source: 1991 survey

The situation is different, however, if we consider wheat area under irrigation. Within the survey sample, about 8% of farmers with access to irrigation water did not irrigate their wheat crop. Most of these farmers are in the higher rainfall zone and use their pump wells for higher value crops, especially cotton and summer vegetables. The irrigated portion of total wheat area covered by the survey was 35%. This is higher than the latest (1987) official figure available for the sampled districts, which is 23%.

These differences can be reconciled in part by considering the rapid growth of government schemes and local pump well systems, particularly in the West and al-Jazirah. Unofficial estimates say thousands of new pump systems have been installed in al-Jazirah alone since 1987, and the survey tends to confirm that, with irrigated area in this region jumping from 13% in 1987 to a surveyed value of 30% in 1991. Irrigated wheat in the West, through smaller areas are involved, shows a similar increase.

But new irrigation systems alone do not account for the disparity between survey figures and official statistics. More important is the type of irrigation reported. As noted earlier, official statistics are calculated on the basis of rated full irrigation potentials only; they do not include supplemental irrigation. The survey covered both methods. Of the total surveyed wheat area, 20% was under supplemental irrigation and 15% full irrigation. Using a rough multiplier of 0.5 to convert the actual observed supplemental area into its full irrigation equivalent, the irrigated area becomes 25%, or slightly less than a 10% increase since 1987. This would seem reasonable.

The survey has been important in establishing three points about recent wheat irrigation trends in Syria. First, the irrigated area has continued to increase despite a general decrease in total wheat area over the past five years. Second, supplemental irrigation of wheat is more widespread than full irrigation, and this situation is particularly marked in the West region and al-Jazirah. Third, farmers do not appear to select varieties for irrigation on the basis of response to extra water. This point will be further elaborated in the following sections.

5.1.6 Use of modern technology

The evidence is clear that, given the opportunity and wherewithal, farmers will adopt irrigation technology. The benefits of irrigation in terms of higher yields are obvious. Moreover, the majority of wheat producers with access to irrigation water apply at least some of it to wheat; 92% of surveyed wheat producers with water irrigated all or part of their wheat crop. About 44% of them used only supplemental irrigation, 34% used full irrigation, and 22% followed a mixed strategy.

Wheat producers have equally embraced mechanization: 99% of surveyed farmers used a tractor for pre-seeding tillage; 69% used some sort of machine for seeding, the rest relying on hand broadcasting; and over 90% harvested by machine. The incidence of hand harvesting was significant only in the Hauran (just over half) and in al-Furat (40%). In the latter, many plots are small and separated by bunds for basin irrigation, which makes mechanization of harvest difficult with existing equipment.

Only 5% of farmers did not use nitrogen fertilizer in 1991. Of those who did, 64% made two applications, one at planting and one later, 16% applied nitrogen only at seeding, and 20% only later. Those not using nitrogen tended to be non-irrigators, on rainfall alone, although the majority of rainfed wheat farmers did apply nitrogen.

Phosphate fertilizer was applied by 87% of the farmers surveyed. Regional distribution of non-phosphate users was fairly even, except in al-Ghab where only 50% of the farmers used phosphate in 1991. Al-Ghab accounts for one-third of the farmers not using phosphate.

Herbicide has the lowest adoption rate of the major external inputs. Fifty-four percent of surveyed farmers applied herbicide to at least one of their wheat fields. The majority of non-users were in al-Jazirah region (74% non-use), but non-use was also high in al-Furat and Hauran, at 55% and 45%, respectively. Herbicides were most popular in al-Ghab (100% use) and the West (76% use). In total, the West accounted for 44% of herbicide use in the sample, and al-Jazirah accounted for 63% of non-users.

Varietal adoption shows a more complex pattern. There has been a dramatic increase in total area sown to improved varieties over the past twenty years, and the 1991 farmer survey broadly confirmed the trends in HYV adoption presented by the official statistics. Table 5.1.4 looks specifically at the districts surveyed in 1991 and compares the results to the statistics for 1987 (the latest year of published district data).

Overall adoption moved from 66% to 87% of the total area between the 1987 and 1991 harvests. However, the pace of change differed between water regimes and locations. Specifically, increases in HYV adoption over the past four years were apparently most significant among rainfed zone 2 producers and farmers located in the West and al-Jazirah. Hauran has still not seen the introduction of new varieties, and irrigated areas, like al-Ghab and al-Furat, were already almost entirely under HYV wheat.

The large increases in rainfed HYV area call for further

Table 5.1.4 Comparative HYV adoption (% wheat area) in survey districts, 1987 and 1991

	Area in HYV wheat (%) Official statistics 1987	Survey 1991	% Increase 1987-91
Total of districts sampled	66	87	32
Full irrigation	97	100	3
Supplemental irrigation	n.a.	98	-
Rainfed (total area)	57	81	42
Rainfed, zone 1	78	85	9
Rainfed, zone 2	34	58	70
West Region	64	85	33
Al-Ghab	99	100	1
Al-Jazirah	69	91	32
Al-Furat	100	100	-
Hauran	0	0	-

Sources: MAAR (1987) and 1991 survey

attention. First, it must be recognized that the survey inadvertantly underrepresented certain zone 2 rainfed areas in the West region, especially in Hama and Homs governorates. In the 1987 statistics these areas have very low HYV adoption rates, and the 1991 sample size may have been too small to give a truly representative picture. Next season, greater emphasis will be put on rainfed zone 2 farmers in the West region. Secondly, the survey indicated important changes in the West and al-Jazirah, with increases of 33% and 32% in the proportion of area grown in HYVs. Statistically, the apparent recent shift in al-Jazirah is crucial at the national level because of the vast wheat areas in that region. Although the 1991 survey more than adequately covered zone 1 rainfed farmers in al-Jazirah, zone 2 needs more attention. Thirdly, there is the issue of supplemental irrigation, a situation not accounted for by national statistics. In terms of area, supplemental irrigation is important in the West and al-Jazirah; and, since farmers using supplemental irrigation overwhelmingly utilize HYVs, we can reasonably assume that recent growth in area under supplemental irrigation goes a long way towards explaining the rapid expansion of HYV area in both regions.

5.1.7 Variety distribution

Unlike the official statistics, the 1991 farmer survey allows us to look at patterns of varietal adoption in several dimensions (Table 5.1.5). The first dimension is spatial distribution of varieties. For example, Cham 1 covers 23% of the total area, but only 14% of the West region. Table 5.1.5 also includes the weighted average ages (WA) for the total and regional HYV areas. The WA measure, developed by Brennan and Byerlee (1991), is useful in comparing rates of varietal change and replacement over time and across regions. It can be seen that varietal distribution within regions is uneven. For example, Hauran contains only a single variety (local Haurani), but the West and al-Jazirah are more heterogeneous, with no single variety occupying more than 28% in either region. Al-Furat, the exclusively irrigated Euphrates basin, is dominated by Mexipak (bread wheat) and Bohouth 1 (durum wheat), both relatively old varieties.

In the varietal distribution across regions, al-Jazirah accounts for most of the sown area of all but a few of the numerous varieties (Table 5.1.5). The exceptions are Bohouth 1, which is predominantly an irrigated variety, and the six HYV and five local varieties of minor importance. Interestingly, more Haurani is grown in al-Jazirah than in Hauran itself. Some 82% of all HYV wheat is grown in al-Jazirah. So, thus, if the proportion of a particular variety grown in al-Jazirah is greater than 82%, then there is a relative concentration of that variety in al-Jazirah. For example,

Table 5.1.5 Distribution of varieties by regions* (in % of areas)

Varieties			Distribution across and within Regions (in %)									
		%	West Region		al-Ghab		Jazirah		Furat		Hauran	
Name	Release date	total area	var. area	region area	var. area	region area	var. area	region area	var. area	region area	var. area	region area
Cham 1	1983	23	7	14	4	35	89	26	-	-	-	-
Mexipak	1971	14	2	3	1	3	89	16	8	44	-	-
Haurani	(local)	12	10	9	-	-	59	9	-	-	31	100
Cham 3	1987	11	2	2	-	-	97	14	1	3	-	-
ACSAD 65	1986	11	5	5	4	16	91	13	-	-	-	-
Cham 4	1986	9	2	1	-	-	98	11	-	-	-	-
Bohouth 1	1980	6	57	28	9	20	19	1	15	35	-	-
Jazirah 17	1974	6	23	11	-	-	76	5	7	15	-	-
Six other HYVs	(various)	7	42	22	11	26	46	5	1	3	-	-
Five other locals	(locals)	1	71	6	-	-	29	-	-	-	-	-
Total HYV distribution			12		3		82		3		-	
Total wheat distribution			12		3		78		3		4	
Weighted average age of HYV area (yrs)			10.8		8.5		9.4		15.6		-	

* For each region, two columns of numbers are given. The left column is the % of the particular variety's total area contained in the region. The right column is the % of the region's area devoted to that variety. Thus, 7% of the total Cham 1 area is grown in the West Region, and this represents 14% of the wheat area in the West Region.

Source: 1991 survey

Cham 3 and Cham 4 could both be characterized as essentially "al-Jazirah varieties", but Cham 1 and Mexipak could not.

The second dimension considered is distribution of varieties across the three water regimes: rainfed, supplemental irrigation, and full irrigation (Table 5.1.6). This invites comparison with the target environments listed in Table 5.1.1. For example, Cham 3, the only variety exclusively targeted for rainfed zone 2, is, in fact, the only major variety not grown under rainfed conditions in zone 2. Instead, 46% of the area sown to Cham 3 in 1991 was in rainfed zone 1, while the remaining 54% was under some form of irrigation. Admittedly, some 93% of supplementally irrigated Cham 3 is located in zone 2, but the use of irrigation water here obviates to a large extent the drier rainfall conditions.

Along with Cham 3, the predominantly irrigated varieties are Bohouth 1, Jazirah 17, and the six minor HYVs. Mexipak, the principal bread wheat variety in Syria is mostly rainfed (74%), despite its importance in al-Furat region. Local varieties are usually rainfed, and Haurani makes up 40% of rainfed zone 2 wheat, the highest proportion at any single variety under any one water regime. The nearest competitor in this is Cham 1, which accounts for 31% of all wheat under full irrigation. Nevertheless, the striking feature of Table 5.1.6 is the large number of varieties grown under each water regime. The only possible exception is full irrigation, but even here over half the available varieties are represented.

The weighted average ages (WAs) of HYV areas raise some interesting observations. First, the survey average of 9.7 years is rather high for a developing country, though not outside the general range. It indicates a fairly low rate of varietal replacement: once farmers adopt an HYV, they tend to retain it rather than try a newer

Table 5.1.6 Variety distribution across water regimes*

Varieties	Rainfed zone 1		Rainfed zone 2		supplemental irrig.		Full irrig.	
	var. area	regime area	var. area	regime area	var. area	regime area	var. area	regime area
Cham 1	52	22	4	10	23	26	21	31
Mexipak	74	20	9	14	4	3	13	13
Haurani (local)	64	14	34	40	2	1	-	-
Cham 3	46	10	-	-	27	15	27	21
ACSAD 65	75	15	1	1	24	13	-	-
Cham 4	79	13	6	5	15	7	-	-
Bohouth 1	20	2	6	3	40	12	34	13
Jazirah 17	6	1	26	15	25	7	43	16
Six other HYVs	21	2	15	10	50	16	14	6
Five other locals	81	1	18	2	1	-	-	-
Total of HYV area surveyed	53	85	7	58	23	99	17	100
Total wheat surveyed	55		10		20		15	
Weighted average age of HYV area (yrs)	9.8		12.2		8.2		10.5	

Distribution across water regimes (in %)

* This table should be read in a similar fashion to Table 5. Rainfed zone 1 contains 52% of the total Cham 1 area, and Cham 1 constitutes 22% of the rainfed zone 1 area. Also, rainfed zone 1 contains 53% of Total HYV area surveyed, and 85% of rainfed zone 1 is planted in HYVs.
Source: 1991 survey

variety. Moreover, recent adopters not infrequently began with fairly old HYVs instead of more contemporary ones. Pre-1981 varieties, such as Mexipak, Jazirah 17, and Bohouth 1, continue to be popular.

The WAs across regions may indicate adoption patterns. The fully irrigated al-Furat has the highest WA, and national statistics indicate that this region was the first to experience a high incidence of HYV adoption (in the 1970s). The West followed somewhat later, and al-Jazirah most recently. The exception is al-Ghab, but here the relative importance of Cham 1 indicates that there has been some variety augmentation or replacement.

The weighted average ages for water regimes are less easily interpreted. They are higher than the overall average, except for supplemental irrigation. That for full irrigation is high, even though al-Furat itself constitutes only 17% of the full irrigation area. This is due to the continued importance of older varieties such as Jazirah 17, Mexipak, and Bohouth 1 in all fully irrigated areas. Rainfed zone 2 is the most interesting case. In this area of relatively recent HYV adoption, the older varieties Mexipak and Jazirah 17 account for about two-thirds of the WA. However, with the exception of Cham 3, noted earlier, there are no new varieties expressly developed for the drier areas. This illustrates that WA can be high even in areas of fairly recent adoption if the HYVs utilized are themselves of older vintage.

The third dimension is the farmers. Table 5.1.7, showing the distribution of varieties among producers, should be viewed in conjunction with Table 5.1.3. The first column indicates the relative "popularity" of varieties. Cham 1 is grown by the largest number of farmers, followed by Mexipak and Haurani; but farmers often produce more than one variety, and the average number of

Table 5.1.7 Variety distribution by producers and producer areas

Varieties	% Farmers growing	Av. area per prod. ha	% of Producers and av. area per producer*										Av. producer farm size ha
			West region		al-Ghab		al-Jazirah		al-Furat		Hauran		
			%	ha	%	ha	%	ha	%	ha	%	ha	
Cham 1	22	14.7	15	4.6	10	16.0	42	17.9	-	-	-	-	39.9
Mexipak	20	10.6	9	1.6	20	0.8	24	20.3	65	2.8	-	-	31.9
Haurani	16	10.3	15	3.2	-	-	6	44.9	-	-	100	5.9	39.9
Cham 3	6	27.0	3	3.5	-	-	12	33.5	5	2.3	-	-	98.0
ACSAD 65	15	10.7	6	3.8	25	3.0	28	13.6	-	-	-	-	44.3
Cham 4	5	24.2	4	1.6	-	-	10	31.8	-	-	-	-	70.1
Bohouth 1	21	4.2	34	4.1	50	1.8	8	5.1	15	9.8	-	-	19.1
Jazirah 17	13	6.4	15	3.7	-	-	11	13.4	40	1.5	-	-	21.0
Six other HYVs	19	4.9	26	4.3	50	2.4	13	8.2	5	3.0	-	-	17.5
Five other locals	7	2.3	18	1.7	-	-	1	10.0	-	-	-	-	11.5
Wheat area per farm (ha)		14.4	5.1		4.6		29.1		4.2		5.9		
Single variety per farm (ha)		10.3	3.6		2.9		18.2		3.2		5.9		
Varieties per farm (number)		1.4	1.4		1.6		1.6		1.3		1.0		

* Since farmers often grow more than one variety, total percentages in each region except Hauran equal more than 100%.
Source: 1991 survey

varieties per farmer is given on the bottom line. The second column shows the average areas per producer. These numbers are, of course, heavily influenced by the situation in al-Jazirah where larger farms predominate.

Some interesting contrasts are revealed. For example, Cham 3 is characteristically grown by large farmers, but the area they plant to Cham 3 is significantly higher than areas of other varieties only in al-Jazirah. This indicates large-scale commercial production of Cham 3 in al-Jazirah but not elsewhere. Similarly, Haurani has received the commercial attention of a small percentage of al-Jazirah farmers. The most "normative" variety, in terms of distribution among farmers and regions and in terms of conforming to norms in farm size and area per farm, is Mexipak. This observation is reinforced by the distribution of Mexipak across water regimes (Table 5.1.6). Second place would go to Cham 1. Both are widely adapted varieties which have a fairly long history of success with Syrian farmers.

5.1.8 HYV adoption patterns

This section examines the distribution of varieties within individual farms and the changes that have taken place over time. Surveyed farmers are put into five groups according to the kinds of wheat they grow: HYV durum producers only; HYV bread wheat producers only; HYV durum and bread producers; HYV and local variety producers; and producers of local varieties only (Table 5.1.8). As can be seen, producers of only HYV durum constitute 51% of the sample, whereas HYV bread wheat only covers 11%. These two groups average slightly over one variety per farm. Farmers growing a mix of HYV bread and durum or HYV and local wheat are more diversified and grow more than twice as many varieties per farm. The most specialized, with fewest varieties per farm, are producers growing

Table 5.1.8 Variety mixes on farms by regions (in % of farmers)

Farm Groupings	Total %	Regions: West Region %	Al-Ghab %	Al-Jazirah %	Al-Furat %	Hauran %	Average var. per farm
HYV durum varieties only	51	51	75	61	35	-	1.2
HYV bread varieties only	11	8	5	12	35	-	1.1
Mix of HYV durum & bread	15	9	20	21	30	-	2.3
Mix of HYV and local	9	18	-	6	-	-	2.5
Local varieties only	14	14	-	-	-	100	1.0
Totals	100	100	100	100	100	100	

Source: 1991 survey

local varieties only. Each farmer in this group grows one variety only.

Across the regions, the West is the most diversified and contains representatives of all groups. Hauran, producing just a single local variety (Haurani), is the least diversified region. The mix of local variety with HYV was found on only 9% of surveyed farms and only in the West and al-Jazirah; but this group represents almost one in five of West region farms.

Surprisingly, there are more HYV bread-wheat specialists in rainfed zone 2 than HYV durum specialists (Table 5.1.9). Less surprisingly, 77% of rainfed zone 2 farmers are growing local varieties only. The relationship between irrigation and HYVs is clear: farmers able to irrigate their entire crop tend to specialize in either HYV durum or HYV bread wheat. For those growing both HYV durum and bread wheat, there are no great differences in relative frequency between rainfed zone 1, full irrigation, and mixed rainfed/irrigated.

The results indicate that few farmers grow local varieties once they have adopted HYVs. This runs counter to the belief that Syrian farmers continue to grow even a small field of local wheat for household consumption while using HYVs as a cash crop. Only 10% of farmers do this.

In order to represent changes in producer decisions over time, HYV farmers have been classified into adoption cohorts according to when they first began to grow HYVs. Two general observations can be made about these cohorts and their variety mixes in 1991 (Table 5.1.10). First, specialization, producing either HYV durum or HYV bread wheat (but not both), tends to come early in the adoption process. Farmers appear to make an initial choice about which type

Table 5.1.9 Percentages of farmers using different variety mixes within water regimes

Farm Groupings	Water regimes				
	Rainfed zone 1	Rainfed zone 2	Supp. irrig.	Full irrigation	Mixed regime
HYV durum varieties only	48	4	77	60	31
HYV bread varieties only	7	15	8	20	6
Mix of HYV durum and bread	19	-	9	20	28
Mix of HYV and local	12	4	5	-	28
Local varieties only	14	77	1	-	7
Totals	**100**	**100**	**100**	**100**	**100**

Source: 1991 survey

Table 5.1.10 Variety mixes according to adoption cohorts*

	Cohorts				
Variety mixes	1 before 1976 n = 11	2 1976-80 n = 27	3 1981-85 n = 52	4 1986-90 n = 108	Total % n=198
HYV durum	46	56	61	60	59
HYV bread	9	22	12	11	13
HYV durum & bread	45	18	15	17	18
HYV & local varieties	-	4	12	12	10
Totals	**100**	**100**	**100**	**100**	**100**

* Numbers represent percentages of each cohort.
Source: 1991 survey

of HYV wheat to grow and then stick with that choice. Second, few farmers continue to grow local varieties as well as HYVs. In the latest cohort (one to five years experience of HYVs), only 12% of farmers still grow local varieties. This proportion persists into the next older cohort, but by the time farmers have been using HYVs for more than 10 years, the incidence of local varieties is down to 4%. In the older cohort (15 or more years), there are no farmers growing local wheat varieties.

Overall, adoption has followed a fairly standard geometric progression (Table 5.1.11). The percent of new adopters has roughly doubled every five years until virtually the maximum has been reached in all regions except Hauran. Hauran is a special case, and the absence of HYVs in this region is probably due more to external factors than to strictly producer choices. Table 5.1.11 also confirms the correlation between early adoption and irrigation. Note the higher proportion of early adopters in the two irrigation development areas of al-Furat and al-Ghab; and the weight of evidence suggests that the rapid growth of HYVs in the West and al-Jazirah is connected with the spread of supplemental irrigation there over the last 10 years.

Table 5.1.11 Distribution of cohorts within regions*

Cohorts	Regions					
	West n-80	al-Ghab n=20	al-Jazirah n=89	al-Furat n=20	Hauran n=20	Total %
1. Adopted before 1976 n=11	1	15	3	20	-	5
2. Adopted 1976-80 n=27	5	30	9	45	-	12
3. adopted 1981-85 n=52	33	45	13	30	-	23
4. Adopted 1986-90 n=108	47	10	75	5	-	47
Non-adopters n=31	14	-	-	-	100	13
Totals	**100**	**100**	**100**	**100**	**100**	**100**

* Figures in columns represent percentages within each region
Source: 1991 survey

Examining the characteristics and selection behaviour of HYV producers in more detail (Table 5.1.12), we find that early adopters have the highest ratio of irrigated to rainfed production (82% have some form of irrigation and 45% have full irrigation). These high values continue into the second cohort, but drop for the later two cohorts. The drop is particular marked for full irrigation, and supplemental irrigation becomes relatively more important. The specialization ratio refers to the proportion of farmers specialized into the type of HYVs they grow: either all durum or all bread wheat. Specialization is fairly consistent except for the first cohort (compare with Table 5.1.10).

Table 5.1.12 Characteristics of adoption cohorts

Characteristics (ratios expressed in fraction of 1.00)	Cohorts based on time of HYV adoption 1 before 1976 n=11	2 1976-80 n=27	3 1981-85 n=52	4 1986-90 n=108	Average for Total n=198
Irrigation*/full irrigation ratios	.82/.45	.81/.56	.65/.19	.72/.19	.72/.25
Specialization ratio**	.55	.78	.73	.71	.72
HYV replacement ratio	-	.07	.13	.03	.06
WA of HYV area (yrs)	15.1	14.7	11.9	8.8	9.7
Avg. varieties per farmer	1.5	1.2	1.3	1.5	1.4
Avg. new varieties per farmer***	0.5	0.1	0.2	n.a.	0.2
New varieties ratio	0.33	0.08	0.15	n.a.	0.15

* Irrigation includes access to supplementary and/or full irrigation source
** Specialization defined as producing exclusively either HYV durum or HYV bread, but not both, and no local wheat
*** New varieties are those release after initial adoption period for each cohort. New varieties are not applicable (n.a.) to cohort 4, and totals are based on cohorts 1, 2, and 3 only.
Source: 1991 survey

The HYV replacement ratio shows the frequency with which farmers have discarded initial HYVs. For example, no farmer in cohort 1 has ever stopped growing any HYV variety, but 13% of farmers in cohort 3 reported replacing one or more HYVs with others since their original adoption. These ratios are low for all cohorts, reinforcing the earlier observation about the persistence of initial variety choices (Table 5.1.10). The non-replacement of initially chosen varieties is well reflected in the weighted average ages of the HYV varieties grown by each cohort.

While farmers may not replace the varieties they initially adopted, they can choose to add a newer variety to the repertory they grow. This behaviour is reflected in the average new varieties per farmer (Table 5.1.12). Of course, each cohort had a different number of varieties available to it originally. Cohort 1 (adoption prior to 1976) had a choice among only the four varieties released prior to 1976; cohort 2 had an initial choice among five varieties, cohort 3 among seven varieties; and cohort 4 had the full range of the 12 varieties released between 1970 and 1987. Post-adoption choice differed conversely. Thus, cohort 4, having adopted during the last five years, has had no new varieties to select from.

For the first three cohorts, the average number of varieties added after the initial adoption period is only one per five farmers. The *new varieties ratio* (Table 5.1.12) shows the proportion of newer varieties, released after the initial adoption period, now grown by farmers in each cohort. The ratio is low across all cohorts, demonstrating both low replacement and low addition rates. In essence, the varietal selection behaviour of Syrian wheat producers appears to lack dynamism. Alternatively, it could be said that farmers do not recognize a great deal of difference among the HYVs, except for the basic distinction between durum wheat and bread wheat. When farmers make a change, it tends to be the addition of a new variety to the existing mix rather than the replacement of old with new. This finding is of fundamental importance in determining the impact of new varieties on the farming system and especially on the nature of farmer linkages to external institutions such as markets and government agricultural organizations.

For example, a common theory about the impact of new technology is that it stimulates differentiation and specialization among producers (Lipton 1989): farmers respond to the economic incentives of the marketplace or government institutions by specializing in those products for which they have a comparative advantage and which will, therefore, give the highest benefits. Adoption of improved varieties is a response to higher yields and higher net returns; and, within the range of choice of new varieties, farmers select and specialize in those varieties that give them the best return under prevailing economic conditions. Individually, farmers are presumed to go through a process with recognizable phases: originally growing local varieties; then adopting and experimentating with a range of HYVs while continuing to grow some local varieties; then a more intensive selection phase focused on HYV alternatives; and finally a specialization phase in which the farmer settles on one or two varieties that give the best return; and this process is accompanied by a gearing of production to the market or progress towards full commercialization, in which both output and inputs are oriented to external linkages.

There is little evidence that any process of specialization and commercialization has occurred among the surveyed farmers. Syrian wheat producers, both HYV and non-HYV growers, are now very much oriented towards external linkages. Seed source and harvest sale are two excellent indicators of linkages with wider systems. According to survey results, the government seed organization is the sole source of supply for just over 77% of HYV producers. Self-provisioning and neighbours together account for only 12% of seed needs of such farmers. The government is also the seed source for 77% of local variety producers. On-farm sources cover another 19%, and the remainder are obtained from the market.

Percentage of harvest sold is similar. HYV producers sell, on average, about 88% of their harvest, and the bulk of this goes to the government marketing organization (where the purchase price is usually as good or better than the open market). In terms of degree of commercialization, there is very little difference between producers of improved and unimproved wheat: 79% of HYV producers, and 74% of local wheat producers, sell between 75 and 100% of their harvest each year. Moreover, there are no significant differences in the external sources of inputs or degree of harvest sale between the different variety mix groups. Those who grow HYV durum only are no more market-oriented than those diversified farmers who grow HYV durum, HYV bread and local wheat.

These findings underline the success of the Syrian government program to introduce modern technology into national wheat production. Moreover, they demonstrate that external resources and commercial considerations are important for all wheat producers, including those who continue to grow local varieties exclusively. In terms of farmer characteristics and use of resources, local varieties should be viewed in much the same way as HYVs.

5.1.9 HYVs and associated technologies

HYVs are rarely introduced to farmers as isolated improvements. New varieties are usually accompanied by changes in crop management practices. Most frequently cited are chemical fertilizers, herbicides, and new agronomic practices. HYV adopters were asked in the survey whether they had changed their production practices for the new varieties. A majority said they had made at least one change, and many listed additional ones (Table 5.1.13). An increased seed rate was the most frequent change associated with HYV adoption, but increased fertilizer use was almost as common.

Table 5.1.13 Change in production practices associated with HYV adoption*

Changes in	Cohorts 1 pre-1976 n=11	2 1976-80 n=27	3 1981-85 n=52	4 1986-90 n=108	% Positive reply for total n=198
Increase seed rate	55	52	39	60	53
Increase use Nitrogen fert.	55	63	44	47	49
Increase use Phosphate fert.	46	63	39	45	46
Increase number of tillages	36	48	19	30	30
Increase herbicide use/rate	27	39	19	16	20
Shift HYV wheat to more fertile soil	18	26	12	6	11
Estimate yield increase	24%	50%	50%	51%	49%

* Numbers represent percentages of farmers giving positive replies. Those giving no answer are counted as negative replies
Source: 1991 survey

Farmers were asked to estimate the percentage yield increase experienced when they adopted HYVs and the associated new production practices. The striking thing in their answers is the gap between cohort 1 and the other cohorts (Table 5.1.13). Either the relatively more experienced early adopters were more realistic than their colleagues about the increases obtained or the gap is a real one and requires a technical explanation. The differences in weighted average age of the cohort 1 varieties may provide a clue, but similar differences exist among the other cohorts. Such considerations of impact will be addressed in Part II of this study.

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5.2 Impact Assessment of Supplemental Irrigation (SI) on the Productivity, Stability, and Sustainability of Rainfed Wheat-Based Farming Systems in Syria

Abdul Bari Salkini

5.2.1 Methodological issues

Impact assessment and evaluation of the changes brought by supplemental irrigation (SI) requires the adoption of the farming systems research approach. However, farming systems or, as Marten (1988) called them, agroecosystems, are complex. The numerous ecological processes that tie people, crops, weeds, pests, animals, micro-organisms, soil and water together into a functioning, on-going farming system are so intricate that they can never be fully described, or fully comprehended. Simplification is a practical necessity of analysis. Simplification is also essential to communicate the results of analysis effectively to farmers. The dilemma is how to simplify without losing the essence of key relationships in the farming system as a whole.

One approach to simplification is **system properties**, which each combine large numbers of farming system processes into a single, highly-aggregated measure of performance that suggests how well a farming system is meeting human objectives. The Southeast Asian Universities Agroecosystem Network (Gypmantasiri et al. 1980; Conway 1985; Rambo and Sajise 1985; Rerkasem and Rambo 1988) have focused on five system properties. These are:

i) **productivity**, defined as the quantity of food, fuel or fibre that an agroecosystem produces for human use;
ii) **stability**, in the sense of production consistency;
iii) **sustainability**, defined as the system ability to maintain a special level of production over the long term;
iv) **equitability**, or sharing agricultural production fairly, and;
v) **autonomy**, or agroecosystem self-sufficiency (Marten 1988).

These properties (Figure 5.2.1) are referred to as system properties (or 'emergent' properties) because they derive from the system as a whole rather than from any one of its parts. The productivity of an SI-wheat farming system is not determined simply by the yield potential of the particular wheat varieties that are employed. Actual yield depends upon the hydrological and nutritional environment the crop experiences at each successive stage of growth, which is, in part, a consequence of how farmers manage the crop. The wheat productivity is therefore a consequence of the functioning of the total interactive agricultural-environmental-social system.

A major reason for evaluating such properties is to compare the performance of alternative forms of agriculture (Conway 1985). This is basically the aim of this research. With SI, the **productivity** of the rainfed system is enhanced because yields per hectare can be considerably higher, because a wide variety of crops can be grown at a greater cropping intensity; and, also, because the

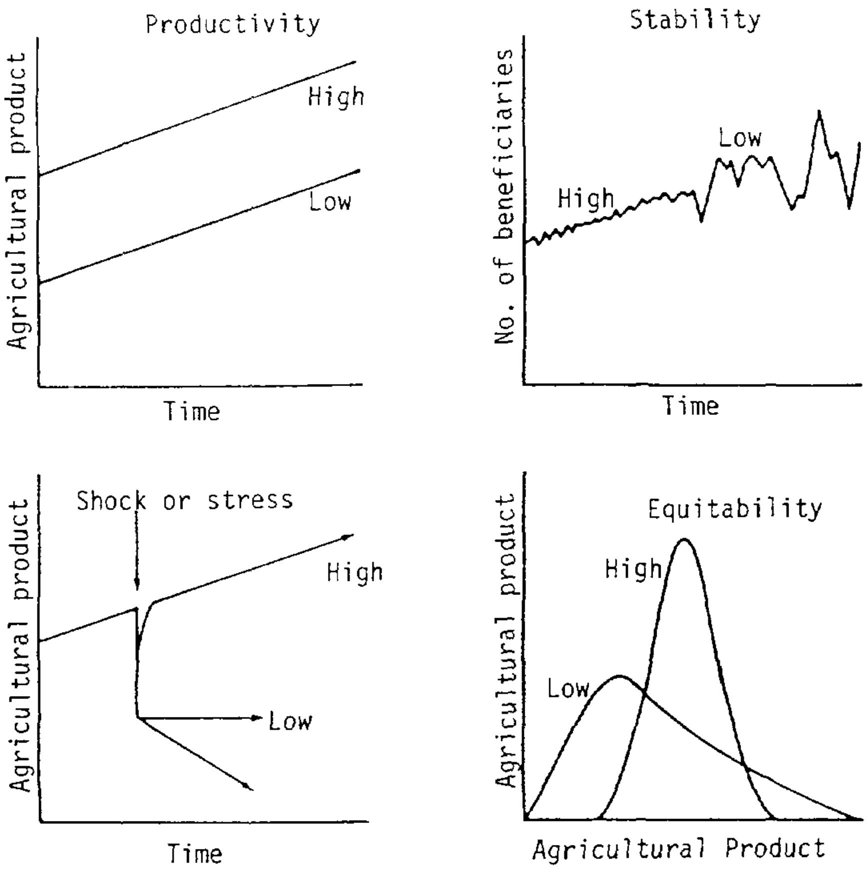

Figure 5.2.1 Indicators of agricultural performance (after Conway, 1987)

improved water supply provides an opportunity to grow crops of higher value than the rainfed crops.

If the irrigation system is reliable, **stability** also increases as farmers are liberated, to some extent, from the vagaries of rainfall. These gains are **sustainable**, however, only if the irrigated agriculture does not encounter serious problems, such as salinization, or administrative problems in the irrigation system that cause its performance eventually to decline.

If those fields near the main canal in a canal system of irrigation receive a better water supply than fields at the end of secondary canals, there may be considerable variation in production from one landholding to another. **Equitability** is then less than it was without irrigation, when production was uniformly low. Further, the **autonomy** of the farmers is reduced, as they are compelled to deal with irrigation officials; as they use exotic high-yielding varieties and associated technologies (fertilizer, pesticides, herbicides, etc.); and as they produce larger quantities of crops for a market economy.

While there are many good reasons to assess these farming systems properties, neither their measurement nor their interpretation is as simple or straightforward as one might like (Dillon 1976; Hardaker et al, 1984; Conway 1985; Marten 1988). Common measures of productivity (Conway and Barbier 1990) are yield or income per hectare, or total production of goods and services per household or nation; but a large number of different measures are possible, depending on the nature of the product and the resources being considered. Stability, defined as the constancy of productivity in the face of small disturbing forces arising from the normal fluctuations and cycles in the surrounding physical, biological, social and economic environments, can be measured by the coefficient of variation in productivity determined from a time series of productivity measurements. Since productivity may be level, rising, or falling, stability will refer to the variability about a trend. Sustainability concepts, definitions, and methodologies are still evolving, as sustainable agriculture represents a new, and as yet barely tried, phase in development thinking. However, defined as a determinant of the persistence or durability of a system's productivity and stability in the long-run, sustainability can be assessed by trend analysis of productivity in a long time series. Intuition and common sense (Hardaker, et al.

1984) can also be used to assess the impact of new technology on system properties. Intuition is used in discussing the sustainability of SI systems by inspecting the level of a system's reliance on both 'internal' and 'external' resources. The greater the reliance on internal resources the more sustainable the system might be.

In this research, the data of farm and village surveys conducted in 1988/89 major wheat-producing areas in northwest (Aleppo) and northeast (Hassakeh) Syria, and the experimental results of 4-year trials on SI are used, in the main, to realize this objective. However, other data sources (cursory survey conducted in 1987, and secondary data) are also used.

To **quantify the changes in productivity** of crop production for the farm as a whole, changes in the cropping pattern (crop types, and cropping intensity) are defined. Incorporating these with the changes in crop yields, the **physical productivity** (in terms of total agricultural production on the farm) is quantified for each of the rainfed and SI systems, i.e., the total quantity of crop products with and without SI is assessed.

Crop production budgets for rainfed and SI crops are estimated using several data sources (for comparison, complementarity, and more confidence in the estimates). These sources are: the sample farmers of the farm survey, the village heads and other respondents of the village survey, and published secondary data. The impact of SI on the system's overall economic (more precisely, financial) productivity is also assessed by establishing whole farm budget models with and without SI.

The impact assessment procedures, above, are carried out to **compare** the rainfed farming system with four situations or levels of productivity of SI. These are:

First situation: poorly managed SI farming system of low cropping intensity (97%), and excessive waste of water due to over-irrigation. Both rainfed and irrigated farming are practised.

Second situation: SI system with moderate managerial skill, cropping intensity 110% (which is most common in practice in the research areas), and both rainfed and SI farming are practised.

Third situation: SI system with a good level of water management, cropping intensity 125%, all farm area is SI.

Fourth situation: high managerial skill of water/crop/land allocation, and farming practices (cropping intensity of 150%, high levels of yield obtained, water losses are minimal, and, all farm area is under SI).

The four situations exist in reality. However, the exact extent of each was difficult to determine. Rough estimates given by the village heads were: 20% of SI farms were operating under low efficiency of water management (i.e., the first situation), 10% are highly productive (the fourth situation) and about 70% are in between (the second and third situations). These situations, however, can also be considered as successive or sequential stages in the developmental process of the SI enterprise.

Efficiency Assumptions. Yields, costs, and revenues, as reported by the sample farmers, were considered representative for the rainfed and the second and third SI situations. A reduction of 20%, and an increase of 25%, were assumed for yields and gross revenue for the first and fourth situations, respectively. These percentages of adjustment, for the lower and higher efficiencies of the SI systems, were determined after consultations with the village heads, irrigation specialists and agronomists, and careful inspection of the ranges (minimum and maximum values of relevant data and their frequency distribution) reported by the sample farmers.

Complete and detailed budgeting was done for rainfed and SI wheat production for the 1987-1988 cropping season. That season was quite good (above normal rainfall). Data of 1988 were adjusted according to yield levels that are usually obtained by farmers in normal and low-rainfall years, and wheat production budgets under variable climatic conditions were estimated accordingly. Time and resource limitations of the research did not allow for detailed budgeting of other crops. However, lump sum estimates were solicited, for each crop, concerning yield, gross revenue, total cost, and net revenue of crop production. As a check procedure, these data were obtained from the sample farmers and the village heads separately. Fortunately, the two reports were not widely different (see Salkini 1992). No substantial cost adjustments per unit area (i.e. one hectare) were made in evaluating the economic productivity of the different SI situations. It was assumed that all items of per hectare production cost (except harvest and disposal cost) are the same for the different situations. However, lower and higher management efficiency should be reflected in crop-land allocation and yield performance and, consequently, in gross and net revenue.

Analysis of the variability of wheat yields and profitability for seasons of different (normal, low, and high) rainfall facilitates the impact assessment of SI on the stability of rainfed wheat production. Variability and trend analysis for time series of crop yields (rainfed and SI) at the aggregate level are, also, used as indicators for the assessment of system stability and sustainability properties. Some characteristics of the groundwater utilization are used to predict future sustainability issues.

5.2.2 Impact of SI on the physical productivity of rainfed wheat-based farming systems

The impact of SI on the physical and economic productivity of rainfed wheat farming systems was assessed for a 10- ha farm. However, the discussion below considers productivity issues on a per hectare basis.

5.2.2.1 Impact of SI on cropping pattern and intensity

Table 5.2.1 summarises the cropping patterns and cropping intensity of the rainfed and SI systems. Wheat is the number one crop, in terms of area, for both systems. Barley, lentil, and chickpea are other winter crops grown, and melons (watermelon and muskmelon) are the only summer crops grown in rainfed systems. Aggregating values from agroclimatic zones 1 and 2 gives a cropping intensity for the rainfed systems of around 85%, with 15% of the land fallowed

Table 5.2.1 Cropping patterns and intensity of rainfed and supplemental irrigation farming systems (% of total area)

Crop	Rainfed system	Supplemental irrigation systems			
		I	II	III	IV
Wheat	37	47	47	44	48
Barley	22	7	7	-	-
Lentil	8	11	11	-	-
Chickpea	3	2	2	-	-
Melons	15	6	8	6	8
Cotton	-	14	14	30	36
Sugarbeet	-	1	1	2	6
Potatoes/other veg.	-	2	10	20	25
Tomatoes	-	2	5	5	5
Maize	-	2	2	9	11
Sesame	-	3	3	9	11
Cropping intensity	85	97	110	125	150
Fallow	15	3	-	-	-

Source: Farm survey

annually. The major changes in cropping pattern brought in by SI are the introduction of high cash-value crops, such as cotton, potatoes, tomatoes, other winter and summer vegetables, maize and sesame.

Cropping intensity is the principal factor influencing the productivity and efficiency of the SI system. In turn, cropping intensity is determined mainly by the water resources and the irrigation system used, types of crops grown, and more importantly the managerial skill of the irrigators. Most likely, SI operates at low productivity for the first one to three years (the first situation), with almost half of the farm area still grown rainfed. As time passes, farmers gain a better understanding of the soil-water-crop relationships, become more experienced with the irrigation system they operate; and system productivity and efficiency increase gradually. Cropping intensity is increased to about 110% (the second situation) with 60% of the cropped area under SI. The cropping intensity can be further increased to 125%, and 150%, with all crops grown with SI, provided farm area and water resources allow.

As productivity and efficiency increase, farmers with SI replace rainfed areas previously allotted to barley and legumes with summer crops and vegetables; the proportion of land area allocated to wheat does not change substantially. It is interesting that it does not decrease, as summer crops and vegetables are more profitable. Economic considerations play a role in land allocation but within the limitations of (i) crop rotation considerations, (ii) the managerial capacity of the farm household to handle large areas of the most profitable crops (vegetables), which also demand the most labour, time, capital, and management skill, and (iii) the minimum requirements (or obligations in some cases) of the government agricultural production plan.

Finally, it should be indicated that the transitional period an SI system requires to approach the higher level of productivity (the fourth situation) is highly variable. Some farmers succeed in operating at 150% cropping intensity within a few years, while others may never be able to arrive at that point.

5.2.2.2 Impact of SI on crop yields

Supplemental irrigation reduces the vagaries of the climatic influences on rainfed crop production, allows for more intensive use of capital inputs (fertilizer, seed, herbicides, etc.) and the utilisation of improved crop varieties (the semi-dwarf, high yielding varieties in the case of wheat) which respond well to water and fertilizer application; therefore, higher yields are obtained.

Table 5.2.2 presents crop yields and variability as reported by the sample farmers. In years of normal rainfall, SI increases their yield of rainfed wheat by 125%. With high rainfall, this is reduced to 80%; but, in years of low rainfall, yields of SI wheat can be nearly 500% of those of rainfed wheat. Legumes are less responsive to SI than cereals, and just a few farmers in the sample reported that small areas of lentils and chickpea may be given a few supplemental irrigations, mostly in dry seasons. These farmers obtained an average yield increase of about 70% and 110% for lentil and chickpea, respectively.

The average yields of rainfed wheat, as reported by the sample farmers, were 1610 kg/ha for a year of normal precipitation, about 2500 kg/ha for seasons of high and well-distributed rains, but only 560 kg/ha in poor seasons. Corresponding figures for SI wheat were 3600, 4500, and 2760 kg/ha, respectively (Figure 5.2.2). Yield variability is discussed, in some detail, at the end of this report.

Table 5.2.2 Yield level and variability of major crops (farm survey 1988)

Crop	Rainfall season		Rainfed Mean kg/ha	Rainfed SD kg/ha	Rainfed CV %	Supp. irrig. Mean kg/ha	Supp. irrig. SD kg/ha	Supp. irrig. CV %
Wheat	Normal,	grain	1610	453	28	3698	714	20
		straw	1040	337	32	2145	722	34[a]
	Low,	grain	560	286	51	2760	771	28
		straw	834	498	60	1680	649	39[a]
	High,	grain	2488	612	25	4500	776	17
		straw	1507	579	38	2588	842	32[a]
	Av. 3 season,							
		grain	1538	398	26	3620	673	18
		straw	1112	385	35	2138	398	19
Lentil	Normal,	grain	1315	360	27	2250	NA	NA
		straw	1378	351	25	1800	NA	NA
Chickpea	Normal,	grain	1152	241	21	2500	410	16
		straw	1000	200	20	1500	260	17
Melon	Normal		8500[b]	NA	NA	19500	11737	60[c]
Cotton	Normal		Not grown, rainfed			3256	425	13
Sugarbeet	Normal		Not grown, rainfed			41182	8436	20
Potatoes	Normal		Not grown, rainfed			21340	5193	24
Tomatoes	Normal		Not grown, rainfed			24340	8076	33
Maize	Normal		Not grown, rainfed			3060	1324	43
Sesame	Normal		Not grown, rainfed			1190	336	28

Source: Farm survey.

a) the high variability in straw yield is caused by significant differences between farmers in terms of their attitudes towards straw collection, and the techniques used. Straw yields, however, were roughly estimated by farmers.
b) estimated figure.
c) the high variability in melons yield is, most likely, due to confused reports; some farmers gave reports on rainfed melons, while others gave reports on supplementally irrigated melons.
NA = not available due to the few cases reported.

Village heads and other respondents of the village survey estimated that, normally, more than half the farmers (52%) obtain yields of 1000-1500 kg/ha for rainfed wheat, 36% obtain 1600-2000 kg/ha, and only 12% can achieve more than 2000 kg/ha. In contrast, the majority (68%) of SI farmers normally realise yields of 3000-

4000 kg/ha, about 12% obtain more than 4000 kg/ha, and 20% get less than 3000 kg/ha (Table 5.2.3).

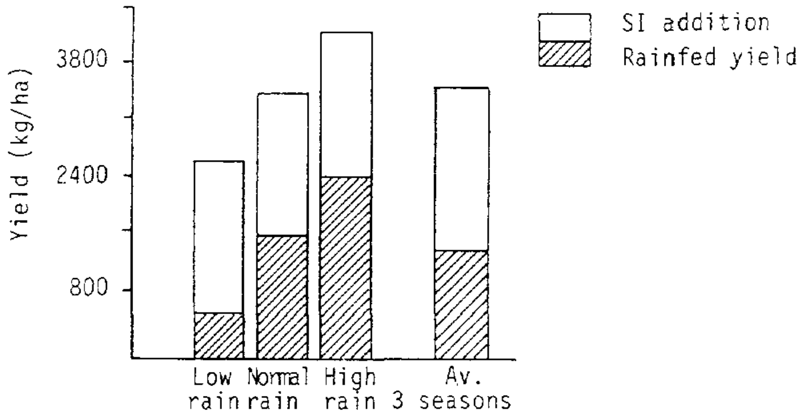

Figure 5.2.2 Impact of SI on wheat yield

Table 5.2.3 Distribution of yield levels normally obtained for wheat crop

System	Product	Yield range (kg/ha)		% of farmers
Rainfed	Grain	1000-1500		52
		1600-2000		36
		2100-2500		12
			Total	100
	Straw	less than 1000		21
		1000-1500		65
		more than 1500		14
			Total	100
Supplemental irrigation	Grain	less than 3000		20
		3000-4000		68
		more than 4000		12
			Total	100
	Straw	less than 1500		12
		1500-2500		60
		more than 2500		28
			Total	100

Source: Village survey

5.2.2.3 Impact of SI on the physical productivity of the whole farm

The physical productivity of a farming system is a function of the cropping intensity, the area allotted for each crop, and the physical yield, actually obtained by farmers, for all crops that are grown on the farm. It can be expressed as:

$$P = f\ (I,\ AC_i,\ YC_i) \qquad (1)$$

where: **P** is the physical productivity, AC_i area of the ith crop, and YC_i is the yield of the ith crop. Since intensity **(I)** is implicitly included in the summation of crops area, Eq. (1) can be rewritten, for the rainfed system,

$$P = \sum_{i=1}^{n} ADC_i * YDC_i \qquad (2)$$

where ADC_i and YDC_i are the area and yield of the ith rainfed crop. And, for the first and second SI situations (with crops grown both rainfed and with SI):

$$P = \sum_{i=1}^{n} ARC_i * YRC_i + ADC_i * YDC_i \qquad (3)$$

where ARC_i and YRC_i are the area and yield of the ith crop supplementally irrigated. When the system operates at a good or high level of water and crop management, and rainfed production is eliminated, ADCi and YDCi will be zero. The physical productivity equation for such cases will be:

$$P = \sum_{i=1}^{n} ARC_i * YRC_i \qquad (4)$$

Table 5.2.4 summarizes the total physical productivity of the rainfed and the various SI situations. A rainfed hectare would

Table 5.2.4 Impact of supplemental irrigation on the physical productivity of rainfed wheat farming system (1988). Total output for 1 hectare (kg)

Product	Rainfed system	Supplemental irrigation systems I	II	III	IV
Wheat, grain	596	1073	1195	1584	2160
straw	383	638	732	1464	1248
Barley, grain	416	132	132	-	-
straw	288	92	92	-	-
Lentil, grain	105	145	145	-	-
straw	110	152	152	-	-
Chickpea	35	32	24	-	-
Melons	1275	723	1010	1170	1950
Cotton	-	365	456	977	1466
Sugarbeet	-	330	412	824	3090
Potatoes/other veg.	-	343	2145	4290	6704
Tomatoes	-	390	1218	1218	1522
Maize	-	49	61	275	403
Sesame	-	29	36	108	585
Total	3208	4493	7810	11910	19128

Source: Farm survey

produce, on average, about 3.21 tonnes of crop products (animal products are not included). Melons, heavy-weight products, contribute about 40% of the total physical output. Operating the SI system at low productivity (first situation) would increase the physical production by 40%. A medium or satisfactory level of water-crop management skill may more than double (243%) or treble (370%) the physical production. With good or exceptional operational conditions (the fourth situation), SI may produce as much as 19.13 t/ha of crop product, i.e. about 6 times the productivity of rainfed agriculture (Figure 5.2.3).

Heavy-weight products (sugarbeet, potatoes, and vegetables) contribute 69% of the total physical production or output. Wheat, allotted 48% of crop area, contributes about 18% of the total

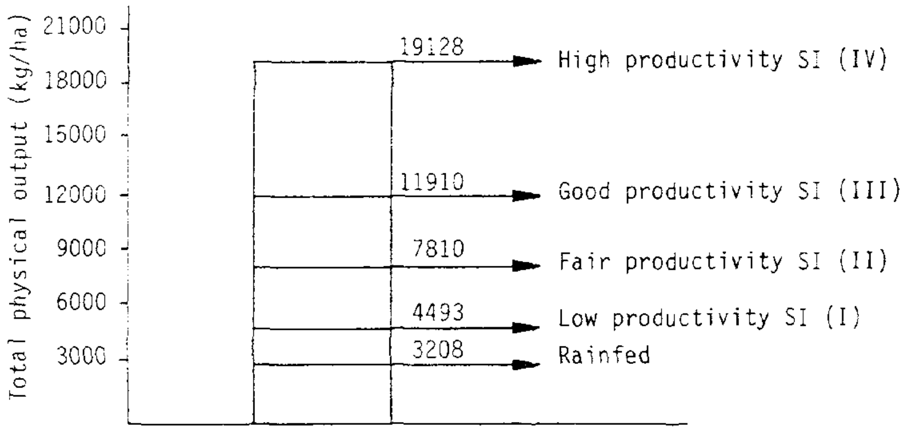

Figure 5.2.3 Impact of SI on total physical productivity of the system

physical output. However, the physical productivity of a system, though used as one measure of system productivity and efficiency, does not give a real evaluation of productivity. Sesame, for example, yielded about 1190 kg/ha (in 1988), but gave a net revenue of 21260 SL/ha (i.e., 17.8 SL/kg), whereas the physical yield of sugarbeet was 41200 kg/ha, but it gave negative net returns (i.e. losses) according to farmers reports, and only 2736 SL/ha (i.e. 0.066 SL/kg) according to village heads' reports. Therefore, the productivity of the system must be evaluated in terms of gains and losses. By incorporating prices of inputs and outputs with the physical productivity of the different farming systems, the economic impact of SI on rainfed farming systems can be assessed.

5.2.3 Impact assessment of SI on the economic productivity of the whole farm

While the costs of SI at farm level are relatively easy to quantify, the benefits can be extremely difficult to quantify because (i) the stochastic nature of rainfall produces a highly variable irrigation demand; (ii) the effect of SI on many crops is not well known and will necessarily be variable from year to year; and, (iii) the economic impact (in terms of total benefits) varies significantly depending on the managerial skill of farmers, the new cropping pattern and intensity and types of crops grown (as elaborated above), and prices (which have inflated drastically in the last few years).

The aim of this analysis is to compare the economic (or more precisely the financial) productivity of existing rainfed wheat systems with existing SI systems of different levels of water - crop - management skill.

5.2.3.1 Budgeting of wheat production

Table 5.2.5 presents detailed budgets for rainfed and SI wheat production for the cropping season 1987-1988. The budgets are calculated from basic data given by the farmers in the farm survey (1988). An exception to this is the irrigation cost which was calculated according to the method presented by Salkini (1992). The rainfall of 1987-1988 was well above the long-term average, and the rainfed yields obtained by the sample farmers were 55% higher than normal (2490 vs 1610 kg/ha). Yields of SI wheat were, also, 25% higher than normal (4500 vs 3600 kg/ha).

The crop production budgets of 1987-1988 are used as base guidelines for the wheat crop budgets presented in Table 5.2.6 which refer to years of normal, low, and high rainfall. **Table 5.2.6a** indicates the following:

i) In a normal season, SI may increase the net revenue of wheat production by 58% over the rainfed wheat production (5950 vs 3770 SL/ha). As expected, the impact of SI decreases as

Table 5.2.5 Crop budget for **rainfed and supplementary irrigated wheat** production (1987/88 cropping season)

Item	Rainfed	Supp. irrig.
Seedbed preparation (SL/ha)	630	830
Seed and sowing (SL/ha)	675	810
Fertilizer and application (SL/ha)	800	1360
Weed control (SL/ha)	75	150
Irrigation (SL/ha)	-	3360
Harvest and transport (SL/ha)	850	1670
Sub-total direct cost (SL/ha)	3030	8180
Indirect cost (SL/ha)	580	1900
Total cost (SL/ha)	3610	10080
Yield, grian (kg/ha)	2490	4500
straw (kg/ha)	1510	2588
Price, grain (SL/kg)	3.90	3.90
straw (SL/kg)	0.77	0.77
Revenue, grain (SL/ha)	9710	17550
straw (SL/ha)	1160	1990
Gross revenue (SL/ha)	10870	19540
Total cost (SL/ha)	3610	10080
Net revenue (Sl/ha)	7260	9460
Cost per kg (SL/kg)	1.45	2.24
Gross revenue per kg (SL/kg)	4.35	4.34
Profit per kg (SL/kg)	2.90	2.10

Source: Farm survey

rainfall increases. The increase in net revenue, from SI over rainfed production is 30% for seasons of high rainfall. However, much greater impact is realised in seasons of low rainfall. In such seasons, rainfed wheat production gives a net loss (-280 SL/ha of net revenue), whereas SI produces a net revenue of 3270 SL/ha (Figure 5.2.4).

ii) The net average rate of return (net revenue divided by total cost) for rainfed production is higher than that of SI in normal and high rainfall years (114% vs. 61% for normal, and 201% vs. 94% for high rainfall years); but in years of low rainfall the corresponding figures could be -9% for rainfed,

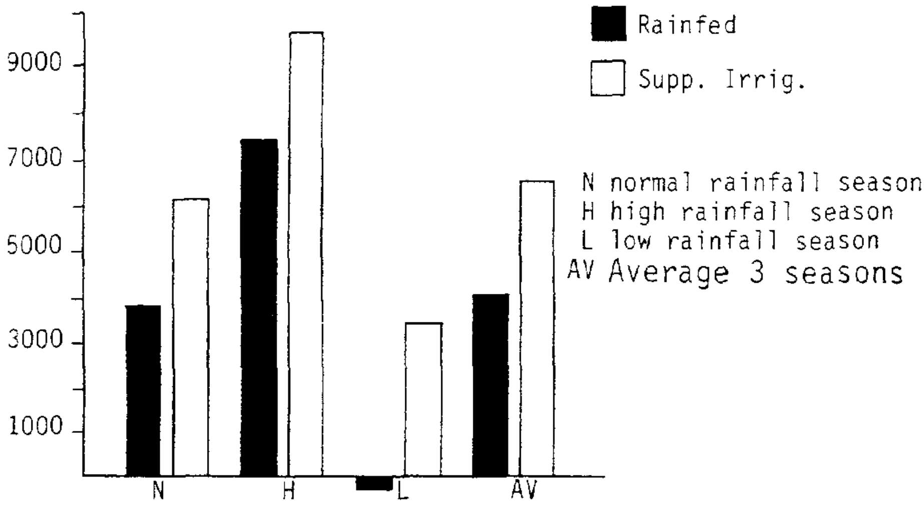

Figure 5.2.4 Economics of wheat production by rainfall

and 37% for SI wheat. It should be noted, that net revenue is calculated by deducting the total cost from the total or gross benefits. Total costs include all direct and indirect costs, including opportunity cost for family labour and machinery, interest on capital expenditures, and rent charge or opportunity cost of land. Therefore, it can be concluded that wheat production, with the exception of rainfed wheat in a poor rainfall season, is a profitable farming enterprise, as each monetary unit (directly or indirectly) spent can be refunded with an extra of 114%-201% for rainfed wheat and 34-94% for SI wheat.

iii) Again, with the exception of low rainfall seasons, profitability per kilogram of rainfed wheat production is higher than that for SI. However, the extra output from SI not only compensates for this but creates increases in total profits (or net revenues), as shown in (i) above and in Figure

5.2.4. Taking the three-seasons average, per-kilogram profit for SI is a little higher than that for rainfed production (1.64 vs 1.58 SL/kg), but per hectare profit is much higher (6230 vs 3580 SL/ha).

iv) In addition to increasing net returns, SI significantly stabilises net benefits (or revenues) of wheat production over seasons of different rainfall. SI decreases between-seasons variability of net returns of rainfed production by more than 52%. The coefficient of variance (CV) is 86% for rainfed wheat net returns compared to 41% for SI wheat (Table 5.2.6b).

v) However, comparing the net revenue of SI wheat production with other irrigated crops (as given by the sample farmers) (Table 5.2.7), indicates that (except for sugarbeet) wheat was by far the least profitable crop. The net revenue of SI wheat was equal to about 70% that of maize, 46% of cotton, 30% of

Table 5.2.6a Summary crop bugdet of wheat production for normal, low, and high rainfall seasons

Item	Normal		Low		High	
	R.	S.I.	R.	S.I.	R.	S.I.
Grain yield (kg/ha)	1610	3600	560	2760	2490	4500
Straw yield (kg/ha)	1040	2150	830	1680	1510	2590
Grain price (SL/kg)	3.90	3.90	3.90	3.90	3.90	3.90
Straw price (SL/kg)	0.77	0.77	0.77	0.77	0.77	0.77
Grain revenue (SL/ha)	6280	14040	2190	10760	9710	17550
Straw revenue (SL/ha)	800	1660	640	1290	1160	1990
Gross revenue (SL/ha)	7080	15700	2830	12050	10870	19540
Total cost (SL/ha)	3310	9750	3110	8780	3610	10080
Net revenue (SL/ha)	3770	5950	-280	3270	7260	9460
Production Economics of wheat						
Cost per kg (SL/kg)	2.05	2.70	5.55	3.18	1.45	2.24
Revenue per kg (SL/kg)	4.40	4.35	5.05	4.36	4.36	4.34
Profit per kg (SL/kg)	2.34	1.65	-0.50	1.18	2.91	2.10

R = rainfed; SI = supplemental irrigation

Table 5.2.6b Role of supplemental irrigation in stabilizing the net benefits from wheat production

Statistics	Rainfed	Supp. irrig.
Mean (SL/ha)	3583	6226
SD (SL/ha)	3081	2635
CV (%)	86%	41%

Source a and b: Farm survey

Table 5.2.7 Summary crop budgets, 1987/88

Crop	Gross revenue (SL/ha)	Total cost (SL/ha)	Net revenue (SL/ha)
Wheat, rainfed, low [1]	2830	3110	-280
Wheat, rainfed, high [1]	10870	3610	7260
Wheat, rainfed, normal [1]	7080	3310	3770
Wheat, supp. irrig., low [1]	12050	8780	3270
Wheat, supp. irrig., high [1]	19540	10080	9460
Wheat, supp. irrig., normal [1]	15700	9750	5950
Barley, rainfed [2]	6300	2320	3980
Lentil, rainfed [2]	14750	6080	8670
Chickpea, rainfed [2]	10350	5930	4420
Chickpea, supp. irrig. [2]	18000	9650	8350
Watermelon, rainfed [2]	13860	5100	8760
Watermelon, supp. irrig. [2]	31810	11710	20100
Cotton [2]	28210	15340	12870
Sugarbeet [2]	17680	14940	2740
Potatoes [2]	96080	43680	52400
Tomatoes [2]	47860	22360	25500
Maize [2]	17780	9310	8470
Sesame [2]	31800	10540	21260

1) Farm Survey
2) Given as lump sum, rough estimates, by farmers

watermelon, 28% of sesame, 23% of tomatoes, and only 11% of potatoes. If we compare wheat with another winter crop, chickpea for example, net revenues for rainfed wheat production are 34% higher than those for rainfed chickpea; but with SI, the situation is reversed with wheat generating net revenues which are 29% lower than chickpea. Of all the crops compared above, wheat and cotton are the only crops which are strictly controlled and handled by governmental institutions.

This could be the main reason why the official price of wheat has substantially *increased during* the last few years (from 1.50 SL/kg of durum wheat in 1986 to 3.75 SL/kg in 1988 and 8.50 SL/kg in 1990), and by now the above economic picture could have changed.

5.2.3.2 The whole-farm budgeting analysis

The economic impact analysis of wheat production, alone, does not reflect the real economic impact of SI on rainfed farming systems. Wheat, as discussed above, is the least profitable of the irrigated crops that can be introduced, as water for SI becomes available. To explore the real dimension of the economic impact, whole-farm budgeting models have been established for rainfed and SI systems at different levels of productivity and management efficiency. Quantitative estimates of physical productivity (based on crop patterns, cropping intensity, and yields) combined with estimates of crop production cost and benefit, as reported by the sample farmers (Table 5.2.7), are used as the basis for building whole-farm budgets. To gain confidence in the farmers' estimates, the same data were also solicited from the respondents of the village survey.

From the findings summrized in Tables 5.2.8 and 5.2.9, it can be inferred:

i) Net benefits per-hectare (or net returns) of SI systems, even in the lowest productivity situation, can be as much as 188% of those of the rainfed system. This can be gradually increased to 310%, to 500%, and to 820% as the system approaches the high

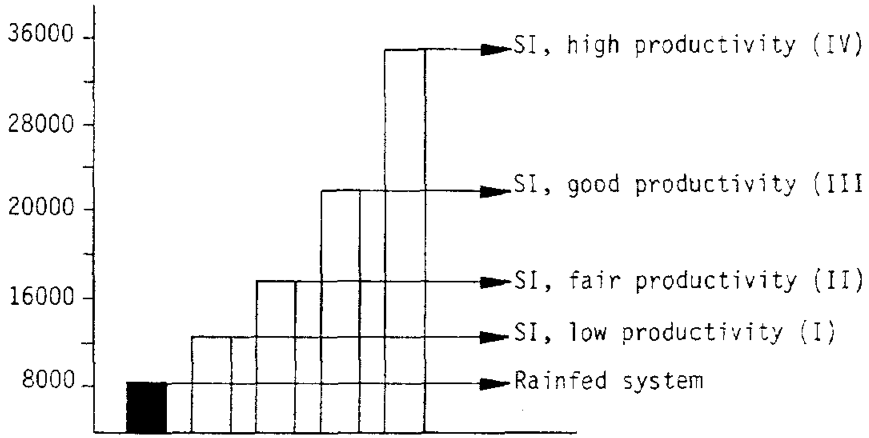

Figure 5.2.5 Economic productivity of the whole farm

level of productivity (Figure 5.2.5). Net revenue per hectare is estimated at SL 4410 for the rainfed system and at 8277, 13766, 22166, and SL 36287 for the four levels of SI efficiency, respectively.

ii) These results, at the whole farm level, confirm (and quantify) the rough estimates given by respondents to the reconnaissance (or cursory) survey and by the literature of impact assessment (see Salkini 1992), which indicated that SI could be 2 - 10 times more remunerative than rainfed systems.

iii) Wheat is the largest contributor to rainfed farm net income (32%), followed by melons (30%). Under SI, at the low productivity level, wheat contributes 25% of total farm net income, but this declines to 15% as the system approaches the high productivity level. The contribution of vegetables correspondingly rises from 19% to 50%.

iv) The annual rate of return (or annual benefit/cost ratio) is high for all alternatives, with the rainfed and the high productivity SI situation having the highest rate (around 2.3), and the other SI situations having almost equal rates (at about

2.0). The high rate of return of the rainfed system, however, does not reduce the case for investment in SI; but, ignoring the risk and uncertainty of the erratic rainfall, it implies that extending rainfed agriculture (if such an extension is available without any new investment cost) might be economically attractive. Such an alternative is limited to the farm area that is fallowed each year (about 15% of total farm area in the sample regions). Most of the fallow occurs in the drier parts of the wheat-producing regions (i.e. agroclimatic zone 2 and 3). Under current farming patterns and practices, it seems that farmers have a strong belief in fallowing for maintaining their soil's fertility. However, the findings of ICARDA research on long-term crop rotations, and the introduction of forage legumes in the cropping pattern of the rainfed systems (of relatively low rainfall, zone 2, and 3), have shown promising alternatives to fallowing for maintaining soil fertility.

Table 5.2.8 Impact of supplemental irrigation on the economic productivity of rainfed wheat farming systems (1987/88) - net revenue for 1 hectare (SL)

Product	Rainfed system	Supplemental irrigation systems I	II	III	IV
Wheat	1395	1990	2252	2618	4541
Barley	876	279	279	-	-
Lentil	693	954	954	-	-
Chickpea	113	116	90	-	-
Melons	1314	745	1041	1206	2010
Cotton	-	1802	1802	3861	5791
Sugarbeet	-	27	27	54	761
Potatoes/other veg.	-	1048	5240	10480	16375
Tomatoes	-	510	1275	1275	1594
Maize	-	169	169	761	1162
Sesame	-	637	637	1911	2919
Total	4411	8277	13766	22166	35153

Source: Farm survey

Table 5.2.9 Summary of the whole farm budgeting analysis for rainfed and supplemental irrigation (1987/88) (SL/ha)

Type of farming system		Gross benefit	Gross cost	Net benefit
Rainfed		7576	3165	4411
Supp. irrig.,	1st situation	16729	8452	8277
	2nd situation	26579	12813	13766
	3rd situation	43702	21536	22166
	4th situation	62849	26562	35153

Source: Farm survey

5.2.4 Stabilising effect of SI on wheat production

The **variability of wheat yields** has been assessed for **(i)** a 16-year time series of Syria's aggregated rainfed and SI wheat yield data; **(ii)** yields obtained by farmers of the farm survey; **(iii)** yields in the 4 years of experiments in ICARDA's SI project; and **(iv)** yields in the on-farm test demonstrations conducted at different locations to test the performance of deficit irrigation technology by farmers on their fields (see FRMP, 1990, pp 253-256). A summary of these analyses (Table 5.2.10) shows that SI, while not eliminating variability, does have a significant effect in making yields higher and more stable than those of rainfed wheat. At the national level, SI and the introduction of improved wheat varieties has reduced the coefficient of variation (CV) of local rainfed wheat varieties (for 1973-1988) by more than 50%; the CV for improved irrigated wheat was 16% compared with 33% for local rainfed varieties. SI alone caused a reduction of 33% in the yield variability of local rainfed wheat and of 27% in that of improved rainfed varieties.

Table 5.2.10 Indicators of the stabilizing effect of supplemental irrigation on rainfed wheat yield (kg/ha)

	Yield kg/ha	SD kg/ha	CV%
1) National level aggregates (1973-1988) [a]			
Improved wheat varieties, irrigted	2570	420	16[e]
Local wheat varieties, irrigated	1910	400	21[e]
Improved wheat varieties, rainfed	1490	330	22[e]
Local wheat varieties, rainfed	810	250	31[e]
Total irrigated wheat	2465	505	20[e]
Total rainfed wheat	1000	330	33[e]
2) Farm survey (1988)[b]			
Normal rainfall, supp. irrig.	3600	714	20[f]
rainfed	1610	463	28[f]
High rainfall, supp. irrig.	4500	776	17[f]
rainfed	2490	613	25[f]
Low rainfall, supp. irrig.	2760	771	28[f]
rainfed	560	286	51[f]
Overall three seasons, supp. irrig.	3620	710	20[e]
rainfed	1553	789	51[e]
3) On-farm test demonstration (1989/90)[c]			
Replenish 100% of WB requir., supp. irrig.	5003	485	10[f]
50% of WB requir., supp. irrig.	4216	270	6[f]
Rainfed	553	568	103[f]
4) ICARDA research (1986/6-1988/9)[d]			
Average 43-season, supp. irrig.	4600	489	10[g]
rainfed	2647	822	31[g]

Source: Calculated based on yield data presented in
(a) AASA (1973-1989) (e) includes time and space variability
(b) Farm survey data (f) includes only space variability
(c and d) Salkini, 1992 (g) includes only time variability

Yield variability aggregated at the national level does not show the real stabilizing effect of SI, as it is confounded by the methods of yield estimation and by aggregation. A more realistic assessment of the stabilising effect of SI is shown by the data from the farm survey and the on-farm test demonstrations. SI decreased the spatial (or location) variability of wheat yields (in the sample areas) by 29% for seasons of normal rainfall, 32% for seasons of high rainfall, and 45% for low rainfall seasons. The spatial and temporal (or between seasons) variability was reduced by 61% (the overall seasons CV was 20% for SI wheat compared with 51% for rainfed yields).

The dramatic influence of SI in stabilising wheat yields is seen in the data from 7 on-farm test demonstrations carried out in 1989-1990, a season of low rainfall. The spatial (between sites) variability was almost nil for SI fields (CV 6-10% according to irrigation treatment), whereas the variability of the rainfed plots yields was very high (CV 104%). It should be noted that these demonstration tests were not controlled by researchers or extension agents. The farmers did all normal farming operations according to their usual practices, with the extension agents supervising and following up the water balance calculations required for irrigation scheduling.

The variability analysis of 4 years field experiments in the ICARDA/MAAR SI research project also revealed considerable effects from SI on yield stability. The CV for SI plots was 8%; but, for rainfed plots it was 31%. However, as El-Sherbini (1979) found, SI yields were still significantly correlated with rainfall; higher yields were obtained, for both rainfed and SI wheat in 1987-1988, which had rainfall 45% above the long-term average.

It can be concluded that SI technologies cannot eliminate all influence of weather, mainly rainfall, on wheat yields, but it can reduce both spatial and temporal variability to a minimum.

5.2.5 Impact of SI on system sustainability

Conway (1987) defines agricultural sustainability as the ability to maintain productivity, whether of a field or farm or nation, in the face of stress or shock. Following stress or shock the productivity of an agricultural system may be unaffected, or may fall and then return to the previous level or trend, or settle to a new lower level, or the system may collapse altogether. Sustainability, thus, determines the persistence or durability of a system's productivity under known or possible conditions. It is a function of the intrinsic characteristics of the system, of the nature and strength of the stresses and shocks to which it is subject, and of the human inputs which may be introduced to counter those stresses and shocks.

Agriculturalists equate sustainability with food sufficiency in the long term, and sustainable agriculture can embrace any measure towards that end. For environmentalists, though, the means are crucial. For them sustainability means a responsibility for the environment - a stewardship of our natural resources. Sustainability for economists is a facet of efficiency, not short-run efficiency alone, but the use of scarce resources in such a fashion as to benefit both present and future generations. Finally, sociologists see sustainable agriculture as a reflection of social values. They define it as a development path consonant with traditional cultures and institutions (Conway and Barbier, 1990).

Virtually everything that is perceived as good or benign is included under the umbrella of "sustainable agriculture":

- high, efficient and stable production;
- low and inexpensive inputs, in particular making full use of the techniques of organic farming and indigenous traditional knowledge;
- food security and self sufficiency;
- conservation of wildlife and biological diversity;
- preservation of traditional values and the small family farm;
- help for the poorest and disadvantaged (in particular those on

marginal land, the landless, women, children and tribal minorities);

- a high level of participation in development decisions by the farmers themselves.

However, while it is relatively straightforward to attain one or two such goals, it becomes progressively difficult as more and more are included in program and project designs. There are trade-offs, in terms of labour, time, skills and capital, for the project and its staff, and for the farmers themselves. Choices have to be made -- productivity at the expense of equity, for example, or sustainability at the expense of productivity. Not surprisingly, attaining sustainable agriculture as currently defined is a difficult task.

One way of establishing, in principle, whether particular agricultural production systems are likely to be inherently sustainable, is to consider the local community or individual farm and to classify the available resources into those which are **"internal"** and **"external"** (Table 5.2.11). Internal resources are inherently renewable and, as such, have the potential to be used on a "sustained" basis, indefinitely, through ecologically sound methods of farming. Such resources include rain and/or small local irrigation schemes (from surface flows or shallow groundwater wells) as sources of water. After reviewing the characteristics of rainfed and SI wheat-based farming systems in Syria, Salkini (1992) concluded that at this stage, and due to the complex structure of the two systems, it is difficult to properly assess their sustainability using the criteria presented in Table 5.2.11. The two systems, though utilizing mainly internal resources, also require some external resources (seed, fertilizer, pesticides).

Therefore, time-series trend analysis of crop productivity

Table 5.2.11 Agricultural production resources which are derived from internal and external sources

Internal resources	External resources
Sun source of energy for plant photosynthesis	**Artificial lights** used in greenhouse food production
Water rain and/or small, local irrigation schemes	**Water** large dams, centralized distribution, deep wells
Nitrogen fixed from air, recycled in soil organic matter	**Nitrogen** primarily from applied synthetic fertilizer
Other nutrients from soil reserves recycled in cropping system	**Other nutrients** mined, processed and imported
Weed and pest control biological, cultural and mechanical	**Weed and pest control** chemical herbicides and insecticides
Seed varieties produced on-farm	**Seed** hybrids or certified varieties purchased annually
Machinery built and maintained on farm or in community	**Machinery** purchased and replaced frequently
Labour most work done by the family living on the farm	**Labour** most work done by hired labour
Capital source is family and community, reinvested locally	**Capital** external indebtedness, benefits leave community
Management information from farmers and local community	**Management** from input suppliers, crop consultants

Source: C.A. Francis and J.A. King (1988).

(wheat and other major rainfed and SI crops) is used as an indication of sustainability. Sayed Issa (1991), in an FRMP/Aleppo University joint research project, and CIMMYT (1989) analyzed wheat data (area, yield, and total output) for the last five decades, 1940-1980s. Both report similar results. Concerning crop productivity in Syria, Sayed Issa reported:

1. **Declining** productivity trend, significant at 5%, for total (rainfed and SI) wheat for **1940-1961** (Figure 5.2.6a), with a linear time trend regression: **Y = 902.5 - 18.1 t**, where **Y** is the yield (kg/ha) and **t** is the time (years). The wheat production system was non-sustainable in that period.
2. The period **1962-1972** was a **non-significant** period, with a declining trend for rainfed, but increasing trend for irrigated wheat yields (Figure 5.2.6b).
   Rainfed: **Y = 817.8 - 4.1 t**, (sig. NS)
   Irrigated: **Y = 948.6 + 58.9 t**, (sig. NS)
   The sustainability of the system in this period was a little better than in the previous period.
3. The period **1973-1988** has witnessed a rapid increase of technology transfer and adoption (improved high-yielding varieties, with improved seed quality; nitrogen and phosphate fertilizer application; and, increasing adoption of SI). Consequently, successive increases in wheat yield have been achieved (with the exception of rainfed improved varieties which have declined, but non-significantly), and the system's **sustainability has been maintained.** The linear time-trend regressions (Figure 5.2.6c) for this period are:
   Y = 1985.5 + 68.5 t (sig. **), for SI improved varieties
   Y = 1521.8 + 45.9 t (sig. **), for SI local varieties
   Y = 1580 - 10.6 t (sig. NS), for rainfed improved varieties
   Y = 543 + 31 t (sig. *), for rainfed local varieties

Table 5.2.12 shows the results of the author's regression analysis of a twenty-year time series (1968-1987) of yields of major crops grown in rainfed and SI systems. All crops have increasing trends of productivity with the exception of rainfed barley and SI sesame (non-significant decline), and rainfed sesame, the only crop with declining productivity, significant at 0.01. However, this can

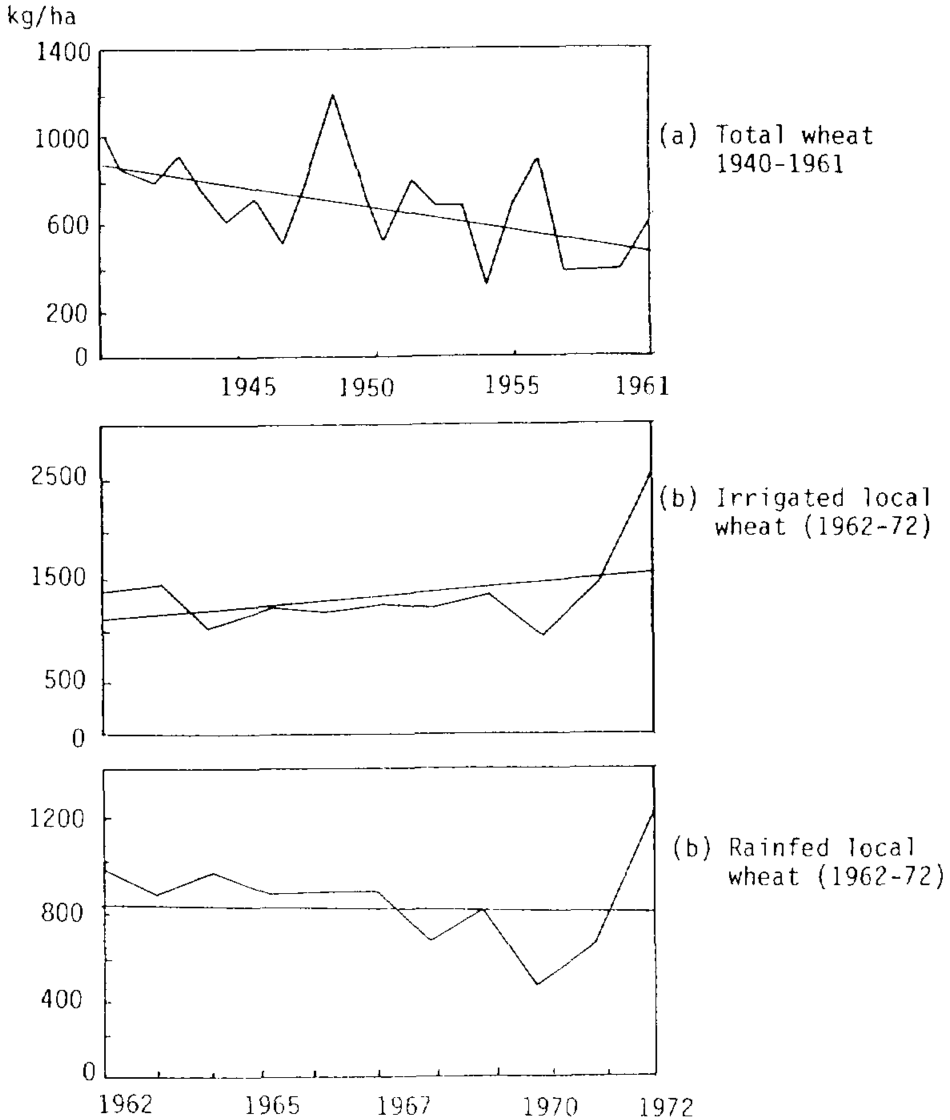

Figure 5.2.6 a,b Trends of wheat productivity in Syria (after Sayed Issa, 1991)

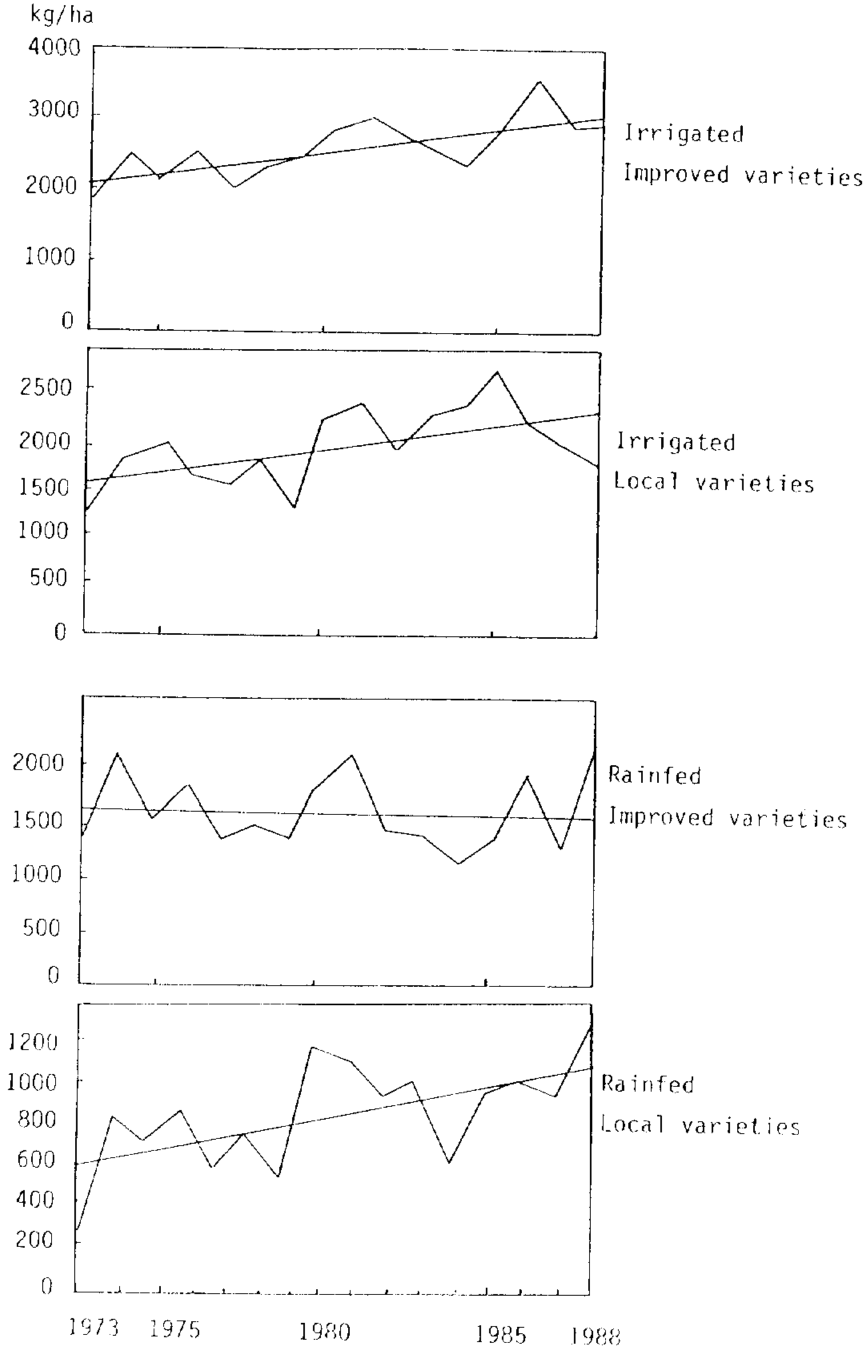

Figure 5.2.6 c Trends of wheat productivity in Syria 1973-1988 (after Sayed Issa, 1991)

Table 5.2.12 Parameters of the trend analysis of major crops productivity of the rainfed and supplementary irrigation farming systems for 20-year time series (1968–1987) in Syria

Crop	System	Intercept.	Slope	R	R2	Sig. level
Wheat	Rainfed	603	+28.5	0.54	0.29	0.007**
	Supp. irrig.	1187	+96	0.86	0.73	0.0000***
Barley	Rainfed	718	−8.2	−0.14	0.019	0.27 NS
	Supp. irrig.	1150	+45.6	0.61	0.37	0.002**
Lentil	Rainfed	597	+12	0.35	0.12	0.06*
	Supp. irrig.	971	+7.7	0.21	0.045	0.18 NS
Chickpea	Rainfed	711	−3.3	−0.16	0.026	0.25 NS
	Supp. irrig.	1120	+11	0.34	0.11	0.07*
Faba bean	Rainfed	837	+25.3	0.72	0.51	0.0002***
	Supp. irrig.	1680	+17.4	0.36	0.13	0.06*
Sesame	Rainfed	336	−8.6	−0.61	0.38	0.002**
	Supp. irrig.	877	−5.7	−0.30	0.09	0.1 NS
Cotton	Rainfed	367	−5.3	−0.11	0.012	0.32 NS
	Supp. irrig.	1558	+69	0.95	0.91	0.0000***
Maize	Rainfed	806	+1.04	0.001	0.000	0.50 NS
	Supp. irrig.	1788	+5.0	0.08	0.007	0.36 NS
Potatoes	Rainfed	6986	+329	0.62	0.39	0.001***
	Supp. irrig.	11837	+289	0.83	0.68	0.0000***
Tomatoes	Rainfed	4560	+39.5	0.28	0.076	0.11 NS
	Supp. irrig.	13930	+604	0.84	0.70	0.0000***
Watermelon	Rainfed	5811	+34	0.12	0.014	0.31 NS
	Supp. irrig.	14173	+206	0.34	0.12	0.07*

Source: Calculated by the author based on raw data included in AASA (1968–1988).

be viewed only as an indication of potential or probable sustainability of the two systems. Valid conclusions might require analysis of a much longer period than 20 years. Nevertheless, it should be emphasized that, although SI has increased crop productivity, the increased lowering of the groundwater (by more than 20 m in about 25 years, on average) must be considered a warning. Wheat-based farming systems utilizing groundwater for SI, under the current system of utilization and management, appear to be non-sustainable in the long-term. The reliance on many "internal" resources (Table 5.2.11) for crop production is, most likely, the base upon which the sustainability of SI systems is built. Its weak point is the overpumping of groundwater in some areas. Urgent and effective control measures on groundwater utilization are needed.

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5.3 Economic Analysis of Chickpea Production in Aleppo and Hassakeh Provinces of Syria

Mustafa Darwich, Onur Erkan,
E. Bailey and R. Tutwiler

5.3.1 Introduction

As reported last year (FRMP 1990), in 1989/90 the Socio-Economic Studies and Training Section of the Syrian ARC and ICARDA organized a survey in Aleppo, Hama and Hassakeh provinces to assess the performance of winter-sown chickpeas under farmer conditions and to hear the farmers' view of their potential for adoption and positive impact. At the same time, in a related thesis study, Mustafa Darwich made a detailed comparison of actual on-farm costs and gross margins of winter and spring chickpea in Hassakeh and Aleppo. This report summarizes the results.

5.3.2 Material and methods

The main material used in this comparative study is data collected from farmers through questionnaires. In selecting chickpea producers to question, it was decided to focus on the areas in which winter chickpeas were grown in the 1989/90 season. So, Aleppo and Hassakeh provinces were chosen, and within each province, the study was conducted in two agricultural stability zones:

Zone 1: Average annual rainfall ranging between 300-600 mm and not less than 300 mm in 2/3 of years.
Zone 2: Average annual rainfall ranging 250-350 mm with not less than 250 mm in 2/3 years.

Eighty farmers, forty from each province, were visited after harvest time, and questionnaires were completed. Data were analyzed by computer using the SPSS statistical package.

5.3.3 Results and discussion

5.3.3.1 Farmers' practices

Generally, the farmers in both provinces did at least two tillages for either winter or spring chickpea. The number of farmers tilling only once was the same for spring and winter chickpea within each province; but, generally, the majority of Hassakeh farmers did fewer cultivations than Aleppo farmers (Table 5.3.1).

Seeding method for winter chickpea is different in Aleppo and Hassakeh. While most farmers (65%) use hand broadcasting in Aleppo,

Table 5.3.1 Land preparation activities (% of farmers)

	Aleppo		Hassakeh	
	Winter	Spring	Winter	Spring
One tillage	5.0	5.0	20.0	20.0
Two tillage	40.0	65.0	60.0	55.0
Three tillage	55.0	25.0	10.0	10.0
Four tillage	0.0	5.0	10.0	15.0
Total	100.0	100.0	100.0	100.0

the majority (75%) use machinery in Hassakeh. For spring chickpea, approximately half of the farmers in each province seed by machine. The majority of Aleppo farmers use a drill, while the majority of Hassakeh farmers use a spinner. This is because the area under chickpea in Hassakeh is larger, and it is easier and faster to seed with a spinner (Table 5.3.2).

5.3.3.2 Seed rate and price

In Aleppo, the average seed rates for each variety were approximately the same. In Hassakeh, there were significant differences in seed rate between winter and spring chickpea, due to the difference in seeding methods. The seed price for winter chickpea was higher than that for spring chickpea in both provinces and higher in Hassakeh than in Aleppo (Table 5.3.3). This probably reflected lower seed availability in Hassakeh. Farmers there obtained their seeds from both the Seed Multiplication Organization and the private sector, while Aleppo farmers obtained their seed from the Seed Multiplication Organization.

Table 5.3.2 Source of power for seeding and covering (% of farmers)

	Aleppo		Hassakeh	
	Winter	Spring	Winter	Spring
Seeding method				
by machine	35.0	55.0	75.0	45.0
by hand	65.0	45.0	25.0	55.0
Machine used for seeding Drill	85.7	90.9	6.7	0.0
Spinner	14.3	0.0	86.7	77.8
Others	0.0	9.1	6.7	22.2
Covering broadcast seed	75.0	40.0*	100.0	95.0
Machine used for covering Cultivator	86.6	62.5*	5.0	0.0
Gana plow	6.7	37.5	0.0	0.0
Disk harrow	6.7	0.0*	20.0	15.8
Disk plough	0.0	0.0	75.0	84.2

* Significant difference between means at 5% level

Table 5.3.3 Seed rate and price

	Aleppo		Hassakeh	
	Winter	Spring	Winter	Spring
Seed rate (kg/da)	10.7	11.2	11.7	7.1 A
Seed price (SL/da)	18.3	16.1 B	19.1	14.3 A
Cost (rate.price)	195.8	180.3	223.5	101.5

Chi-squared value between groups significant:
A = 0.1%; B = 1%

Qualitative fertilizer use on chickpeas is shown in Table 5.3.4. Proportionately more farmers in Aleppo than Hassakeh fertilized their chickpeas, but in both provinces winter chickpeas were more likely to be fertilized than spring chickpeas. Average rates of fertilizer used were higher in Aleppo province (Table 5.3.5).

Table 5.3.4 Kind of fertilizer used (% of farmers)

	Aleppo		Hassakeh	
	Winter	Spring	Winter	Spring
Phosphate	100.0	45.0***	70.0	20.0***
Nitrogen	60.0	55.0	25.0	5.0
Potassium	30.0	0.0**	0.0	0.0

Significant differences between means: *** 0.1%; ** 1%.

Table 5.3.5 Average fertilizer rates (kg/decare)

	Aleppo				Hassakeh				Total			
	Winter	n*	Spring	n*	Winter	n*	Spring	n*	Winter	n*	Spring	n*
P	14.2	20	12.7	9	8.9	14	8.8	4	12.0	34	11.5	13
N	9.9	12	7.9	11	7.1	5	5.0	1	9.0	17	7.6	12
K	7.9	6	-	-	-	-	-	-	7.9	6	-	-

n*: Number of observations

5.3.3.4 Chickpea harvesting

In both provinces all the farmers who grew spring chickpea harvested by hand, but there were differences between Aleppo and Hassakeh in the harvesting of winter chickpea. The majority of the farmers (75%) growing winter chickpea in Hassakeh harvested by combine harvester, but Aleppo farmers prefer to use hand harvesting because they have small holdings and sufficient family labor is available.

For threshing, the majority of farmers in both provinces used threshing machines, but a few of the Aleppo farmers (35%) growing spring chickpea used tractors.

In Hassakeh, farmers growing winter chickpea spent less on harvesting than spring chickpea farmers, because the cost of harvesting by combine is lower than hand harvest. However, in Aleppo, farmers growing winter chickpea spent more on harvesting than those growing spring chickpea, because the higher yields of the winter-sown crop require more harvest labor (Table 5.3.6).

5.3.3.5 Chickpea yield

Agronomic studies in Syria of various winter chickpea production packages have established that weather conditions are the most important determinant of yield (Pala and Mazid 1990). In the 1989/90 season, total rainfall ranged from an average of 282 mm in Aleppo to 463 mm in Hassakeh.

Interviewed farmers were asked how they rated their chickpea yield this season (1989/90). Whereas the 75% and 45% of farmers who grew winter and spring chickpea, respectively, in Hassakeh province reported good yields, 55% and 65% of Aleppo farmers said the yield was bad (Table 5.3.7). We can attribute this to rainfall differences.

5.3.3.6 Economic indicators

Production costs of winter and spring chickpea: Table 5.3.8 compares production costs of winter and spring chickpea in the two provinces. The major costs were for land rent, harvest, seed and, in Aleppo, irrigation.

Table 5.3.6 Average harvesting costs (SL/decare)

	Aleppo				Hassakeh				Total			
	Winter	n*	Spring	n*	Winter	n*	Spring	n*	Winter	n*	Spring	n*
Harvest cost	117.9	20	86.6B	20	160.7	20	189.0	20	139.3	40	137.8	40
Transport cost	43.8	17	32.7	18	49.7	12	52.1	20	46.3	29	42.9	38
Threshing cost	79.5	20	42.8B	20	112.1	7	58.7A	20	87.9	27	50.8A	40
Winnowing cost	15.3	11	28.7B	13	44.4	11	22.5	8	29.8	22	26.3	21
Packing cost	30.1	20	15.4B	20	34.4	20	20.0A	20	32.2	40	17.7A	40
Total cost	273.1	20	192.9A	20	288.6	20	328.8	20	280.9	40	260.9	40

n*: number of observations
Chi-squared value between groups significant: A 0.1%, B 1%.

Table 5.3.7 Average chickpea area per farmer and grain yields

	Aleppo		Hassakeh		Total		
	Winter	Spring	Winter	Spring	Winter	Spring	
Area (da)	40.3		67.6	360.6	147.2B	200.4	107.4
Yield (kg/da)	92.3		56.3B	135.2	75.9A	113.7	66.1A

(A, B: as above)

Table 5.3.8 Production cost of winter and spring chickpea in Aleppo and Hassakeh (SL/decare)

	Aleppo				Hassakeh				Total			
	Winter	%	Spring	%	Winter	%	Spring	%	Winter	%	Spring	%
Land rent	852.6	47.5	866.7	57.8	1125.0	63.5	723.0	58.4	988.8	55.4	794.9	58.1
Tillage cost	67.0	3.7	70.5	4.7	42.5	2.4	46.7	3.8	54.7	3.1	58.6	4.3
Seed cost	195.8	10.9	181.7	12.1	219.1	12.4	101.5A	8.2	207.5	11.6	141.6A	10.3
Seeding cost	13.5	0.8	25.6A	1.7	8.7	0.5	9.6	0.8	11.1	0.6	17.6	1.3
Covering cost	10.0	0.6	7.8	0.5	16.7	0.9	15.7	1.3	13.3	0.8	11.7	0.8
P fert. cost	84.7	4.7	35.7	2.4	38.0	2.1	10.4	0.8	61.3	3.4	23.0	1.7
M fert. cost	32.4	1.8	23.7	1.6	9.9	0.6	1.5	0.1	21.2	1.2	12.6	0.9
K fert. cost	16.8	0.9	0.0	0.0	0.0	0.0	0.0	0.0	8.4	0.5	0.0	0.0
Irrigation cost	107.8	6.0	76.7	5.1	0.0	0.0	0.0	0.0	53.9	3.0	38.4	2.8
Weeding cost	103.2	5.7	14.4	1.0	23.7	1.3	0.0	0.0	63.7	3.6	7.2	0.5
Dis. cont. cost	2.9	0.2	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.1	0.0	0.0
Inse. cont. cost	35.9	2.0	3.0	0.2	0.1	0.0	1.2	0.1	18.0	1.0	2.3	0.2
Harvesting cost	273.1	15.2	192.9A	12.9	288.6	16.3	328.8	26.5	280.9	15.7	260.9	19.1
TOTAL COST	1795.7	100.0	1499.0	100.0	1772.3	100.0	1238.4	100.1	1783.9	100.0	1368.8	100.0
Interest (4%)	71.8	-	60.0	-	70.9	-	49.5	-	71.4	-	54.8	-
GRAND TOTAL	1867.5	-	1559.0	-	1843.2	-	1287.9	-	1855.3	-	1423.6	-
Grain cost/kg	18.6	-	24.9	-	13.5	-	15.8	-	15.7	-	19.8	-
Straw cost/kg	2.0	-	2.6	-	0.9	-	1.2	-	1.0	-	1.3	-

A Chi-squared value is significant at 0.1% between groups

Tillage costs for both winter and spring chickpea were higher in Aleppo than in Hassakeh, because Aleppo farmers did more tillage than Hassakeh farmers.

Seed costs were generally higher for winter chickpea than for spring chickpea, reflecting both higher seed rate and seed price. Similarly, since farmers tended to apply more fertilizer to winter chickpea, fertilizing costs were also higher.

Weeds are an important factor affecting yield, and weeding is a major variable cost in winter chickpea production. Average weeding costs were higher in Aleppo, because the sample included some farmers who irrigated their chickpea.

Harvesting costs were the second highest variable cost in both provinces. Differences between varieties and between provinces are attributable to different harvesting methods and different yield levels, as indicated above.

Total production cost was higher for winter chickpea than for spring chickpea in both provinces. This total cost should be distributed beween chickpea grain and straw to obtain a measure of cost per unit yield. Costs per kg of grain and per kg of straw were higher for both type of chickpea in Aleppo than in Hassakeh.

Gross margins of winter and spring chickpea: In estimating gross margins, the imputed value of family labor is not included in the variable costs. Thus, the gross margin represents the return to the family's labor. The imputed value of family labor is included in the estimated total production costs (Table 5.3.8). Thus, we can see the contribution of family labor cost to total production costs by comparing Tables 5.3.8 and 5.3.9. Family labor costs contributed 9-22% and 10-13% of total costs for winter and spring chickpea, respectively.

Results in Table 5.3.9 indicate that gross margins were higher for winter chickpea than for spring chickpea by 23% and 102% in Aleppo and Hassakeh, respectively. Comparing provinces, in Hassakeh gross margins of winter and spring chickpea were 83% and 12% respectively higher than in Aleppo (Table 5.3.9).

Table 5.3.9 Gross margins of winter and spring chickpea in Aleppo and Hassakeh (SL/decare)

	Aleppo		Hassakeh		Total	
	Winter	Spring	Winter	Spring	Winter	Spring
Variable costs						
Tillage	60.5	66.5	38.0	41.3	49.2	53.9
Seed	195.8	181.7	219.1	101.5	207.5	141.6
Seeding	10.5	17.9	6.7	5.2	8.5	11.5
Covering	10.0	7.3	15.5	14.8	12.7	11.0
P fertilizer	83.3	34.2	36.8	10.3	60.1	22.2
N fertilizer	32.4	23.7	9.9	1.4	21.2	12.5
K fertilizer	16.8	0.0	0.0	0.0	8.4	0.0
Irrigation	101.5	72.5	0.0	0.0	50.8	36.3
Weeding	80.0	8.4	7.2	0.0	43.6	4.2
Disease control	2.3	0.0	0.0	0.0	1.2	0.0
Insect control	33.3	3.1	0.1	0.9	16.7	2.0
Harvesting	234.4	127.8	248.2	272.7	241.3	200.0
TOT VARIABLE COST	860.8	543.1	581.5	448.1	721.2	495.4
Grain value	1385.5	965.4	1748.2	969.7	1566.9	967.6
Straw value	123.9	102.1	20.3	66.7	72.1	84.4
Residual value	1.3	2.0	1.6	0.0	1.4	1.0
Gross production Value	1510.7	1069.5	1770.1	1036.5	1640.4	1053.0
Gross margin	649.9	526.4	1188.6	588.4	919.2	557.6

Note: There were 3 farmers growing spring chickpea in Hassakeh and 1 farmer growing winter chickpea in Aleppo paying land rent. Average land rents, computed from data for these farmers, were 500 and 106 SL/decare in Aleppo and Hassakeh, respectively. Land rents were not included in the calculation of gross margin, because mean value of the sample was too small to be representative.

5.3.4 Summary and conclusions

In Syria, chickpea is the next most important legume crop after lentil. The comparison made in the present study of winter and spring-sown chickpeas, in respect of actual on-farm cost and gross margins, is the first one in Syria based on a large sample of ordinary farmers growing these crops under commercial conditions. All previous budget data on winter chickpea were based on small numbers of farmers purposely selected to participate in on-farm trials. Thus, the present study adds considerable legitimacy to the findings of the earlier on-farm research, confirming them in the "real world" of northern Syria.

Survey results indicated that: farmers applied higher rates of phosphate and nitrate fertilizer on winter chickpea than on spring chickpea; weeding is important for reducing yield losses in winter chickpea; the average cost of combine harvesting was lower than that for hand harvesting.

Average yields of winter chickpea were 78% and 64% higher than those of spring chickpea in Hassakeh and Aleppo, respectively. Economic analysis shows that in Aleppo province the cost of grain production was 24.9 SL/kg for spring chickpea and 18.6 SL/kg for winter chickpea, while in Hassakeh it was 15.8 SL/kg and 13.5 SL/kg, respectively. Further, when we compare gross margins, those for winter chickpea were 102% and 23% higher than those for spring chickpea in Hassakeh and Aleppo provinces, respectively.

Altogether, this research shows that the yields and gross margin of winter chickpea are higher than those of spring chickpea. However, this fact is not known by most farmers. Some efficient extension work is necessary. Moreover, the government should take steps to provide winter chickpea seeds and herbicides and a more efficient marketing organization.

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6. TRAINING AND AGROTECHNOLOGY TRANSFER

During 1990/91 season, FRMP staff conducted a number of training activities which included group training both at headquarters and in-country, individual training and other miscellaneous training activities.

6.1 Group Training Courses

WMO/ICARDA training workshop on agroclimatic analysis in semi-arid areas

This training workshop was conducted at Tel Hadya in collaboration with the World Meteorological Organization (WMO) during the period 6-17 October 1991. It was attended by 28 participants coming from 13 countries.

Survey methods and data collection

This course was conducted at Tel Hadya during the period 11-21 February 1991. It was attended by 15 participants coming from different Agricultural Research Stations in Syria.

Soil and plant analysis

The course was attended by four participants, two from Syria and two from Jordan. It was held at Tel Hadya during the period 10-21 February 1991.

Supplemental irrigation technology

The course was attended by 10 participants from the Agricultural

Extension Directorate, Syria. It was conducted at Tel Hadya during the period 29 September to 10 October 1991.

Computer use of statistical analysis of agricultural experiments

This course was conducted in collaboration with the Computer Services Unit at ICARAD. It was attended by six participants from Syria.

Farm survey methods

This was a sub-regional course conducted in cooperation with the Agricultural Research Center, Libya. It was held in Misurata, Libya, during the period 1-11 June 1991 and attended by participants from Libya (10, Algeria (2) and Tunisia (1).

IDRC/ICARDA training workshop on regionalization of climatic data for application in agroclimatology

This was the first of three in-country training workshops on spatial weather generation and crop modelling. It was held in Casablanca, Morocco, during the priod 28 October to 1 November 1991 and attended by nine participants from eight different institutes and services in Morocco. It was conducted in cooperation with the Direction de la Meteorologie Nationale (DMN) and Institut National pour la Recherche Agronomique (NRA) in Morocco, as an activity of the IDRC/ICARDA Project for Agroecological Characterization (PAC).

Satellite imagery for interpreting rainfall data

This course was conducted jointly with WMO in Geneva, Switzerland, during the period 26-30 August 1991. It was attended by four participants, two from Morocco and two from Turkey.

Dryland agriculture

This course was conducted in Amman, Jordan, by the ICARDA Jordan office, but with major FRMP input, as part of the Mashreq Project, during the period 13-22 October 1991. It was attended by participants from Iraq (5), Jordan (4) and Syria (4).

Crop modelling

This was an in-country training course conducted in Turkey during the period 15-24 January 1991. It was attended by 21 participants from Turkey.

6.2 Individual Training

Table 6.1 Individual training, degree-related

Name	Country	Degree	University	Topic
O.H. Ibrahim	Sudan	MSc	Gezira	Crop water use (wheat)
A. Mekhail	Syria	MSc	Aleppo	Effect of nitrogen fertilization and supplemental irrigation on the yield and quality of wheat
E. Afif	Syria	PhD	Cordoba	Phosphorus behavior in calcareous soils of the Mediterranean region
M. Shahin	Syria	MSc	Aleppo	Crop rotations
M.A. Khazmeh	Syria	MSc	Damascus	Adoption of medics
M. Darwich	Syria	MSc	Cukurova	Economics of chickpea production
A.H. Yousef	Jordan	MSc	Jordan	Water balance of crop rotations under different tillage/residue practices
M.M. Khalaf	Jordan	MSc	Jordan	Nitrogen fertilizer management of crop rotations under different tillage/residue practices
A.S. Jabarin	Jordan	PhD	Jordan	Impact of technology on the production of selected field crops

Table 6.2 Individual training, non-degree

	Country	Subject	Duration
H.M. Swei	Libya	Soil and plant analysis	2 weeks
S.M. Hemaly	Libya	FSR methodologies and economic evaluation of trials	2 weeks
S.I. Hraga	Libya	----------- " -----------	2 weeks
A.S. Hassan	Syria	Using PC for scheduling supp. irrig. of wheat	1 week
F. Shami	Syria	-------- " --------	1 week
M.E. Kahwaji	Syria	-------- " --------	1 week
A.G. Zarka	Syria	Data entry and analysis	2 months
F. Hariri	Syria	-------- " --------	2 months
A. Manlahassan (Ms)	Syria	Economic analysis of on-farm trials	3 weeks
M.F. Sawaf	Syria	---------- " ---------	3 weeks
A.H. Hassan	Syria	Harvesting of experiments	3 weeks
S. Zinkah	Syria	---------- " ---------	3 weeks
F.G. Ied	Syria	Use of neutron probe	1 month
M.K. Beni	Syria	---------- " ---------	1 month
G. Tibi	Syria	Use of computer in statistical analysis	3 weeks
M. Barbandi	Syria	---------- " ---------	3 weeks
M.A.H. Hassan	Syria	Planting methods	2 weeks
S. Zinkah	Syria	----- " -------	2 weeks
N.S. Khoury	Syria	Fertilizer recommendations	2 weeks
T. Khadra	Syria	---------- " ---------	2 weeks
W. Hosni	Syria	---------- " ---------	2 weeks

6.3 Miscelleaneous activities

A number of FRMP scientists, as in previous seasons, contributed to training courses conducted by other programs, at headquarter and in-country.

APPENDIX A

FARM RESOURCE MANAGEMENT PROGRAM

Staff List for 1991

Michael Jones	Program Leader - Barley-Based Systems Agronomist
Hazel Harris	Soil Water Conservation Scientist
Abdallah Matar	Consultant - Soil Chemist
Mustafa Pala	Wheat Based Systems Agronomist
Mohamed Bakheit Said [1]	Senior Training Scientist
Richard Tutwiler	Adoption Anthropologist
Theib Oweis [2]	Water Management Specialist
Graham Walker [2]	Agroclimatologist
Wolfgang Goebel	Post-Doc fellow/Agroclimatology
Ahmed Mazid	Agricultural Economist
Abdul Bari Salkini	Agricultural Economist
Elizabeth Bailey	Visiting Scientist/Agricultural Economist
Karel Bernhard Timmerman [3]	Post-Doc fellow/Wind Erosion
Dobhi Dozom	Research Assosiate I
Mahmoud Oglah	Research Associate I
Afif Dakermanji	Training Assistant
Sonia Garabed	Research Assistant II
Rafik Makboul	Research Assistant II
Leith el-Mehdy	Research Assistant II
Zuhair Arous	Research Assistant II
Atef Haddad	Research Assistant II
Haitham Halimeh	Research Assistant II
Nerses Chapanian	Research Assistant II
Mohamed Salem	Research Assistant II
Ghalia Martini	Research Assistant II
Hassan Jokhadar	Research Assistant II
Mohamed Samir Masri	Research Assistant II
Shahba Morali	Research Assistant II
Hisham Salahieh	Research Assistant II
Mohamed Tahhan	Research Assistant II
Pierre Hayek	Research Assistant I
Sabih Dehni	Research Assistant I
Malika Abdul-ali	Research Assistant I
Samir Barbar	Research Assistant I
Mohamed Aziz Kassem	Research Assistant I
Ahmed Nael Hamwieh	Research Technician II
Mohamed Lababidi	Research Technician II
Issam Halimeh	Research Technician II
Dolly Mousally	Research Technician II

George Estephan	Research Technician II
Mohamed Zeki	Research Technician I
Nabil Musattat	Research Technician I
Shereen Baddour	Research Technician I
Ghassan Kanjo	Research Techincian I
Ralla Naeb	Research Technician I
Ghazi Yassin	Research Technician I
Ali Haj Dibo	Research Technician I
Elianor Nasseh [2]	Research Technician I
Hayel el Shakher	Assistant Research Technician
Jihad Abdullah	Assistant Research Technician
Mohamed Elewi Karram	Assistant Research Technician
Abdul Baset Khatib [2]	Assistant Research Technician
Marica Boyagi	Senior Secretary III
Katia Artinian [4]	Secretary II
Zuka Istanbouli	Secretary I

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1. Moved to the office of the International Cooperation
2. Joined in 1991
3. Joined in 1990
4. Left in 1991

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إيكاردا

ص. ب. 5466 حلب ، سورية

INTERNATIONAL CENTER FOR AGRICULTURAL RESEARCH IN THE DRY AREAS
Box 5466, Aleppo, Syria

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