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FARM RESOURCE MANAGEMENT PROGRAM

Annual Report for 1988

ICARDA

Farm Resource Management Program

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

TABLE OF CONTENTS

PAGE

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DRAFT ANNUAL REPORT 1988

1. INTRODUCTION

1.1 1987/88: A Year of Contrast

The 1987/88 season was one of great contrast within West Asia and North Africa. Severe rain deficits were experienced in Algeria and Tunisia for example, whilst one of the wettest years on record occurred in our host country Syria. Crucial livestock feed shortages resulted in widespread grazing of badly stressed and immature wheat and barley crops in North Africa and at the same time we measured near record yields in Syria, and observed substantial burning of excess cereal stubble in the summer.

Such climatic variability is a salient feature of the Mediterranean region. Not only is such "spatial" variability common, but also, individual farmers may expect similar uncertainty at any given location over the years. It is within this context that research workers and farmers alike must seek to identify and put into practice improved production technologies. It was thus a year which highlighted the challenges facing ICARDA and National Agricultural Research Systems, challenges which still have to be met if the large projected regional food and feed deficits are to be ameliorated.

It is of course a truism that almost without exception, the productivity and profitability of any technology will be strongly dependent upon the season's weather. We must therefore understand and quantify these relationships if we are to be able to predict the long term likelyhood of success of alternative production choices which may be offered to farmers. 1987/88 provided conditions in Syria under which many technologies being tested produced near maximum benefits that farmers may expect. It is of note, however, that even in this very wet year at Tel Hadya (504 mm), the yields of wheat were increased from 5.0 t/ha to over 7.0 t/ha through the application of carefully scheduled supplemental irrigation (see SWAN-23, p 19). It has been a striking year. Not only have we been able to further quantify climate/technology interactions, but we have also been able to collect valuable information on how farmers react in years of climatic extremes.

1.2 ICARDA's Second External Program Review

1988 was also the year of ICARDA's second external program review (EPR) during which our current and future research strategies were examined in depth. The outcome of this review has been adequately presented elsewhere, and need not be dealt with in any detail in this report. In summary, the EPR panel thoroughly endorsed almost all ICARDA's research activities and produced several recommendations on how these might be strengthened further. Specific to FRMP were the recommendations that:

- ICARDA's social science work be strengthened through the addition of one extra senior staff member,
- added resources be allocated to the very important area of agro-ecological characterization,
- one senior staff economist position be transferred to the Pasture, Forage and Livestock Program to provide greater focus on the economics of improved and alternative methods of fodder production.

We welcome these recommendations as ones which will result in an improved balance of research activities within the program and the center. Steps to implement all three have been taken.

1.3 Content of this Report

In addition to this introduction, the report contains eight chapters. **Chapter 2** highlights and summarizes results from our research and training activities. Not all our activities are included here, and some of those which are mentioned are also reported in more detail in subsequent sections. A full listing of our research activities are given in Appendix A. **Chapter 3** presents several reports of our research in Project 1, The Management of Soil, Water and Nutrients. This year we report the long-term effects of crop and soil management factors on the productivity and sustainability of alternative technologies. **Chapter 4** presents research progress on two basic building blocks required for agro-ecological characterization of variable environments, namely the spatial generation of long term weather data, and the linking of such data with crop growth simulation models which predict the long term probability of success associated with new technologies. **Chapter 5** reports progress made in an important area affecting the adoption and efficient use of new technology, in this case, fertilizer. It describes a framework which allows the economic optimization of fertilizer allocation to different crops across a range of agro-ecological zones. **Chapter 6** provides an update of the activities of three networks in which we play a coordinating role, and also reports collaborative research activities in Syria, Jordan, Turkey, Algeria and Tunisia. **Chapter 7** summarizes our training activities during the year, and in this activity we have also made good progress. Increasingly, we are conducting in-country training in which National Scientists play a key role. **Chapter 8** and **Chapter 9** list our publications and staff respectively.

1987/88 has been a productive year in which much has been achieved, and which indicates great promise for the future. As always, it is with great pleasure that we express our sincere gratitude to the hard work of program regional staff and the National Scientists with whom we work.

1.4 Staff Changes

During 1988 two of our senior staff, Dr. Kutlu Somel (Economist) and Dr. Dennis Tully (Anthropologist) left ICARDA to take up appointments elsewhere. During their several years at ICARDA they both made invaluable contributions to the Center, both within their specific disciplines of research and as members of multi-disciplinary research teams. We thank them both for all that they have contributed and wish them well in the future. Miss Andree Rassam (Sociologist) married and started a new life in Rome. Our thanks also for all her contributions over the 10 years she spent with us, and our best wishes for her future.

Dr. Hamid Fakki (Post-Doc. Economist), completed his draft manual on Crop On-Farm Trials and returned to Sudan. Hamid will be rejoining us for a few weeks next year to assist in our residential training course. Dr. Mohamed E. Sheykhoun (Post-Doc. Economist) has also returned to Egypt following his year with us quantifying the economics of water harvesting in the NW Coast of Egypt. Mr. Ahmed Moussa El Ali, after 4 years with our wheat based systems agronomy group, was transferred to the DG's office. Our sincere thanks for his hard work. Several regional staff resigned for personal reasons, namely Samuel Abdul Ahad, Hiam Kassar, Kawthar Chehidi, and Hind Bikandi. We miss them personally and professionally and wish them well in their new careers.

During the year we also welcomed several new comers to the program. Prof. Onur Erkan (Economist) joined us from Cukurova University in Adana, Turkey as a visiting scientist. Onur's research has concentrated on a comparative analyses of barley production in Syria and Turkey (see section 6.4), and he was also instrumental in organizing an International Seminar on FSR at Cukurova. Dr. Richard Tutwiler (Anthropologist) has come for two years on a Rockefeller Post-Doctoral Fellowship. Richard has already completed a survey on cereal stubble burning in this wet year, and has become an integral part of a new collaborative research activity in Jordan (see section 6.5). Mr. Ciro D'Acunzo, an FAO Associate Expert is also a welcome addition to our staff. Ciro is working in our supplemental irrigation project, focusing on barley. His work provides further strong cooperative links between FRMP and the Cereals Program. Mrs. Meri Whitaker joined us toward the end of the season as a PhD student. Her research concerns farm level risks and strategies associated with the nitrogen fertilization of wheat. Both farm level surveys and crop growth simulation models will be basic tools used in her research. She will be working jointly with Mr. Majdeddin S. Issa (MSc student, Aleppo University) on this topic, and we welcome his participation.

Mr. Ali Hussein and Miss Widad Shehadeh came for the complete season as trainees from the Syrian Soils Directorate. We hope their time with us proved useful; from our part we certainly benefitted from their dedicated hard work. We were also joined by many other trainees for varying periods of time. They are too numerous to record here, but they are listed in full in Table 7.2. They all contributed to our knowledge of the region, and we wish them well on their return to their respective countries.

1.5 The Weather in Syria During the 1987/88 Season

The 1987/88 season was the wettest in NW Syria since 1940/41, when seasonal rainfall totals exceeded those of 1987/88 by 10 to 20%. The average recurrence interval of seasons with the same rainfall as 1987/88 or more is estimated to be around 30 years. As the increased rainfall was due to increased cyclonic activity and, therefore, was of the advective type, the relative increase was more pronounced in the drier part of the region: Jinderess, our wettest site received 48% more than the long-term seasonal average of 483 mm; but Boueider, where the long-term average is 212 mm, had 386 mm, or 81% more than "normal".

The season started early with heavy rains from 17 October to November 6. Then followed the only prolonged dry spell of the season which lasted, only interrupted by minor showers at some sites, until 4 December. This period was ideal for planting. December brought less than average rainfall at some sites, more than average elsewhere. January, February and March were wetter than average across the whole of Syria. The last significant rains of the season fell around the middle of April. However the good accumulated supply of soil moisture allowed the crops to mature with less stress than in most seasons.

The temperature throughout the season was close to the long-term average with no extremes of note. There were fewer frost days than in most seasons, in particular at the drier sites, as the frequent cloud cover reduced the occurrence of radiation frosts. Altogether the weather in Syria during the 1987/88 season laid the foundation for a bumper crop, which was widely achieved.

Table 1.1 Monthly precipitation (mm) for the 1987/88 season

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	TOTAL
Jindiress													
1987/88 season	0.0	117.4	65.7	85.0	100.8	78.2	167.1	71.8	22.5	6.4	0.0	0.0	714.9
Long term average (29s.)	1.3	28.4	52.0	98.6	92.2	75.9	65.9	44.9	19.4	3.3	0.0	0.9	482.8
% of long term average	0	413	126	86	109	103	254	160	116	194	n/a	0	148
Tel Hadya													
1987/88 season	1.4	71.0	45.7	74.4	84.7	97.4	92.6	29.4	2.6	4.4	0.0	0.6	504.2
Long term average (10s.)	0.5	26.3	44.9	55.9	68.1	56.2	47.1	31.7	14.3	3.7	0.0	0.1	348.7
% of long term average	280	270	102	133	124	173	197	93	18	119	n/a	1000	145
Breda													
1987/88 season	0.0	68.2	36.4	41.0	85.6	82.4	65.6	19.4	9.8	6.4	0.0	0.0	414.8
Long term average (30s.)	1.4	13.2	29.5	52.2	48.8	39.0	33.4	33.6	15.8	1.6	0.2	0.0	268.7
% of long term average	0.0	517	123	79	175	211	196	58	62	400	0	n/a	154
Boueider													
1987/88 season	0.6	69.9	37.2	44.6	80.2	77.8	41.0	25.4	5.2	3.8	0.0	0.0	385.7
Long term average (16s.)	1.5	13.9	21.0	35.9	43.5	38.6	27.2	20.1	10.2	0.7	0.2	0.0	212.8
% of long term average	40	502	177	124	184	201	151	126	51	543	0	n/a	181
Ghrerife													
1987/88 season	0.0	102.0	33.8	38.7	76.2	88.6	71.6	19.6	7.0	4.2	0.0	0.0	441.7
Terbol (Lebanon)													
1987/88 season	0.0	22.4	52.4	164.7	153.4	113.2	187.2	8.2	7.0	0.0	0.0	0.0	708.6

Table 1.2 Monthly air temperatures (^{o}C) for the 1987/88 season

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
Jindiress												
Mean max.	32.9	26.0	18.9	12.3	11.1	12.3	15.2	22.0	28.0	32.2	36.7	35.0
Mean min.	17.2	12.4	7.0	5.9	3.5	4.3	6.1	10.1	13.2	16.8	21.2	21.7
Average	25.1	19.2	13.0	9.1	7.3	8.3	10.7	16.1	20.6	24.5	29.0	28.4
Abs. max.	38.0	32.6	23.3	19.2	16.0	16.2	20.9	27.8	38.0	40.0	41.2	38.0
Abs. min.	13.0	5.2	2.0	-6.0	-2.0	-1.2	-2.0	4.2	7.9	9.9	18.0	15.7
Tel Hadya												
Mean max.	35.3	26.4	18.7	12.4	10.9	12.8	15.8	22.7	30.2	32.6	38.3	37.3
Mean min.	16.8	11.4	5.1	5.3	2.1	4.0	5.1	8.0	12.4	17.3	21.4	21.8
Average	26.1	18.9	11.9	8.9	6.5	8.4	10.5	15.4	21.3	25.0	29.9	29.6
Abs. max.	38.8	38.2	21.8	18.4	16.5	17.4	22.1	29.0	39.6	40.2	42.2	41.1
Abs. min.	11.4	3.8	0.2	-7.4	-2.2	-2.4	-2.8	0.4	5.8	12.8	18.4	14.2
Breda												
Mean max.	34.2	25.3	17.9	11.5	10.5	11.7	16.0	22.8	31.7	36.3	39.6	37.4
Mean min.	15.8	11.7	5.0	4.4	2.4	3.7	5.5	9.6	12.9	18.1	16.6	19.7
Average	25.0	18.5	11.5	8.0	6.5	7.7	10.8	16.2	22.3	27.2	28.1	28.6
Abs. max.	38.4	36.0	21.0	19.0	16.0	16.0	22.8	29.2	41.8	41.1	43.7	40.0
Abs. min.	11.0	4.8	-0.3	-8.0	-2.8	-2.0	-3.0	2.0	6.2	13.5	18.6	13.3
Boueider												
Mean max.	35.0	27.1	18.0	12.2	10.1	11.2	13.5	21.6	31.2	35.7	38.4	36.9
Mean min.	13.7	10.9	4.2	4.4	2.3	3.4	4.6	7.7	11.1	16.2	19.1	13.9
Average	24.4	19.0	11.1	8.3	6.2	7.3	9.1	14.7	21.2	26.0	28.8	25.4
Abs. max.	38.0	38.0	20.4	19.0	15.9	15.0	21.0	30.0	40.4	40.0	41.2	40.2
Abs. min.	8.6	3.0	-1.2	-11.5	-2.6	-1.9	-1.8	-0.4	5.1	11.8	17.1	12.1
Ghrerife												
Mean max.	34.3	24.9	17.4	11.2	10.3	11.3	15.3	21.1	30.6	34.2	37.2	36.4
Mean min.	17.9	12.4	5.6	4.9	2.8	4.0	6.0	10.2	14.3	19.1	20.8	20.2
Average	26.1	18.4	11.5	8.1	6.6	7.7	10.7	15.7	22.5	26.7	29.0	28.3
Abs. max.	38.2	37.2	21.3	17.6	15.3	15.0	21.4	28.8	40.0	37.4	40.4	39.8
Abs. min.	13.4	5.0	1.2	-9.5	-2.2	0.0	-1.4	3.5	8.0	13.4	18.5	15.0
Terbol												
Mean max.	31.8	24.4	20.0	12.7	10.8	10.8	13.5	22.0	28.0	30.7	33.7	32.2
Mean min.	10.0	6.9	1.3	2.1	0.0	-0.5	1.8	5.4	8.7	11.4	13.6	13.9
Average	20.9	15.7	10.7	7.4	5.4	5.2	7.7	13.7	18.4	21.1	23.7	23.1
Abs. max.	35.0	34.5	26.0	22.0	18.0	17.0	23.0	30.0	35.0	35.0	37.0	36.0
Abs. min.	7.5	-0.5	-3.0	-8.0	-8.5	-14.5	-3.0	-0.5	2.0	6.0	10.5	10.0

Table 1.3 Frost events during the 1987/88 season

	OCT	NOV	DEC	JAN	FEB	MAR	APR	SEASON
Jindiress								
No of frost days	-	-	4	5	3	1	-	13
Abs. min. (°C)	-	-	-6.0	-2.0	-1.2	-2.0	-	-6.0
Tel Hadya								
No of frost days	-	-	4	8	7	2	-	21
Abs. min. (°C)	-	-	-7.4	-2.2	-2.4	-2.8	-	-7.4
Breda								
No of frost days	-	2	8	8	5	1	-	24
Abs. min. (°C)	-	-0.3	-8.0	-2.8	-2.0	-3.0		-8.0
Boueider								
No of frost days	-	1	6	7	3	2	2	21
Abs. min. (°C)		-1.2	-11.5	-2.6	-1.9	-1.8	-0.4	-11.5
Ghrerife								
No of frost days	-	-	3	5	1	1	-	10
Abs. min. (°C)			-9.5	-2.2	0.0	-1.4	-	-9.5
Terbol								
No of frost days	1	12	6	13	19	7	-	58
Abs. min. (°C)	-0.5	-3.0	-8.0	-8.5	-14.5	-3.0	-	-14.5

Table 1.4 Frost events at 5 cm above the ground during the 1987/88 season

	OCT	NOV	DEC	JAN	FEB	MAR	APR	SEASON
Tel Hadya								
Frost days	-	1	8	9	9	2	1	30
Abs. min.	-	-1.0	-8.0	-3.5	-3.0	-3.4	-0.4	-8.0

2. ACTIVITIES AND HIGHLIGHTS RESEARCH AND TRAINING PROGRAM

1987-1988

A full listing of experiments and research activities conducted in the 1987/88 season are provided in Appendix A of this report. Many of these activities are ongoing, and not all are reported fully in this annual program report. Below we briefly indicate some of the more interesting results obtained in this very high rainfall season, and also refer the reader to specific sections of this report in cases where the results are presented and discussed in more detail.

2.1 PROJECT 1. THE MANAGEMENT OF SOIL, WATER AND NUTRIENTS

Improved Fertilizer Use Efficiency

SWAN-1: Nitrogen and phosphate use for wheat in farmers' fields in North Syria

Fertilizer use on durum wheat (Sham-1) was evaluated in N. Syria in 20 on-farm trials in collaboration with the Syrian Soils Directorate. Grain and straw yield responded positively and significantly to N fertilizer with mean yield increases of 21 and 29% in grain, and 26 and 42% in straw, for the rates of 40 and 80 kg/ha of N respectively. As found last year, response to P was not significant. The nitrate-N in the top 40 cm of soils at planting correlated well with the relative response of wheat to N fertilization. Net revenue values indicate that fertilizer use on wheat was profitable in all treatments compared with the control (see also section 6.7 of this report).

SWAN-2: Effect of rate and method of phosphate placement on wheat in farmers' fields

As observed in SWAN-1, wheat responses to phosphate are negligible in fields with a previous history of P-fertilization and, hence, high soil available-P levels. Although no response to phosphate application was observed in any of the four farms, sowing by drill was found to give between a 20 and 23% yield increase over the farmers' method of broadcasting seed over ridges, and covering the seed through ridge splitting. After two seasons work we conclude that when phosphate fertilizer is required, maximum yield benefit will be obtained if the seed is drill sown and the phosphate fertilizer is banded with the seed.

SWAN-3: Contribution of the mineralization potential in soil to the nitrogen nutrition of wheat

For two consecutive seasons, the nitrogen mineralization potential (as determined by laboratory incubation) has been compared with other standard soil-N analytical procedures as a predictor of fertilizer requirements and responses in a range of contrasting soils. (The soils used were taken from farmers' fields in which NP trials were being conducted, see SWAN-1.) It was found that mineralization potentials for both xerochrepts and chromoxerectic soils, dominant in the wheat area, are practically the same, with an overall average of 115 to 125 mg N per kg of soil. For sites with low mineral-N content at sampling, the correlation coefficients between mineralization potential and total N uptake by wheat crop, grain and total dry matter yields were the best among all N tests. However, over all the sites studied, the best correlation with yield was given by nitrate-N in the top 60 cm of soil. Although mineralization potential is a good soil test, simple nitrate content (0-60 cm) is more practical and can be used for fertilizer recommendation under variable conditions (see also section 3.6 of this report).

SWAN-4 and -5: On-farm barley fertilizer research

Barley fertilization in twenty on-farm trials in Northern Syria, again and for the fourth year, showed a substantial biological and economic response to fertilizer (N and P). However, due to the wet season this year, nitrogen increased barley yields more than phosphorus. This is in contrast to the past three years when phosphorus increased barley yields more than nitrogen. Yields averaged 4.98 t/ha total dry matter in unfertilized plots with an increase of 2.70 t/ha (1.5 fold) from fertilizer (40 N and 90 P_2O_5 kg/ha).

This year, for the first time, fertilizers were also tested under the farmers' own management. The results showed that in the absence of fertilizer use, the total dry matter (average of 11 sites) was 4.2 t/ha, and an increase of 2.26 t/ha (1.5 fold) was obtained when fertilizer was applied (40 N and 90 P_2O_5 kg/ha).

Fertilizer use is generally considered to increase yield variance, a factor that influences risk. The effects of N and P fertilizer on barley yield variability were assessed with data from the first 3 years of these on-farm trials in N. Syria. Three approaches, viz. treatment mean-variance tradeoffs, sensitivity to environmental variables and stochastic dominance analysis were used as analytical tools. The results indicated that certain fertilizer treatments offer higher yields without higher yield variance as compared to no fertilizer use. The analysis focused on conditions when risk preferences are not known, however it was assumed that farmers are risk averse.

SWAN-6: On-farm responses of a vetch/barley mixture to residual fertilizer

In 14 on-farm trials, responses of mixed vetch/barley hay crops to phosphate residual from fertilizer applied to the previous season's barley crop were significantly related to the initial native phosphate status of the soil. The relationship was logarithmic. Residual responses tended to be large where initial soil available-P was less than 3 ppm but negligible when it was greater than 4 ppm (see also section 3.5 of this report).

SWAN-7: Phosphate soil test calibration with food and forage legumes

For three consecutive seasons, the responses to phosphate application of lentil and chickpea grown in farmers' fields and main ICARDA stations have been studied. Faba bean, peas and vetch responses to P were also studied for the last two years on ICARDA's main station. Response to P application depended on levels of previous fertilizer (P) application, the climatic conditions of the season and the legume species. In normal years, all legume species responded to both residual and applied phosphate fertilizer. However the response to P was much less in the wet year of 1987/88 when only peas and faba beans responded in total dry matter to P application (see also section 3.4 of this report).

Tillage and Stubble Management

SWAN-11: The effect of long term tillage systems on the stability of wheat/lentil rotation

Last year we reported on water infiltration studies in a trial where tillage is carried out at different times and soil moisture conditions. Infiltration was reduced where both primary and secondary tillages are completed prior to rain. Dry sieving analyses carried out in the laboratory this year show that there is a difference in the stable aggregate size distribution between this dry tillage and treatments where some or all of the tillage follows rain. A greater proportion of the aggregates in the 0-10 cm soil layer fall into the smaller size categories (0.5-1.0 mm; 0.2-0.5 mm; and <0.2 mm) with dry tillage. This appears to support the hypothesis that dry tillage is causing soil structural degradation, but further work is required to clarify a complex situation.

We have also reported in previous years on the dynamics of weed populations over time in relation to the timing of tillage and weed control methods. The weed control treatments were discontinued three years ago and weeds have been uniformly controlled since then. However, in this wet year wheat plots previously hand weeded suffered severe infestation of a grassy weed resistant to herbicide. There was a similar situation in lentil where a leguminous weed invaded plots previously treated with a broad spectrum herbicide. The effects were most severe in zero till plots which are sown before the opening rains, and have implications for the sustainability of zero tillage which is showing promising results in another trial.

SWAN-12: Tillage method comparison in 3-course wheat/legume/summer crop rotations

This trial tests the hypothesis that the type of primary tillage does not affect crop yield, but reduced tillage leads to cost savings and is thus beneficial. The tillages used are deep discing, deep chisel ploughing, ducksfoot cultivation and zero till. The unexpected result from this season was that soil-water storage was about 50 mm less where the primary tillage was deep discing. Other tillages showed no differences. The season was unusually wet and the effect was not reflected in crop yields. The trial is a long-term one conducted within three-course rotations of wheat with legumes and water melon, and we will continue to closely monitor the water balance.

SWAN-13: The effect of stubble burning on a wheat/lentil rotation

The effect of stubble burning and different seedbed preparation systems on crop yield, weed infestation levels and, in the long run soil structural stability and organic carbon are being examined in a two course wheat/lentil rotation. In this first season, stubble burning gave only slightly higher yields. Deep plowing before or after rain provided the lowest weed infestation and eventually higher lentil grain yields. However, considering degradation of the soil in the long run, shallower cultivation or direct planting seems highly promising.

SWAN-14: The effect of wheat stubble management on the productivity of contrasting farming systems

This year we have the first full set of results from stubble management studies begun two years ago in two-course wheat-legume rotations. Chickpea and lentil yielded as well when sown into the standing stubble of a previous wheat crop as they did where the stubble was heavily grazed. However, there was a reduction in the yield of wheat where stubble was fully retained or grazed at a moderate level two years ago. The most likely explanation is that the amount of stubble affected the nitrogen balance of the wheat crops, even though there was no apparent interaction between stubble retention and nitrogen treatments. However, we may be seeing the start of such an interaction, and the effect of stubble on nitrogen dynamics will be included in the FLIP/FRMP work in this trial.

For the second year in succession we have measured a response of lentil seed yield to residual nitrogen. In this rotation trial, nitrogen at four levels -- 0, 30, 60, and 90 kg N/ha -- is applied in the wheat phase of the rotation. This year there was a yield increase in the lentil following 30 kg N applied last year, despite the fact that Sitona weevil, which reduces BNF by feeding on root nodules of lentil, was controlled. And, for the second year in a row, lentil seed yield was depressed by the application of 90 kg N to the preceding wheat crop.

SWAN-16: The effects of sowing method, cultivars and seed rate on wheat production (cooperative with Aleppo University, MSc study)

The effect of drill use and the usual farmers' method of planting (broadcasting) together with different seed rates on the stand establishment, yield components and yield levels of two different durum wheat cultivars was studied at Tel Hadya and Jindiress research stations during 1986/87 and 1987/88 seasons. Drill application produced 3881 kg/ha mean grain yield, 29% more than that achieved by the farmers' method. 300 seeds/m^2 provided the highest yield, 23% more than that obtained with 100 seeds/m^2. It can be concluded that drills are necessary for more efficient use of resources such as water, fertilizer and seed.

Weed Control

SWAN-17: Chemical weed control in wheat

Many years of chemical weed control research have shown that broad spectrum, post-emergence herbicides are available for both broad-leaves and grasses in wheat. The most effective herbicides are bromoxynil (Brominal, 0.5 kg ai/ha) for broad leaves and diclofop-methyl (Illoxan, 1.0 kg ai/ha) for grasses, especially wild oats and phalaris . During the last two seasons Granstar (10-20 g preparate/ha) was found to be a very effective soil active herbicide for broadleaves as an alternative to 2,4-D type of herbicides, the main chemical currently used by most farmers in the region.

SWAN-18: Chemical weed control in food legumes

Again, many years of chemical weed control research in food legumes has shown that terbutryne (Igran, 1.6-2.0 kg ai/ha) for broadleaves and pronamide (Kerb, 0.5 kg ai/ha) for grasses and volunteer cereals are the best pre-emergence herbicides. There are also post-emergence herbicides such as dinoseb-acetate (Aretit, 1.0 kg ai/ha) for broadleaves and fluazifop-butyl (Fusilade, 0.25 kg ai/ha) and fenoxy propethyl (Furore, 0.15 kg ai/ha) for grasses and volunteer cereals.

Improved Production Practices for Food Legumes

SWAN-19: Improved production practices for lentil

Improved production practices for lentil were again evaluated in N.W. Syria in 7 on-farm trials. Despite some site to site variation in yield levels and net revenue, early planting, Sitona weevil control and weed control were found to be profitable at all locations. Yields in this very wet season were higher than in the last two seasons. Mean grain yield obtained by early planting was 1940 kg/ha, 49% greater than that of late planting.

Sitona control and weed control provided 1740 and 1725 kg/ha mean yields, representing a 16 and 42% yield increase respectively. They were more effective in early planting. P application increased yield only 4% and N fertilizer was not able to replace carbofuran use for Sitona control (see also section 3.7 of this report).

SWAN-20: Improved production practices for chickpea

Improved production practices for chickpea were again assessed in N.W. Syria in 6 on-farm trials. Despite some site by site variation in yield levels and net revenue, early winter planting, drill use and chemical weed control were found to be profitable at all locations. Mean grain yield obtained by early winter planting was 1475 kg/ha, 46% higher than that of late winter planting. However, this year we had 3 dates of planting due to weather conditions, early December, early February and spring, which resulted in mean grain yields of 2080, 1505 and 895 kg/ha. Drill use and P application provided 1300 and 1285 kg/ha mean yields representing a 10% and 7% yield increase respectively. Weed control gave mean grain yield of 1240 kg/ha which was 35% higher than that of the weedy check.

Fallow Replacement Research

SWAN-21: Fodder legume potential in dry areas

For the first time, ten forage legume cultivars (of Vicia, Lathyrus, Pisum) were planted at six sites along a transect from Breda to Bouider, and their hay and seed and straw production compared. The purpose was to identify cultivars suitable for particularly dry areas, but that was frustrated by this year's high rainfall. However, we noted major cultivar differences in resistance to bird damage and in harvest index. Vicia narbonensis was the most productive cultivar, achieving 10 t/ha dry matter, including 3.4 t/ha seed, at Bouider.

SWAN-22: Vetch utilization trial

In a new trial at Breda, timing of the vetch harvest in the 1987/87 season had a significant effect on the yield of the succeeding barley crop this year. Barley following vetch under a green grazing treatment outyielded barley following vetch grown to maturity (grain, 23%; straw, 27%), with barley following vetch cut as hay at the green pod stage intermediate. The original hypothesis was that early vetch harvest would leave more water stored in the soil for the barley; but in this wet year, any such effect would have been unimportant. This was confirmed by neutron-probe monitoring of water use by barley, which indicated no treatment differences. It seems likely that it was differences in nitrogen availability that were more influential (see also section 3.2.2 of this report).

SWAN-29: Continuous barley trial

In the second year of trials to study the implications of continuous barley cropping, responses to N-fertilizer were large at Breda and very large at Tel Hadya (30 and 73 kg DM/kg N, respectively for the first 60 kg N/ha applied). Unfertilized yields were higher in plots fallowed last year than in plots under barley last year, by a small margin at Breda (6.47 v. 5.78 t DM/ha) but a much larger one at Tel Hadya (3.68 v. 1.67 t DM/ha). Although there were likely to have been other factors involved as well, these results confirm the importance of nitrogen supply for continuous cereals, particularly in high-yielding situations.

Water Management Studies

SWAN-23: Supplemental irrigation of wheat: nitrogen and variety studies

Rainfed wheat yield is usually less than 2 t/ha in the local environment but it can be increased to more than 5 t/ha when rainfall is supplemented by limited volumes (600 to 1200 m^3/ha) of irrigation water which is carefully scheduled in accordance with rainfall and plant growth periods sensitive to moisture.

Three years of supplemental irrigation research at Tel Hadya has shown that wheat varieties Sham-1 (durum) and Sham-IV (bread) are more responsive to this type of water management than several other varieties.

In the first two years of this study (years receiving 315 and 316 mm rainfall), 600 m^3/ha of carefully scheduled supplemental irrigation, costing less than 0.5 SL/m^3, increased yields by an average 3.9 t/ha of grain and 4.0 t/ha of straw giving a profit of 16.7 SL/m^3 of water applied. In the much wetter season of 1987/88 (507 mm), rainfed grain yields were high at around 5.0 t/ha, but even so supplemental irrigation increased yields to over 7 t/ha, giving a return of 8.0 SL for each Syrian Lira spent on irrigation.

2.2 PROJECT 2. AGROECOLOGICAL CHARACTERIZATION FOR RESOURCE MANAGEMENT

ACRM-2: Development of spatial climatic model

Our research on this essential tool has been progressing steadily. Initial testing of the rainfall spatial generator highlighted specific problems associated with data availability and quality. The "availability" problem comprises two aspects, sub-optimal lengths of observation periods of rainfall stations, and sub-optimal density of stations. Associated with the former is the problem of how to deal with extreme rainfall events of very low probability in records of restricted length.

Problems with data quality arise from both random and systematic errors in long term data sets. Systematic errors can arise from several causes. Re-location of a station, change in the physical surrounds of a station, failure to record small rainfall events and "rounding off" of records. These problems must be addressed during the stage of coefficient determination of the model before the spatial rainfall generator can be run. Our research during 1988 has largely overcome these problems (see section 4.3 of this report).

ACRM-5: Ceres-N wheat and barley models

During 1988 we obtained an updated version of the Ceres-N wheat model and an initial version of a Ceres-N barley model which was jointly developed by ICARDA, Michigan State University and IFDC. An in-house workshop was held during which senior staff of ICARDA were introduced to the theory, development and use of these models (see section 7.4 of this report). This was the first time ICARDA has held a special course to introduce its own senior scientists to a new technique for research, and the course was a great success.

During the year we have tested the performance of the Ceres-N wheat model against specific data sets and assessed its sensitivity in predicting observed crop rotation and climate effects on the nitrogen responses of wheat. The results are very encouraging indeed (see section 4.2 of this report). We have been joined by a visiting scientist from Stanford University who will be utilizing these models together with farm survey data in assessing farm level risks and strategies associated with nitrogen fertilizer use on cereals in the Mediterranean Region.

2.3 PROJECT 3. ADOPTION AND IMPACT OF TECHNOLOGY

Special Project: Agricultural Labor and Technological Change

The regional overviews on Labor Markets in Non-agricultural Sectors, Mechanization, Off-farm Employment and Agriculture; and Changing Availability and Allocation of Household Labor as well as country review papers from Turkey, Cyprus, Syria, Jordan, Iraq, Yemen Arab Republic, Tunisia and Morocco have all been completed, edited and will shortly be published. The eight case studies (see FRMP Annual Report 1987, section 5.4) from Jordan, Turkey, Algeria, Tunisia and Morocco have also been completed and were presented and discussed at a workshop in July 1988 (see section 7.4 of this report). They are currently being edited and will also be published in 1989.

ADIM-2: Economic factors influencing the adoption of new technologies in dry areas. A case study of fertilizer use on barley

This research is closely associated with our research in SWAN-4 and SWAN-5.

During the last three seasons, 130 farmers in villages adjacent to our on-farm fertilizer trials have been questioned on their barley production practices, their yields and their reaction to our trials. Only 8% of these farmers had ever used fertilizer on barley themselves, but even though our trials were not intended as demonstration, on average 20% of the interviewed farmers used fertilizer in the year after seeing the trials. Another 50% said that they would have liked to have used fertilizer but were unable to for a number of reasons. Current analyses of this large dataset are focusing on the identification of socio-economic indicators which appear to influence farmers' decisions on fertilizer use in such arid and climatically variable environments.

ADIM-3: Factors affecting the adoption and impact of supplemental irrigation in Syria

Three-years of on-farm research and surveys revealed (1) an escalating interest in supplemental irrigation (SI) officially and individually and (2) considerable impact in terms of fallow elimination higher cropping intensity, yield, income and living standard. Lower unemployment and reduced migration of rural communities are also observed.

Major constraints affecting SI adoption are: uncertainty involved in the establishment of wells; very limited supply of water from government irrigation schemes for SI; and shortage of pumps and other irrigation equipment. Factors affecting SI impact on farm productivity are: improper land preparation for irrigation, delayed planting, and improper timing and supply of water and other capital inputs and operations.

However, the potential for adoption and impact of SI is considerable. More than 65% of the total rainfed area is located in zone 1 and 2 (good agroclimatic conditions), only 33% of total water resources of the country are already utilized and current irrigation efficiency is low (40%). Recent government policies strongly support SI, and potential increases in wheat production would be about 0.75-1.5 million tons if 25-50% of rainfed wheat area were supplementally irrigated and a moderate yield level of 4.5 t/ha was obtained.

ADIM-7: Economic allocation of fertilizer in Syria

A mechanism for the development of an economic framework for planning centralized allocation of fertilizers across a country's contrasting crops and production zones has been produced. The framework simultaneously considers competing crop and zone-specific yield responses to N and P, balancing their marginal production values against options for exporting domestically manufactured fertilizer and options for importing. Implications of alternative policy choices may be traced through the framework. The framework will be most useful for centrally planned agricultural sectors facing severe limitations on the availability of fertilizer inputs due to low levels of domestic manufacture or to foreign currency constraints.

ADIM-8: Comparative analysis of barley production in N. Syria and S.E. Turkey

Two barley production surveys indicate that there is a significant difference between Turkey and Syria in yield per hectare at the survey area level. This arises from differences in climate, socio-economic factors, production systems, farmers' practices, soil and the amount of fertilizer applied by farmers. All these factors interact. The determination of the relative impact of each factor requires further analysis.

A comparison of the yields in Zone (A) in Turkey and Zone (2) in Syria, chosen because of their climatic similarities, shows far fewer significant differences. Analysis of socio-economic indicators, production systems, farmers' practices, soil and amount of fertilizer application show many similarities, although some differences remain.

The average barley yield in Zone A is 930 kg/ha and is 920 kg/ha in Zone 2. Four years of on-farm research conducted by ICARDA/Soils Directorate of Syria has shown that there is a potential to increase barley yields in Zone 2 in Syria by between 1300-1630 kg/ha. Preliminary yield gap analysis indicates that of this potential increase, 630-920 kg/ha are directly attributable to fertilizer use, the remainder of the potential increase being due to other management factors. Given the apparent similarity of Zone 2 in Syria and Zone A in Turkey, the results of on-farm trials in Syria show that there is also a potential to increase barley production in Zone A of Turkey.

2.4 PROJECT 4. TRAINING AND AGROTECHNOLOGY TRANSFER

In our Training and Agrotechnology Transfer Project we:

- Held our third Annual Residential Course in Farming Systems Research and Resource Management (attended by 18 participants from 8 countries of the region).

- Held three short courses on "Research on Effective Use of Fertilizers", in collaboration with IFDC, in Aleppo, "Methods of Farm Survey" in Tunisia and "Agronomy Trials" in Morocco (45 participants attended these three courses).

- Jointly supervised 8 postgraduates (4 PhD and 4 MSc) and provided individual non-degree training to 14 participants.

- Held 5 workshops on the following topics:

  a) Supplemental Irrigation, in Morocco
  b) Evaluation of Farm Resource Management in the Northwest Coast of Egypt, in Alexandria
  c) Agricultural Labor and Technological Change, in Aleppo
  d) Soil Test Calibration, in Jordan
  e) Crop Models, in Aleppo

- Provided opportunities to four visiting scientists and three postdoctoral fellows to join the program and work with the program's staff on topics of mutual interest.

- Produced a full draft of a manual on crop on-farm trials.

During the season, FRMP scientists visited many countries of the region for meetings and discussion with scientists of national programs (see section 7 of this report).

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

3.1 Introduction

Research on the resources, soil, water, and nutrients is a major focus of the Farm Resource Management Program. The research is carried out within a farming systems perspective with the use of diagnostic surveys for problem identification and socio-economic monitoring to assess the applicability of research products. Studies of a basic nature are carried out within the core program, and we aim to introduce the findings to systems of West Asia and North Africa through outreach projects with National Programs. Co-operation with National Programs will be sought for this purpose, and collaboration will attempt to foster a systems perspective in national research structure in order to promote their research and extension capabilities.

In all this work close collaboration is maintained with other programs of ICARDA. A particular need for joint work with PFLP is recognized, as resource management strategies must allow for the close integration of livestock in the farming systems of the region.

In this research, our long-term goal is to assist National Programs in the development of productive and sustainable cropping systems which optimize the efficiency of use and conserve the basic and vital resources of soil, water and crop nutrients. We will attain this goal through the following medium term objectives:

1. To develop an understanding of physical, chemical, biological and environmental principles which underlie and control the productivity and sustainability of cropping systems with respect to soil characteristics and to water and nutrient dynamics.

2. To develop strategies for efficient management of soil, water and nutrients in cropping systems.

3. 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.]

4. To provide socio-economic 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.]

The proper management of soil, water and crop nutrients lies at the heart not only of increasing productivity in West Asia and North Africa, but also of sustaining those increases over time. Research on these topics is neither rapid nor easy and by necessity requires that the long term implications of alternative management strategies should be studied. Such research is an integral part of Project 1, and this year our report highlights some of the results of this work.

3.2 Crop Sequences and Their Effects on Productivity

M. Jones and H. Harris

3.2.1 Barley-Based Rotation Trials at Tel Hadya and Breda

Yield stability and yield sustainability are recognized as issues of fundamental importance, particularly in fragile environments. We need to know what effects repeated sequences of cropping, fertilization and management have on the pattern of productivity over time. For any given sequence we have to ask: does it tend to buffer or exacerbate the annual variation in production and profitability due to weather differences? And, over and above annual variability, does it, in the long term, promote an increasing or stable or decreasing trend of production? Finally, what is the cost to the environment, especially the soil?

These are not questions that can be answered easily or quickly. They require long time sequences of experimental observations. They require also an understanding of the mechanisms behind the cumulative effects, physical, chemical and biological, of particular combinations of treatments, so that reliable predictions can be made about their viability over much longer periods of time. With this in mind, we have recently analysed 4 and 6-year yield sequences in three small-plot trials comparing different barley-based rotations in the 250-350 mm rainfall zone (Jones 1989). The present report summarizes the main findings along with results for the 1987/88 season from the same trials.

The three trials are:

"New" Rotation (NR-TH), at Tel Hadya, initiated 1982/83,
"New" Rotation (NR-Br), at Breda, initiated 1982/83, and
"Old" Rotation (OR), at Breda, initiated 1980/81.

Each NR trial comprises three replicates of both phases of an incomplete factorial combination of six two-year rotations of barley with barley or fallow or a forage (legume or legume/barley mixture) and six fertilizer regimes (zero or a fixed NP rate variously distributed over the two years). The OR trial is similar but includes food legumes also, has one fewer fertilizer regime and has fewer factorial combinations. More treatment details are given elsewhere (Jones 1989). In the analysis of yields and yield trends, results from the year of trial establishment were ignored. Thus there were data from four years for each NR trial, 1983-87, and from six years for the OR trial, 1981-87; and we now also have the 1987/88 data. The main findings have been:

1. Consistently, between 1981 and 1987, though with wide variation in actual degree from year to year (from 10% to nearly 200%), barley crops following vetch (Vicia sativa) or fallow outyielded barley crops following barley; and

barley following fallow outyielded barley following vetch, by 10–30% (Figure 3.1). This was true in both fertilized and unfertilized situations; but on a percentage basis (though not always in absolute terms), differences between rotations tended to be greater where no fertilizer was used.

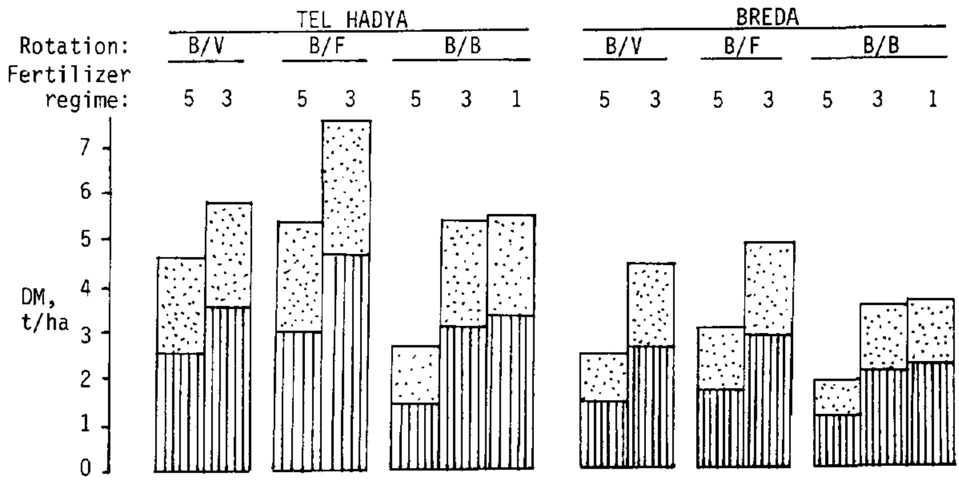
Under the high-yielding conditions of 1987/88, barley in rotation with vetch or fallow again outyielded continuously cropped barley. The difference was approximately 50% in fertilized rotations (9 t dry matter/ha compared with 6 t/ha) and almost 100% in unfertilized rotations (5–6 t/ha compared with 2.5 – 3 t/ha). Differences between barley-vetch and barley-fallow rotations, however, were small and non-significant.

2. In barley-barley rotations receiving NP fertilizer biennially, long-term results showed little yield response in the non-fertilizer year to any residues of previous fertilization; but in barley-vetch rotations, barley usually responded to phosphate applied to the previous vetch crop. It was suggested that differences could probably be attributed to differences in nitrogen availability.

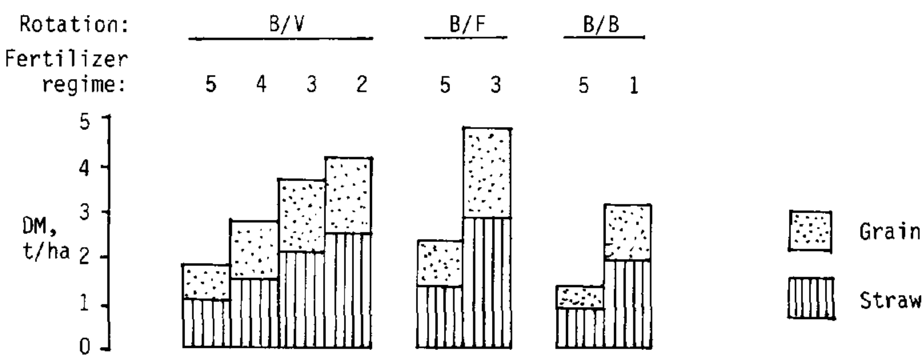
   There were similar findings in 1987/88 at Breda (Table 3.1). The key role of nitrogen, particularly nitrogen applied as fertilizer, was again evident. In the OR trial, unfertilized barley after P-fertilized legumes yielded 25% more dry matter than the zero-fertilizer control, presumably a residual phosphate effect; but in the NR trial, while N-fertilized barley following P-fertilized legumes yielded 73% more than the zero-fertilizer control, unfertilized barley following NP-fertilized barley yielded appreciably less than the control. In a nitrogen-hungry continuous cereal rotation, residual phosphate in the soil is of little use without added nitrogen.

Figure 3.1 The effect of rotation and fertilizer regime on total barley dry matter production (a) four-year means of NR trials, (b) six-year means in OR trial

A) NEW ROTATION, 1983-87



B) OLD ROTATION, 1981-87



Rotations: B/V=barley-vetch; B/F=barley-fallow; B/B=barley-barley

Fertilizer regimes, $N:P_2O_5$ (kg/ha) to:

	Barley	Alternative crop
1	20:60	20:60
2	20:60	0:60
3	20:60	0:0
4	0:0	0:60
5	0:0	0:0

(N rate is double, i.e. 40, at Tel Hadya)

3. The 4-year NR data set showed that no great advantage or disadvantage had resulted from using legume+barley mixtures instead of pure legumes in barley-forage rotations. Higher productivity (of hay) from vetch+barley compared with pure vetch (7% at Tel Hadya, 15% at Breda) had been partly offset by yield reductions in the following barley crops (5% at Tel Hadya, 7% at Breda).

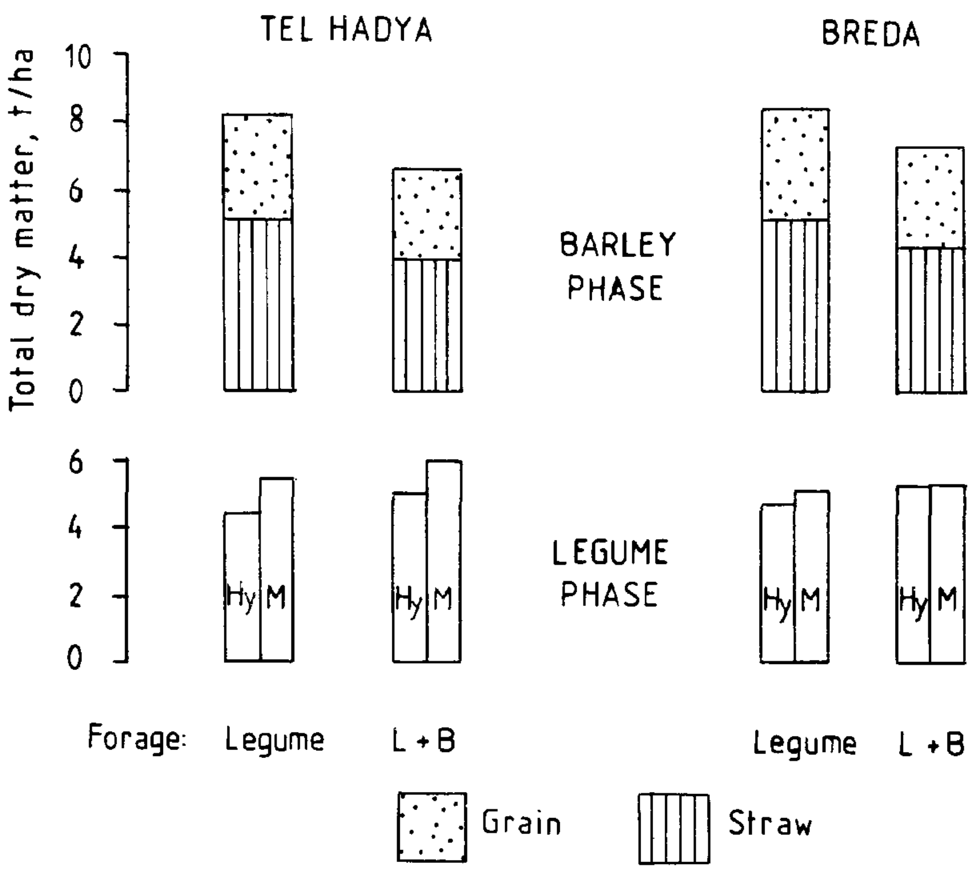
Table 3.1 Effect of rotation on barley responses to fertilizer regime at Breda, 1987/88 (t/ha)

Fertilizer regime 1/		Barley after barley		Barley after legume			
		NR		NR		OR	
Barley	Alt. Crop	Grain	Straw	Grain	Straw	Grain	Straw
NP	0	2.41	3.65	3.31	5.25	3.71	4.15
0	NP	1.27	1.68				
N	P			3.50	5.68		
0	P					2.89	3.11
0	0	1.54	1.85	2.31	2.99	2.31	2.49

1/ All N dressings, 20 kg N/ha; all P dressings, 60 kg P_2O_5/ha

However, the relative reductions in the yield of barley following mixtures were larger in 1987/88 and were not fully compensated by increased forage production in the other half of the rotation (Figure 3.2). The discrepancy within a total yield of around 12-13 t dry matter per 2 ha rotation was about 1 t, including about 0.4 t of barley grain. We do not know whether this difference from earlier years was due to the high rainfall or to a recent change in the management of the forage phase. For the last two years, the forage crops have not been harvested as hay, as previously, but allowed instead to grow to maturity (with

Figure 3.2 Barley-forage sequences in New Rotation trials: total dry matter production in both phases, 1987/88, as affected by the forage crop, pure legume .v. legume/barley mixture (Hy - harvested as hay; M - harvested mature)



appropriate samples being taken to maintain measurements of productivity at the hay stage). The time of forage harvest may well affect the productivity of the following barley crop (as a report of another trial, below, indicates), and such effects may possibly differ between pure and mixed forages.

It should also be noted that there were differences between legume species in 1987/88. At both sites and whether harvested at the hay or mature stage, lathyrus (Lathyrus sativus) was generally more productive than vetch (Vicia sativa). However, the increase in forage production from mixing barley with the legume was greater with vetch than with lathyrus. So the yield pattern may be approximately summarized: Lath + B > Lath > Vetch + B > Vetch.

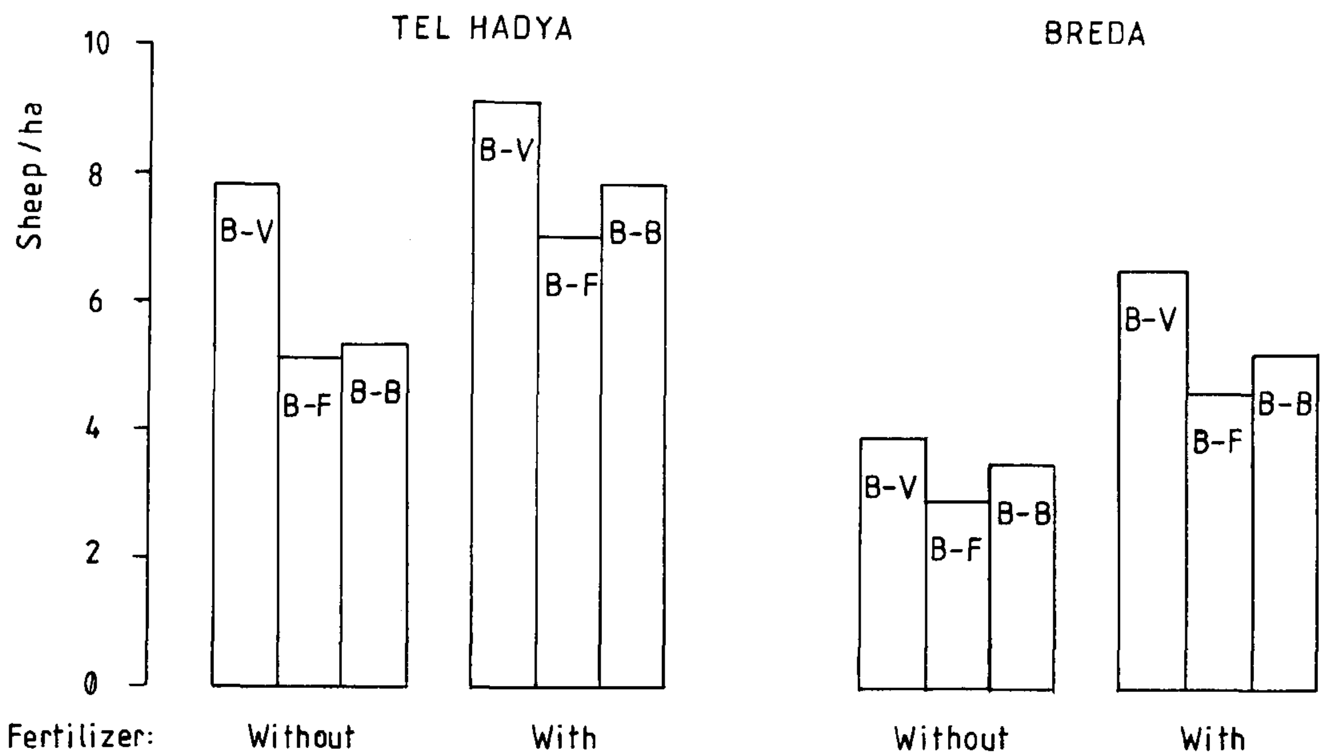
4. As the previous discussion suggests, because the yields of one crop are not independent of the nature of the previous crop, rotation trials are best evaluated in terms of the productivity of a whole cycle. This may be done in a variety of ways, both biological and economic. In the present case, the 4-year data of the NR trials was evaluated in terms of total dry matter production and the calculated theoretical value of that dry matter as sheep feed. Both productivity indices show that under any given fertilizer regime:

   - the barley-vetch rotation in all cases outyielded the barley-fallow rotation;

   - the barley-barley rotation in all cases outyielded the barley-fallow rotation (although differences were either small or negligible in the absence of fertilizer);

   - the barley-vetch rotation in all cases outyielded the barley-barley rotation (Figure 3.3).

Figure 3.3 Mean four-year production of three rotations, barley-vetch (B-V), barley-fallow (B/F) and barley-barley (B/B) in New Rotation trials, expressed in terms of sheep equivalents (sheep/ha/annum based upon *metabolizable energy values* of barley grain and straw and vetch hay). Fertilizer treatment was 20N and 60 P_2O_5 applied biennially to the barley.



Annually fertilized barley-barley rotations gave slightly higher sheep feed yields than did biennially fertilized barley-vetch rotations when these were calculated in terms of metabolizable energy but not when calculated in terms of crude protein. Generally, calculation in terms of crude protein boosted the relative advantage of barley-vetch rotations.

5. The total productivity of all rotations was much increased by fertilizer. For instance, in the OR trial, increases over zero fertilizer control were:

	Barley-vetch	Barley-fallow	Barley-barley
From biennial fertilizer	73 %	108 %	-
From annual fertilizer	107 %	-	150 %

However, in continuously-cropped rotations (barley-vetch and barley-barley), these increases were accompanied by large increases in annual variability (cv's rising from 15-20% to 30-35%), whereas in the barley-fallow rotation there was a decrease (from 35 to 19%). Clearly, such a finding has important implications for yield stability. It will need to be checked and rechecked in all three trials, and the underlying reasons sought, as more years' data become available.

3.2.2 Vetch Utilization Trial, Breda

Crop sequence effects are inescapable. The soil, which is not a blackboard wiped clean by ploughing, carries forward residual effects, good and bad, from one crop to the next. Thus barley grown after a legume will — all else equal — usually produce a higher yield than barley grown after another barley crop. The factors involved may include pest and disease build-up as well as differences in soil nutrient availability and soil water storage.

Nutrient availability and water storage may also be influenced by how and when a crop is harvested. Forage legumes grown in rotation with barley, in the drier arable areas of Syria, offer at least three different modes of utilization: (a) green grazing in the spring, to fatten lambs or increase milk production; (b) as hay, cut at the time of pod formation, to conserve good quality feed for the winter; or (c) mature harvesting, of grain and straw, also to conserve high quality feed for the winter.

The first of these modes includes the complete removal of the crop at a fairly early stage, probably towards the end of March, while the third leaves the crop growing until perhaps the middle of May. The experiment described here was intended to test the hypothesis that such different harvest times would, by leaving different amounts of water stored in the soil profile, influence the productivity of the following barley crop. In the first year, 1986/87, plots marked out in a uniform field of unfertilized vetch (Vicia sativa) were subject to three harvesting treatments: (i) simulated green grazing (cut to ground level); (ii) hay cutting; (iii) mature removal. Each treatment was replicated six times. In the second year, 1987/88, a neutron-probe access tube was installed in each plot and a uniform barley crop planted. (To maintain the rotation policy of the experimental field, this crop was also unfertilized.)

Contrary to what might have been expected in such a wet year, barley yields showed a significant response to mode of vetch utilization (Table 3.2). Total dry matter, grain, straw and water-use efficiency all increased with increasing earliness of vetch harvest. However, it is most unlikely that this was the consequence of differences in soil water stored from the previous season. In fact, water use by barley was almost identical in the three treatments. A more likely, though unproven, cause is thought to have been differences in nitrogen availability. Previous research has shown that Sitona weevil larvae cause

Table 3.2 The yield and water use of a barley crop following vetch harvested in three different ways, Breda, 1987/88

Time of vetch harvest in 1986/87	Crop yield, t/ha			Water use, mm	Water-use efficiency (kg/ha/mm)	
	Grain	Straw	Total d.m.		Grain	Total d.m.
	+	*	*	ns		
Green grazing	1.55	1.65	3.20	316	4.9	10.1
Hay	1.43	1.44	2.87	310	4.6	9.3
Mature	1.26	1.30	2.57	310	4.1	8.3
SE (±)	0.074	0.080	0.149			
CV, %	12.8	13.4	12.7			

For period from first to last neutron-probe reading: rain 358.8 mm
Epan 654.2 mm

Significance levels: * $P<0.05$; + $P<0.10$

widespread and severe damage to the nitrogen fixing root nodules of vetch, resulting in greatly reduced nitrogen fixation. The onset of such damage is usually noted around mid-March, thus vetch which continues to grow beyond this time will progressively deplete soil nitrogen reserves to meet its own requirements (see ICARDA Research Highlights 1984, p 68-71). It is suggested that in this trial, the earlier the legume was cut, the more the nitrogen left in the soil for the subsequent barley crop. Further trials of this type are in progress.

3.3 Crop Water Use and Water Use Efficiency in Contrasting Barley Rotations

H. Harris

3.3.1 Introduction

Barley is commonly grown in areas with less than 300 mm of annual precipitation. In this zone it is the major feed source for a large sheep industry, and is fed either as a green or mature standing crop or as stubble. Both grain and straw are also stored and fed at times of feed deficit. Traditionally the crop was grown in fallow/barley rotations, possibly in part with the objective of conserving water during the fallow to increase the yield of the following crop. However, in the past two or three decades expanded mechanization and population pressures have caused intensification of land use and most barley is now produced in a continuous monoculture. A resulting yield decline cannot be wholly reversed by the use of phosphate and nitrogen fertilizers, and the viability of the system appears to be under threat.

In the light of these facts, a two-course rotation trial was laid down at Breda (annual rainfall 280 mm), the stated objective of which was "to compare, from a technical and economic perspective, existing and alternative rotational systems which could make more profitable use of land resources and provide a more stable source of food and income, while maintaining or improving soil fertility" (ICARDA 1982). Treatments in the trial include barley in sequence with fallow, vetch (Vicia sativa cv. local landrace), chickpea, lentil, and peas, in addition to continuous barley monoculture. Fertilizer applications in various combinations are superimposed on the crop sequences (see Tables 3.3, 3.6). This trial is known as the "old Rotation Trial" (see also section 3.2 of this report).

Since its inception, water studies have been carried out within the trial. In the early years (1980/81 to 1983/84) these focused on species comparisons (e.g., vetch vs. chickpea vs. lentil), or on the effects of fertilizer on water use efficiency. There was, however, limited continuity in the sampling of treatments.

In 1984 the results of the trial were reviewed. It was decided that long term water balance studies of rotations should be undertaken as part of a continuing evaluation of alternative systems. Evidence from this and other trials in the area, strongly indicated that there is little likelihood that the system will be sustainable without the use of fertilizer. A subset of 5 treatments involving cropping sequences with fertilizer applied in one or both phases therefore was selected for long-term water balance studies (Table 3.3).

3.3.2 Trial Management

The trial is laid out in three replicates, each replicate comprising two ranges of plots (12.5 x 6.5 m) in which both phases of the rotations are planted each year. Soil water measurements are made in two replicates, and two neutron probe access tubes are installed in each plot of the selected treatments.

Table 3.3 Rotations selected for long term water balance studies in a two course rotation trial at Breda, Northern Syria

Rotation	Description	Code*
Fallow/Barley	Fertilized barley following a weed-free fallow	B_{NP}/F
Barley/Barley	Fertilized continuous barley	B_{NP}/B_{NP}
Barley/Vetch	Fertilized barley following unfertilized vetch	B_{NP}/V_P
	Fertilized barley following fertilized vetch	B_{NP}/V_P
	Unfertilized barley following fertilized vetch	B_0/V_P

* The code is reversed to indicate the non-barley phase, e.g. F/B_{NP}=Fallow following barley.

A seedbed is prepared by one pass (occasionally two) with a duckfoot cultivator and one with a spike toothed harrow. Seed and fertilizer are drilled with a plot seeder at 17.5 cm row spacing.

Vetch is hand harvested at the hay stage (early pod set), and all above ground material is removed from the plots. Barley (cv. Beecher) is combine harvested and the stubble is grazed during the summer. Beecher is unpalatable to sheep and much of the stubble remains.

Few of these practices are implemented by farmers. Farm crops are normally established by hand broadcasting (see e.g. FRMP 1987), although there has been a rapid expansion in the use of seed drills in the past two or three seasons. Fertilizer is not yet generally available in the area. The research is thus somewhat futuristic, but there are strong indications that the methods used will be freely available within the next decade. The one practice which is unlikely to find a place in the system is haymaking from the legumes. This is a high-cost, high-risk operation and farmers seem likely to chose an alternative practice (see also section 3.2 of this report).

3.3.3 Measurement of Soil Water

Soil water is measured gravimetrically in the 0-15 cm soil layer and with a neutron soil moisture probe at 15 cm intervals in the rest of the profile to 150 cm. Neutron probe access tubes have been permanently installed, some since 1982 and the remainder since the start of the 1984/85 crop season.

Tables 3.4 and 3.5 show examples of estimates of soil water made with the neutron probes in plots continuously cropped with barley. Features of the data are the apparent difference in water content between the replicates which is a permanent phenomenon (replicate values are the mean of 2 access tubes), and the repeatability of the estimates.

Apparent differences in water content between plots, or between access tubes within a plot, are a characteristic of the site and have a regular distribution which can be mapped in relation to the position of sampling points. Because they exist, all interpretation of the data is done on the basis of change in water content between samplings. The high degree of repeatability in the data gives confidence that small changes can realistically be detected.

Table 3.4 Volumetric water content (mm/15 cm soil layer) of soil profile at the end of summer (October) in four seasons of a continuous-barley crop sequence (R=replicate)

	Year							
	1983		1984		1985		1986	
Depth	R1	R2	R1	R2	R1	R2	R1	R2
15–30	23.3	23.8	22.9	24.0	22.4	22.7	22.0	22.7
30–45	31.1	33.6	29.4	32.3	28.9	30.8	29.2	31.1
45–60	34.7	38.8	33.9	37.3	32.6	36.1	32.8	36.3
60–75	33.3	40.8	33.4	40.0	33.1	39.4	33.2	39.4
75–90	30.5	41.2	30.4	40.8	29.6	40.4	29.6	40.6
90–105	34.2	41.5	33.5	41.8	32.9	41.4	32.6	41.2
Total	187.1	219.7	183.5	216.2	179.5	210.8	179.4	211.3

Table 3.5 Volumetric water content (mm/15 cm soil layer) of the soil profile at harvest of the barley crop (May) in four seasons of a continuous barley crop sequence (R=replicate)

	Year							
	1984		1985		1986		1987	
Depth	R1	R2	R1	R2	R1	R2	R1	R2
15–30	28.9	28.3	27.2	27.1	26.8	26.8	26.3	26.2
30–45	32.6	34.7	32.8	34.0	31.7	33.5	31.3	33.0
45–60	34.5	38.3	34.8	37.5	33.4	37.2	33.1	37.1
60–75	33.3	40.7	33.7	40.2	33.3	39.7	32.7	38.8
75–90	30.3	40.7	30.3	41.0	29.7	40.5	29.6	40.0
90–105	33.6	41.5	33.5	41.5	32.6	41.1	32.1	40.7
Total	193.2	224.2	192.3	221.3	187.5	218.8	185.1	215.8

3.3.4 The Efficiency of Fallows

The use of a weed-free fallow to store water from precipitation in the soil profile is widely advocated in semi-arid rainfed cropping regions. Water stored in this way can both increase the yield of the succeeding crop and buffer against yield fluctuations due to variable season-to-season precipitation.

Table 3.6 shows the quantity of water stored in the soil profile at the maximum measured point when plots were fallowed or cropped to barley or vetch. The proportion of rainfall which is stored and the maximum depth of storage are also shown, as is the proportion of seasonal rainfall still stored in the fallow at the time of harvest of barley crops, and at the end of the following summer.

Fallow efficiency is low. During the period of profile recharge there is little, if any, more water stored by a clean fallow than where the land is cropped to barley or vetch. This is due to more evaporation from bare soil than where the surface is shaded by a crop canopy (Cooper 1983; Allen 1989). Water transpired by crops is compensated by the reduced evaporation.

By the time of barley harvest the fallow efficiency has fallen further, although it is highly variable at this time depending on the nature and timing of rainfall events. In both 1985/86 and 1986/87 when the efficiency was greatest, the rain occurred as relatively few large falls (Figure 3.4a). Where the efficiency was lower, as in 1984/85 or 1987/88, the rainfall occurred, respectively, early in the season only or was exceptionally high and included many smaller events. In 1983/84 there was only sufficient rain to wet the soil to a depth of 30 cm and the efficiency of storage was very low indeed.

Further evaporation occurs during the summer and by the beginning of the next wet season less than 10% of the rain which fell in the previous season remains in the profile of fallowed plots (Table 3.6).

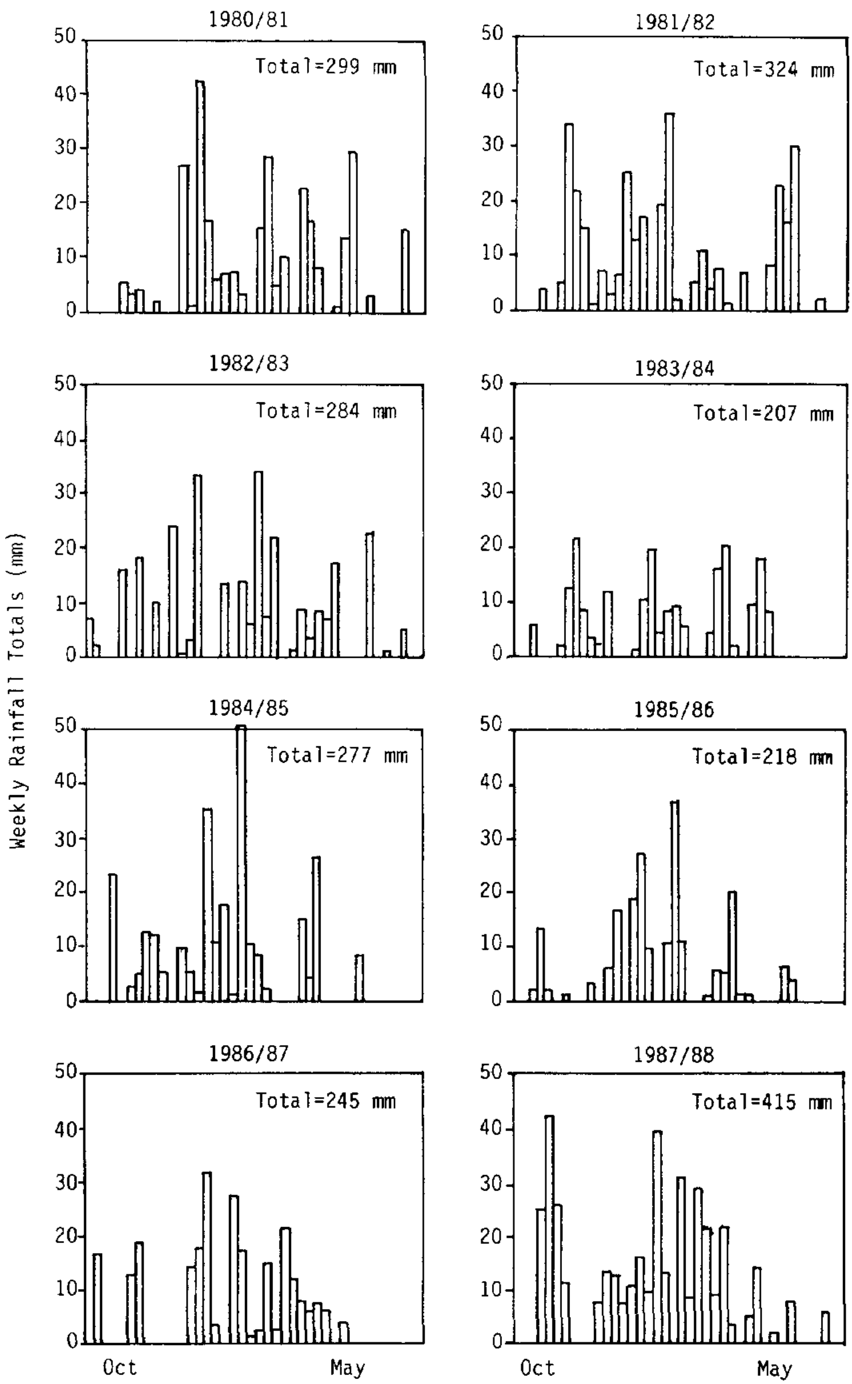


Figure 3.4a Weekly rainfall at Breda, 1980/81 to 1987/88. Figures are seasonal totals.

Table 3.6 The amount (mm) and proportion (%) of current season's rainfall stored under fallow, or barley and vetch crops at the time of maximum recharge of the soil water profile in the seasons 1983/84 to 1987/88. Also shown are the maximum depth of soil wetting in each season, and the proportion of rainfall stored under fallow at the time of harvest of barley crops and at the end of the following summer.

Treatment		Season 83/84	84/85	85/86	86/87	87/88
F/B_{NP}	stored water mm	37	97	94	56[1]	164
	% of rain	33.0	53.0	54.0	27.0	47.0
	max. depth cm	30	90	75	60	>150
B_{NP}/F	stored water mm	35	108	86	46	144
	% of rain	31.1	59.0	49.2	31.7	41.0
	max. depth cm	30	90	75	45	>135
B_{NP}/B_{NP}	stored water mm	36	97	82	51	146
	% of rain	32.1	52.6	46.8	35.6	41.5
	max. depth cm	30	90	60	45	150
B_{NP}/V_0	stored water mm	33	112	82	56	146
	% of rain	29.6	60.9	46.8	35.6	41.5
	max. depth cm	30	90	60	45	120
B_0/V_P	stored water mm	35	109	83	56	156
	% of rain	31.1	59.2	47.4	39.1	44.4
	max. depth cm	30	90	60	45	150
V_0/B_{NP}	stored water mm	36	103	95	53	141
	% of rain	32.6	55.9	54.0	37.1	45.9
	max. depth cm	30	90	75	45	135
V_P/B_{NP}	stored water mm	-	112	84	51	148
	% of rain	-	60.9	47.5	35.6	42.2
	max. depth cm	-	90	75	45	120
Fallow (% of rain)		33	53	54	27	47
Barley (% of rain)[2]		33	53	47	36	42
Vetch (% of rain)[2]		29	58	51	36	44
% Fallow-stored rain at barley harvest		14	25	46	37	29
% Fallow-stored rain at end of summer		2.8	6.7	4.6	7.8	8.5

1. Maximum later in the season than in other treatments
2. Mean of the above for each crop

Note: In this and further tables and figures, F=Fallow, B=Barley; V=Vetch; subscript N and/or P refers to application of 20 kg/ha of elemental N and/or 60 kg/ha of P_2O_5; and subscript O=no fertilizer.

The data of Tables 3.4 and 3.5 show that loss of water also occurs during the summer from plots that have been cropped during the season. Averaged over treatments (except fallow), this loss amounts to approximately 10 mm from the 0-15 cm soil layer, plus a similar amount from the remainder of the soil profile. It represents drying of the profile beyond the lower limit of plant extractable water towards air dryness. Whilst these are small quantities, they represent water which must be replenished in the following season before the accumulation of plant extractable water can begin.

3.3.5 Fertilizer and Water Use Efficiency

The increase in water use efficiency of both barley and vetch in response to fertilizer, especially phosphate, at this site and in this trial has been documented in detail elsewhere (e.g., ICARDA 1981; ICARDA 1983; Cooper 1983; ICARDA 1984; Rached 1986; Cooper et al. 1987). Some findings are summarized in Table 3.7 for completeness of this report, but are not discussed in detail.

One effect of fertilizer is to enhance early growth. This leads to the more effective storage of water noted in the previous section, and causes a greater proportion of the water to be transpired by the growing crop. Since biomass production is linearly related to the amount of water transpired, any increase in transpiration at the expense of soil evaporation will increase the efficiency of water use. Phosphate promotes growth early in the season when the vapour pressure deficit of the atmosphere is low and the transpiration efficiency is at its maximum for the environment (Cooper and Gregory 1987).

One of the consequences of phosphate deficiency is delayed physiological development. Fertilized crops reach both anthesis and maturity a few days to 2 weeks earlier than unfertilized ones. In an environment where both the temperatures and evaporation rates rise quickly in the spring (Figure 3.4b) earliness helps to

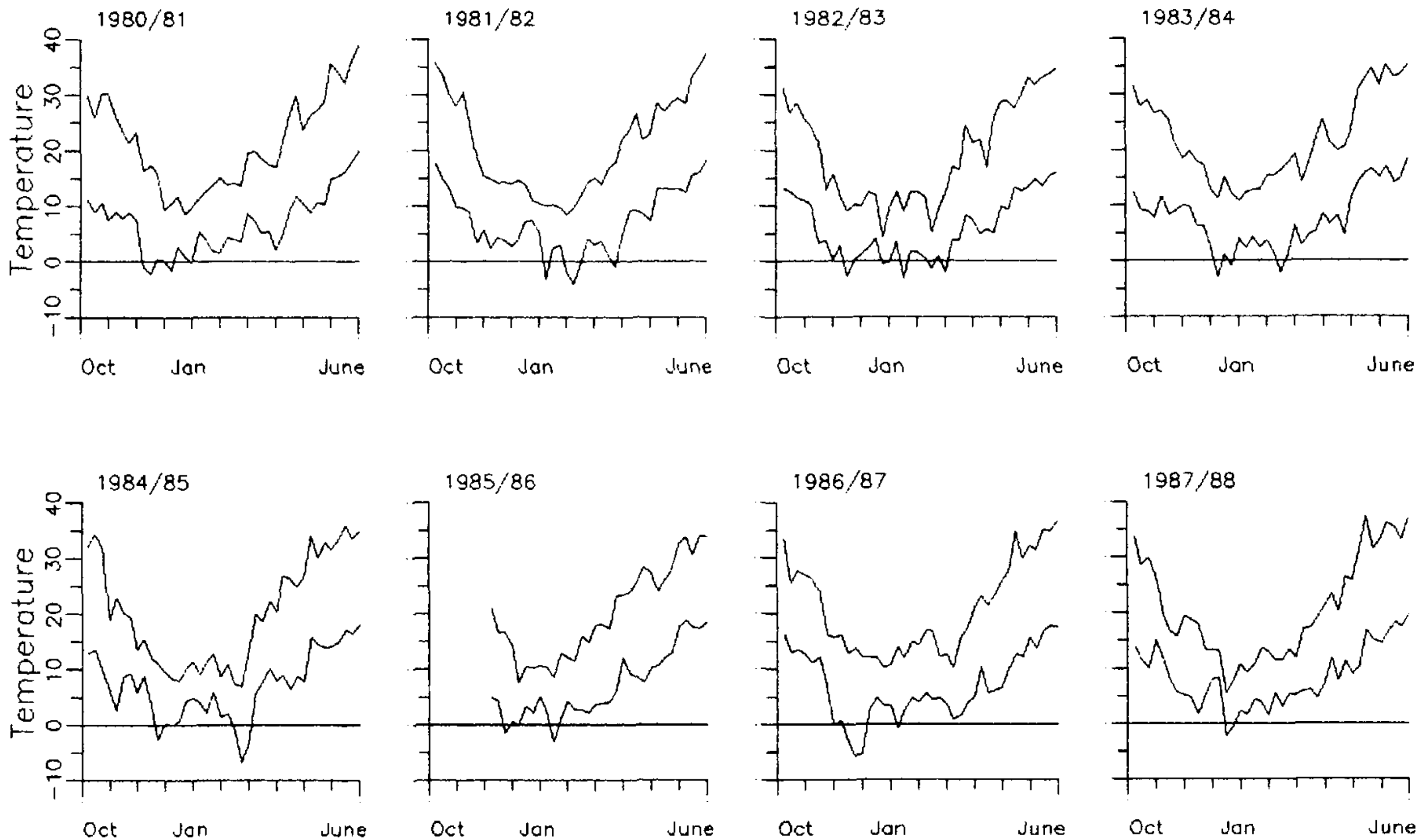


Figure 3.4b Weekly mean maximum and minimum temperatures at Breda during the crop growth season

reduce the severity of these stresses in the final stages of crop development.

Table 3.7 Total biological yield (kg/ha) and water use efficiency (kg/ha/mm) of barley and vetch with and without fertilizer

	Season							
	Fertilized				Unfertilized			
Treatment	80/81	81/82	82/83	83/84	80/81	81/82	82/83	83/84
B/F TBY	4500	5085	5325	3430	2770	4030	2015	1740
WUE	19.7	-	21.6	17.2	11.4	15.1	8.8	9.1
V/B[1] TBY	3330[2]	1830	2300	815	2130[2]	1165	1460	575
WUE	17.3	8.4	-	5.1	11.5	5.6	-	-

TBY = Total biological yield, WUE = Water use efficiency.
1. Fertilizer applied either in the barley or vetch phase.
2. Following fallow in the first year of the trial.

3.3.6 Water Use Efficiency by Barley and Vetch

Total biomass production, water use and water use efficiency of vetch and barley have varied substantially from year to year (Table 3.8). In general, and as is to be expected, the variation is largely related to the total quantity of rainfall and its distribution throughout the season. The amount of rain in the preceding season modifies the water available to the crop not only in the fallow/barley sequence but also when barley follows vetch. As has been reported previously (ICARDA 1986), vetch harvested at the hay stage does not always use all of the water stored in the profile and there may be carry over to the next season. This is used by the succeeding barley crop. Some of the difference in barley yield between 1985/86 and 1986/87, two years with similar total rainfall and rainfall distribution, is due to water remaining after vetch crops in 1984/85.

Table 3.8 Yield, water use and water use efficiency of barley and vetch crops in two course rotations at Breda from 1982/83 to 1987/88

Treatment		82/83	83/84	84/85	85/86	86/87	87/88
B_{NP}/F	TBY	5325	3430	4755	5465	3395	8785
	WU	247	200	246	208	237	333
	WUE	21.6	17.2	19.4	26.3	14.3	26.4
B_{NP}/B_{NP}	TBY	3040	2125	4310	2085	2255	4095
	WU	227	185	236	177	227	310
	WUE	13.4	11.5	18.3	11.8	9.9	13.2
B_{NP}/V_0	TBY	4175	2405	4825	4115	3120	7975
	WU	226	189	237	190	231	346
	WUE	18.5	12.7	20.3	21.6	13.5	23.0
B_{NP}/V_P	TBY	5080	2925	5055	4555	3545	8030
	WU	-	190	236	192	220	329
	WUE	-	15.4	21.4	23.7	16.1	24.4
B_0/V_P	TBY	2895	2105	3345	3026	2175	5985
	WU	-	189	237	186	230	312
	WUE	-	11.1	14.1	16.5	9.5	19.2
V_0/B_{NP}	TBY	2295	815	2830	2495	2525	3670
	WU	-	160	218	153	205	258
	WUE	-	5.1	13.0	16.3	12.3	14.3
V_P/B_{NP}	TBY	3250	960	4315	2620	3360	3670
	WU	-	-	224	159	207	267
	WUE	-	-	19.3	16.5	16.2	13.7
V_P/B_0	TBY	2310	910	3555	2910	2765	3750
	WU	-	148	218	157	204	258
		-	6.2	16.3	18.6	13.6	14.5

TBY = Total biological yield (kg/ha); WU = Water use (mm); WUE = Water use efficiency (kg/ha/mm).
Data refer to the first mentioned crop in the treatment code.

The relative yield of the two crops also differs between years. Barley is harvested approximately one month after vetch and weather events in that time can strongly influence the yield of barley. For example, in 1986/87 vetch yields were among the best recorded, but barley yields were poor. An early end to effective rain and a heatwave in early May severely stressed the barley, whereas growing conditions were excellent up to the time of vetch harvest in early April.

Barley following fallow has the greatest water use efficiency, although only slightly more so than the B_{NP}/V_P sequence. This is more evident in total biomass (Table 3.8) than in grain yield (Figure 3.5). Continuous barley crops are the least efficient. This was most clearly demonstrated in 1987/88 when crops in this sequence were less able to respond to the favorable seasonal conditions than those in any other sequence, and the water use efficiency was only half of that of barley following fallow. If all of the yield increase due to fallow is a result of additional water then the extra 10 to 30 mm available to the fallow/barley crops, over and above the quantity available to continuous barley, must be used extremely efficiently indeed. However, it seems unlikely that all of the yield difference between these two crop sequences is due to water alone. Other factors, of which nitrogen is speculatively one, undoubtedly contribute.

In vetch, the application of phosphate in the year of the crop increases the efficiency of water use, and there is a trend for it to be further improved by the addition of phosphate in both phases of the rotation. The anomalous results for the 1987/88 season, where vetch yields were equal in all fertilizer sequences, was due to grazing of the crop by birds from a neighboring village. In the drought year of 1983/84 the water use efficiency of vetch was more severely reduced than that of barley, suggesting physiological differences between the species.

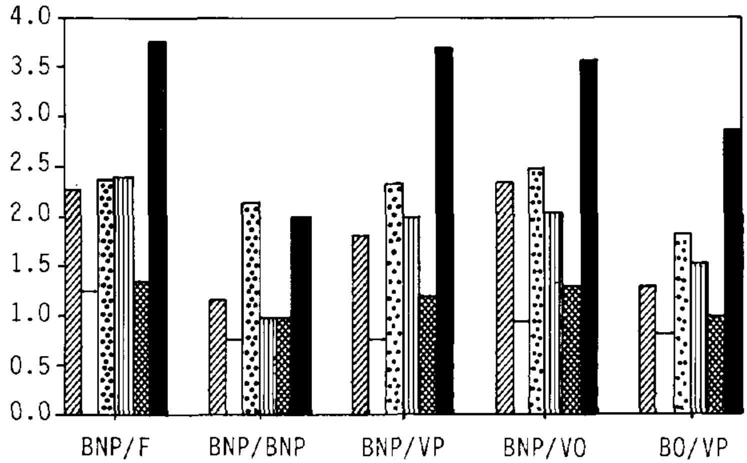


Figure 3.5a Barley grain yield in 5 crop sequences, in the seasons 1982/83 to 1987/88. Bars from left to right represent crop seasons from 1982/83 to 1987/88

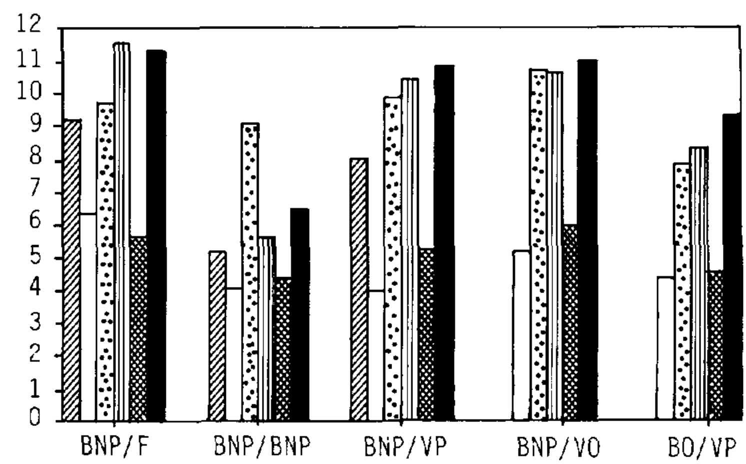


Figure 3.5b Water use efficiency for grain in 5 crop sequences. Bars from left to right represent years from 1982/83 to 1987/88

3.3.7 Water Use Efficiency of Rotations

To this point the water use efficiency has been considered only for individual crops within one season. However, in a system where there appear to be options for utilization of one or more of several crop and fertilizer sequences it is more relevant to evaluate the water use efficiency of the rotations.

If a farmer has an area of land it could be expected that he would put half of it into each phase of a rotation each year. The water use efficiency would then need to be estimated as the sum of the yield of each crop divided by the sum of the water use of each crop. These estimates (Table 3.9) show clearly that a rotation including fallow is the least efficient. Fertilized continuous barley or unfertilized barley in rotation with fertilized vetch are both more efficient, but fertilizer in the barley phase, or in both phases, gives a continuing increase in yield and water use efficiency.

Alternatively, water use efficiency can be estimated by considering sequential crop yields. In this case, data from two years are used to estimate the efficiency, e.g. one year with vetch, the next with barley, the next with vetch etc. These estimates are shown in Table 3.10. The differences in relative yield between the crops in any one year can influence the outcome of this assessment. The data of Table 3.10 have been derived by considering crop sequences beginning with either barley or the alternative in the same year. These are referred to as Phase I and Phase II. Obviously, it does not make sense to consider fallow following barley, so this has been omitted.

The estimates of water use efficiency made in this way differ somewhat from those of Table 3.9, but the conclusion reached is the same. The most efficient crop and fertilizer sequence is fertilized barley followed by, or following, fertilized vetch, and the least efficient is barley following fallow. Overall efficiency can be improved by the inclusion of a legume, rather than through barley monoculture, and is better when

Table 3.9 Total biological yield (kg/ha), water use (mm), and water use efficiency (kg/ha/mm) of the two phases of a rotation in a single year

Crop Rotation	Season	Total Biological Yield kg/ha	Total Water Use (mm)	Water Use Efficiency kg/ha/mm
B_{NP}/F	1983/84	1715	190	9.0
	1984/85	2380	217	11.0
	1985/86	2735	176	15.6
	1986/87	1700	221	7.7
	1987/88	4390	287	15.3
B_{NP}/B_{NP}	1983/84	2125	186	11.5
	1984/85	4080	235	17.4
	1985/86	2205	176	12.5
	1986/87	2360	227	10.4
	1987/88	4040	311	13.0
B_{NP}/V_0	1983/84	1610	175	9.2
	1984/85	3830	228	16.8
	1985/86	3305	172	19.3
	1986/87	2825	218	13.0
	1987/88	5825	302	19.3
B_{NP}/V_P	1984/85	4685	230	20.4
	1985/86	3590	176	20.4
	1986/87	3455	213	16.2
	1987/88	5850	299	19.6
B_0/V_P	1983/84	1510	169	9.0
	1984/85	3450	228	15.1
	1985/86	2990	172	17.4
	1986/87	2470	217	11.4
	1987/88	4870	286	17.0

phosphate is applied in the barley phase than in the legume phase.

3.3.8 Conclusion

While these findings relate to small plot areas, there seems to be no reason why the principles should not also apply on a large scale. It thus appears that it should be biologically

Table 3.10 Total biomass yield, water use, and water use efficiency of two course rotations of forage crops, estimated from 2-year sequences

Crop Sequence	Years	Phase I			Phase II			Mean	
		TTBY	TWU	WUE	TTBY	TWU	WUE	TTBY	WUE
B_{NP}/F	1983/85	4755	426	11.2	-	-	-	4755	11.2
	1984/86	5465	396	13.8	-	-	-	5465	13.8
	1985/87	3395	380	8.9	-	-	-	3395	8.9
	1986/88	8785	536	16.4	-	-	-	8785	16.4
B_{NP}/B_{NP}	1983/85	5970	418	14.3	na	na		(5970)	(14.3)
	1984/86	6165	410	15.1	6395	412	15.5	6280	15.3
	1985/87	4780	403	11.9	4345	403	10.8	4565	11.3
	1986/88	6440	538	12.0	6350	537	11.8	6400	11.9
B_{NP}/V_0	1983/85	5640	398	14.5	5235	407	12.9	5440	13.5
	1984/86	7320	391	18.7	6945	408	17.0	7130	17.9
	1985/87	5615	384	14.6	6640	396	16.6	6130	15.7
	1986/88	6790	488	13.9	10500	551	19.0	8645	16.5
B_{NP}/V_P	1983/85	6015	na		7240	414	17.5	(7240)	(17.5)
	1984/86	7675	395	19.4	8870	416	21.3	7040	20.4
	1985/87	6165	378	16.3	7915	399	19.8	5460	17.1
	1986/88	7215	487	14.8	11390	536	21.2	9300	18.0
B_0/V_P	1983/85	4255	385	11.0	5660	407	13.9	4960	12.5
	1984/86	6255	394	15.9	6620	404	16.4	6440	16.1
	1985/87	5085	387	13.1	5830	390	15.0	5460	14.0
	1986/88	5925	488	12.1	8750	516	17.0	7335	14.5

TTBY = Total biological yield from both phases of a crop sequence (kg/ha/2 years)
TWU = Total water use by both phases of the crop sequence (mm (/2 ha))
Figures in parentheses are from only one phase of the rotation.

feasible to replace fallows with a legume to both increase the productivity of the system and to sustain production in the long term.

The ultimate test of whether these changes to the system can be adopted by farmers is their economic feasibility, and whether farmers see opportunities in the changes that will fit their goals and management skills.

Large scale on-farm trials carried out over several years have indicated that vetch (and Lathyrus sativus (chickling)) can provide very satisfactory economic returns when they are grazed in the green stage for the fattening of weaner lambs, or when they are harvested at maturity (PFLP 1986). Farmers participating in the trials had initial reservations about a possible adverse effect of legumes on barley yield, but were satisfied by the end of the trial that these were not justified (PFLP 1987). However, their ability to implement the new crop sequences is limited by their ability to purchase fertilizer, and by the supply of both fertilizer and vetch seed. A recent policy change which makes credit available for the purchase of fertilizer has relieved the first of these constraints, but the supply of fertilizer still remains a problem.

The supply of vetch seed could be achieved by reserving about one quarter of the sown area for harvest for seed. In this case the residue would be stored for feeding during the winter. One consequence of this could be that the vetch would use more water, and the benefit of water which remains after the hay harvest would be lost to the following barley crop. This is being tested in a small subsidiary trial (see section 3.2.2 of this report).

Alternatively, a demand for seed in the dry areas could lead to the development of a seed production industry in wetter areas of the country where production would be more secure. In either environment costs of hand harvesting are likely to be a problem until methods for mechanical harvesting are perfected. Vetch has a very similar growth habit to lentil and methods being developed for that crop (FLIP 1987) are also expected to be suitable for it.

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3.4 Phosphorus Requirement of Food and Forage Legumes: Residual and Applied Fertilizer Effects

A.E. Matar, M. Saxena and S. Silim

3.4.1 Introduction

In West Asia and North Africa, food and forage legumes are almost always grown under rainfed conditions after cereals, and the highly calcareous soils on which they are grown and which predominate in the region are typically low in available native phosphorus. It is not surprising, therefore, that economic responses to phosphorus application have been observed for lentil, vetch and faba bean in Syria (Loizides 1970, Matar 1976), Libya (Badawy 1976), Pakistan (Sharar et al. 1976) and other parts of the region. However, the relationships between the level of available P in soil, and the response of food and forage legumes to phosphate fertilization remain unclear since studies along this line have been very limited. The earlier work (Matar 1976) had shown that in average rainfall years (300 mm), 3.5 to 4 parts per million of available P in soils, as determined by the Olsen-P test, led to maximum production of lentil grain on the Houran Plain of Syria, but that higher levels were required in drier than normal years. Given the limitation of earlier work, expanded studies were initiated with three principal objectives:

1. To study the effect of residual and newly applied phosphate on grain, total biological yields, total P and N uptakes of pea, chickpea, faba bean, lentil and vetch;

2. To relate soil tests for P with the response of legumes to P fertilization;

3. To determine the levels of soil P that maximize production of food and forage legumes.

The experiments were conducted in Northern Syria for three consecutive seasons on soils derived from calcareous rocks and classified as typic Chromoxererts and/or Vertic Xerochrepts.

3.4.2 Phosphate Experiments in Farmers' Fields, 1985/86

Eighteen fertilizer P experiments with lentil and chickpea were conducted in farmers' fields in the Idleb-Aleppo region at sites where available P in soils (Olsen test) ranged between 3.7 and 24 parts per million. A randomized complete block design with 4 levels of P applied (0, 50, 100 and 150 kg P_2O_5/ha) and three replicates was used. Total dry matter and total P uptake were determined at flowering and grain and straw yields were recorded at harvest.

3.4.3 Results

The total P uptake by lentil at flowering and total dry matter obtained on the unfertilized plots was significantly ($P<0.01$) related to the level of available-P determined at sowing. However, the relationship was less significant with grain yield ($P<0.05$). The equations relating P-uptake, total dry matter and grain yield to the initial levels of available-P are presented in Table 3.11.

Table 3.11 Linear equations relating P uptake at flowering, total dry matter (TDM) at harvest, and grain yield of lentil to Olsen-P values in unfertilized plots in 1985/86 season

Variable	Regression equations	R
P uptake at flowering (kg/ha)	= 0.459 P + 3.0185	0.63**
Total dry matter (t/ha)	= 0.200 P + 1.764	0.68**
Grain yield (kg/ha)	= 35.19 P + 1154	0.25*

Pooled analyses of all experiments showed highly significant responses to P fertilizer in farmers' fields with less than 5 ppm of available P in the top soil. However, no response to P was observed in sites where available P exceeded 7 ppm.

In contrast to lentil, P-uptake at flowering, total dry matter and grain yield of chickpeas correlated poorly with the Olsen-P at sowing. Responses to P fertilization were only observed in 3 trials out of the eighteen, and these occurred in fields with very low levels of available P (less than 3 ppm). Even at these locations, responses were only observed in P-uptake at flowering and total dry matter. No relationship was observed between grain yield and rate of P applied.

Several explanations for the lack of chickpea response to P fertilization as compared to other food legume crops have been advanced. Firstly, the seed reserve of P in chickpea (approx. 0.96 mg P) is 9 times greater than that found in the smaller seeds of the local lentil used in this study leading to an excellent start for chickpea even in low-P soils. Secondly, few active roots of chickpea are found in the top 10 cm of the soil, and this is where phosphate fertilizer is incorporated. Since diffusion of applied P is very slow in calcareous clay soils, little if any downward movement of fertilizer occurs. Thirdly, the pH of the rhizosphere around the chickpea roots has been shown to be quite low and consequently insoluble native calcium phosphates could become available for uptake by the chickpea roots.

3.4.4 Phosphate Experiments on Tel Hadya Station: 1986/87 and 1987/88

To calibrate the response of food and forage legumes to P fertilization under more controlled conditions than was possible in farmers' fields, experiments were conducted on Tel Hadya farm during the 1986/87 and 1987/88 season. In the season preceding each experiment, the experimental area was divided into 5 large blocks of land which received varying levels of P-fertilizer (0, 50, 100, 150, 200 kg P_2O_5/ha). The whole area was then sown to wheat. This pre-treatment of the experimental area provided a range of residual available P-levels under which responses of food and forage legumes could be evaluated. In the subsequent year, these main plots were split for legume species (pea, chickpea, faba bean, lentil[1] and vetch) and for three levels of phosphate placed with the seed at planting (0, 50, 100 kg P_2O_5/ha). At harvest, total dry matter, grain yield, total P uptake and total N uptake were recorded. In reporting our results this year, we will focus on total dry matter production, but reference will also be made to nutrient uptake in the seed.

3.4.5 Results

The significance levels of response of total dry matter, phosphorus and nitrogen uptake in the seed for the two years are given in Table 3.12. Table 3.13 presents the main effect responses in total dry matter to 100 kg P_2O_5/ha of residual or applied phosphorus for each of the five legume species. More detailed results of total dry matter responses are given in Tables 3.15 to 3.19. Grain yield data, which closely reflected those for Total Dry Matter (TDM) are not presented in this report.

The 1987/88 season was much wetter than the 1986/87 season, and this clearly influenced legume productivity and responses to phosphate in general.

The maximum TDM values recorded in the wet and dry year (irrespective of treatment) for the five legumes were: pea 7.8 vs 6.0 t/ha, chickpea 4.3 vs 4.3 t/ha, faba bean 6.7 v 4.6 t/ha, lentil 7.8 vs 5.1 t/ha and vetch 9.0 v 7.4 t/ha. The results in Tables 3.12 and 3.13 confirm that, with the exception of the pea crop, responses to phosphate were much greater and more consistent in the dry year of 1986/87 than in the following wetter year. This has also been observed and reported for barley and wheat (see sections 2.1 and 6.7 of this report). Due to the immobility of

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1. The lentil component of this trial forms part of an MSc thesis study in cooperation with Aleppo University.

phosphate in calcareous soils, P-uptake depends upon root contact with available-P sources in the soils. In wetter years, more extensive root systems develop which are better able to exploit native soil available-P, and in addition, in such years the soil surface horizons (which contain the highest levels of available-P) remain moist for longer periods thus enhancing root activity and P-uptake from these layers.

Table 3.12 Significance levels of total dry matter (TDM), total P uptake by grain (TPU), total N uptake by grain (TNU) responses to residual or applied phosphate fertilizer at Tel Hadya, Syria, 1986/87 and 1987/88[1]

	1986/87 Rainfall 358 mm			1987/88 Rainfall 504 mm		
Crop and variable	Residual P	Applied P	Interaction Res x App	Residual P	Applied P	Interaction Res x App
Pea						
TDM	***	***	+	*	–	–
TPU	***	***	+	*	**	*
TNU	***	***	**	–	–	–
Chickpea						
TDM	–	*	+	–	–	–
TPU	*	**	+	–	–	–
TNU	+	*	*	–	+	–
Fababean						
TDM	**	***	–	–	–	–
TPU	**	***	–	–	–	–
TNU	**	**	–	–	–	–
Lentil						
TDM	+	**	–	***	–	–
TPU	+	**	–	–	**	–
TNU	–	–	–	–	**	–
Vetch						
TDM	*	***	*	–	–	–
TPU	*	***	*	–	–	–
TNU	–	***	*	–	–	–

1) ***P<0.001, **P<0.01, *P<0.05, +P<0.10

Table 3.13 The main responses (kg/ha) of total dry matter in five legume species to 100 kg P_2O_5/ha of residual or applied phosphorus at Tel Hadya, Syria

	Pea	Chickpea	Faba bean	Lentil	Vetch	Mean
			1986/87			
Residual-P	1072	969	683	983	738	889
Applied-P	1292	352	553	570	1459	845
Mean	1182	660	618	776	1098	
			1987/88			
Residual-P	1604	16	381	290	42	466
Applied-P	1244	156	0	656	56	422
Mean	1424	86	190	473	49	

As indicated, the pea crop was most consistent, and gave the greatest response in both years. Phosphate uptake is soil temperature dependent, slower rates occurring at lower temperatures, and thus uptake is retarded during the winter months in Mediterranean environments. Other research (FLIP 1984) has shown that of these five legumes, the pea crop has the fastest rate of growth, and thus P-uptake requirements, in the winter months. It thus seems probable that large responses of the pea crop to both residual and applied phosphate are closely related to this faster growth during the winter months. This temperature dependency of P-uptake has also been found in barley, where greater responses to P-fertilizer are generally observed in years with frequent frost events.

Of equal interest, and certainly of great economic significance is the fact that legumes appear almost equally responsive to both applied and residual phosphate (Tables 3.13 and 3.15 to 3.19). The interactions between residual and applied phosphate are also important. P application to a previous wheat crop raises the overall level of productivity of the succeeding legume, but does not in general substantially reduce the response obtained to P applied with the legume seed. However, the interactions do indicate, as would be expected, that responses are reduced in some instances when high levels (200 kg P_2O_5/ha) of P were applied to preceding wheat. Biologically speaking, residual and applied-P are likely to have different "timing" of availability, thus we would expect that the relative importance of the two sources will not only depend upon the characteristics of legume root development, but also the temperature and moisture distributions of the season. Phosphate applied with the legume seed will be immediately available to provide a boost to young seedlings with poorly developed root systems. However, as these root systems develop, they increasingly become able to utilize residual-P fertilizer which will have been distributed throughout the cultivation layer by pre-planting tillage and seeding operations. Moisture conditions will also play a role. Applied-P is placed with the seed at around 5 cm depth, and will only be available for uptake as long as this shallow layer of soil is sufficiently moist to allow root activity. Residual-P will be more uniformly distributed to the depth of cultivation (up to 30 cm), and thus not only becomes utilized at a later stage, but due to the slower drying of deep soil layers, will also remain available for longer periods. This is illustrated by the data in Table 3.14 which presents seasonal changes in TDM of pea and vetch under four contrasting fertilizer treatments in the 1986/87 season, a relatively 'normal' year. Early dry matter production (2nd sampling date) was given a significant boost by 100 kg P_2O_5 applied phosphate, but at this stage, the effect of residual-P was small. As the season progressed, the effect of residual-P (both in the presence and absence of applied-P) became more significant.

Table 3.14 Seasonal changes in dry matter production (kg/ha) of peas and vetch in contrasting P-fertilizer treatments at Tel Hadya, Syria 1986/87

P-Fertilizer (kg P_2O_5/ha)		Peas Date of Sample				
Residual	Applied	18/2	1/4	14/4	1/5	19/5
0	0	97	271	706	1947	2866
100	0	112	383	1204	2405	3956
0	100	98	477	1138	2722	4519
100	100	105	451	1561	3236	5392
LSD 0.05		33	161	574	1024	768
		Vetch Date of Sample				
		18/2	8/3	9/4	29/4	22/5
0	0	342	688	1798	4374	4583
100	0	405	984	2510	4018	5863
0	100	580	1267	2989	5544	6503
100	100	497	1342	2954	5738	6703
LSD 0.05		217	376	984	971	854

Table 3.15 Effects of residual and applied phosphate on total dry matter at harvest of peas in 1986/87 and 1987/88 at Tel Hadya, Syria (kg/ha)

Applied P kg P_2O_5/ha	1986/87 Residual Phosphate (kg P_2O_5/ha)					
	0	50	100	150	200	Mean
0	2866	3368	3996	4999	4827	4011
50	4447	4695	5700	5673	5838	5269
100	4519	5408	5392	5104	6058	5295
Mean	3944	4490	5016	5259	5574	
Signif. Level	Applied P(***); Residual P(***); Interaction (+)					

Applied P kg P_2O_5/ha	1987/88 Residual Phosphate (kg P_2O_5/ha)					
	0	50	100	150	200	Mean
0	3540	5243	6382	6276	6875	5663
50	4575	5810	5853	6965	7628	6166
100	6282	6188	6973	7778	7315	6907
Mean	4799	5747	6403	7006	7272	
Signif. Level	Applied P(NS); Residual P(*); Interaction (NS)					
Significance	P<0.001(***); P<0.01(**); P<0.05(*) and P<0.10(+)					

Table 3.16 Effects of residual and applied phosphate on total dry matter at harvest of chickpea in 1986/87 and 1987/88 at Tel Hadya, Syria (kg/ha)

Applied P kg P_2O_5/ha	1986/87 Residual Phosphate (kg P_2O_5/ha)					
	0	50	100	150	200	Mean
0	2281	3494	3166	3375	3294	3122
50	2566	2974	3368	3959	3177	3208
100	2819	3145	4038	4287	3083	3474
Mean	2555	3204	3524	3874	3184	
Signif. Level	Applied P(*); Residual P(ns); Interaction (+)					

Applied P kg P_2O_5/ha	1987/88 Residual Phosphate (kg P_2O_5/ha)					
	0	50	100	150	200	Mean
0	3541	3425	3927	3723	3940	3711
50	3383	3525	3433	3630	3583	3710
100	3895	3638	3508	4025	4270	3867
Mean	3606	3529	3622	3792	4264	
Signif. Level	Applied P(NS); Residual P(NS); Interaction (NS)					
Significance	P<0.001 (***); P<0.01(**); P<0.05(*) and P<0.10(+)					

Table 3.17 Effects of residual and applied phosphate on total dry matter at harvest of faba bean in 1986/87 and 1987/88 at Tel Hadya, Syria (kg/ha)

Applied P kg P_2O_5/ha	1986/87 Residual Phosphate (kg P_2O_5/ha)					
	0	50	100	150	200	Mean
0	3191	3648	3847	3528	3935	3630
50	3599	3815	4424	4407	4640	4177
100	3750	4287	4318	4077	4485	4183
Mean	3513	3917	4196	4004	4353	
Signif. Level	Applied P(***); Residual P(**); Interaction (NS)					

Applied P kg P_2O_5/ha	1987/88 Residual Phosphate (kg P_2O_5/ha)					
	0	50	100	150	200	Mean
0	4567	5394	5497	6706	6047	5642
50	5219	6439	5915	6350	6715	6127
100	5419	5706	4936	5983	5752	5559
Mean	5068	5846	5449	6346	6171	
Signif. Level	Applied P(NS); Residual P(NS); Interaction (NS)					
Significance	P<0.001 (***); P<0.01(**); P<0.05(*) and P<0.10(+)					

Table 3.18 Effects of residual and applied phosphate on total dry matter at harvest of lentil in 1986/87 and 1987/88 at Tel Hadya, Syria (kg/ha)

Applied P kg P_2O_5/ha	1986/87 Residual Phosphate (kg P_2O_5/ha)					
	0	50	100	150	200	Mean
0	3447	4160	4833	4427	4597	4293
50	3873	4230	4600	5003	5180	4577
100	4260	4890	5097	5063	5007	4863
Mean	3860	4427	4843	4831	4928	
Signif. Level	Applied P(**); Residual P(+); Interaction (NS)					

Applied P kg P_2O_5/ha	1987/88 Residual Phosphate (kg P_2O_5/ha)					
	0	50	100	150	200	Mean
0	6092	6740	6811	7301	7557	6900
50	7416	7410	7582	7846	7588	7569
100	7625	7726	7610	7294	7524	7556
Mean	7044	7292	7334	7480	7556	
Signif. Level	Applied P(NS); Residual P(***); Interaction (NS)					
Significance	P<0.001 (***); P<0.01(**); P<0.05(*) and P<0.10(+), NS					

Table 3.19 Effects of residual and applied phosphate on total dry matter at harvest of vetch in 1986/87 and 1987/88 at Tel Hadya, Syria (kg/ha)

Applied P kg P_2O_5/ha	1986/87 Residual Phosphate (kg P_2O_5/ha)					
	0	50	100	150	200	Mean
0	4583	4960	5863	6103	6153	5533
50	5923	6590	6658	6863	5530	6313
100	6503	7195	6703	7351	7210	6992
Mean	5670	6248	6408	6772	6298	
Signif. Level	Applied P(***); Residual P(*); Interaction (*)					

Applied P kg P_2O_5/ha	1987/88 Residual Phosphate (kg P_2O_5/ha)					
	0	50	100	150	200	Mean
0	7120	7648	7312	7470	9005	7711
50	7242	8063	7390	7216	7913	7565
100	7453	7858	7238	8232	8055	7767
Mean	7271	7856	7313	7639	8324	
Signif. Level	Applied P(NS); Residual P(NS); Interaction (NS)					
Significance	P<0.001 (***); P<0.01(**); P<0.05(*) and P<0.10(+)					

Where large responses to phosphate were found, it was also observed that total nitrogen uptake was increased, although the %N in the seed remained relatively constant across phosphate treatments within any one species. Available mineral soil-nitrogen levels following a wheat crop are generally low, and thus the extra nitrogen uptake stimulated by phosphorus fertilizer will largely come from enhanced biological nitrogen fixation (BNF). This has been clearly demonstrated by specific studies examining factors affecting BNF by food and forage legumes in the phosphate deficient soils of the Mediterranean region (ICARDA 1985). In addition to this, it is probable that the more extensive root systems of P-fertilized legumes were better able to utilize whatever native soil nitrogen was available for uptake.

3.4.6 Conclusion

The effects observed in this research result from many soil and climate factors and root and shoot growth characteristics, and the interactions between them. Our current knowledge of the effect of these season and location specific factors is still imperfect, and thus our ability to predict the outcome of different P-fertilizer strategies within cropping systems is also limited. However, economically speaking, two important facts are clear. Firstly, calculations of the economics of fertilizer application should never be restricted to the year and crop of application. In this specific experiment, calculations of rate of return to money spent on fertilizing the wheat crop alone would seriously underestimate the overall profit obtained from phosphate fertilizer in wheat/legume rotations. This places a question mark on the value of single season fertilizer trials which do not measure residual effects in subsequent years. Secondly, it is also clear that even when residual P-fertilizer raises the levels of soil available-P to levels at which "% relative yield increases" due to applied-P (relative yield is calculated as the increase in yield due to fertilizer as a % of the control) are likely to decrease, in absolute terms, such yield increases are still likely to be both statistically significant and economically worthwhile.

3.4.7 References

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3.5 Second-Year Residual Effects from N and P Fertilizers in Barley On-Farm Trials

M.J. Jones and A. Wahbi

Each year a small number of the sites carrying on-farm barley fertilizer trials (FRMP/Soils Directorate collaborative work, see section 2.1 of this report) has been retained for a second year, so that residual effects of those fertilizers on the following crop can be monitored. The test crop used has been a vetch/barley mixture harvested as hay.

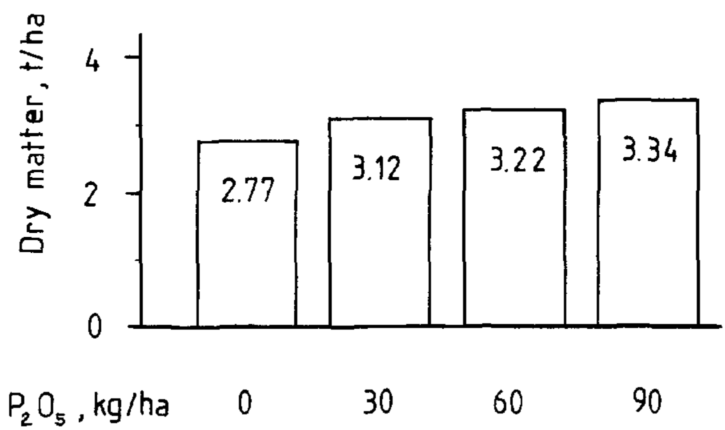
Results, from a total of 14 sites, showed a marked reduction in the number of statistically significant responses (at 10% level or better) from the first crop to the second:

	Number of significant responses to fertilizer	
	N	P
1st year barley (dry matter)	10	14
2nd year vetch/barley hay	1	5

Detectable responses of hay yield to previous N fertilization were few. There was some tendency for the vetch component of the dry matter to decrease with increasing N-rate (significant at 2 sites) and for the barley component to increase (significant at 1 site); but at most sites, and on average over the 14 sites, such effects were negligible.

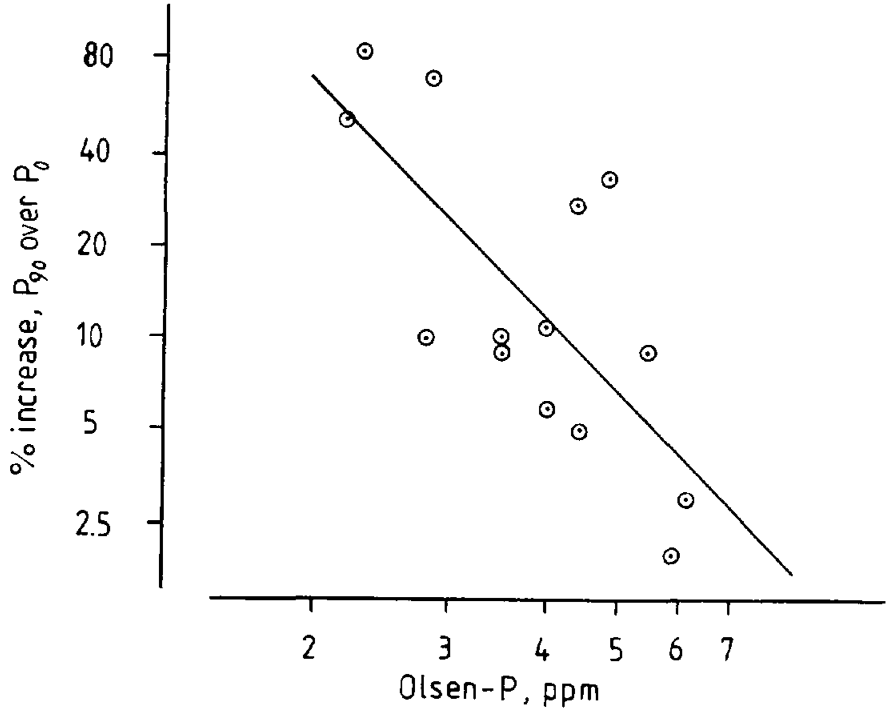
Responses to previous P fertilization were more frequent and larger. At some sites it was the vetch component that responded, at others it was the barley. Only at one site did both components show separate significant responses. Averaged over the 14 sites, total hay dry matter production was increased in regular increments up to 0.57 t/ha (20%) by the three increments of previous phosphate application, 30, 60 and 90 kg P_2O_5/ha (Figure 3.6).

Figure 3.6 Residual effect of phosphate fertilizer on vetch/barley hay yields: means of fourteen sites



These increases were related to the available phosphate content of the original soil, as measured by the Olsen method at the time the first barley crop was planted. A log-log regression on these Olsen-P values accounts for 53% of the variance of the percentage increases (relative to control) of the hay yield from the 90 kg/ha P_2O_5 treatment (Figure 3.7). Given that these data derive from crops grown on different soil types in seasons of widely different rainfall amounts, such a degree of fit is remarkably good. Broadly, it shows that the residual response of a mixed vetch/barley hay crop to a high rate of phosphate fertilizer (90 kg P_2O_5/ha) is unlikely to exceed 20% unless the initial soil content of available-P was less than 3 ppm (or 10% unless less than 4 ppm).

Figure 3.7 Relationship between relative response of hay yield to residual phosphate and native soil phosphate status before planting and fertilization the previous year



Equation: $\ln (DM_{90}/DM_0) = 6.017 - 2.571 \ln (0\text{-Olsen})$

$r = 0.728^{**}$ $(r^2=0.530)$

While the derived equation cannot be expected to apply precisely to other crops growing on residual phosphate, relationships of similar form, showing a rapid fall off in residual response with increase in initial Olsen-P values, are probable. Such simple models might prove useful for assigning economic value to the residual effects of phosphate fertilizer.

3.6 Nitrogen Soil Tests for Wheat Fertilizer Recommendations

A.E. Matar, M. Pala and D. Beck

3.6.1 Introduction

Because of the importance of nitrogen for crop growth, much effort has been spent in devising techniques for predicting the quantity of soil nitrogen that will be available to a crop during the growing season. If this quantity is known, the amount of fertilizer that would have to be applied could be predicted. Such predictions would result in a more economic use of fertilizer, and greater return from investment to farmers.

The amount of plant N derived from soil under a particular rainfall regime depends on the initial inorganic N present in the soil at planting plus the mineralization of soil organic N during the whole period of crop growth. Inorganic N is easily measured as extractable NO_3^--N and NH_4^+-N in soil at sowing. The potential N mineralization is more difficult to estimate, because microbial activity in the field over varying moisture and temperature regimes must be predicted by a suitable technique in the laboratory.

3.6.2 Potential Nitrogen Mineralization

The incubation method used in this study to estimate the mineralizable N in soil involves storing a soil sample in a cylinder at a specific temperature and moisture content over time, and leaching the soil cylinder at one-week intervals. The amounts of NH_4^+-N and NO_3^--N obtained in the leachate during incubation are determined and combined to give a total amount of N mineralized during a period of 2 to 10 weeks. The method used has been described in detail by Stanford and Smith (1972).

The soil N mineralization potential, N_o, is determined based on the equation:

$$\log (N_o - N_t) = \log N_o - kt/2.303 \qquad \ldots(1)$$

where N_t = total amount of N mineralized during a period t of incubation.

k = rate constant (= rate of mineralization)

The rate constant k was determined by plotting the regression of N_t over $t^{1/2}$. The slope of the linear regression represents the rate constant; rate constants in wheat soils ranged between 0.054 and 0.091/week.

The nitrogen mineralization potentials were determined for top soil (0-20 cm) taken from 40 sites where NP experiments were conducted in two consecutive seasons in the wheat belt of Syria; sites represented the various soil sub-groups and rotations. Within the same subgroup, experiments were conducted on fields where wheat was preceded by lentil, chickpea or summer crops (sunflower, water melon, etc.). All soil samples were analyzed for total nitrogen, organic matter, nitrate and ammonium nitrogen, for the top (0-20 cm) and all other layers by 20 cm increments to 100 cm depth in the soil profile.

Average N mineralization potential was approximated by the relationship $N_o = 6.5 \ N_t/t^{1/2}$ and were equivalent to 130 and 115 mg N/kg for typic chromoxerert and vertic Xerochrepts soils respectively (Table 3.20). The crops preceding wheat had little effect on the mineralization potentials within the given soil sub-group. The results indicate that the 2 main groups of soils in the wheat area had similar mineralization potentials.

Table 3.20 Nitrogen mineralization potentials (No) of wheat soils as related to previous crops and soil subgroups

Soil subgroups	N mineralization potentials (mg/kg)		
	Lentil	Chickpea	Summer Crops
Typic Chromoxererts	136.1	124.6	126.2
Vertic Xerochrept	104.1	123.2	99.5

3.6.3 Relationships Between Wheat Growth and Soil N Supply Estimated by Various Tests

Grain yields (GY), total dry matter (TDM) and total crop N uptake (TNU) at harvest from the zero N treatments in the field experiments (see section 6.7 of this report) were correlated with various pre-sowing soil N tests e.g. mineralization potential, total N and organic matter in the top 20 cm of soil, NO_3^--N, NH_4^+-N and mineral-N (NO_3^-+NH_4^+) in the soil profile.

Across all sites, NO_3^--nitrogen in the top 0-60 cm of soil, measured at sowing, correlated well (at $P<0.01$) with total N uptake ($r=0.77$), total dry matter ($r=0.71$) and wheat grain yield ($r=0.60$) (Table 3.21). However, measurements of total N in soil (Kjeldahl-N) and organic matter (OM) content had no significant correlations with GY, TDM or total N uptake by wheat (Table 3.22).

When used across all sites and for both seasons, the N mineralization potential measurement gave a relatively poor correlation ($P<0.05$) with TDM ($r=+0.32$), GY ($r=0.36$) and TNU (0.33). However, when sites with soils containing high pre-sowing levels of N were excluded (NO_3^- > 7 ppm in surface 60 cm), leaving only sites at which the wheat was preceded by a legume crop, the correlation coefficients improved considerably ($P<0.01$) (Table 3.23). In these low N sites, mineralization potential correlated even better with total N uptake, grain and total dry matter yields than did NO_3^- level at presowing, suggesting that the mineralization of organic N in soils poor in mineral N plays a major role in meeting the N requirement of wheat.

Table 3.21 Correlation coefficients between NO_3^--nitrogen in various soil layers at sowing and total dry matter, grain yield and total N uptake by wheat from zero N treatments in 40 NP experiments conducted over two seasons (1986/87 and 1987/88) in N. Syria

Yield parameters	NO_3^--N (mg/kg)				
	0-20 cm	0-40 cm	0-60 cm	0-80 cm	0-100 cm
Total dry matter	0.28	0.64**	0.71**	0.73**	0.70**
Grain yield	0.11	0.49*	0.60**	0.62**	0.60**
Total N uptake	0.49*	0.75**	0.77**	0.78**	0.77**

* $P<0.05$ ** $P<0.001$

Table 3.22 Correlation coefficients between grain yield, total dry matter and total N uptake by wheat and various soil N tests, from zero N treatments in 40 NP experiments conducted over two seasons (1986/87) and 1987/88) in N. Syria

Yield components	NO_3^--N 0-60cm	NH_4^+-N 0-60cm	Mineral N 0-60cm	Kjeldahl N	Organic matter	Minerl. potential
Total dry matter	0.72**	0.33**	0.70**	-0.12 NS	-0.29NS	0.32*
Grain yield	0.60**	0.43*	0.63**	-0.17 NS	-0.39NS	0.36*
Total N uptake	0.77	0.21NS	0.71**	-0.05 NS	-0.13NS	0.33*

* $P<0.05$ ** $P<0.001$

Table 3.23 Correlation coefficients between grain yield, total dry matter and total N uptake by wheat and various soil N tests, from zero N treatments at low N sites from the 40 NP experiments conducted over two seasons (1986/87) and (1987/88) in N. Syria

Yield components	NO_3^--N 0-60cm	NH_4^+-N 0-60cm	Mineral N 0-60cm	Kjeldahl N	Organic matter	Minerl. potential
Total dry matter	0.63**	0.30*	0.59**	0.21NS	-0.02NS	0.68**
Grain yield	0.61**	0.33*	0.60**	0.18NS	-0.06NS	0.71**
Total N uptake	0.67**	0.27NS	0.59**	0.19NS	-0.04NS	0.74**

* P<0.05 ** P<0.001

3.6.4 Further Developments of this Research

In summary, the results and analysis of this research encourage us to believe that a simple predictive model can be developed which will allow more targeted N-fertilizer recommendations to be made. Several important criteria will influence the development of such a model. Firstly, the critical level of soil available mineral nitrogen above which responses will be small, will depend on the season specific and location specific expected yield of wheat. Our on-farm research has shown that both the preceding crop and the amount of rainfall received up to the time of top dressing of N (end of February in Syria) are important factors influencing final grain yield potential. Secondly, as the results in this report indicate, both initially available mineral nitrogen and the mineralization potential of soils are important contributors to nitrogen uptake by wheat. Thirdly, the efficiency with which nitrogen fertilizer is utilized by the wheat crop is also rainfall dependent. Previous research at Tel Hadya in a dry year (1983/84) and a wetter year (1984/85) resulted in 20% and 50% nitrogen fertilizer efficiency values respectively (A. Monem 1986). Lastly, however precise fertilizer recommendation models may be in biological terms, they will only become practical tools when the economics of fertilizer use are also incorporated. The development of this model is on-going and involves the contribution of soil chemists, soil microbiologists, agronomists and economists.

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3.7 Improved Production Practices for Lentil: On-Farm Assessments in N. Syria

M. Pala and A. Mazid

3.7.1 Introduction

About 2.9 million hectares are sown to lentil in the world as a whole (FAO 1986), which represents only 0.36% of the total cereal+pulses area of the world. However, lentil accounts for 4.2% of the total world area of pulses, and 41% of the total lentil area is found in ICARDA region (Table 3.24).

Table 3.24 Area and production of lentil in the World and in ICARDA region (FAO 1986)

Region	Lentil Status			
	Area harvested (1000 ha)	% of the world	Production (1000 tons)	Yield (kg/ha)
World	2882	-	2284	792
ICARDA region	1183	41.0	1093	924
- North Africa	159	5.5	136	855
- West Asia	1024	35.5	957	935

Yields of lentil in West Asia and North Africa are still low compared with potential yields obtained with newly developed crop genotypes and improved agronomic practices where yields of over 2000 kg/ha have been reported (FLIP 1986, 1987).

The majority of lentils produced in the region are local land races and almost all of the few released cultivars available to farmers have originated through selection within these land races. However, yields can be increased significantly through improved management practices.

Agronomic requirements of lentils vary from location to location depending on the cropping systems and agro-ecological conditions. In the low elevation areas of Syria, Jordan, Iraq, Cyprus, Turkey and countries which experience the Mediterranean-type of environment, lentil is grown during the wet winters, and matures during the onset of the hot dry summer.

The date of sowing substantially affects the performance of lentil due to the change in the environmental conditions to which the crop is exposed at various stages of phenological development. As would be expected, the optimum date of sowing varies from location to location, and, within one location, to some extent from genotype to genotype (Saxena 1981).

In the low elevation areas of West Asia, early winter sowing generally gives a substantial yield advantage over late winter sowing. Saxena (1981) showed, at Tel Hadya research station, progressive advancement of the sowing date from January 31st to December 28th, and December 4th in the 1977/78 season, gave corresponding increases in yield of 500 and 820%. Much of this advantage comes from the extended period of vegetative growth and, to some extent, from the slightly increased seed filling period. In the later dates of sowing, the vegetative period is reduced because of the early exposure of the crop to longer day length and higher temperatures. Also, the reproductive period is reduced because of the rapid rise in temperature late in the season (Saxena 1981). In addition, lentils are mainly grown in areas where annual rainfall ranges between 300 and 400 mm and are generally sown during the late winter which is also, to some extent responsible for the low yield and lower water use efficiency. In spite of the many potential advantages of early winter over late winter sowing, a number of problems had to be resolved.

The early winter sown crop faces a more serious weed problem than the late winter sown crop as most of the weeds that would have competed with the late sown crop are killed by the preparatory tillage. In the early sowing, weeds emerge with the crop and this creates serious competition for water, nutrients and light. Lentil need to be kept free of weeds for almost the entire cropping season to ensure maximum yield. They do not grow tall and can not build up a protective canopy to prevent the late establishment of weeds. Lentil yield losses due to weeds have been estimated to range from 42 to 63% in West Asia (Basler 1981, FLIP 1982, 1983, 1984, 1986, 1987).

Traditional local methods of controlling weeds in the region involve mechanical weeding such as hoeing during the early growth stage, hand pulling of weeds for fodder, or a combination of both (Basler 1981). All weeding systems have been shown to lead to greater yields, but rising labor costs impose increasing limitations on hand weeding in the region.

Mechanical means of eliminating weeds are one solution to increasing labor costs, but require special and carefully set equipment as well as improved crop sowing geometry. Because of this, chemical weed control has also been investigated. Several herbicides have been tested in different countries as well as at the ICARDA research station for weed control and crop tolerance. The combination of pre-emergence applications of cyanazine with pronamide or post-emergence applications of dinocebacetate with fluazifop butyl, have proved to be promising for broad-spectrum weed control.

Another important problem for lentil growing is insects, especially Sitona spp. In the Eastern Mediterranean (e.g. Syria, Jordan, Lebanon), five species of Sitona are of considerable economic importance to legumes. The three most important Sitona species which attack lentils as well as other food legumes are *S. macularius*, *S. limosus* and *S. lineatus*. The Sitona adults feed on the leaf margins, chewing out small semicircular sections. Young plants may be greatly injured or killed. At this stage of growth, the plants may not be able to feed their young roots because of the loss of the cotyledonous leaves. The larvae of *Sitona* also feed on the roots, especially on the nodules in which nitrogen fixation occurs. The larvae attack leads to the destruction of the nitrogen fixing capacity of the nodules, consequently weakening the plant and reducing yield. Damage by the larvae to the roots allows the entry of decay organisms which may destroy the root and kill the plant (Hariri 1981). It is also reported that the adult weevils emerge during early summer in warm climates, aestivate in the soil and become active during early winter. Therefore the early sown lentil crop is subjected to Sitona attack more than the late sown lentil crop. Consequently introducing early sowing will almost certainly require Sitona weevil control.

Since the yield levels of an early sown crop are higher than those of the late sown crop, it might be expected that the mineral nutrient requirement of the former would also be considerably higher. On the soils with a poor fertility status, the limitation of mineral nutrients might prove a significant constraint to the realization of the greater yield potential of an early winter sown crop.

If the potential demonstrated in research trials in Syria can be repeated throughout the region, and extended to its farmers, it might be expected that total lentil production could be increased from its present level of just about 1 million tonnes to almost 1.7 million tonnes.

3.7.2 On-Farm Trials in Syria

During the 1985/86, 1986/87 and 1987/88 seasons, a series of on-farm trials was undertaken in NW Syria which examined the main effects and interactions of several management practices which were thought to be important in improving lentil production. These results have been fully analysed and subjected to economic evaluation. In this report, we will first present highlights of lentil grain and straw yield responses to management through a summary examination of pooled data for each season. In the Mediterranean region, the value of lentil straw as a high quality animal feed is often as great as, or exceeds, that of the grain. What will not be apparent from this discussion is the substantial variation in response to treatment combinations which we have observed, both between sites and years. In the second part of our discussion we focus on this aspect through a comparison of net revenues for each treatment combination, and their associated variability. Finally, we will conclude with a discussion of the implication of these results for our future research strategy for improved lentil production.

3.7.3 Treatments Applied

All soil was prepared and seeds sown according to the farmers' method: hand broad-casting seed and fertilizer over ridged land, and subsequent splitting of the ridges with a duckfoot cultivator. The treatments imposed in the three years are given in Table 3.25.

3.7.4 Pooled Analysis for 1985/86, 1986/87 and 1987/88

The main effects, first order interactions and levels of significance for grain, and straw yield responses are presented in Table 3.26 and 3.27.

Advancing the date of sowing resulted in yield increases across locations and years, with 13 out of 24 trials giving significant responses. The response to early sowing was less in

Table 3.25 Treatments imposed in on-farm lentil trials in 1985/86, 1986/87 and 1987/88

	1985/86	1986/87	1987/88
Number of sites	10	7	7
Trial design	2^4 factorial	2^4 factorial	2^4 factorial
No. of reps/sites	2	2	2
Cultivar	ILL 4401[1]	ILL 4401	ILL 4401
Treatment imposed			
a) Time of sowing	Early .v. late	Early .v. late	Early .v. late
b) P_2O_5 (kg/ha)	50 .v. 0	50 .v. 0	50 .v. 0
c) Sitona control	+ .v. 0[2]	+ .v. 0	+ .v. 0
d) N (kg/ha)	na	50 .v. 0	50 .v. 0
e) Weed control	Ch .v. 0[3]	Ch .v. 0[4]	Ch .v. 0[4]

1. Syrian local small, with 80 kg/ha seed rate.
2. Sitona weevil control: Carbofuran, as 20 kg of furadan (5%)/ha at sowing.
3. Chemical weed control: Cyanazine+Pronamide, 0.5+5.0 mk ai/ha
4. Chemical weed control was not a part of the treatment combinations but it was applied across all treatments compared separately with weedy check plots, which were specially included for this purpose

the first two seasons because in general it was dry between first and second sowing dates. The 1987/88 season was a wet year and early sowing provided a substantial growth difference compared with late sowing, and at all locations early sowing brought about a significant yield increase of both grain and straw. Overall increases in grain and straw by early sowing were 20 and 26% over late sowing respectively.

Significant responses to phosphate were observed in all years, but the response was erratic with only 4 in grain and 6 in straw out of the 24 sites showing positive responses. In general it can be concluded that P application is not currently an economic option under farmers' sowing methods with overall

Table 3.26 Main effect and first order interactions of lentil grain yield responses in Syria (kg/ha)

Treatment			1985/86	1986/87	1987/88
Time of sowing	(E)	Nov	965	1617**	1937**
	(L)	Jan	931	1481	1300
P_2O_5 (kg/ha)	(50)		978*	1598**	1654**
	(0)		918	1500	1583
Sitona control	(+)		1036**	1662**	1741**
	(0)		861	1435	1496
N (kg/ha)	(50)		na	1530	1610
	(0)			1568	1627
Weed control	(+)		1024**	1749**	1725**
	(-)		872	1343	1215
LSD (0.05)			44	51 148(w)	49 123(w)

First order interactions

Sitona control

		1985/86			1986/87			1987/88		
		+		-	+		-	+		-
Time of sowing	(E)	1071	*	859	1770	*	1464	2084	*	1789
	(L)	999		861	1555		1408	1397		1204
LSD (0.05)			62			72			70	

Weed control

		+		-	+		-	+		-
Time of sowing	(E)	1066	*	864	1849	*	1314	1996	**	1302
	(L)	982		879	1648		1371	1454		1127
LSD (0.05)			62			209			174	

* P<0.05
** P<0.01
(W) = LSD for weed control only

Table 3.27 Main effect and first order interactions of lentil straw yield responses in Syria (kg/ha)

Treatment		1985/86	1986/87	1987/88
Time of sowing	(E)	2038*	3073**	3975**
	(L)	1839	2819	2473
P_2O_5 (kg/ha)	(50)	1979**	3053**	3384**
	(0)	1869	2840	3065
Sitona control	(+)	2057**	3088**	3510**
	(0)	1791	2804	2939
N (kg/ha)	(50)	na	3009**	3335**
	(0)		2844	3113
Weed control	(+)	2003**	3302*	3692**
	(0)	1845	2829	2894
LSD (0.05)		77	124 282(w)	103 322(w)

<u>First order interactions</u>

Sitona control

		1985/86			1986/87			1987/88		
		+		−	+		−	+		−
Time of sowing	(E)	2198	*	1879	3277		2870	4274		3677
	(L)	1917		1702	2901		2739	2746		2201
LSD (0.05)			95			NS			NS	

Weed control

		+		−	+		−	+		−
Time of sowing	(E)	2168	**	1908	3545	**	2663	4263	**	3137
	(L)	1837		1781	3058		2994	3121		2650
LSD (0.05)			95			399			456	

* P<0.05
** P<0.01
(W) = LSD for weed control only

increases of 7 and 8% in grain and straw yields respectively over the control. It should be remembered that in these trials, phosphate was broadcast over ridged land with the seed, and then mixed with the seed and soil during subsequent ridge splitting. In other trials (see section 3.4 of this report), where the phosphate was banded with drill sown lentil, greater responses were found, even when available soil-P levels were high.

Sitona weevil control had substantial effects on both grain and straw yields across locations and years at 19 (grain) and 17 (straw) out of the 24 sites. Overall increases of 17 and 15% in grain and straw yields respectively over the control were achieved. Significant interactions indicated that in the first two years responses of grain yield to Sitona control were greater in the early sowing than in the later sown crop, but these differences were smaller in the third season which was outstandingly wet (Table 3.26). The percentage of nodule damage was thought to be the main reason for above mentioned interactions. The effects of Sitona control on nodule damage in early and late sowing are presented for each year in Table 3.28.

Table 3.28 The effect of sitona control on nodule damage in lentil on-farm trials in NW Syria, 1985-1988

	Nodule damage, %					
	Early Planting			Late Planting		
Seasons	Sc+	Sc-	mean	Sc+	Sc-	mean
1985/86 (6 loc)	6.5	47.3	27	4.7	27.0	16
1986/87 (7 loc)	11.8	44.3	28	4.1	24.5	14
1987/88 (7 loc)	9.4	40.2	25	5.6	33.8	19

As seen from Table 3.28 average nodule damage in early sowing was more than in late sowing in all years and it was much larger under the control treatment where no insecticides were applied. Nodule damage was increased 75 and 81% in early sowing compared with the late under the control treatment for the first and second season respectively but the increase was only 19% in the third season. These results are consistent with the greater yield increases observed with early sowing and Sitona control.

In the second two seasons, nitrogen application was tested as a possible option of replacing carbofuran which is a poisonous and expensive chemical. Results indicated that crop responses to N were not significant and were negative for grain but positive for straw in both seasons even though they were completely different from each other as far as rainfall was concerned. Studies on nitrogen nutrition have shown that under good symbiotic association with lentils, more than 85% of the total nitrogen requirements of the crop can be met by symbiotic N_2 fixation (Rizk 1966). Hence generally no large increases in yield are obtained with the application of fertilizer N in the presence of naturalized or introduced lentil Rhizobium (Chowdhury et al 1974, Hamissa 1974, Saxena and Yadav 1976). However, significant interactions (not shown in Table 3.25 and 3.26) indicated that in the third season, crop responses to N were greater in the absence of Sitona control.

Chemical weed control was clearly effective. In all seasons it resulted in consistent yield increases compared with no weed control. As indicated in the introduction, weeds pose a more serious threat in early planted lentil, and this was again confirmed by a significant interaction between time of sowing and herbicide use (Table 3.25 and 3.26). However mean yield increase over the control was 30% in grain and only 13% in straw indicating that the importance of weed control is more clearly reflected in grain yields. In moisture limiting environments, competition for moisture by weeds is likely to be the main cause of yield depression, and it is well known that legumes in general are particularly sensitive to moisture stress at flowering and seed set.

3.7.5 Economic Analysis

In general economic results reflect the results for biological yields because the costs of all treatments were relatively low compared to crop values. In each season, the base treatments for economic analysis were those with the lowest levels of inputs. Partial budget analysis of the lentil agronomy results are presented in Table 3.29.

Table 3.29 The overall effects of treatments on net revenue and increase in net revenue in on-farm lentil trials in NW Syria 1/

	1985/86		1986/87		1987/88	
Treat. No.	Net Rev SL/ha	In. Net Rev SL/ha	Net Rev SL/ha	In. Net Rev SL/ha	Net Rev SL/ha	In. Net Rev SL/ha
1-	4115	0	14315	0	11025	0
2-	4062	-53	15155	841	16005	4980
3-	4618	503	14507	192	13252	2227
4-	4797	681	17008(3)	2693	21136(2)	10111
5-	4408	292	14794	480	12268	1243
6-	4598	482	13950	-364	18736	7711
7-	4678	563	14434	119	12797	1772
8-	5722(1)	1606	16220(4)	1906	19489(4)	8464
9-	4359	243	13969	-345	12408	1383
10-	4391	276	15952	1637	19280	8255
11-	4936	821	15976	1661	13241	2216
12-	5089(3)	972	17939(2)	3624	21800(1)	10776
13-	4259	143	14870	556	11806	781
14-	4762	646	15404	1089	18708	7683
15-	5002(4)	886	15753	1438	14029	3004
16-	5670(2)	1555	18093(1)	3778	19620(3)	8595

(*) Treatment number is indicated in Figure 3.8, 3.9 and 3.10 for each season

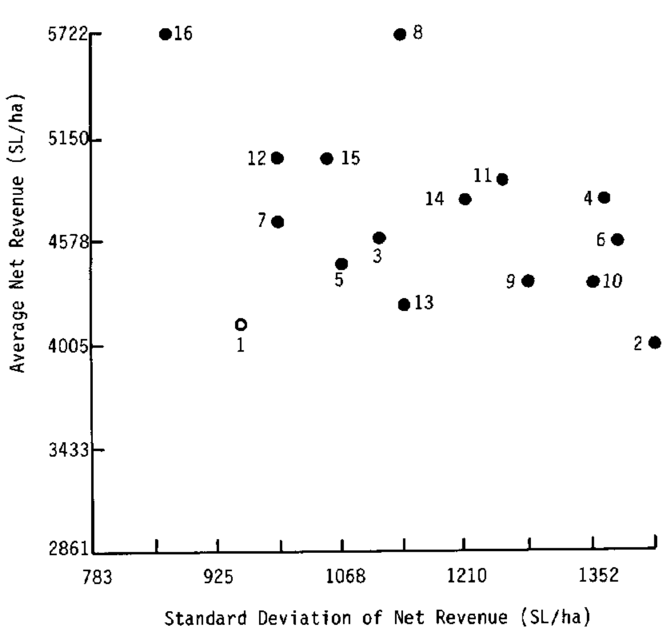
		1985/86	1986/87	1987/88
Seed Price:	SL/kg	3.25	6.50	8.00
Straw Price:	SL/kg	1.00	2.00	1.10
Sitona cost:	SL/ha	140	600	692
P Cost :	SL/ha	121	121	148.5
N Cost:	SL/ha	-	160	197.5
Weed Cost:	SL/ha	313	-	-

1. Numbers in parentheses indicate ranking of the 4 most profitable treatments in each season.

Net revenues for each set of treatments were calculated by assigning costs for each of the treatment elements (for field scale application) and subtracting these from the products of seed and straw prices and yields. "Increases in net revenues" were derived by further subtracting the value of the base treatment. The base treatment in the first season comprised late sowing with no insecticide, herbicide or phosphate applications. In the last two seasons, the base treatment for economic analysis was the late sowing with no insecticide, nitrogen or phosphate applications. For risk analysis average net revenues for each treatment combination were plotted against their associated standard deviation. These are presented in Figure 3.8, 3.9 and 3.10 for the three seasons. Each treatment combination is assigned a number for reference in the subsequent text. These are indicated in each of the above figures.

Figure 3.8 Risk Analysis of lentil agronomy treatments at ten locations in NW Syria, 1985/86

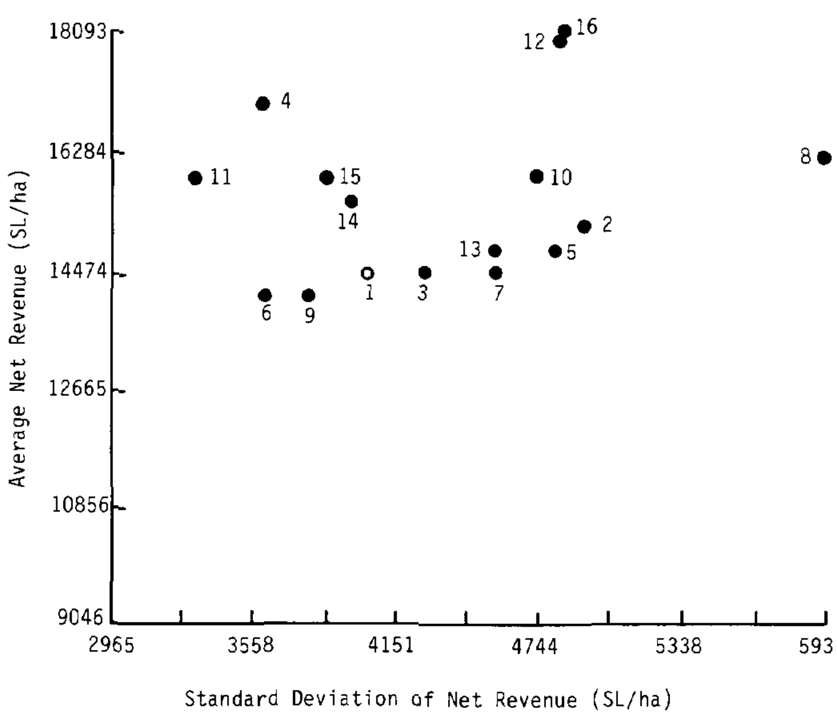
Treatment Number:			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Sowing Date: Early	(E),	Late (L):	L	E	L	E	L	E	L	E	L	E	L	E	L	E	L	E
Sitona Control	(0)	(+):	0	0	+	+	0	0	+	+	0	0	+	+	0	0	+	+
Herbicide	(0)	(+):	0	0	0	0	+	+	+	+	0	0	0	0	+	+	+	+
Phosphate	(0)	(+):	0	0	0	0	0	0	0	0	+	+	+	+	+	+	+	+



In 1985/86, except for treatment No. 2, all treatments with early sowing dominated the comparable late sowing treatments in terms of higher average net revenues for the same costs. Consistently positive effects on net revenues, across the 10 locations, were found in only three treatments (8, 12 and 16), while all other treatments gave negative results at some locations. Treatments 8 and 16 were further distinguished as giving the highest average net revenues. Treatment 16 had also the lowest standard deviation in net revenue (Figure 3.8).

Figure 3.9 Risk Analysis of lentil agronomy treatments at seven locations in NW Syria, 1986/87

Treatment Number:			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Sowing Date: Early	(E), Late	(L):	L	E	L	E	L	E	L	E	L	E	L	E	L	E	L	E
Sitona Control	(0)	(+):	0	0	+	+	0	0	+	+	0	0	+	+	0	0	+	+
Nitrogen	(0)	(+):	0	0	0	0	+	+	+	+	0	0	0	0	+	+	+	+
Phosphate	(0)	(+):	0	0	0	0	0	0	0	0	+	+	+	+	+	+	+	+
Herbicide		:	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+



In 1986/87 season, except treatment No. 6, all treatments with early sowing again dominated the comparable late sowing treatments in terms of higher average net revenues. Consistently positive effects on net revenues, across the 7 locations, were found in only four treatments (4, 12, 15 and 16), while all other treatments gave negative results at some locations. Treatments 4, 12 and 16 were further distinguished as giving the highest average net revenues. Treatment 4 had also one of the lowest standard deviation in net revenue (Figure 3.9).

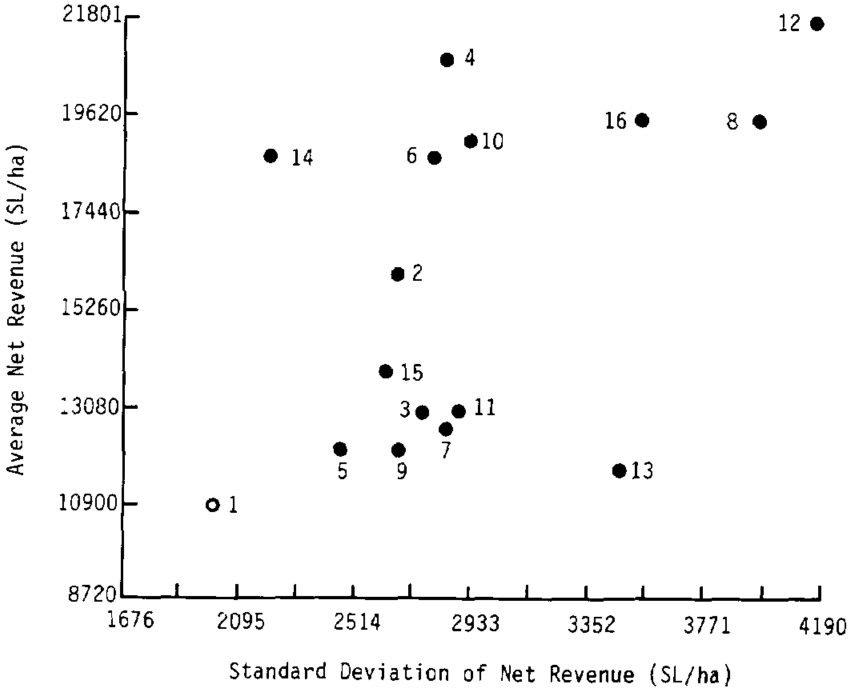
In 1987/88, all the treatments with early sowing again dominated the comparable late sowing treatments in terms of higher average increases in net revenues. Due to favorable weather conditions in this season, all the treatments, except treatments No. 9 and 13, gave consistently positive effects on increases in net revenues, across the 7 locations. As in the previous season treatments 4 and 12 were further distinguished as giving the highest average net revenues. In general, standard deviations of net revenues for all treatments were not large compared with average net revenues (Figure 3.10).

Large variability in responses of specific treatment combinations across location was observed in the first two years, but in the third season the variation was reduced remarkably due to unusually favorable weather conditions. However, the first two years were more representative of the normal growing conditions which farmers may expect to experience. Our results suggest a need to identify the principal factors responsible for this variability since a single "package" of recommendations will clearly not be equally profitable at all locations. An understanding of the soil and climatic factors responsible for this variation should allow for better targeted research and recommendations in the future.

However, in spite of the variations across sites during the first two seasons, there were some consistent trends over the three years. The common treatments which provided substantially

Figure 3.10 Risk Analysis of lentil agronomy treatments at seven locations in NW Syria, 1987/88

Treatment Number:			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Sowing Date: Early	(E),	Late (L):	L	E	L	E	L	E	L	E	L	E	L	E	L	E	L	E
Sitona Control	(0)	(+):	0	0	+	+	0	0	+	+	0	0	+	+	0	0	+	+
Nitrogen	(0)	(+):	0	0	0	0	+	+	+	+	0	0	0	0	+	+	+	+
Phosphate Fertilizer	(0)	(+):	0	0	0	0	0	0	0	0	+	+	+	+	+	+	+	+
Herbicide		:	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+



high average increases in net revenues were early sowing with Sitona weevil and weed control measures. The poor performance of early sowing, without weed and Sitona weevil control is consistent with results of on-farm trials conducted in four previous seasons (ICARDA 1983).

3.7.6 Conclusion

Early sowing of lentil combined with weed control and Sitona weevil control has proved to be consistently profitable in these trials. We believe that the results are sufficiently encouraging for this research to move forward from the complex "scientist-managed on-farm trial" stage to a simpler and more widespread set of "farmer-managed trials".

Further research is still required to find a safer alternative to carbofuran which would require careful handling and safety precautions by farmers. In addition, earlier sown lentil will always run the risk of late frost damage at flowering. Analyses of long term climatic data are required to identify areas where such events have an unacceptably high level of probability.

Given these results, and those of other research aimed at producing taller and non-shattering lentil types (more suitable for mechanical harvesting), we believe that substantial and economic increases in production of lentil can be achieved in the near future, both at the farm and the national level.

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4. PROJECT 2. AGRO-ECOLOGICAL CHARACTERIZATION FOR RESOURCE MANAGEMENT

4.1 Introduction

In this project, our long term goals are to help ICARDA and national programs 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 the impact of new technology. We will attain this goal through the following medium term objectives:

1. To develop, test and make available techniques which characterize and map agro-ecological variability and define homogeneous recommendation domains for improved targeting of research and technology development.

2. To develop, test and make available techniques which integrate and translate the effects of agro-ecological variability, crop genotype differences and management strategies into associated expressions of crop productivity, thereby assisting the assessment of the long term suitability, adaptability and impact of new technology.

3. To combine the above techniques with economic and livestock performance data to evaluate the long term impact of new technology on production and economic return at the farm, recommendation domain, district and national level.

In last year's report we outlined our strategy for agro-ecological characterization (FRMP 1987) in which we discussed our objectives to quantify variability in the environments in which we work, to identify potentials and constraints, to delineate areas of similarity or difference, and to examine strategies for minimizing constraints and reducing the impact of the inherent variability. In that review, we indicated that several tools were being developed or adapted for use in achieving these goals. This year we report on the **verification** and **calibration** of some of these tools.

In the first section (4.2) we examine the performance of the CERES-N Wheat Growth Simulation Model in predicting the outcome of experiments specifically designed for model validation. We then link the model with long run climatic datasets from two contrasting stations in N. Syria with the relevant soil physical, moisture and nutrient data and test its sensitivity in predicting the observed interaction of crop rotation and nitrogen fertilizer on wheat responses. In the second section, 4.3 we discuss another crucial tool required in the agro-ecological characterization of West Asia and North Africa; a spatial rainfall generator for regions with sub-optimal data availability and quality.

It is the linking of long run climatic data sets of sufficient quality and spatial density, the required soil parameters and reliable crop growth simulation models which provides the foundation upon which an applied and practical agro-ecological characterization is built.

4.2 Crop Growth Simulation Model

H. Harris (ICARDA), D. Godwin (IFDC)

4.2.1 Validation Data

In the 1984/85 season an experiment was carried out to examine the response to nitrogen fertilizer of a single cultivar of wheat in a range of environments. The fertilizer treatments were 0, 30, 60, and 90 kg N/ha; the cultivar, Sham-1, a durum wheat; and the environments were three permanent or semi-permanent sites: Jindiress, with a mean season rainfall of 480 mm, Tel Hadya with 330 mm, and Breda 280 mm.

In addition to measuring the total biomass and grain yield of the crops at maturity, supplementary measurements were taken with the objective of providing validation data for a wheat model, CERES-N (Ritchie, Godwin and Otter-Nacke 1988). These data included soil nitrogen at planting and maturity, crop dry matter and soil water profiles at intervals during crop growth, yield components at maturity, and weather data at each site. The soils had previously been classified as a Palexerollic Chromoxerert, a Chromoxerertic-Rhodoxeralf, and a Typic Calciorthid at Jindiress, Tel Hadya, and Breda respectively (ICARDA 1981).

The seasonal weather conditions during the experiment were noteworthy for two reasons. First, there were excellent early rains and a build-up of substantial soil water reserves. However, effective rain ceased in February (see e.g Figure 3.3a), and the crops suffered severe water stress in the later stages of growth. And secondly, mild temperatures and good growing conditions in December and January were succeeded by an extreme cold spell in the last two weeks of February and early March. Crops at all sites were damaged by frost, those at Jindiress being the worst affected.

The trial results have been reported (ICARDA 1986), but in brief were as follows. There was a response to 60 kg N/ha at the tillering stage and to 30 kg N/ha in both grain and straw yield at Jindiress, the wettest site. Nitrogen gave no response at Tel Hadya, but at Breda straw yield was significantly increased by 60 kg N/ha.

4.2.2 Model Testing

The CERES-N wheat growth simulation model was run using the weather data from each site, soil nitrogen at planting, and soil water characteristics previously determined (Stapper 1984). Its performance against the measured data was not good (Tables 4.1 and 4.2). Simulated total biomass compared relatively well with the observed (Figure 4.1a) but grain yield was consistently, and at Breda very markedly, underestimated (Figure 4.1c). This

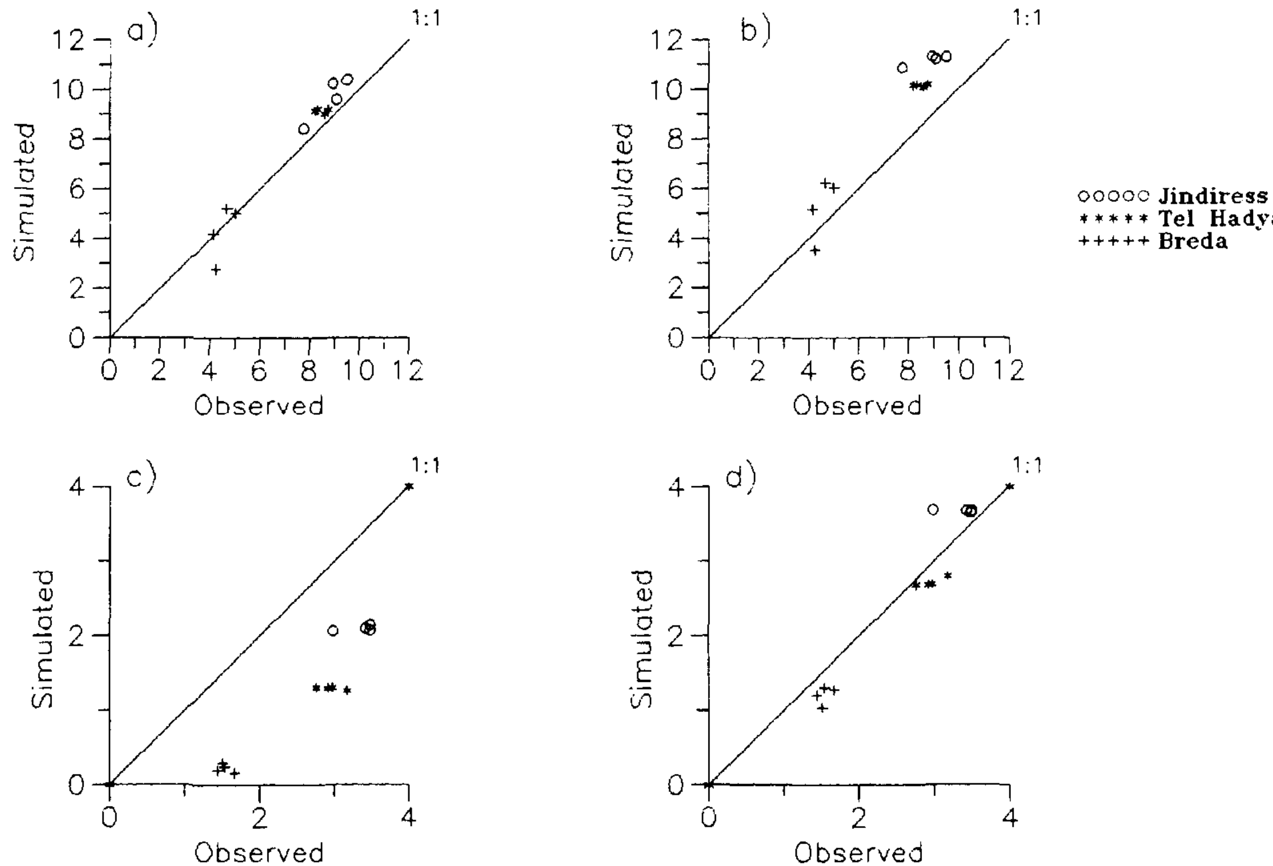

Figure 4.1 Simulated total biomass (t/ha) before (a) and after (b), and simulated grain yield (t/ha) before (c) and after (d) PHINT was modified from 95 to 85 dd.

underestimation came from two sources — simulation of low grain weight and, except at Jindiress, low grain numbers per unit area (Table 4.1).

Table 4.1 Comparison of measured and simulated components of yield of durum wheat in three environments, before and after the calibration of the CERES-N crop growth simulation model

Yield component	N Level	Jindiress[1]			Tel Hadya[1]			Breda[1]		
		0	S1	S2	0	S1	S2	0	S1	S2
Grains Wt (mg)	0	30.5	23.4	29.7	28.2	20.0	24.7	26.4	20.0	28.0
	30	31.2	20.2	28.5	24.5	20.0	23.5	24.4	20.0	25.1
	60	30.7	20.0	28.5	25.6	20.0	23.5	23.2	20.0	23.8
	90	32.8	20.0	27.2	23.2	20.0	23.5	22.4	20.0	23.8
Grains/m^2	0	9495	8838	12398	6372	11297	5740	1448	3714	
	30	11190	10253	12825	11930	6507	11407	5900	939	4765
	60	11750	10508	12920	11920	6555	11422	7200	790	5382
	90	11330	10733	12862	11880	6556	11354	6890	1174	5474
Grains/ spike	0	29.0	5.2	8.5	30.0	4.7	10.9	22.0	1.2	4.0
	30	31.0	6.1	11.3	32.0	5.9	12.5	22.0	0.7	4.2
	60	34.0	7.6	13.5	33.0	6.8	13.4	23.0	0.6	5.6
	90	34.0	9.6	14.6	31.0	7.1	13.5	22.0	1.1	7.0
Fertile spikes/ m^2	0	327	1710	1456	375	1351	1033	260	1191	926
	30	360	1670	1134	373	1095	915	268	1367	1127
	60	345	1392	955	361	968	855	313	1241	965
	90	333	1120	880	383	919	844	300	1058	786

[1] O = Observed; S1 = First simulation (PHINT = 95); S2 = Second simulation (PHINT = 85)

Reasons were sought as to why the simulations were not more accurate. Cereal Improvement Program staff at ICARDA suggested that there is a difference in the rate of leaf appearance between bread wheat (Triticum aestivum), for which the model was developed, and durum wheat (Triticum turgidum var. durum). In the model this variable is expressed as a function of thermal time (degree days) and drives crop physiological development. The phyllochron interval (PHINT), or the thermal time for the appearance of a leaf, was modified from the default value of 95 to 85 degree days. This improved the agreement between the simulated and measured data for grain yield, grain weights, grain number and nitrogen percentage in the grain (Figure 4.1d; Table 4.1 and 4.2). However it caused total biomass to increase to 15 to 25% more than the observed (Figure 4.1b). Total N uptake also was overestimated.

The major reason for production by the model of excess biomass appears to be that the number of stems (main stems and tillers) is overestimated. This is apparent in the data for fertile spike number, and grains per spike in Table 4.1. Tiller dynamics is one of the most difficult parts of cereal growth to model accurately, and the difficulty is possibly exacerbated by conditions in Mediterranean-type environments. For accuracy it is necessary to be able to predict the increase in tiller numbers in early growth, and then to mimic the abortion of tillers which inevitably occurs in the three or four weeks prior to anthesis. During the period of tiller formation water is rarely limiting, as the process takes place when there is the greatest chance of rain and evaporation rates are low. Cereals tiller freely in these conditions, but rarely, if ever, are able to support the tiller population to maturity. In the spring, during March in lowland environments, both temperatures and the saturation deficit of the atmosphere increase rapidly and the radiation intensity is high. Transient to severe water stress is experienced and a large proportion of tillers is lost. Presumably when the stress is not too abrupt or severe there is retranslocation of material from the

Table 4.2 Comparison of measured and simulated nitrogen balance of durum wheat in three environments, before and after the calibration of the CERES-N crop growth simulation model

Yield component	N Level	Jindiress[1]			Tel Hadya[1]			Breda[1]		
		0	S1	S2	0	S1	S2	0	S1	S2
N % in grain	0	1.82	3.25	2.32	2.45	5.96	3.27	2.01	6.44	2.47
	30	1.97	3.92	2.82	2.47	5.91	3.45	2.23	13.33	3.50
	60	2.23	4.20	2.88	3.02	5.87	3.45	2.68	19.86	3.69
	90	2.25	4.18	3.02	3.09	5.83	3.44	1.82	13.94	2.32
Total N uptake	0	66.6	95.8	118.1	97.9	137.4	141.2	39.2	36.6	35.8
	30	88.4	119.9	142.5	104.3	157.1	155.9	40.8	65.3	65.5
	60	94.3	141.7	157.3	119.9	173.1	167.2	58.8	88.0	92.6
	90	102.7	160.0	169.7	119.3	184.6	177.8	62.2	101.6	113.9

[1] O = Observed; S1 = First simulation (PHINT = 95); S2 = Second simulation (PHINT = 85)

tillers that are shed to the rest of the plant to increase the size of the main stems and the few surviving tillers.

It would appear that there will be a need to incorporate more of the mechanisms and driving forces of these processes into the model, and perhaps a need to improve our understanding of them before that can be done. The problem was addressed by Stapper (1984) in the development of the SIMTAG model, and some success in mimicking the dynamics was achieved by the incorporation of a factor related to the intensity of radiation to drive tiller loss. This will provide a starting point for modifications to CERES-N.

4.2.3 Model Sensitivity

Given our plans to use a model as a central tool in the exploration of variability we were interested to test the capacity of CERES-N to mimic some of the factors of cropping systems which we know influence the response of wheat to nitrogen fertilizer. Work in the wheat-based systems of northern Syria has provided data on the influence of crop sequence on this response (see section 6.7 of this report) and a modelling experiment was carried out to look at whether the effects we observe in the field can be reproduced in the computer.

Using data from on-farm trials on the nitrogen status of soil profiles following two crops which commonly precede wheat in rotations, namely lentil and summer crop (usually water melon), and soil water profiles measured following the same crops, the model was run with long-term weather data records from two sites with different seasonal rainfalls and temperatures. Two levels of nitrogen were used, zero and 80 kg/ha. Because we are not yet able to simulate the alternative crops grown in rotation with wheat, the soil conditions were reset to the same values at the start of each season. Yields were simulated for the 25 years from 1960 to 1985 at Muslmieh and 22 years from 1965 to 1987 at Jindiress.

The model predictions conform to the patterns we observe in the field. At the wetter site, Jindiress, wheat yields are more reliable, as is to be expected, but they do appear to be somewhat more consistent than would be anticipated (Figure 4.3). One probable reason for this is the "start of season" soil water profile that was used in these model runs. It was measured following a water melon crop in a year of quite high rainfall and it is possible that more water remained than would be usual. This would mean that the model would underestimate stress in some years. The level of yield is high but not unrealistic and can be achieved by well managed farmers' crops. There is a consistent and quite similar response to nitrogen following both crops, but as our field data show it is greater (7%) after lentil than after water melon. This difference in the response following the two crops is not as great as has been observed in the past two seasons, but a direct comparison cannot be made from the data to hand.

At Muslmieh, the drier site, the yields are more variable (Figure 4.2), again conforming to expectations. Yields following lentil are lower than those after summer crop, a pattern we have measured at Tel Hadya in four of the last five seasons, and in on-farm trials (see section 3.7). The response to nitrogen is appreciably (40%) greater after lentil than after melon and this is more similar to our experimental data than the predictions at Jindiress. As in reality there is a strong interaction between nitrogen and water, and the size of the yield increase due to fertilizer is quite variable, especially at the drier site where a negative response following summer crop is predicted in some years.

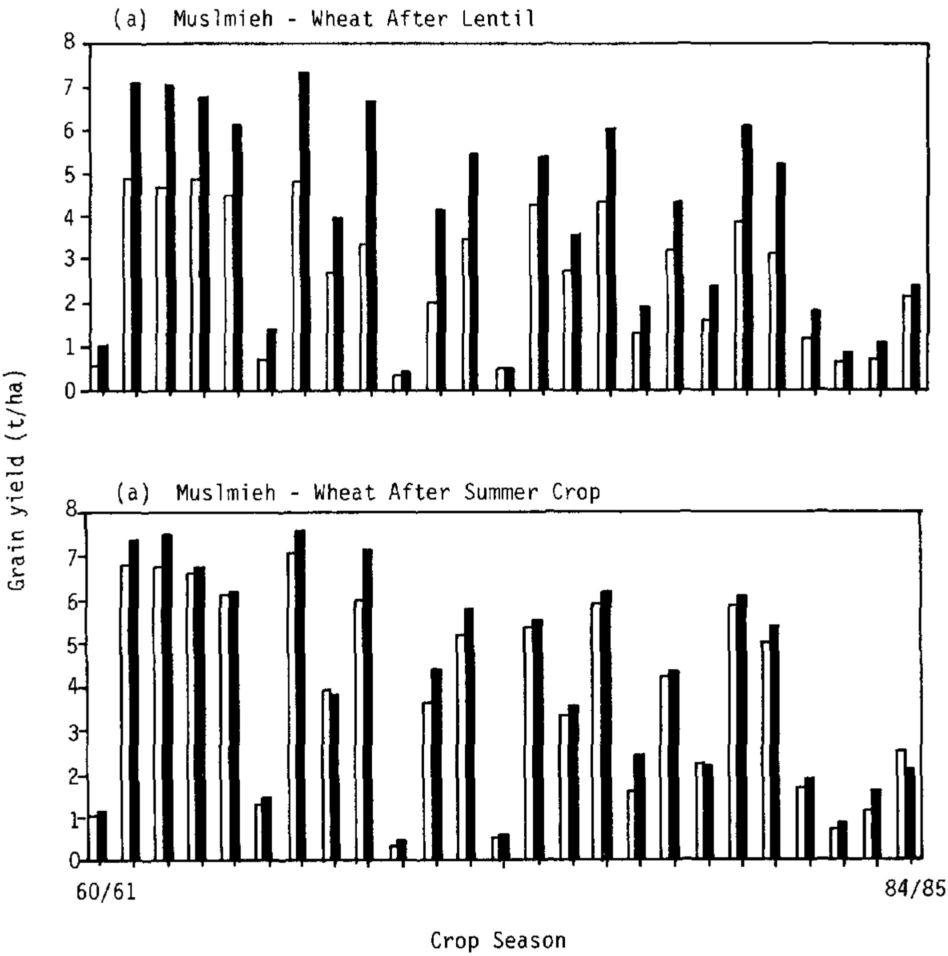

Figure 4.2 Simulated grain yield (t/ha) of Sham 1 wheat following (a) lentil and (b) melon at Muslmieh, using 25 years of daily weather data from 1960 to 1985. The left hand bar for each pair (years') of data is for zero N and the right hand one for 80 kg N/ha.

These results are pleasing. They indicate that in the model we have a tool which predicts grain yield with sufficient sensitivity to allow us to examine a number of important issues. One of the objectives of work on fertilizer is to improve the efficiency of its use by refining recommended application levels

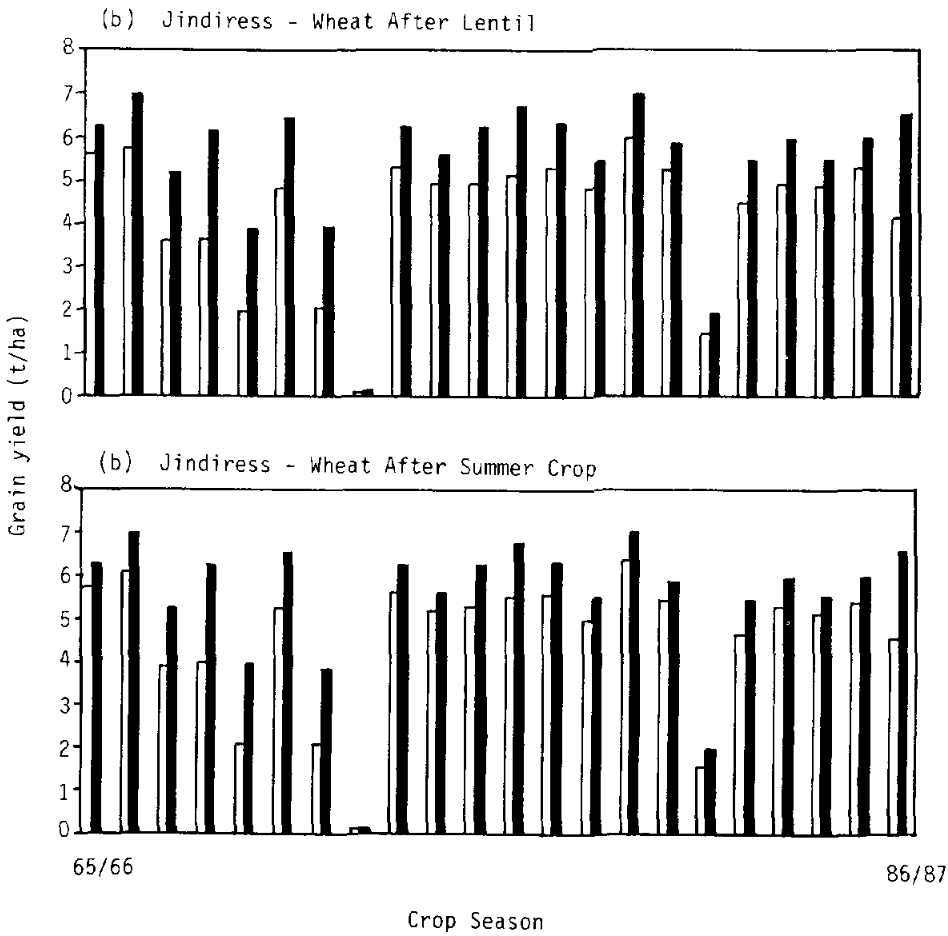

Figure 4.3 Simulated grain yield (t/ha) of Sham 1 wheat following (a) lentil and (b) melon at Jindiress, using 22 years of daily weather data from 1965 to 1987. The left hand bar of each pair (years') data is for zero N and the right hand one for 80 kg N/ha.

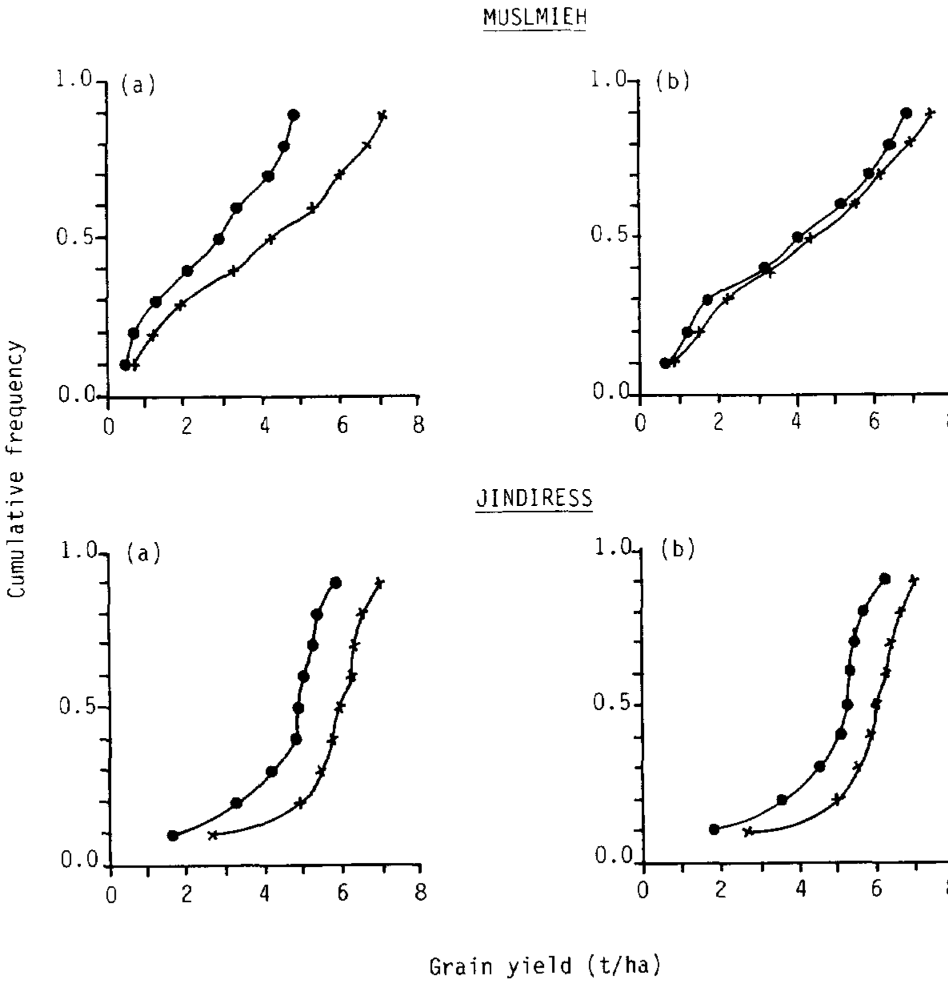

Figure 4.4 Cumulative frequency that yield will be less than a specified amount at Muslmieh, (a) following lentil and (b) following melon, and at Jindiress, (a) following lentil and (b) following melon.

0 = Zero N + = 80 kg N/ha

according to seasonal conditions. There is scope to do this because most of the nitrogen is topdressed in the late winter or early spring. By this time soil water storage is at its maximum for the season and better judgements should be able to be made on how much N to apply. One planned use for a model is to examine the probable outcome of strategies based on this knowledge of soil water storage and the probability of rain in the remainder of the season. By using long runs of real, or realistically generated weather data (see section 4.3), it will be possible to assess the risk, both biological and economic, of alternatives for fertilizer management.

An example of this type of analysis is shown in Figure 4.4, where the simple case of plus or minus fertilizer is illustrated using the simulated data for Jindiress and Muslmieh. The figures illustrate that, from a biological standpoint, the application of nitrogen has a low risk i.e. at all levels of probability the yield of fertilized crops will be greater than unfertilized ones. The exception is when wheat follows summer crop at Muslmieh where the yield margin is very small. This form of analysis, translated into economic terms, can be used to assess management strategies.

4.2.4 References

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4.3 A Spatial Rainfall Generator for Regions With Suboptimal Data Availability and Quality

W. Goebel

The usefulness of spatial weather generating techniques increases with their ability to cope with suboptimal data availability and poor data quality. Failure of techniques developed so far to allow for such frequently encountered data problems has limited their more widespread application in agricultural research. During the development of a spatial weather generator at ICARDA, emphasis has therefore been put on the capability of its parameter estimation section to determine robust, "best-bet" estimates of the generator coefficients in such situations. The following paragraphs describe problems of rainfall data which have been identified during validation of the rainfall generator, and their solutions for them.

4.3.1 Problems of Data Availability

Problems of data availability fall into two groups: problems caused by suboptimal lengths of the observation periods of rainfall stations, and those caused by a suboptimal density of the station network.

50 years are frequently regarded as optimal length for the observation period of rainfall, shorter periods may be sufficient in coastal areas and on plains (Landsberg and Jacobs 1951). If the observation period is too short, the confidence limits for the rainfall generator coefficients become two wide; if it is too long, climatic change during the observation period may decrease the predictive power of the model. The records of all stations in an area to be covered by a spatial rainfall model should cover the same standard reference period. This is rarely the case; usually some stations are closed down during the period, some new ones are established, some have observation gaps due to various reasons. Inevitably in such cases, the period actually observed by one station has different characteristics from that observed by

another station. It may be drier or wetter, more or less variable with regard to totals during certain periods of the year, have longer or shorter dry or wet spells, etc. The rainfall generator coefficients of stations with incomplete records, therefore, have to be adjusted to be representative of the standard reference period. For arithmetic means, the ratio or logarithmic difference method is used (Essenwanger 1986). The adjusted mean is estimated as the mean of a reference station for the full standard period, multiplied by the ratio between the unadjusted mean and the mean of the reference station for the identical part of the standard period. Similar relationships for other coefficients have been developed and the method has been expanded to more complex cases, where no stations with records covering the entire standard period are available (Figure 4.5a, b).

Figure 4.5a. Adjustment of the arithmetic mean of rainfall to a standard reference period, simple case (A,B,C = Data Available, _ = Missing Data)

```
Station   I: AAAAAAAAAABBBBBBBBBBBBBBB
Station  II: __________CCCCCCCCCCCCCCC
```

The estimated mean for Station II for the whole period is calculated as (mean of values A and B) * (mean of values C) / (mean of values B).

Figure 4.5b. Adjustment of the arithmetic mean of rainfall to a standard reference period, complex case (x = Data Available, _ = Missing Data)

```
Station   I: _____xxx__xxxx_x__xxxx_____xxxx
Station  II: xxxxxxxxxx__x_______xxxx--xxxxx
Station III: xx__xxx____xxxxx_____xxx_xx____
Station  IV: _____xxxxxxxxxxxxxx____xxxxxx__
```

Even in such a case, the coefficients of all stations can be adjusted to the reference period.

Outlying data points are another problem associated with short observation periods. These are not outliers in the sense of faulty data; they are extreme real values with a low probability of occuring during a relatively short observation period. Since their expected recurrence interval is very long, these outliers may get an undue weight in the calculation of rainfall generator coefficients, resulting in unrealistically high or low means and excessive variability of the generated data (Table 4.3). Therefore, they need to be identified and may need to be replaced with more probable values. The optimal setting of the boundary between accepted and rejected values, as well as how outliers should best be treated in conjunction with the adjustment of shorter records to the standard period, has to be examined further when larger sets of data from stations with long observation periods become available. The test statistic used to identify outliers in gamma-distributed data is the kurtosis of the cube-root transformed values (Barnett and Lewis 1984).

Table 4.3 The origin of outliers in short rainfall records[1]

1931:	36.5	1941:	92.5	1951:	67.0
	6.0		34.9		44.0
	176.3		33.4		71.0
	123.0		88.0		246.0
	89.0		43.9		89.3
	83.5		31.5		74.9
	24.0		32.8		49.2
	82.0		86.3		44.6
	71.3		133.0		30.5
1940:	124.9	1950:	35.0	1960:	30.2
1961:	79.2	1971:	85.0	1981:	57.0
	83.7		4.9		63.2
	46.7		73.3		9.7
	33.7		75.9		27.5
	37.7		62.4		53.2
	102.5		51.7	1986:	46.8
	79.6		98.2		
	157.8		67.2		
	39.5		55.9		
1970:	38.6	1980:	80.9		

1. The December rainfall totals for Aleppo, Syria, from 1931 to 1986 are free from outliers at the 5% level. If the data from before 1954 were not available, the values 246.0 mm in 1954 and 4.9 mm in 1972 would become outliers at the 5% level. Data compiled from various sources.

An optimal density for a rainfall station network would require enough stations to reflect with their data every single trend of the rainfall generator coefficients across space. In such a situation, straightforward interpolation methods, such as Laplacian smoothing splines or Kriging, would be sufficient to generate detailed maps of the coefficients. As rainfall is strongly influenced by relief in rather complex ways which up to now have eluded attempts to put them into the form of programmable algorithms, the network density would have to be very high in hilly or mountainous terrain, whereas on large plains distances of thirty or even more kilometers between stations would be permissible. Such dense rainfall station networks are, however, rare and probably do not exist in mountainous regions anywhere in the world. The problem is best overcome by the time-honoured method of manual mapping of the coefficients, guided by local topography and a knowledge of the rainbringing synoptic weather situations in the region throughout the year (Figure 4.6). The influence of relief on rainfall in tropical and temperate regions has been analysed and summarized by Weischet (1965 and in Bluethgen 1980). Van der Laan (1986) has demonstrated how satellite imagery (especially LANDSAT) can be used to refine the interpolation further. Care has to be taken to preserve correct relationships between the various coefficients throughout the area. It has yet to be established whether this can be achieved more satisfactorily when all coefficients are interpolated manually, or when only some are interpolated manually and the others are interpolated using Laplacian smoothing splines (Wahba 1980) while including the manually interpolated coefficients as independent variables.

4.3.2 Problems of Data Quality

Problems of data quality can be divided into problems caused by random errors and those caused by errors which are to some degree systematic. A station with poor data quality caused by too many random errors is identified through the "double-mass" method (Scultetus 1969); i.e. by plotting cumulative values of its uncorrected rainfall coefficients against the average of a large

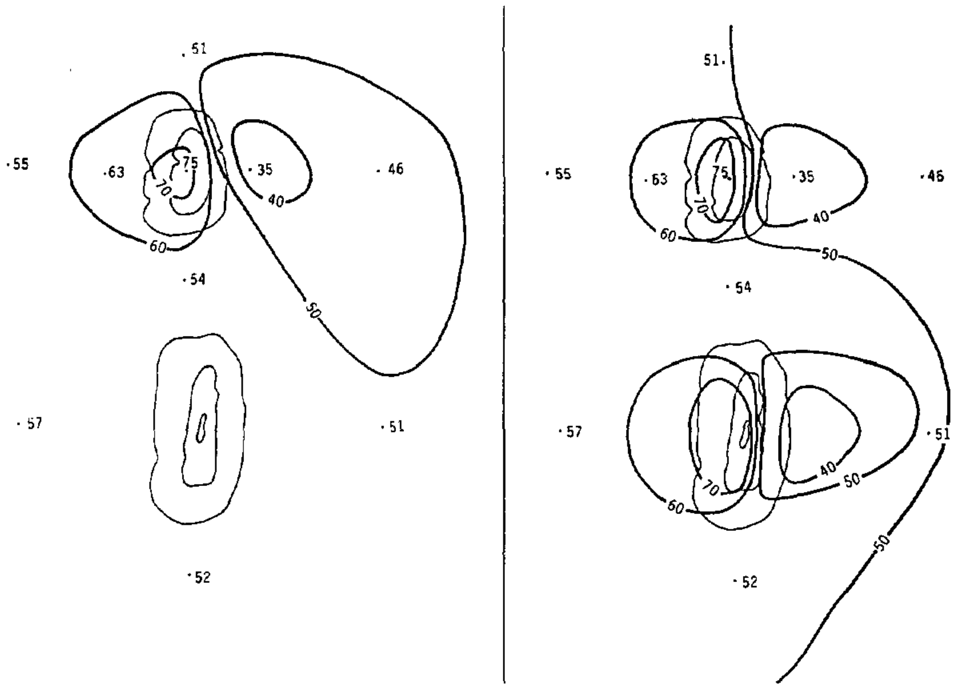


Figure 4.6 Comparison of straightforward interpolation of mean monthly rainfall totals (left) with topography guided interpolation (right). The straightforward interpolation completely ignores the influence of the mountain without rainfall station at the top.

(thin lines = contours, thick lines = isohyets in mm, points = rainfall stations with totals in mm)

number of surrounding stations. Random errors in the data of the tested station show as excessive scatter of the plotted points around a fitted straight regression line through the origin. The Chi-square statistic of the regression line provides a measure of the overall data quality of the station if inhomogeneities (see below) are absent. As corrective measures for random errors do not exist, stations with exceedingly poor data quality are excluded from the calculation of any correction factors for coefficients of other stations. Best estimates of their own coefficients are nevertheless determined, as they may still have indicative value for the spatial interpolation of rainfall coefficients if used prudently.

In contrast to random errors, series of errors which are to a degree systematic can be rectified to that extent by statistical methods. One type of such errors are inhomogeneities in rainfall records. They are detected by the same method of double-mass analysis as used to detect random errors, although the method is not as sensitive as would be desirable. An inhomogeneity shows as a nonlinearity of the resulting curve. If the inhomogeneity is caused by a single event, two regression lines of different slopes can be determined for the periods before and after the event. In such cases, the cause of the inhomogeneity frequently is a relocation of the station or the construction of a building at two close a distance from the raingauge. More complex nonlinearities of the double-mass curve may be caused by a gradual build-up of the surroundings of the station. If an inhomogeneity can be traced to a change of the station location, the remedy for the purpose of spatial rainfall generation is to treat the records from before and after the relocation as those of two altogether separate stations. In all other cases, the curve of the double-mass analysis is used to determine correction factors for the various rainfall generator coefficients of the tested station which compensate the inhomogeneity.

Failure to record small rainfall events of less than one or two millimeters is another fairly widespread "systematic error", especially at stations which take only one reading per day. Figure 4.7 shows examples of a station afflicted by this problem in comparison with a station with a reliable, complete record. In hot climates, the traces of some of these small rainfalls may simply have evaporated out of the raingauge before the next reading was due. These small rainfalls as such may not be important for crops, but the absence of a smaller or larger part of their number deteriorates the performance of the Markov-chain model employed by the rainfall generator to generate a realistic sequence of dry and wet days. Also the generation of temperature and radiation is affected, since the distinction between rainy and dry days is of fundamental importance for this process.

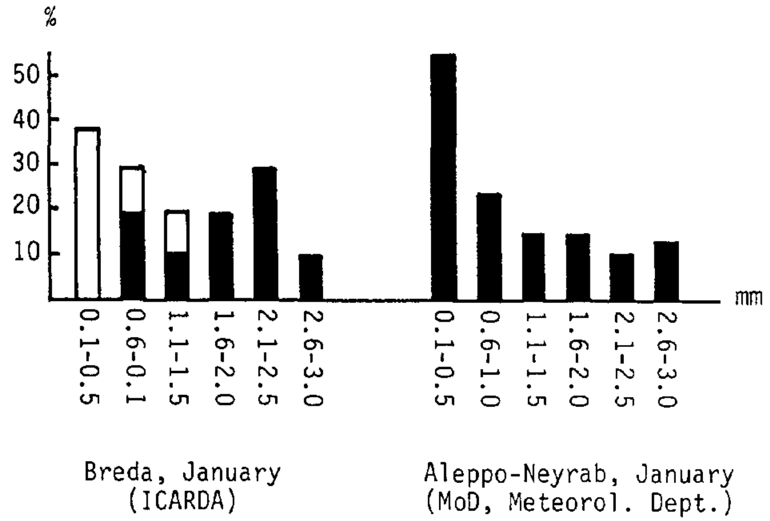
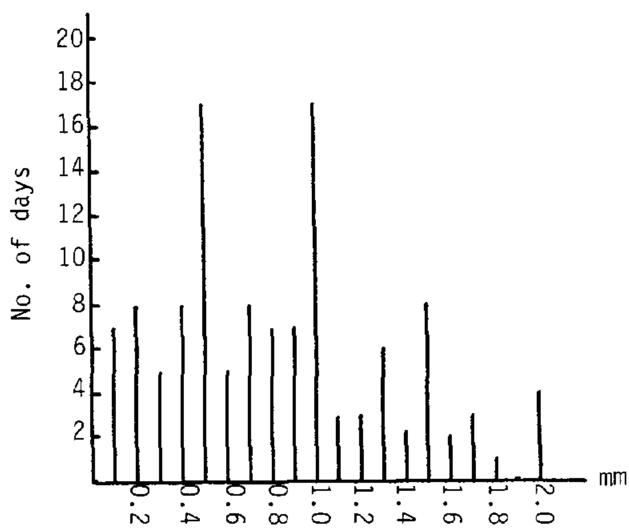


Figure 4.7 Comparison of a station which has failed to record some of the small rainfall events (Breda) with a synoptic station (Aleppo-Neyrab). The solid bars represent the frequencies of rainfall events below 3 mm in classes of 0.5 mm width as percentages of the rainfall events in excess of 3 mm. For Breda, estimates of the corrected frequencies are shown in outline.

Furthermore, the varying reliability from station to station with which such small rainfall events are reported may make a sensible spatial interpolation of the coefficients of the Markov-chain model impossible. It is, therefore, necessary to introduce the missing rainfall events into the station records. How many of them a particular station has failed to record is determined by comparing its record with those of the closest of the synoptic stations and those of other stations in the vicinity, whose records are judged to be highly reliable. This comparison permits us to calculate for every day a probability that such an unreported rainfall may indeed have fallen. This is then used to replace dry days in the record of the examined station with small rainfall values in a stochastic process.

The same stations sometime also show a marked preference for rounded values, in particular observations of 1.0, 2.0 and 3.0 mm, also 0.5, 1,5 and 2.5 mm, may be far more frequent than any values in between (Figure 4.8). For large rainfall events, rounding them to the nearest full millimeter hardly matters, but for small events the resulting relative error is considerable and may adversely affect the coefficient estimation, in particular for the shape factor of the gamma distribution used by the generator to model daily rainfall. The problem is addressed by retransforming some of the rounded data points into their presumptive values before they were inadvertently rounded off by the observer.



Jarablus, January
(MoD, Meteorol. Dept.)

Figure 4.8 Example of a rainfall station with a preference for recording round values (note the number of days with observations of 0.5, 1.0, 1.5 and 2.0 mm)

4.3.3 Integration of the Steps of Rainfall Coefficient Estimation

The integration of the described steps in the estimation of coefficients for the spatial rainfall generator is shown in Figure 4.9. After the elimination of any stations with unacceptable random errors, other aspects of data quality (bias against small rainfall events, preference for round values) are addressed. If further validation with larger volumes of data proof the usefulness of it, outliers can now, or parallel to later steps, be replaced by values with a higher probability of occurrence.

Whereas the previous steps affect single values in the records of the stations, the last three steps follow the determination of the rainfall generator coefficients of each station and modify these: first, correction factors for inhomogeneities are determined, then the coefficients are corrected for both, inhomogeneities and for missing observation periods in one process. The resulting corrected coefficients are the basis for the manual spatial interpolation which, after digitizing, supplies the coefficients for each cell of a spatial grid for the project area under consideration.

The rainfall generator then is trivial compared to the coefficient estimation; all it does is to generate the desired number of values from the coefficients of each grid cell using a comparatively simple algorithm. It can be linked to an event evaluator which counts how often a certain rainfall event is generated in each grid cell and thus facilitates the mapping of rainfall event probabilities.

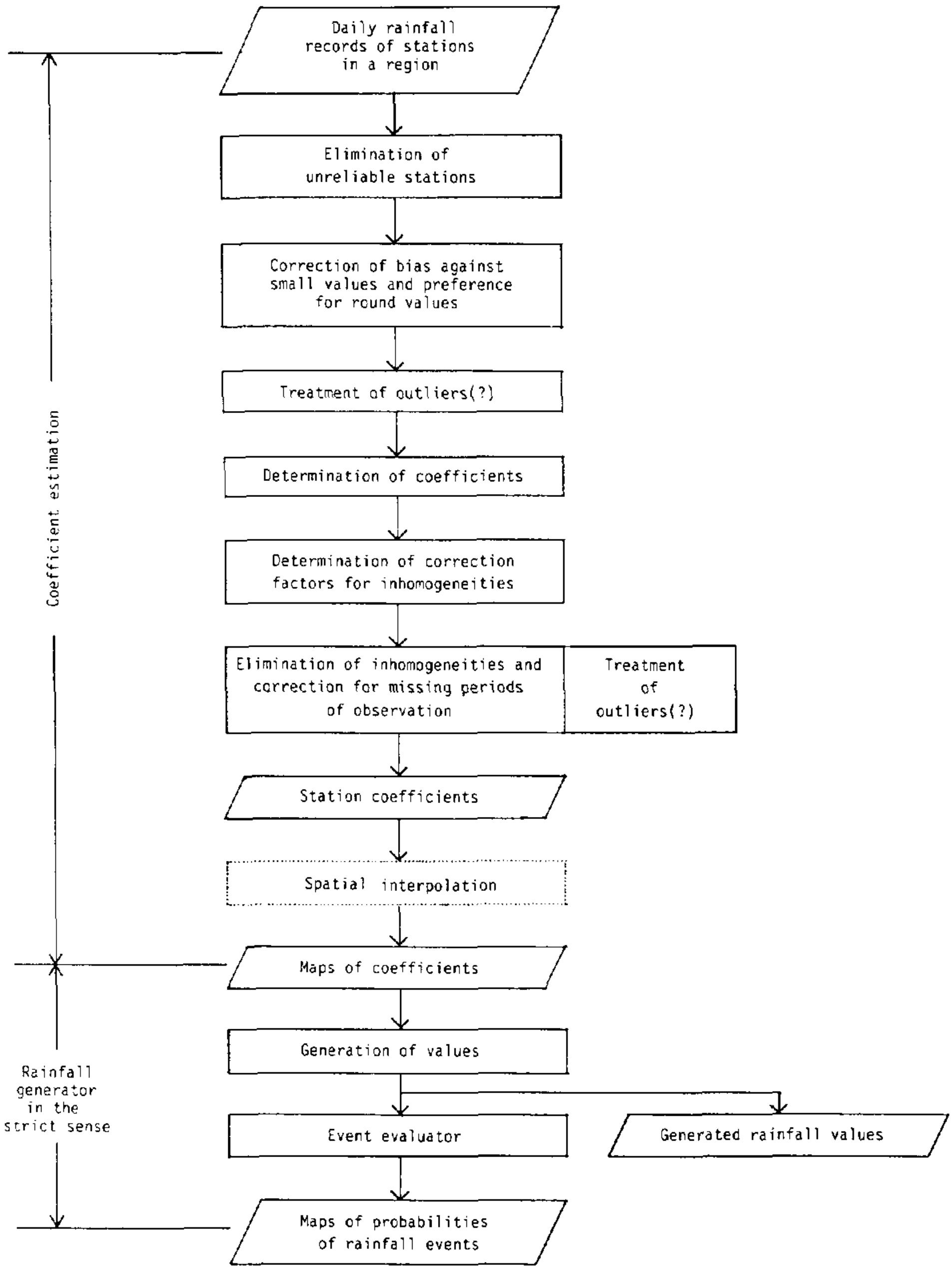


Figure 4.9 Flowchart of the spatial rainfall generator

4.3.4 References

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5. PROJECT 3. ADOPTION AND IMPACT OF TECHNOLOGIES

5.1 Introduction

The formation of a project focused on questions of adoption and impact is a reflection of both National Programs' and ICARDA's maturation. New technologies have been developed which are now available for farmers. In many countries farmers are already using some of these improved farming methods. The extent to which farmers are able to adopt new technology, and the impact such technology has on productivity and economic return must continually be monitored to assess the relevance of research programs. This project will develop methods of predicting, assessing, and improving the adoption and impact of new technologies.

Technologies must be acceptable to many parties in order to be put to widespread use. The farmer is usually considered the end user; for him, a new technology must be appropriate and profitable within his means and abilities, culturally permissible, and not unreasonably risky. In this region, where governments play an important role in the agricultural sector, their priorities also must be understood; these concern food self-sufficiency, pricing policies, and allocation of production inputs among sectors. It is also necessary in some cases to consider the consumer of farm produce, as in the case of crops which must meet certain standards to be marketable. A better understanding of these factors will allow ICARDA and national research programs to concentrate efforts on technologies which will most likely be extended and adopted.

It is useful to quantify the potential impact of technologies on food production and agricultural national income in order to establish priorities for research. We must be prepared to predict and monitor the impact of new technologies on the economic well-being of farm families. Lessons of previous technological change (i.e., the "green revolution") indicate that impact must be considered in a broader sense, including the side effects of new technologies and unbalanced costs and benefits within different parts of the agricultural sector. These include effects on employment, nutrition, women's opportunities and income distribution.

In this project, our long term goal 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 will 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 interpretation 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 benefits 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.

Our research in this important project is currently limited due to staffing constraints. During 1989 however, we plan to recruit both an "impact" oriented economist and an "adoption" oriented social scientist who will play a major role in developing and expanding the scope of our work. Current research, although limited, is nonetheless exciting and is making good progress. In this year's report, we focus on a major issue which will affect both the ability of farmers to adopt new technologies, and the impact those technologies will have: namely the allocation by National Governments of production inputs among different agricultural sectors.

5.2 An Economic Framework for Centralized Fertilizer Allocations to Crops in Contrasting Production Zones

T. Nordblom (ICARDA)
M. Al-Ashram (Aleppo University)

5.2.1 The Problem

Central planners wish to maximize economic benefits from their country's set of agricultural and industrial resources. The problem faced by planners in many countries of West Asia and North Africa is how to allocate limited quantities of domestically manufactured agricultural inputs among alternative productive uses and/or export sales, and to what extent should gaps in domestic inputs be filled with imported inputs.

The problem is more narrowly focused here on nitrogen (N) and phosphate (P) fertilizers: key points are presented for a framework which can be used to simultaneously consider multiple crop and zone specific yield responses to N and P while balancing their marginal production values against options for exporting domestically manufactured fertilizer and options for importing. Examples from a hypothetical country illustrate how the implications of alternative fertilizer policy choices can be traced by the allocation framework.

The hypothetical case, which refers to no specific country and which, therefore, leads to no actual policy prescription is posed by four sets of assumptions:

a) The quantities of domestically manufactured chemical fertilizer nutrients (N and P_2O_5) are limited to some fixed amounts and these can be produced at costs lower than their export prices. Therefore, the planners wish to economically allocate fertilizers to domestic crops up to the point where the increase in crop value due to the last kg applied equals the export price.

b) Imports of fertilizer nutrients are also an option. Chemically identical to the domestically manufactured fertilizers, the imported fertilizers have the disadvantages of prices noticeably higher than export prices and that they need to be paid for in foreign currency.

c) Farming is limited to rainfed crops grown on fixed land areas in three contrasting production zones: wheat in zone 1, the highest rainfall area, and barley in both zones 2 and 3 which receive medium and low average rainfalls, respectively. Over many years of experimentation with fertilizers under farmers' conditions national scientists have discovered great differences in crop response to N and P among the three zones. The highest total response is in zone 1 and the lowest is in zone 3.

d) The hypothetical country has been importing a large part of the wheat and barley it consumes annually, so that any increase in domestic production of grain would directly substitute for imports and could be valued at import prices.

5.2.2 The Framework

The framework begins where the agronomists and biometricians leave off: the response functions. These relate crop yields to nutrient applications and environment, and are the heart of the framework. The framework assumes static production and price relationships to derive solutions which could be seen as "first approximations" in the planner's real world of dynamic relations.

The study begins with response surfaces defined by production functions of the form:

$$Y = b_0 + b_1N + b_2N^2 + b_3P + b_4P^2 + b_5NP$$

Subject to N, P, $Y \geq 0$

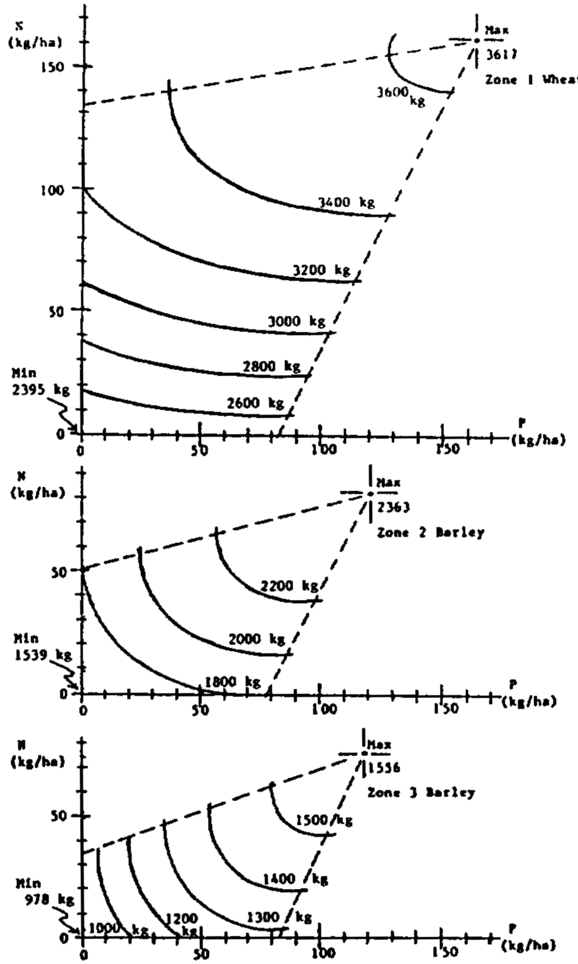
where: Y = kg grain yield per hectare
N = kg N applied per hectare
P = kg P_2O_5 applied per hectare
and, for each specific crop area,
parameters b_0, b_1, b_3, b_5 > 0 and b_2, b_4 < 0.

Parameter values used in this hypothetical example, for wheat in zone 1, and barley in zones 2 and 3, are borrowed from analyses of ICARDA field trials in NW Syria. For any practical application of the framework, planners in a country would want to use response function parameters representing their own best estimates of expected response under farmers' conditions.

Based on the specific parameter estimates, isoquants (equal-yield curves) are plotted for the three crop areas in Figure 5.1. These isoquants provide visual references to yield responses, just as a topographic contour map indicates areas with steep or shallow slopes. The economic range of interest in N and P use will be within the subset of N and P combinations which give positive marginal returns to both nutrients. The outer boundaries of the economic range are called "ridge lines" (dashed lines from points of maximum yield in Figure 5.1). Nutrient applications beyond this range will waste fertilizer and possibly reduce yields.

What should be noted in Figure 5.1 are the differences in responses to N and P in the three crop areas. The zone 1 wheat shows high responses to N applied alone, but low responses to P alone; the lower isoquants are nearly parallel to the P axis. The greatest contrast to this is found in zone 3 barley where responses to N applied alone are negligible but those to P alone are substantial; the lower isoquants are nearly parallel to the N axis. In all three crops, however, the response functions show

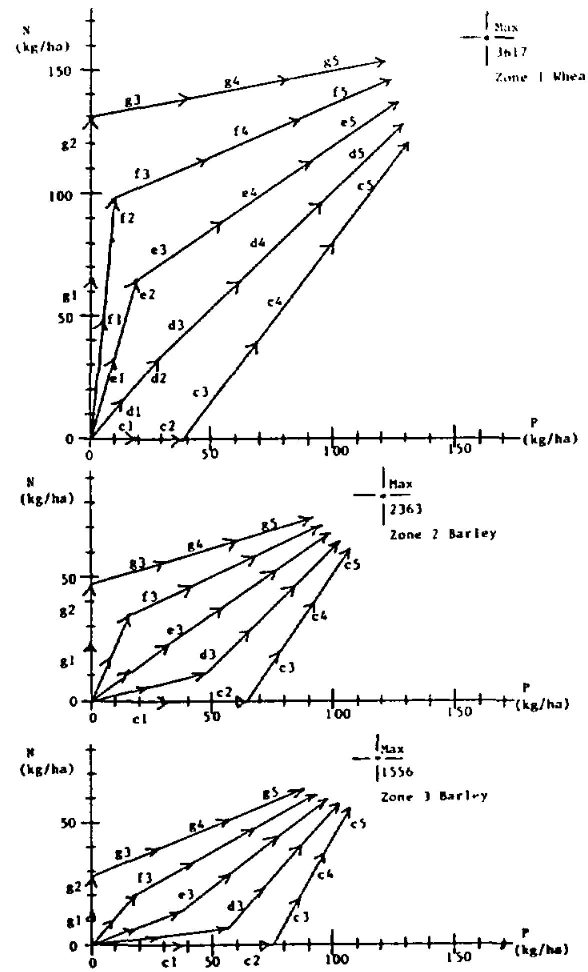
Figure 5.1 Grain yield isoquants for Zone 1 Wheat, Zone 2 Barley and Zone 3 Barley



strong interactions between N and P; moderate to high levels of both are needed to approach the highest yield potentials. It is important to note here that the allocation framework aims for the best economic solutions rather than yield-maximizing ones per se.

Chains of three-dimensional N, P, Y vectors are defined by the framework to largely cover the economic range of allocation

Figure 5.2 Nutrient application vectors for the three crop areas



choices along each response surface. These are plotted in two dimensions (N and P) in Figure 5.2. Linear combinations of the vectors can reach virtually all points in the range.

The allocation framework takes the form of a linear programming model in which the vectors are arranged as competing activities: competing across crops for the limited quantities of N and P. Import options are defined to relieve these limitations, at a cost, and export options for N and P provide reserve prices below which marginal values of crop production will not attract fertilizer use.

Sources of N and P, then, are domestic production and imports. Exports take away amounts of domestically produced N or P which cannot more profitably be used in the three crop areas. The objective to be maximized by linear programming represents the sum of crop sales values, plus the values of fertilizer exports, minus the costs of fertilizer imports.

The underlying economic principles used in this allocation framework can be summarized briefly:

1. The expected value of the last increment of yield in each crop should be greater than or equal to the opportunity cost (export or import price) of the last increment of nutrient to be applied, and

2. The expected value of the yield increase from the last kg of nutrients for one crop should equal the expected value of the yield increase from last kg of nutrients for the other crops.

The above rules are layman's language versions of what economists call "equimarginal conditions." Satisfaction of these rules may be obtained through the technique of separable linear programming, where the national allocation problem is decomposed into a simpler problem of competition across crops among the elementary fertilizer vectors.

5.2.3 Four Scenarios

Results of the analysis of four hypothetical scenarios are presented here. The scenarios differ from one another in one or more of the following dimensions:

* policy limitations on allocations to zone 3 barley.
* policy limitations on imports of N or P.
* domestic production levels of N and P.

In common among the four scenarios are the prices assumed for wheat and barley, the prices of exported or imported N and P, and the amounts of land under production in each zone, as follows:

Rainfall Zone	Crop	Land Area (ha)
zone 1	wheat	43,000
zone 2	barley	199,000
zone 3	barley	80,000

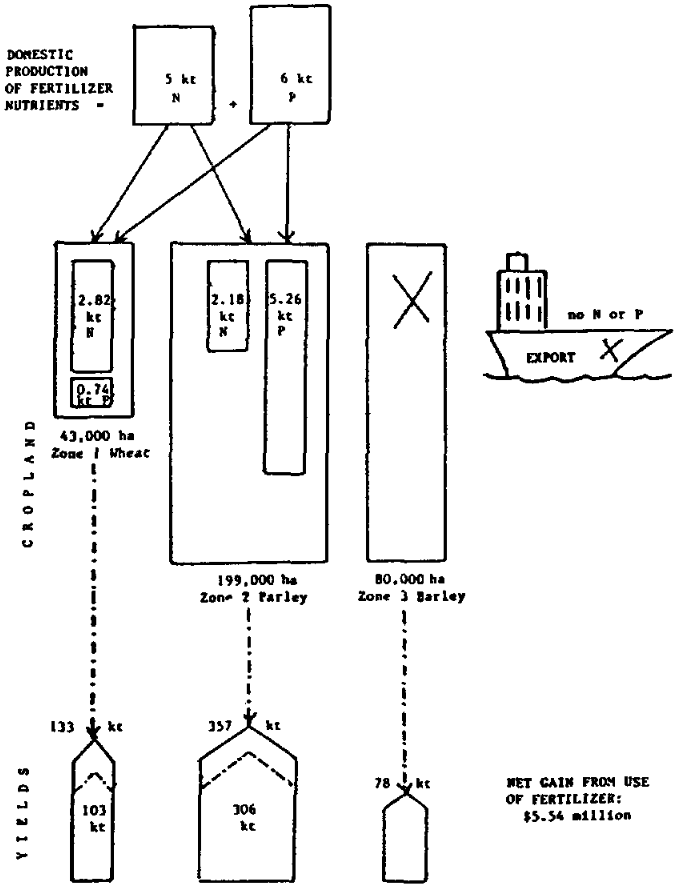
Prices ($/kg)	Exports	Imports
wheat grain	-	0.14
barley grain	-	0.09
N	0.25	0.40
P	0.32	0.45

The levels of domestically produced N and P are assumed to be the same in the first three scenarios, limited to 5 and 6 thousand tons (kt), respectively, to compare the effects of different policy choices.

In scenario 1 (Figure 5.3), allocations of the domestic N and P were calculated given two policy constraints: that no fertilizer should go to zone 3 barley and that no fertilizer may be imported. The result was allocations of N and P to zone 1 wheat and zone 2 barley, with the majority of N going to the wheat, and most of the P going to the zone 2 barley.

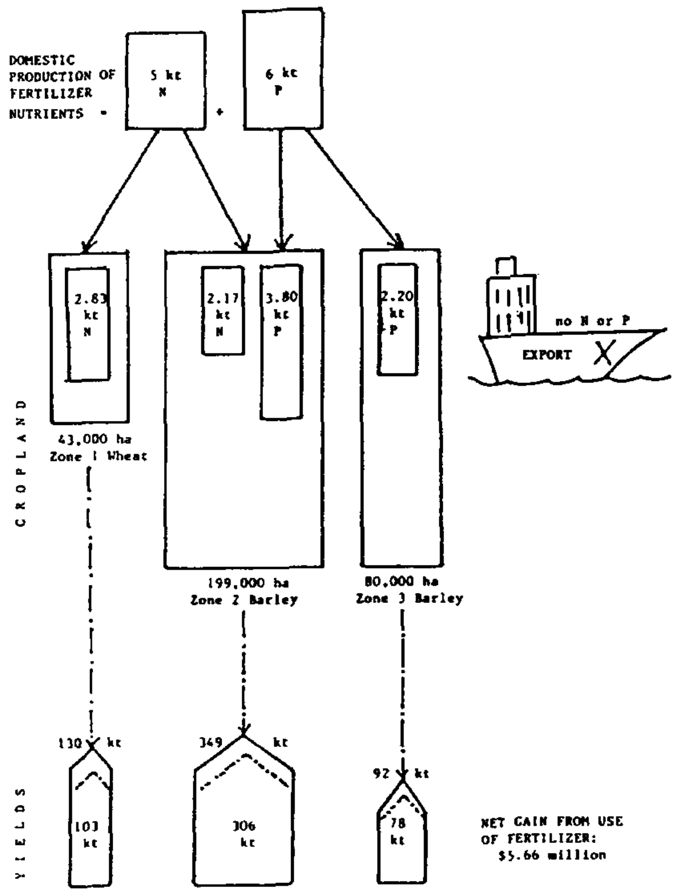
With no fertilizer, the 80 thousand hectares of zone 3 barley should produce about 78 thousand tons (kt) of grain. With the fertilizers all going to the higher rainfall areas, the 43 thousand hectares of zone 1 wheat should produce about 133 kt of grain, and the 199 thousand hectares of zone 2 barley, 357 kt. With no fertilizer at all, the wheat and zone 2 barley areas should have produced 103 and 306 kt, respectively, according to their response functions.

Figure 5.3 Optimal allocations of domestically produced N and P among Zone 1 Wheat, Zone 2 Barley and exports, given a policy that none may go to Zone 3



Conditions for scenario 2 (Figure 5.4) differ from those of scenario 1 in that fertilizer may be allocated to zone 3 barley, as well as to the wheat and zone 2 barley areas, on the basis of their comparative responses. Under this policy, the optimal allocation is to continue sending the majority of the N to the wheat area and the rest to zone 2 barley while diverting over a third (2.2 kt) of the P to zone 3 barley, with the rest going to

Figure 5.4 Optimal allocations of domestically produced N and P among Zone 1 Wheat, Zone 2 Barley, Zone 3 Barley and exports

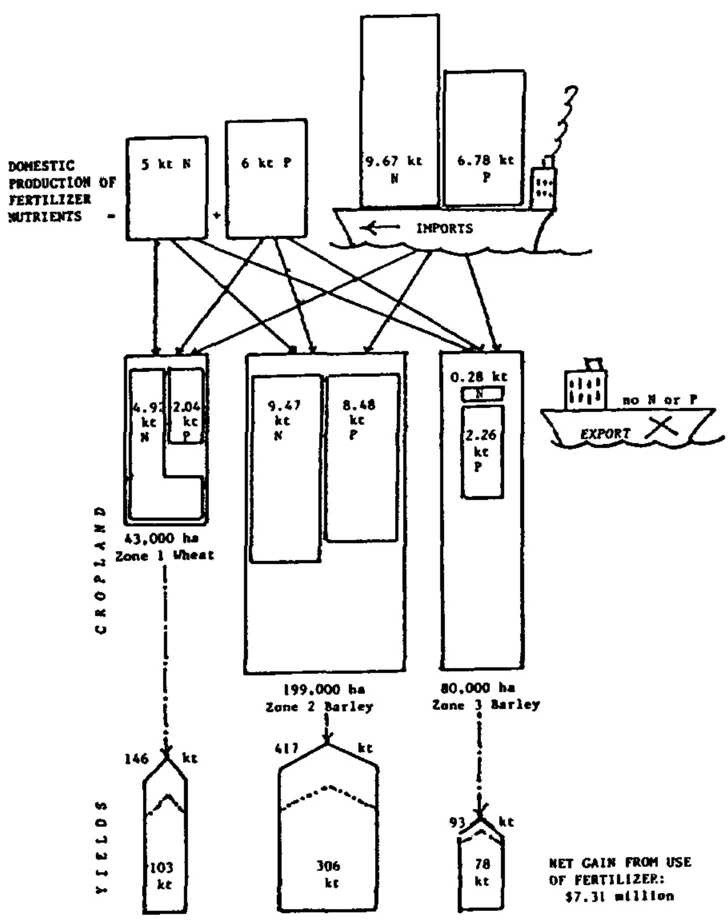


zone 2 barley. No P would be allocated to the wheat area in this case because of the higher responses available in the barley areas.

In the optimal diversion of P from wheat and zone 2 barley to zone 3 barley in scenario 2, grain production in the latter would increase from 78 to 92 kt, while production in the higher rainfall areas would be reduced slightly from their levels in scenario 1. The trade-off is worth while, however, because net gains from the use of the same limited quantities of domestic fertilizers would increase from \$5.54 million in scenario 1 to \$ 5.66 million in scenario 2.

Scenario 3 (Figure 5.5) differs from scenario 2 in that policy now allows fertilizers to be imported to complement domestic production up to the point where the value of marginal

Figure 5.5 Optimal allocations of imported and domestically produced N and P among Zone 1 Wheat, Zone 2 Barley, Zone 3 Barley and exports

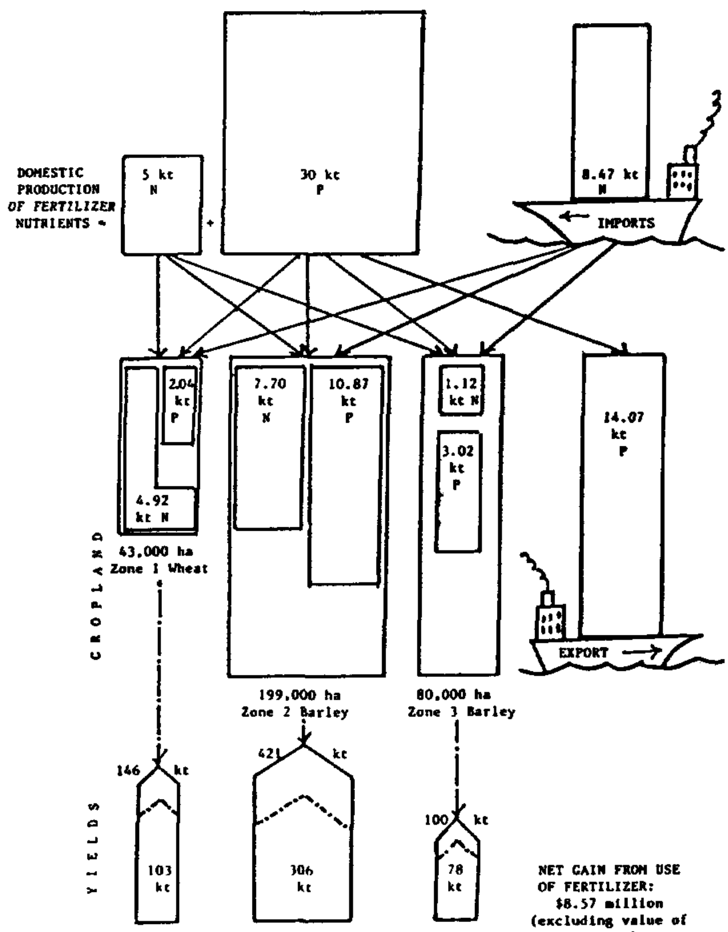


yield responses are greater than or equal to the import prices. The optimal plan in this case includes allocations of both N and P to all three crop areas such that imports of 9.67 kt of N and 7.78 kt of P should be purchased. The result is a calculated net (after cost) gain from fertilizer use of $ 7.31 million. This was due to the considerable reserve of response potentials beyond those attainable with the limited production of domestic N and P. An increase of $ 1.65 million in net gains over scenario 2 translates into a 23.8% net return on an investment of $ 6.92 million for the imported fertilizers.

Scenario 4 is not directly comparable to the first three in that it assumes a five-fold increase in domestic production of P, to 30 kt. This amount is far in excess of domestic demand from the three crop areas. The question is: how much P should be allocated to each area and to export sales given that N can be imported to complement the limited quantities produced domestically? The optimal plan (Figure 5.6) is intuitively clear: allocations of P to the crop areas are generally greater than in scenario 3 because the opportunity cost (export price) of the large quantities of domestic P is less than the import price of P in the later, so use of P will be expanded to levels with lower values of marginal productivity where returns equal the export price; excesses of P, some 14 kt beyond this, should be exported; the large levels of cheaper P use, particularly in the barley areas, are combined in the optimal plan with lower import and use levels of N; this is a case of input substitution, P for N.

Given the lower cost and higher use of P for barley areas in scenario 4 than in scenario 3, higher production is calculated. In the zone 3 barley area, 1.12 kt of N is called for in optimal combination with 3.02 kt of P, for a planned production level of 100 kt of grain. Recall that zone 3 barley production without fertilizers was only expected to be 78 kt. The 22 kt (or 28%) extra planned production of barley grain from this low rainfall area is in balance with other opportunities for fertilizer use, including export sales.

Figure 5.6 Optimal allocations of imported and domestically produced N and P (with more P) among Zone 1 Wheat, Zone 2 Barley, Zone 3 Barley and exports



What should be clear to the reader in the above four scenarios is how much policies can affect the outcome of production. In fact, because policies often extend to farm commodity price controls, taxes and subsidies, investments in infrastructure and human capital (training), their scope for affecting production is much broader than depicted in these examples.

5.2.4 Remaining Issues on Fertilizer Allocation

1. The examples above consider only three crop-zone opportunities while a valid planning model must account for all main potential opportunities for fertilizer use in a particular country, and many of these involve crops outside ICARDA's mandate (e.g. sugar beets, cotton, olives, etc.). Therefore, future practical applications of this allocation framework will chiefly be the responsibility of national programs, with ICARDA staff involved in consulting and training roles.

2. The data requirements are formidable: the response coefficients for all main crops in all main zones must be available before valid planning can take place with such a framework. Data requirements are formidable, however, for all central planning. In this case, the same data are needed for extension work at the local level. It is the collation and up-dating of a centralized national data base on actual responses that provides the biggest challenge to the successful use of this tool.

3. Yield responses to fertilizers under researcher-management, whether in on-station of on-farm trials, are typically higher than those obtained by farmers in their own fields. For valid planning, it is necessary to have estimates of yield responses under the management of farmers, for each main crop in each main zone.

4. The framework presented here is static: it assumes fixed response functions which represent expected responses prior to the onset of the season, at the time when fertilizer production, imports and distribution are being planned. Abundant evidence clearly illustrates that fertilizer responses are dependent on seasonal weather, principally rainfall and temperature. It is important to test the value of considering variable, risky, responses vs. static ones.

5. The quadratic form of response function used in the framework is neither the only nor the best for representing all yield responses to fertilizers; it is a convenient form for the present purpose but others should be explored. A related issue is in regard to the treatment of crop rotations and carry-over effects: interactions, accumulation and loss rates under different cropping patterns may need to be considered explicitly (see sections 3.4 and 3.5 of this report).

6. The framework may seem complicated, but the problem is a complex one of simultaneously considering multiple opportunities for use, import and export of major agricultural inputs across a nation. However, by decomposing the national allocation problem into one of competition among elementary use vectors, it becomes manageable with existing standard linear programming software.

Full documentation of the development and preliminary testing of the framework presented in this report is currently being prepared by the authors and will become available in 1989 under the same title.

5.2.5 Summary

We have presented key points of an economic framework for planning centralized allocations of fertilizers across a country's contrasting crops and production zones. The framework simultaneously considers competing crop and zone specific yield responses to N and P, balancing their marginal production values against options for exporting domestically manufactured fertilizer and options for importing. Implications of alternative policy choices may be traced through the framework. The framework will be most useful for centrally planned agricultural sectors facing severe limitations on availability of fertilizer inputs due to low levels of domestic manufacture or to foreign currency constraints.

6. COLLABORATIVE RESEARCH WITH NATIONAL AGRICULTURAL RESEARCH INSTITUTES AND UNIVERSITIES

6.1 Introduction

During the last years FRMP has sought to expand its research and influence from our host country Syria to other countries of the region. In doing so we have utilized our considerable knowledge of the farming systems in Syria, their problems and their potential as a basis upon which to build. We have moved carefully and have tried to allocate our resources and expertise to cooperative projects which have the greatest chance of success. We remain very much aware of the need to maintain a proper balance between a vigorous forward looking core research program and a more applied research program in cooperation with National Programs. Finite resources (both human and financial) can only be spread so thin before quality of research, the hallmark of the International Centers, becomes jeopardised. For this reason, we have endeavored to attract special funding wherever possible to support our international cooperation, and in this we have been largely successful.

Two major strategies for international cooperation have been developed. First, together with ICARDA's other programs, we seek to establish "systems oriented" cooperative research targeted towards the four broadly defined farming systems of our region. In doing so, we recognize that substantial variability in socio-economic, biological and environmental factors will exist within these broadly defined areas, and thus we do not attempt to transfer technology directly from equivalent systems in Syria. Rather, we use that experience, both of research findings and research methodology to establish projects with realistic objectives, a FSR perspective and applied research methodologies.

Secondly, we believe that we have made substantial progress in specific areas of resource management, and that we have much to offer the region in this respect. Thus we have also established networks of cooperative activities which focus on single components of resource management into which, when appropriate, we try to build a systems perspective.

In last year's report we focused on the activities of our current networks, and this year we provide a brief update of activities during 1988. In addition, we present a series of reports of collaborative research activities in Turkey, Syria, Jordan, Algeria and Tunisia. We record here our appreciation of the work of our colleagues in National Institutes who have contributed so much to these results and reports.

6.2 Regional Networks

During 1988, we were involved in the support of three regional networks which bring together scientists whose research addresses specific aspects of resource management, namely Supplemental Irrigation, Soil Test Calibration, and Agricultural Labor and Technological Change. In the following sections we present a summary report of these activities.

6.2.1 ICARDA/FAO Regional Network on Supplemental Irrigation

This study conducted by 12 national scientists in cooperation with ICARDA and FAO investigated the current situation of soil and water resources and potentials for introducing and/or improving supplemental irrigation technologies in their respective countries. The countries involved are: Algeria, Cyprus, Iran, Iraq, Jordan, Libya, Morocco, North Yemen, Pakistan, Syria, Tunisia, and Turkey (see also FRMP Annual Report 1987, section 5.5). Data analyses and a manuscript is in preparation describing the state-of-the-art of Supplemental Irrigation Systems of the Near East and North Africa.

Findings, presented and discussed in Rabat at the Regional Workshop, December 1987, revealed that (1) the food gap is drastically increasing in most countries of the region due to reliance on rainfed agriculture of low and uncertain productivity; (2) supplemental irrigation technologies are rarely adopted by farmers in most countries due to inadequate training although water resources are inefficiently utilized or not used at all at the farm level; (3) potential for increasing agricultural production is considerable. Limited research activities on supplemental irrigation, already conducted in a few countries, have shown a yield increases ranging between 50 and 500%.

Workshop participants recommended that (1) more efforts should be exerted by international and national organizations to increase the interest of planners and policy makers in supplemental irrigation and water harvesting issues in terms of resource assessment, research activities, data base establishment and information exchange, etc., and (2) cooperation between ICARDA and FAO on water management issues to be continued and enhanced.

6.2.2 Soil Test Calibration Network

During 1988, participants in this network continued to examine, through field trials, the relationships between laboratory determinations of soil fertility status and crop responses to the major plant nutrients, nitrogen and phosphorus. The third annual workshop was held in Amman, Jordan at which the participants discussed their results, and summarized their conclusion and recommendations under three broad headings:

Practical Application

- The critical P value of 5 to 7 ppm P (Olsen $NaHCO_3$) was confirmed as being valid for countries of the North Africa - West Asia region.

- Banding of P was considered more efficient than broadcasting especially at low soil P levels; this is the Network's recommendation where drills are used. The Network further encourages the adoption of grain drills with capability for banding fertilizers.

- Nitrogen fertilization is essential under most cropping conditions, except perhaps where a cereal follows a previous legume crop, or in very dry years/locations.

Research

- Scientists in cooperating countries were encouraged to use single element experiments rather than factorial ones; these are easier to conduct, involve less resources and are more appropriate to field conditions where N and P deficiencies do not necessarily occur at the same time.

- The Network strongly urged delegates to have the soils at all proposed experimental sites sampled and analysed for P and NO_3^- before planting; experimentation should not take place where test levels for these elements are considered adequate, since no response is likely to occur and resources could be wasted.

- In view of delegates concern about soil test variability within experimental sites, it was recommended that, at minimum, three composite samples be taken per replicate, and at maximum, a composite sample should be taken from each plot.

- The meeting confirmed the general usefulness of the Olsen $NaHCO_3$ procedure as an index of available P in countries of the region; however, research aimed at improving soil testing or using other procedures was welcomed.

- In view of the inconsistency of results obtained using NO_3^--N as an index of available N in wheat grown under dryland conditions, researchers were encouraged to continue their quest for an N availability index as a basis for N fertilizer recommendation, and to continue searching for reliable models that could be used for N recommendations to farmers.

- While the major focus should continue on N and P in dryland farming conditions, the importance of other elements, especially Fe and Zn, should not be ignored.

- In view of some inexplicable and conflicting results, detailed studies were encouraged in the following areas:

  a) impact of soil moisture on P placement efficiency,
  b) organic matter in relation to soil mineralization potential, and
  c) the dynamics of P in soils.

Future Meetings

- The next Network meeting was scheduled for the spring of 1990. Morocco was considered a suitable venue, and the Moroccan delegation warmly welcomed this proposition.

- National delegates were encouraged to review their countries findings in soil test calibration for presentation at the next Network meeting.

- The Network welcomed the proposal that a special symposium be held on the general topic of soil fertility and soil test calibration at the American Society of Agronomy Meetings in San Antonio, Texas, in October 1990. Delegates were encouraged to plan for a significant contribution by the countries of the region at this international meeting.

6.2.3 Agricultural Labor and Technological Change

The regional overviews on Labor Markets in Non-agricultural Sectors, Mechanization, Off-farm Employment and Agriculture; and Changing Availability and Allocation of Household Labor as well as country review papers from Turkey, Cyprus, Syria, Jordan, Iraq, Yemen Arab Republic, Tunisia and Morocco have all been completed, edited and will shortly be published. The eight case studies (see FRMP Annual Report 1987, section 5.4) from Jordan, Turkey, Algeria, Tunisia and Morocco have also been completed and were presented and discussed at a workshop in July 1988 (see section 7.4 of this report). They are currently being edited and will also be published in 1989.

The future, both its desirability and focus, of this Network was discussed at some length by workshop participants. The following points were clear:

- Participants thoroughly endorsed the activities of the network to date. They appreciated the chance to meet together and discuss the results of field research activities. They indicated strongly that they would like to continue and expand the network, and maintain their contact with the social and biological scientists of ICARDA.

- Participants requested that ICARDA should continue to coordinate the network and should play a leading role as an intermediary between national scientists and donors. They highlighted the substantial impact that relatively small grants can have on their ability to conduct field research.

- In looking to the future of the network, participants agreed on several issues that they would like to see incorporated:

  a) A newsletter and other procedures to stimulate frequent exchange of information on socio-economic issues influencing the choices, adoption and impact of new technology.

  b) Regular workshops to discuss field activities and findings. They suggested that in future, a previously agreed common theme should provide the focus for such field activities.

  c) A forward looking approach to field studies. The future impact of agricultural labor forces on technology adoption was thought to be more relevant to researchers and policy makers than the analysis of past events.

- The participants requested ICARDA to develop a proposal which incorporated these points and to use its good offices to encourage donors to support the future of this network. We are responding to this request.

6.3 Goubellat Farming Systems Project, Tunisia Summary of 1987/88 Research Results

6.3.1 Introduction

Starting with the 1987/88 crop year the Goubellat FSR project began a more intensive series of experiments in which all researchers performed their research on the same plots in farmers' fields. This series has the objective of integrating research on improved forage and livestock production practices while evaluating their effect on cereal production, soil fertility and conservation.

The simultaneous work by many researchers on a single multifaceted problem has required close cooperation on details as minor as the dates of discing. All the researchers involved are intimately aware of the details of their colleagues' work and how each person's work affects all others. This has resulted in some compromises as well as greater efficiency in use of available resources.

The researchers involved in the Goubellat FSR project were:

Mrs. R. Khaldi, Economist, INRAT
Dr. M. Djemali, Animal Scientist, INAT
Dr. G. Khaldi, Animal Scientist, INRAT
Dr. T. Stilwell, Agronomist, ICARDA
Mrs. H. Amara, Barley Breeder, INAT
Mr. M. Kaabia, Soil Conservation, INRAT
Mr. H. Mellouli, Water Use Efficiency, INRAT
Mr. M. Mezni, Forages, INRAT

The experiment on which all researchers collaborated is shown in Figure 6.1.

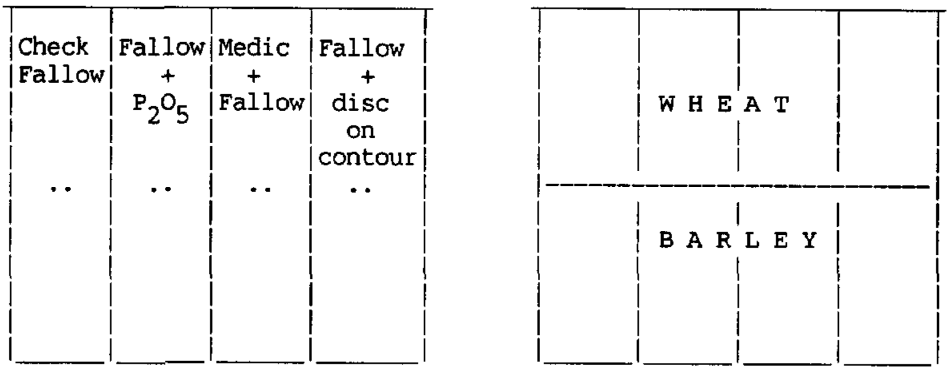


Figure 6.1. Rotation experiment plots for 1987/88.

During the 1988/89 year the fallow treatments will be placed over the previous years' cereal crops as indicated by the dotted lines and the cereal plots will be on last year's fallow plots. All research, including grazing was done on this experiment replicated on 6 farms in Goubellat. Three of the farms are located on hilly terrain and three farms on plain topography.

The experimental plots consist of two, one hectare parcels. Each year there are four fallow treatments on the hilly sites. The countour discing is not included on the plain sites. The Check Fallow is left without discing following the usual farmer practice in the zone. For the fallow with P_2O_5, 45 kg/ha of P_2O_5 are broadcast in October and lightly disced with no other treatments until spring plowing. For the medic plots a mixture of Australian Medic varieties (Gemalong + Paraggio) were seeded in October along with an application of P_2O_5. On hilly sites the fourth fallow treatment was prepared with only discing on contour. The wheat and barley plots were cultivated using the predominant farmer practices in the zone. The barley variety Tej was used since it is well adapted to both green stage grazing and grain production.

The 1987/88 agricultural year was marked by much lower than normal rainfall and a very unfavorable distribution. This is summarized in Figure 6.2. The long term mean is shown and for comparison the precipitation for 1986/87 is included. The September-November rainfall was 23% below average while from December through February it was 48% below average. For the entire year the rainfall was 40% below average.

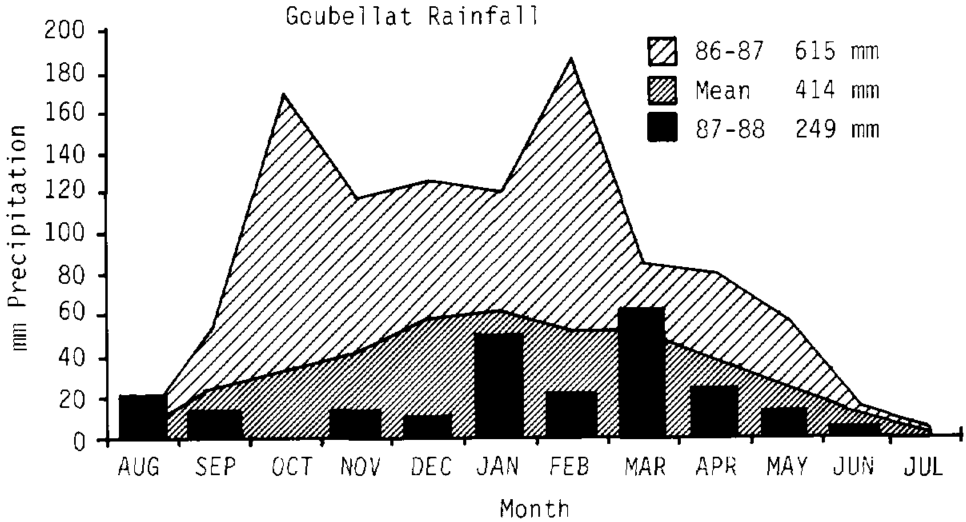


Figure 6.2 Precipitation in Goubellat

6.3.2 Forage Production of Fallows

Evaluation of the plots for forage production was made by dividing the plant populations into groups of grasses, legumes and other plants. As shown in Table 6.1 there were significantly higher numbers of grassy and leguminous plants in the medic plots. There was no difference in numbers of plants between the check fallow and fallow with application of P_2O_5.

Table 6.1 Population of plants/treatment (mean of 6 farms)

Treatment	Plants/m^2 Grasses	Legumes
Check fallow	153 a*	24 a
Fallow + P_2O_5	138 a	22 a
Medic	233 b	288 b

* DMR 0.01 significance

In Table 6.2 we see that the medic plots had less percent ground cover by grasses and "others" but did have significantly more ground cover by legumes as we would expect. The medic plots were less infested by other weeds. The palatability of this class is variable from one location to another. The species least desired by sheep are Calendula arvensis and Euphorbia spp.

Table 6.2 Percent ground cover for each treatment (mean of 6 farms)

Treatment	Grasses	Legumes	Others
Control	9 a*	2 a	10 a
Fallow + P_2O_5	9 a	1 a	10 a
Medic	6 b	12 b	7 b

* DMR 0.01 significance

6.3.3 Dry Matter Production of the Fallows

Due to the poor rainfall, grazing was delayed nearly three months. At last it was no longer possible to restrain the farmers' animals and the plots were grazed. Because of the lack of other grazing opportunities these plots were heavily overgrazed. At the end of the season field observations showed a total absence of medic seeds in the pastured plots. However, in small wire cages protecting a one m^2 patch there were up to 220 seed pods/m^2. The result of this overgrazing was a nearly total elimination of the medic and the seeds that could provide for a regeneration of the pasture in subsequent years.

Table 6.3 shows the total dry matter yields of plant material in the three fallow plots. Although the total production of dry matter did not vary significantly among treatments the proportion of the yield due to grasses and legumes did vary. The yield of legumes was significantly higher while the yield of grasses was correspondingly lower in the medic treatment.

Table 6.3 Total dry matter production per treatment (mean of 6 farms)

	Dry matter t/ha		
Treatment	Total DM	Grasses	Legumes
Control	0.86 ns	0.50 a*	0.05 a
With P_2O_5	1.06 ns	0.47 a	0.12 a
Medic	0.90 ns	0.28 b	0.65 b

* DMR 0.01 significance

6.3.4 Value of Different Fallows for Sheep Production

One of the objectives of the animal scientists working with the project was to evaluate the different fallow treatments using actual grazing by the farmer's sheep. The quantity of the grazing provided by the fallow treatments was evaluated by recording the length of time spent grazing each treatment. In more productive years it is also intended to monitor the weight changes of the grazing flock.

Due to the poor plant growth this year it was not possible to carry out the planned replicated grazing trials. After only one or two days grazing the plots were so degraded that replicated data collection was not possible. The results reported here concern only the means from one replication and can not be considered statistically significant. However, these data do represent trends of grazing productivity in relatively dry conditions, and as such they are extremely useful guides to fallow productivity during dry years.

Table 6.4 represents the numbers of grazing days achieved in each treatment. For the five farmers who participated in these trials there is a clear tendency for the phosphate treated fallow to give a higher number of days grazing than either the check fallow or medic. Both the check fallow and medic gave similar results.

Table 6.4 Number of grazing days on fallow and medic plots

			Number of days (hours)			
Farmer	Field	Period	Check	Fallow P_2O_5	Fallow contours	Medics
Neffati	Plain	March	2 (9)*	3 (12)		3 (12)
Sebai	Plain	April	4 (17)	5 (21)		3 (15)
Filahi	Plain	March/Apr	2 (14)	5 (30)	—	3 (11)
Hammami	Hill	March/Apr	2 (14)	2 (20)	3 (22)	3 (14)
Trabelsi	Hill	March/Apr	3 (22)	3 (16)	2 (16)	2 (8)

* ( ) = Number of hours of grazing

When we consider the amount of grazing offered by the barley plots in Table 6.5 we can see larger differences. For the three farmers who participated in this experiment the number of grazing days obtained from their barley plots was higher than any fallow treatment. It should be remembered that, except for the case of Mr. Trabelsi, the barley field was completely grazed and no plants were left for grain production. In the case of Mr. Trabelsi he did graze lightly and harvested some grain later in the year.

Table 6.5 Number of grazing days on barley plots

Farmer	Field	Period	Number of days
Neffati	Plain	April/May	12 (54)*
Sebai	Plain	April/May	7 (48)
Trabelsi	Hill	April/May	9 (40)

* ( ) = Number of hours of pasturing

The tentative conclusion is that application of phosphate to fallow may result in better forage production in dry years. These results are tentative and subject to confirmation in succeeding years.

6.3.5 Value of Barley for Sheep Production

For this first year of the rotation experiment the barley plots were treated as a single treatment. There were no subdivisions for previous year fallow treatments. Due to the very dry conditions it was not possible to graze all the plots and later harvest grain. The plots were grazed to remove all forage and only small one m^2 plots were protected with wire cages to provide an estimate of grain and straw yield.

The data showing forage dry matter yields are presented in

Table 6.6. These data represent the dry matter available at time of grazing. The average grain yield estimated from protected cages was 692 kg/ha and estimated straw yield was 1903 kg/ha. Again it should be remembered that these are estimates only and not statistically tested results. Other data taken from adjacent farmers' fields showed statistically significant differences between Tej and the farmers' varieties. Tej had better germination (120 versus 86 plants/m^2) and more tillers per plant (7 versus 2/plant) than the farmers' varieties.

Table 6.6 Yields of dual purpose barley (kg/ha)

Farmer	Dry matter	Grain	Straw
Neffati	2001	433	1400
Sebai	1227	691	1902
Trabelsi	1073	900	2200

6.3.6 Wheat Yields under Extreme Water Stress

All plots were seeded in mid-December 1987. Due to very poor rainfall planting was done in dry soil conditions following local farmer practice. Superphosphate (45% P_2O_5) was applied prior to planting at the rate of 100 kg superphosphate/ha. Germination occurred 2-3 weeks later and varied from good to poor. Plant development was poor. On 15 February most plants were in the 6 leaf stage when the crop suffered severe wind damage. This resulted in both physical leaf damage and severe drying. Application of 50 kg Ammonium Nitrate/ha (33% N) was made on 2 February but no further applications of fertilizer or herbicide were made. The germination of the recommended variety Karim was significantly better than adjacent farmers varieties being 85 versus 60 plants/m^2. Karim also had significantly more tillers than the farmer's variety (2.8 versus 2.3 tillers/plant).

Due to the poor development of the crop many farmers started grazing their wheat in April. Small plots of 25 m^2 were protected from grazing till hand harvest on 19 May. It was not possible to preserve plots adjacent to farmers' fields until grain harvest. In spite of efforts to preserve these plots all farmers removed most grain bearing spikes a few days before our harvest. As a result the grain yields results which were recorded are meaningless.

The straw yields are shown in Figure 6.3. The location of T. Trabelsi gave significantly higher (P=.05) straw yields than the other five locations. The most likely explanation of the high yields for Trabelsi is that his soils are a lighter texture (more sand content) than the other locations, and the limited rainfall penetrated to a greater depth. This enabled the crop to utilize more of the relatively poor rainfall. The average straw yield was 925 kg/ha. Weeds covered less than 10% of the surface area of the plots, but these low values reflect the very dry year.

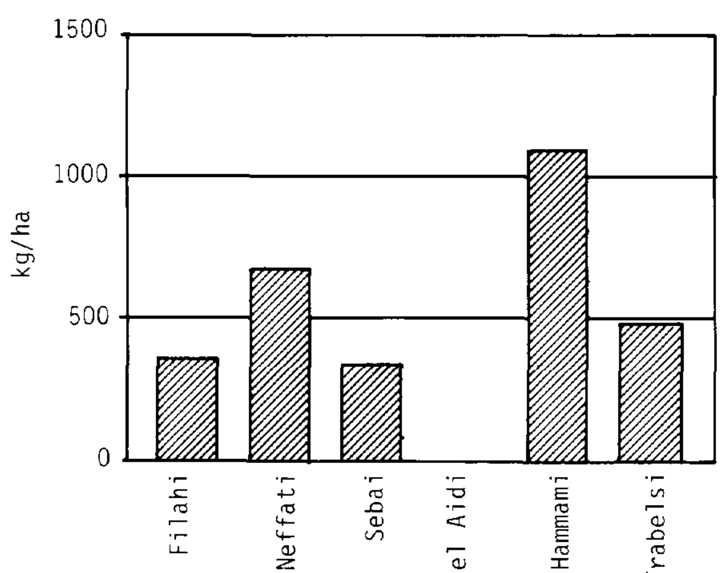


Figure 6.3 Durum wheat straw yields obtained by 6 farmers in Goubellat, Tunisia, 1987/88

6.3.7 Storage of Water Under Different Fallows

The purpose of the water use efficiency research is to study the water storage efficiency of the different fallow treatments and to explain differences in fallow or subsequent cereal productivity. The use of a neutron probe enabled us to follow soil moisture contents throughout the cropping season. Two locations were monitored. Due to the very low rainfall during the season and the extremely poor crop development there was little change in soil water status. Most crops were not able to utilize the water stored in the soil profile from the previous year due to the poor development of their root systems. As a result all crops were under continuous water stress. Only in the contour discing fallow treatment did we see a difference as shown in Figure 6.4. The water content rose throughout the season to end with a higher soil water content than at the start. Other treatments showed no storage of water by the end of the season.

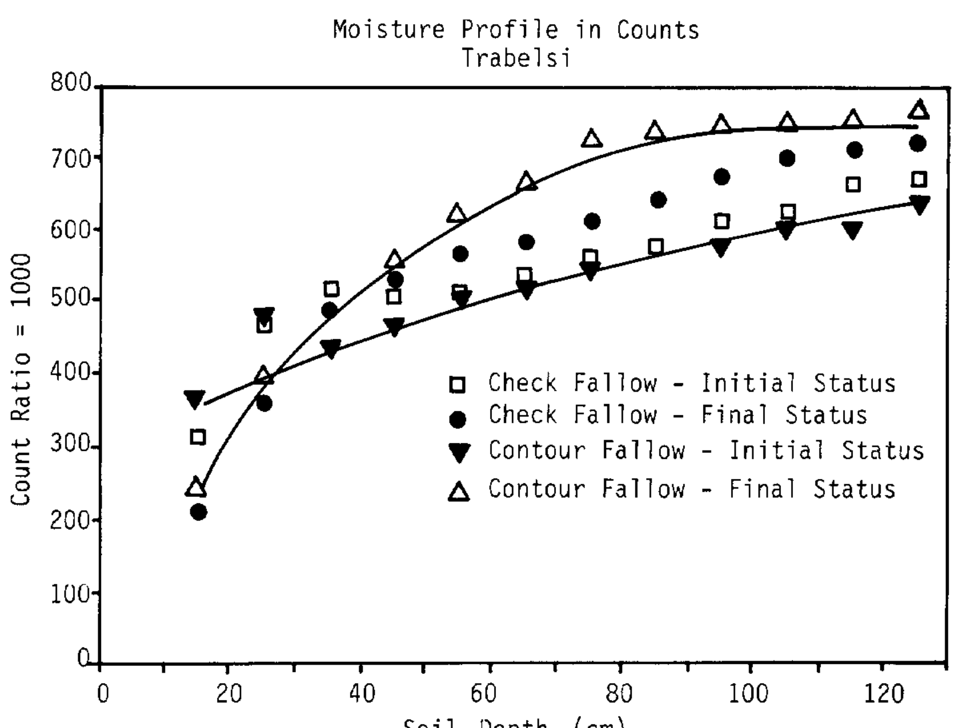


Figure 6.4 Water storage under fallow

6.3.8 Effect of Different Fallows on Run-off and Erosion

The different fallow treatments for improved forage production will also affect water run-off and soil erosion since many small sheep farms are located on hilly lands. This component of the Goubellat FSP is designed to evaluate the effect of these alternatives on soil erosion, run-off and soil fertility. The simple alternative of working soil on contours is included as a means of reducing soil erosion.

To study erosion on farmers' fields special equipment was designed to be easily transported and set up quickly in any farmers' fields. Locally available materials were used.

Even though there was little rainfall during 1987/88, some results were observed from January through June 1988. The equipment was installed on two locations. Summary data is shown in Table 6.7. It should again be noted that these data represent only one or two rainfall events and were not subject to statistical analysis. Under normal rainfall there may well be more erosion and a more rigorous treatment of data would be possible.

Table 6.7 Erosion losses for each treatment

Location	Rainfall mm	Treatment	Erosion kg/ha
Trabelsi	149.88 mm	Barley	82
11% slope		Wheat	62
Sandy clay		Check fallow	227
		Fallow plus contours	56
		Medic	52
Hammami	145.6 mm	Barley	115
8.5% slope		Wheat	106
Sandy clay loam		Check fallow	153
		Fallow plus contours	94
		Medic	127

Table 6.7 shows that even though the amounts of eroded soil were small, all improved fallow treatments suffered less erosion than the traditional fallow.

6.3.9 Costs of Production of Cereals

Work continued on the analysis and interpretation of survey data collected from 1984 through 1987. Emphasis was given to the costs of production of durum wheat since little data is available on the economics of wheat production at the farm level in Tunisia.

Costs were calculated three different ways:

- using costs equivalent to current market prices
- using calculated costs of equipment (with depreciation) and the opportunity cost of farm family labor
- using calculated costs of equipment but not assigning costs to family labor.

The costs for all three methods of calculation were similar so for reporting purposes only, the current equivalent market costs are presented here. The predominant cultural patterns were defined and costs calculated for each cultural pattern.

The four most commonly practiced cultural patterns are shown in Table 6.8. It was found that 56% of the farmers followed the recommended sequence of cultural practices. This consisted of deep spring plowing; discing; application of phosphate, nitrogen and weed control. Suprisingly, the highest grain yields were reported for the ten percent of the farmers who did not do spring plowing or apply herbicide.

The costs of each of these operations was calculated on the bases previously mentioned. A summary of the cash costs are presented in Table 6.9 and Figure 6.5. As can be seen, the greatest investment is made up to the time of planting (57%).

This means that over half of the cost of wheat production is made before the farmer has any idea of the rainfall or the likely yield for the year.

Table 6.8 Cultural patterns of durum wheat

Cultural practices	% of farmers	Average yield t/ha
1. Deep plowing - discing - phosphate Nitrogen - weed control	56%	1.94
2. Deep plowing - discing Manure - phosphate Nitrogen - weed control	10%	1.64
3. - discing - phosphate Nitrogen -	10%	2.61
4. Deep plowing - discing - Nitrogen - weed control	8%	1.85

Table 6.9 Distribution of cash costs for each operation[1]

Operation	TD/ha	% total
Deep plowing	15.14	10
Discing	28.48	18
Manure	15.30	10
Phosphate	8.38	5
Planting	22.96	14
Nitrogen	9.15	6
Weed control	6.43	4
Grain harvest	31.34	20
Straw harvest	21.80	14

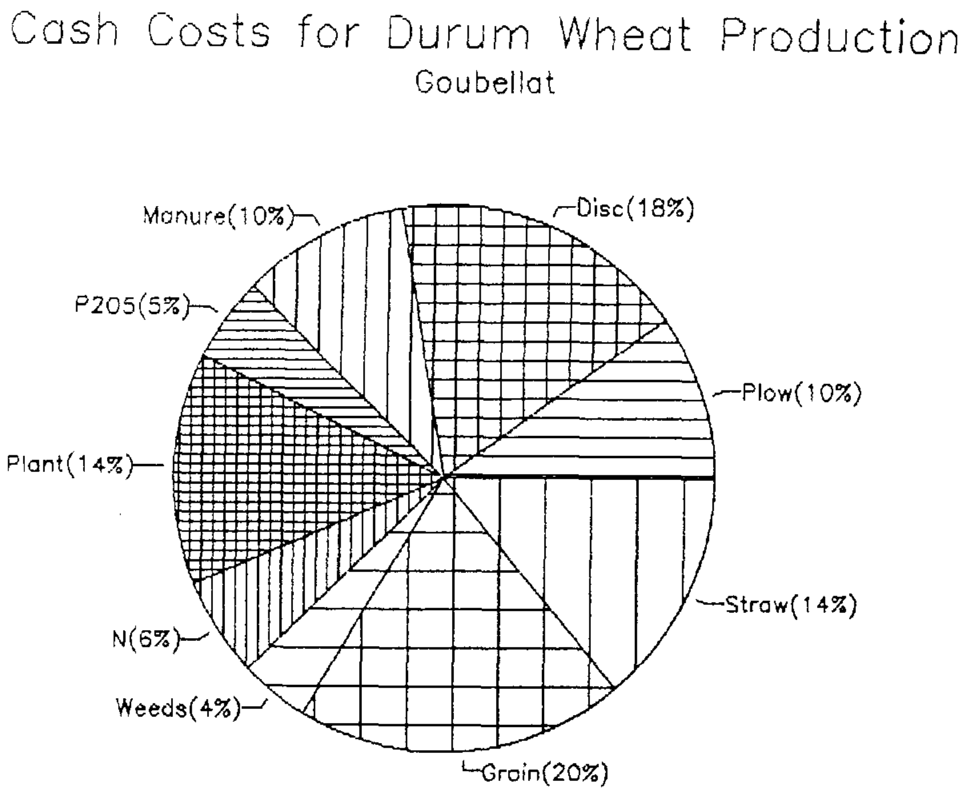


Figure 6.5 Distribution of costs for wheat production

Review of the results in Table 6.10 shows that the farmers following the recommended series of cultural practices (number 1) did not necessary have the greatest profit. The most effective way of increasing profit seems to be reducing costs of cultivation.

The farmers were further subdivided into groups on the basis of land owned, sheep ownership and off-farm employment. Table 6.11 shows the yields and costs for the recommended series of cultural practices for each of the subgroups. The best yields were found in subgroups 1 and 5. The high net profit of group five was due to low costs per ton. The observations of groups 3 and 5 shows that off-farm employment did not result in greater investment in wheat production as previously thought. There was also no relationship between ownership of sheep and yields or profits. The information being processed in this study will form a basis for improved wheat production practices by farmers in the region.

Table 6.10 Average cost[1] of production and profit of durum wheat

Cultural practices		Cost TD/ha	Cost TD/t	Profit TD/t
1. Deep plowing	- discing	121.91	60.9	124.0
	- phosphate			
Nitrogen	- weed control			
2. Deep plowing	- discing	137.18	82.3	102.6
Manure	- phosphate			
Nitrogen	- weed control			
3.	- discing	100.27	40.1	144.8
	- phosphate			
Nitrogen	-			
4. Deep plowing	- discing	113.55	56.7	128.2
	-			
Nitrogen	- weed control			

1 Note: One Tunisian dinar is approximately 1.1 US Dollars

Table 6.11 Cost of production and profit of durum wheat production in different farm types

Farmer Group[1]	Yield kg/ha	Cost DT/t	Profit DT/t
1. Mechanized > 30 ha	2670	51.60	133.4
2. < 30 ha O-L-	1820	57.01	127.9
3. < 30 ha O+L-	1570	63.08	121.9
4. < 30 ha O-L+	1780	62.36	122.6
5. < 30 ha O+L+	2360	52.57	143.6

1. O± = presence or absence of off farm employment
L± = presence or absence of sheep ownership

6.3.10 Summary

Yearly rainfall in Goubellat was 40% below average during the 1987/88 season. The highest production of legumes for forage was in plots seeded to medic while highest production of grassy plants occurred in the check fallow and fallow fertilized with phosphate. Non-replicated grazing trials indicated that best gains were obtained on fallow fertilized with phosphate. The dual purpose barley variety Tej had better germination and tillering than adjacent farmers varieties. Durum wheat grain yields were low or non-existent. Study of the soil moisture distribution showed only the contour fallow plots accumulated moisture over the season. The highest erosion was in the traditional fallow plots. Calculation of costs of production of durum wheat showed that 56% of farmers followed the recommended series of practices. At the end of planting the average farmer has spent 57% of his costs for wheat production. The profit per ton varied between TD 102.6 to TD 144.8.

6.4 Comparison of Some Barley Production Indicators: Northern Syria and Southeast Turkey

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6.4.1 Introduction

To gain a better understanding of the barley production environment, a survey was conducted by ICARDA during the 1981/82 season in northern Syria. A similar survey was later conducted by researchers from Cukurova University, with support of ICARDA, in southeast Turkey during the 1984/85 season. The survey area in Syria covered the provinces of Hassakeh, Raqqa, Aleppo, Homs and Hama; whilst in Turkey it covered Gaziantep, Sanliurfa and Mardin. These three provinces in Turkey border on Northern Syria. A detailed comparative study is on-going, and the present summary offers some of the interesting findings to date. In the discussion, Turkey is used to mean the survey area in southeast

Turkey and Syria is used to mean the survey area in north Syria.

Our approach was to start with the comparison of mean yields of each survey area in Syria and Turkey and if there was a significant difference between them, try to understand the reasons behind it.

6.4.2 Barley Yields in Survey Areas in Syria and Turkey

The barley surveys in Syria and Turkey were conducted in different years. Therefore a direct comparison of the yields recorded in the two years is not appropriate due to the different climatic conditions of the two seasons. Using the data obtained from farmers, long term average yields were calculated by countries and by zones. These values were then statistically compared.

The calculated long term average barley yield in Turkey was 1544 kg/ha and 764 kg/ha in Syria. This difference is statistically significant at 0.001 level. Our objective here is to discuss some of the reasons that cause this difference. Do these differences come from climate, soil or social and economic factors, or do they result from differences in the production techniques? In the subsequent sections these factors are examined for each survey area.

6.4.3 Comparative Analysis of Barley Production at the Survey Area Level

Socio-Economic Environment: Major socio-economic indicators of barley producers in the survey areas of Turkey and Syria are given in Table 6.12.

There is no significant difference between size of farms in Turkey and Syria, but there is in the areas allocated to barley production which in Syria is significantly higher than Turkey.

Table 6.12 Major socio-economic indicators of barley producers in Turkey and Syria

	Turkey	Syria	Sig.
Total farm area (ha)	40	52	N.S.
Total barley area (ha)	12	24	**
Barley area (%)	30	48	
Average education (years)	2.3	1.6	*
Income farm (%)	86.3	75.4	***
Income from agr. nonfarm (%)	5.7	6.7	N.S.
Income from nonagri. (%)	8.0	17.9	***
Cooperative membership (%)	12.5	48.7	***
Tractor ownership (%)	45.2	15.6	***
Water pump ownership (%)	4.8	26.8	***
Largest barley plot ownership (%)	66.3	67.8	N.S.

Although there is difference in education in terms of years, the number of years spent for formal education is low in both countries.

With respect to sources of income of families, the majority of income is earned from the farm in both countries but income from non-agricultural activities in percentage terms is higher in Syria.

Cooperative membership and water pump ownership is significantly higher in Syria. But the tractor ownership is higher in Turkey.

Production Systems: Examination of the land use by crops indicates that wheat is the dominant enterprise in Turkey, whereas barley is the most important crop in Syria.

In both countries, the majority of the farmers own livestock, but the number of sheep owned by Syrian farmers is significantly higher than Turkish farmers (Table 6.13). In Turkey

Table 6.13 Production systems in Turkey and Syria

	Turkey	Syria	Sig.
Land Use by Crops (%)			***
Wheat	54.9	17.9	
Barley	32.5	77.9	
Other crops	12.6	4.2	
Livestock Ownership (%)			
Sheep and goats	58.6	88.9	***
Cattle	29.8	8.5	***
Average Number of Livestock (head)			
Sheep	14	49	***
Goat	3	2	N.S.
Cattle	0.7	0.2	**

wheat is the dominant activity and barley-sheep ranks the second, whereas barley-sheep combination is the major enterprise in Syria.

Farmer's Practices: The barley varieties used show some difference between countries but these differences are not large. The majority of the farmers in both countries prefer the Black (local 2 row) variety. Some farmers in Turkey plant 6 row barley varieties but it is not widespread. Seeding methods differ significantly in Turkey and Syria. Turkish farmers mainly use drills whereas Syrian farmers rely upon broadcasting methods (Table 6.14).

Average seed rates are over 50 percent higher in Turkey. This probably reflects better soil and climatic conditions. These seed rate differences are reflected in higher plant populations observed during the surveys. The number of barley plants per m^2 was 625 in Turkey and 323 in Syria. In Turkey 87.5% of the farmers also use chemical seed treatment, a practice which is scarce in Syria.

Table 6.14 Farmers' practices in Turkey and Syria

	Turkey	Syria	Sig.
Varieties Planted in the Survey Year (%)			*
Black (local 2 rows)	69.3	74.2	
White (local 2 rows)	24.4	23.2	
6 rows	5.1	0	
Other	1.1	2.6	
Seeding Method (%)			***
Drill	76.4	31.8	
Box on disc	1.9	14.4	
Broadcast (1)	21.7	58.8	
Use of Treated Seed (%)	87.5	2.0	***
Seed Rate (kg/ha)	164	107	***
Plant Population/m^2	625	323	***

1. Broadcasting method includes both hand and mechanical broadcasting.

Soil Quality: During the surveys, farmers were asked about their soil quality. Soil depth, stoniness and slope were used as principal indicators. More than 50% of the farmers in Turkey indicated that their soil is of good quality whereas only 29.7% of the Syrian farmers reported good quality soil (Table 6.15).

Fertilizer Application by Farmers: The use of fertilizer in Turkey and Syria is perhaps the most striking contrast with the majority of the farmers in Turkey using fertilizer on all crops they produce (Table 6.16). This is also true for barley production; 78% of Turkish farmers reported that they apply P_2O_5 and N on the largest barley plot. This large difference in the use of fertilizer between Turkey and Syria is probably the result of differences in the physical environmental conditions and fertilizer policies of the government.

Table 6.15 Quality of soil in Turkey and Syria

	Turkey	Syria	Sig.
Quality of the Soil in General on the Largest Plot (%)			***
Good	53.7	29.7	
Average	40.7	55.2	
Poor	5.6	15.0	

Table 6.16 Fertilizer use of barley producers in Turkey and Syria (%)

	Turkey	Syria	Sig.
Using fertilizer on any crop in the past	93	33	***
Using P_2O_5 on the largest barley plot	78	11	***
Using N at planting time on the largest plot	78	10	***

Reasons of Difference between Barley Yields in Turkey and Syria: There are significant differences between Turkish and Syrian producers, in socio-economic indicators, production systems, farmers' practices, quality of soil in general and fertilizer use. It is clear that all these factors have an impact on the difference in yields. The relative importance of each factor could not be explained at this stage of the study. However, as discussed in subsequent sections, the generally more favorable environmental conditions in the Turkish survey area undoubtedly play a major role in influencing the level of inputs used by farmers, and the yields they obtain.

6.4.4 Comparison of Zone (A) in Turkey and Zone (2) in Syria

The preceding sections compared major differences in barley production practices and yields between the two survey areas. However, as indicated in Figure 6.6, each survey area was comprised of several agricultural zones. In general, the climatic conditions (with respect to rainfall) are more favorable in the Turkish area, and this is certainly a major factor contributing to the observed yield differences. Figure 6.6 illustrates that Zone (A) in Turkey and Zone (2) in Syria are very similar with regard to rainfall. The main area of Zone (A) in Turkey is Akcakale county which is located at the Syrian border neighboring to Tel el Abyad.

When we compare the yields of these two zones we find that average barley yield in Zone (A) is 931 kg/ha and is 919 kg/ha in Zone 2 (Figure 6.6). There is not a significant difference between the yields in Zone (A) and Zone (2). A further comparison of some variables that were used at the survey area level in previous sections produce some interesting results.

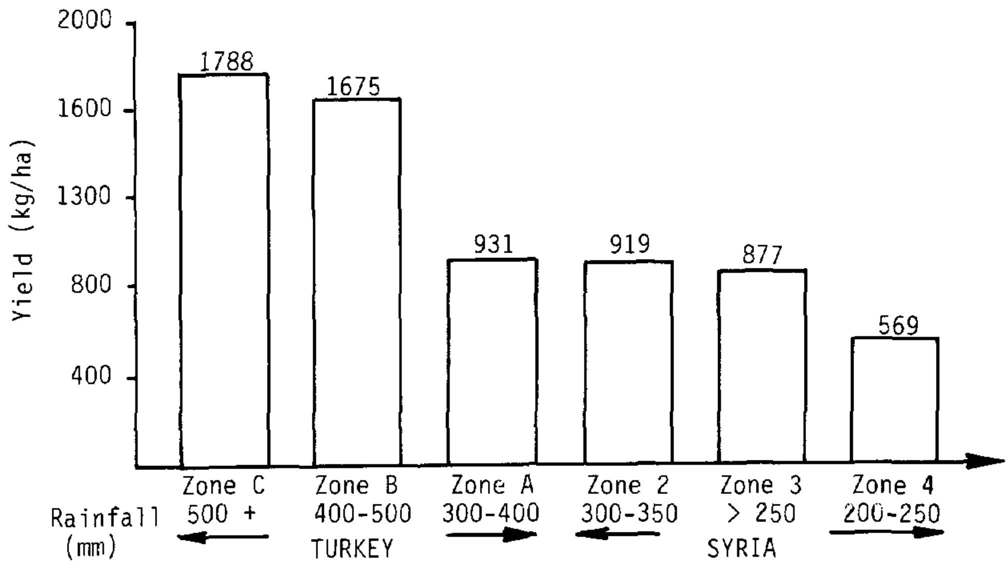

Figure 6.6 Estimated rainfed barley yields (kg/ha) by countries and zones

Socio-economic Environment: When we examine the major socio-economic indicators of the two zones, in contrast to that found at the survey area level, we observe similarities. For example average farm area, average education years, income from farm, income from nonagricultural activities and tractor ownership are not statistically different in the two zones (Table 6.17).

Table 6.17 Major socio-economic indicators of Zone (A) and Zone (2)

	Zone A	Zone 2	Sig.	Survey area[1] Sig.
Sample size	37	51		
Total farm area (ha)	28	43	N.S.	N.S.
Total barley area (ha)	7	17	*	**
Barley area (%)	25	39.5		
Average education (years)	2.6	2.0	N.S.	*
Income from farm (%)	78.3	84.3	N.S.	***
Income from agr. off-farm (%)	14.2	2.5	**	N.S.
Income from nonagr (%)	7.5	13.2	N.S.	***
Cooperative membership (%)	15.6	45.1	*	***
Tractor ownership (%)	31.3	25.5	N.S.	***
Water pump ownership (%)	15.6	41.2	*	***
Largest barley plot own. (%)	62.2	72.5	*	N.S.

1. For ease of comparison the survey area levels of significance are included in the last column of this table and subsequent tables

Although there are differences in some socio-economic indicators, the general socio-economic structure of the two zones is similar.

Production Systems: As was the case at the survey area level wheat in Turkey and barley in Syria remain the dominant crops. However, the percentage area used for wheat production has increased in both zones as compared with the survey area level study. Sheep production is the second most important enterprise in both zones. There is no significant difference in the average number of the sheep owned by farmers. Although there are significant differences in certain variables between the two zones, the level of significance is not as great as found at the survey area level (Table 6.18).

Table 6.18 Production systems in Zone A and Zone 2

	Zone A	Zone 2	Sig.	Survey area Sig.
Land use by crops (%)			**	***
Wheat	74.3	34.3		
Barley	20.0	55.9		
Other crops	5.7	9.8		
Livestock ownership (%)				
Sheep or goat	67.6	86.3	*	***
Cattle	32.4	15.7	*	***
Average number of livestock (head)				
Sheep	23	31	N.S.	***
Goats	5	3	N.S.	N.S.
Cattle	1	0.3	*	**

Farmers' Practices: The barley varieties planted by farmers in both zones are similar to that observed at the survey area level, although there is a slight decline in the percentage of black varieties in both zones.

There is no significant difference in seeding methods between zones. A slight decline in the percentage of farmers that use drill in Zone A but an increase in Zone 2 was observed. However, the use of treated seed remains significantly higher in Zone A of Turkey than in Zone 2 of Syria (Table 6.19).

Table 6.19 Farmers' practices in Zone A and Zone 2

	Zone A	Zone 2	Sig.	Survey area Sig.
Varieties planted in the monitored year (%)			*	*
Black (local 2 rows)	61.1	68.6		
White (local 2 rows)	16.7	27.5		
6 rows	16.7	0.0		
Others	5.6	3.9		
Seeding method (%)			N.S.	***
Drill	64.5	52.2		
Box on disc	0.0	2.2		
Broadcast (1)	35.5	45.6		
Use of treated seed (%)	78.3	3.9	***	***
Seed rate (kg/ha)	132	120	N.S.	***
Plant Population/m^2	393	395	N.S.	***

1. Broadcasting method includes both hand and mechanical broadcasting.

An important similarity is the seed rates. The seed rate in Zone A is 132 kg/ha and in Zone 2 120 kg/ha. This is in sharp contrast to the survey area level study which showed that on the average the seed rates were 164 in Turkey and 107 kg/ha in Syria. This similarity of seeding rates is also reflected in observed plant populations of 393 and 395 plants/m^2 in Zone A, and in Zone 2 respectively.

Quality of Soil: There was no significant difference between the two zones in the quality of the soil in general on the largest plot, whereas there is a significant difference at the survey area level. The percentage of good quality soils in the two zones is higher than at the survey area level (Table 6.20).

Table 6.20 Quality of soil in Zone A and Zone 2

	Zone A	Zone 2	Sig.	Survey area Sig.
Quality of the soil in general on the largest plot (%)			N.S.	***
Good	61.1	41.2		
Average	30.6	41.2		
Poor	8.3	17.6		

Table 6.21 Fertilizer use of barley producers in Zone (A) and Zone (2) (%)

	Zone A	Zone 2	Sig.	Survey area Sig.
Using fertilizer on any crop in the past	80.0	51.0	**	***
Using P_2O_5 on the largest barley plot	36.4	31.4	N.S.	***
Using N at planting time on the largest barley plot	30.0	29.4	N.S.	***

Fertilizer Application by Farmers: When we examine the use of fertilizer in these two zones, we do not see the striking contrast observed at the survey level studies (Table 6.21). The percentage of farmers in Turkey who had used fertilizer on any crop in the past was 93 at the survey area level but fell to 80% in Zone A. On the other hand, the percentage of Syrian farmers who had used fertilizer on any crop in the past was 33% at the survey area level, but rose to 51% in Zone 2. However, these differences, although less, were still significant. In contrast, the percentage of farmers using P_2O_5 and N at planting time on barley in Zone A and in Zone 2 does not differ statistically. This is an important observation, and reflects the close association between the use of inputs such as fertilizer and the degree of climatic risk experienced by farmers.

6.4.5 Summary and Preliminary Conclusions

The two barley production surveys indicate that there is a significant difference between the yield per hectare in Turkey and Syria at the survey area level. The reasons behind the yield difference arise from climate, socio-economic factors, production systems, farmers' practices, soil and the amount of fertilizer application by farmers. All these factors interact. But the determination of the relative impact of each factor requires further analysis.

The comparison of the yields in Zone (A) in Turkey and Zone (2) in Syria, chosen because of their climatic similarities, shows that there were far fewer significant differences between the two zones. Analysis of socio-economic indicators, production systems, farmers' practices, soil and amount of fertilizer application show many similarities, and some differences. The average barley yield in Zone A is 931 kg/ha and is 919 kg/ha in Zone 2.

Three years of on-farm research conducted by ICARDA/Soils Directorate of Syria has shown that there is a potential to increase barley yields in Zone 2 in Syria by between 1300-1630 kg/ha. Preliminary yield gap analysis indicates that of this potential increase, 630-919 kg/ha are directly attributable to fertilizer use, the remainder of the potential increase being due to other management factors (Mazid and Somel 1987). The findings of this study and the results of ICARDA/Syrian Soils Directorate on-farm trials show that there is a potential to achieve similar increases in barley production in both Zone A of Turkey and Zone 2 of Syria.

6.5 Improving Dryland Farming Systems in the Arid Zones of Jordan: A Jordan University of Science and Technology/ICARDA Joint Research Project

A. Jaradat (JUST)
M. Oglah and R. Tutwiler (ICARDA)

6.5.1 Introduction

Agricultural land in Jordan is a scarce and extremely fragile resource. It is estimated that only 9% (or about 0.8 million hectares) of Jordan receives more than 200 mm of rainfall annually and can thus be considered arable land. Variability is the outstanding agroecological characteristic. Apart from small perennially irrigated areas concentrated in the Jordan Valley with scattered locations in the highlands, the arable drylands are divided into three distinct zones based upon rainfall, topography, temperature patterns, and other factors (Table 6.22).

Table 6.22 Agroecological Zones in Jordan

Agroecological zones	Long-term average annual precipitation	Area (ha)	% of Jordan's population resident in zone
Arid zone (non-arable)	0-200 mm	8,456,900	31%
Marginal zone	200-350 mm	563,400	41%
Semiarid zone	350-500 mm	135,900	19%
Semihumid zone	500-800 mm	98,900	9%

Within and among the arable zones actual rainfall amounts are highly variable from year to year and place to place. Similarly, the onset date and duration of the yearly winter wet season fluctuate considerably. The summers, however, are uniformly hot and dry in Jordan's basically Mediterranean climate. The unreliability and variability of rainfall tends to increase as the amount of long-term average precipitation decreases from the semihumid zone to the marginal zone.

Despite the adversity caused by low and unreliable rainfall, rainfed agriculture remains and important component of Jordan's economy. On an average, it has contributed roughly 12% of the GDP and employed a higher proportion of the labor force. Jordanian farmers have been ingenious in devising ways of managing and manipulating difficult environmental constraints in the context of their meagre financial resources. Unfortunately, traditional methods of coping with the risks and hazards of dryland agriculture are experiencing unprecedented demographic and economic pressures which threaten in combination with environmental degradation, to destroy the existing fragile farming system. The threat is especially immediate and severe for agriculturists living in the marginal zone.

In terms of area and population, the marginal zone constitutes the single most important region for Jordan's long-term agricultural future. Lying on the frontiers of the non-arable desert of the arid zone, marginal zone farmers traditionally raise cereals, wheat for their families while feeding barley grain and crop residues to herds of sheep and goats which represent their principal capital assets. Surrounding natural grazing lands are an important feed supplement to agricultural products in the existing system of animal husbandry.

Population pressures and economic needs have forced recent changes on the established farming system of the marginal zone. The conversion of natural grazing lands to cropped lands in an attempt to increase productivity has resulted in soil erosion and expansion of the desert in the last 20 to 30 years. The practice of fallowing cereal land in alternate years is giving way to annual cropping. Overexploitation of moisture and soil fertility reserves and reduced yields associated with continuous cropping have increased the incidence of soil erosion and destructive run-off spates from high-intensity rainstorms. Despite intensified cropping and livestock herding, the productivity of the marginal zone has actually decreased in the past decade, a trend which serves as a strong warning of future disruption if immediate attention is not given to developing new techniques and methods or establishing a more productive and sustainable agricultural system in the marginal zones.

6.5.2 Project Development

The challenge facing farmers, agricultural scientists, and policy makers in Jordan is how to raise productivity of the dryland farming areas in the country while simultaneously conserving and enhancing the natural agricultural resources. Additionally, new technologies identified and developed for adoption by farmers must be adapted to the farmers' socioeconomic circumstances, both those internal and external to the farm. Historically, the Jordanian public and private sectors have invested heavily in irrigated agriculture while giving rainfed area lower priority. However, in this decade the government of Jordan is directing major efforts in conjunction with national universities towards the development of rainfed areas with the goal of maximizing local cereal and livestock production and reducing dependency on basic food imports.

As part of this effort to increase productivity in rainfed agriculture, the Jordan University of Science and Technology (JUST) and ICARDA began a cooperative research program in early 1988 aimed specifically at the problems of the marginal zone. A representative region, bounded on the north by the Syrian border, on the south by the Zarqa valley, on the east by the Hejaz railway, and on the west by the Ramtha-Jerash highway (hereafter referred to as the al-Mafraq area), was chosen as a focus area for a combination of agronomic and socioeconomic studies aimed at selecting recommended technologies to improve the productivity of marginal zone farmers while enhancing the sustainability of their farming system.

An initial farmer survey enquiring into agroclimatic, socio-economic, and agronomic conditions was conducted among a sample of 55 farmers throughout the al-Mafrag area. Generally speaking, the survey confirmed and reinforced impressions gained from a review of the existing literature about the marginal zone. In summary, the JUST/ICARDA team drew the following broad conclusions from the survey data:

1. Overall cereal productivity is low, even after accounting for rainfall levels, and there is considerable variability in reported yields among the sample population.

2. In terms of long-term yield patterns, farmers on an average can expect a grain harvest in only 5 out of 9 years planted. Fallowing occurs in about 1 year out of 10.

3. Inputs are at very low levels, with virtually no modern inputs in cereal production other than widespread use of tractors.

4. Farmers appear extremely risk-adverse, usually responding to weather, ecological, and yield uncertainties with low input technologies and mixed resource allocation patterns.

5. There is a high level of heterogeneity in farmer circumstances and production strategies.

6. A fragile poorly-integrated cereal-livestock farming system predominates that is linked with, and indeed dependent upon, external resources.

During the annual planning meetings at ICARDA, the research team reviewed the survey results, the results of previous agronomy research at ICARDA and JUST into dryland barley-livestock systems, and resources available for further activities in the coming year. Areas in which information is lacking were identified, and research priorities were delineated.

6.5.3 Research Plan and 1989 Activities

Considering the lack of basic information regarding the farming systems of the al-Mafrag area and the marginal zone generally, a modest research plan was devised for 1989 which concentrates on the fundamental work of diagnostic agronomy and basic description of farmer circumstances and production objectives. Two simultaneous lines of inquiry will be followed. First, diagnostic trials experimenting with barley variety, sowing date, fertilizer application, weed control, and seeding method will be undertaken at three sites in the research area, including the established site at the JUST experimental farm. Additional agronomy work will consist of barley and forage legume nurseries and a number of farmer managed diagnostic experiments sited through the area. If resources allow, a separate tillage experiment will be undertaken.

The second line of inquiry involves research into farmers' situations. Two complementary studies will be done. The first is a diagnostic farmer survey. The expanded survey will concentrate on four aspects of farmers' production activities: (1) agroecological circumstances, (2) management practices, (3) socioeconomic characteristics, and (4) individual farmer production objectives. The goal of this diagnosis is to determine why farmers produce what they produce and under what incentives/constraints production takes place.

A second study, narrower in scope and sample than the first, is aimed toward constructing models of farmer production "calculi" for each of the four current production strategies identified in the initial survey, i.e., (1) cereal and olives and livestock (2) cereal and livestock, (3) cereal and olives, and (4) cereal only. Farmer "calculus" is a term denoting the factors and their interrelationships which underlie farmer resource allocations and production decisions during an annual cycle and in the long-term.

At the end of the 1989 harvest season, the results of the diagnostic agronomy work and the socioeconomic studies will be integrated in a planning analysis of farmers' internal circumstances. The planning analysis will lead to identification of homogeneous farmers groups within the project area who will serve as the target populations for advanced on-farm trials to test improved production technologies in succeeding years. It is envisioned that at the end of 1990 it will be possible to form basic research activities to begin the work of disseminating recommended technologies through an expanded program.

At this point in the project it would, of course, be premature to suggest what technologies might be most appropriate for farmer adoption in the research area and the marginal zone generally. The research activities of the JUST/ICARDA team constitute an innovative approach which incorporates present agronomic knowledge with an understanding of real farmer circumstances at each stage of a process designed to discover and adapt technological improvements to the specific physical, economic, and institutional environments of farmers. The ultimate test of the approach will be its ability to deliver appropriate technologies which are adaptable to farmer circumstances, improve productivity within the farmers' constraint matrix, and serve to enhance the sustainability of the farming system.

6.6 Algeria: Summary Results of A Survey of Food Legume Production Practices in the Wilaya of Sidi Bel Abbes

A. Haddad, M. Pala (ICARDA)
A. Djaloul (ITGC)

During the first ten days of April 1988, staff from ICARDA and the Sidi Bel Abbes research station conducted a farm survey of lentil and chickpea production practices. A brief questionnaire was developed which covered the following aspects of food legume production: field history, applied rotation and management practices such as tillage, sowing method, row spacing, fertilizer use, weed control methods, harvesting. Thirty one farmers, largely in zones 1 and 2 of the project area, were visited during the survey. All farms visited were large cooperative units since very few small private farms grow either lentil or chickpea. On such farms, legumes such as faba bean and peas are grown as a green vegetable. In the subsequent sections of this report we highlight some of the major findings of the survey, and conclude with some recommendations for high priority topics for future research.

6.6.1 Crop and Season Conditions

The 1987/88 season in Algeria was, in contrast to Syria, an unusually dry one. At the time of the survey, only 28 raindays had occurred, and the rainfall recorded at the research station was only 199 mm. Drought symptoms were evident in cereal crops, and due to severe shortage of natural grazing, and expected low cereal yields, many farmers had started grazing their cereal crops. Lentil had reached the flowering/podding stage, whereas spring sown chickpea was still being seeded.

6.6.2 Crop Rotations

The recommended rotation for zones 1 and 2 of this district is a three course wheat/cereal-forage mixture/food legume rotation. In practice, several farmers grow continuous wheat, and others allow natural pastures to develop on uncultivated fallow land. As a result, legumes (food and forage) only occupy 12% of the cultivated land, and of this area, lentil occupies 32 and chickpea 36%. Farmers stated that high labor requirements and low yields are the principal factors which discourage food legume production.

6.6.3 Tillage Practices for Legumes

Following grazing of the preceding cereal stubble, a deep disc ploughing is done in August or September, followed by a disc harrowing after the first rains in October and November. A second harrowing is done prior to drill sowing the lentil in December or January. Spring sown chickpea requires a third harrowing in February, prior to sowing.

6.6.4 Fertillizer Use

Phosphorus (Triple Super Phosphate) is usually applied early to the soil, either just before or just following the deep summer tillage. Rates vary, but on average of 46 kg P_2O_5/ha was recorded. No nitrogen is applied, but some farmers apply small amounts of potassium fertilizer with the TSP. Tractor mounted spinners are used to broadcast the fertilizer, but in many instances farmers used seed drills from which the planting tynes have been removed.

6.6.5 Seeding Methods

Lentil is usually drilled at a seed rate of 100 kg/ha, but with variable row spacing ranging from 20 to 250 cm. Large row spacing are required by farmers who practice inter-row cultivations for weed control. A small seeded landrace (imported from Syria in 1930) is most commonly grown (Syrian 229). Chickpea is sown from mid-February to mid-March with seed rates ranging from 70 to 130 kg/ha. 70% of chickpea is machine drilled and 30% is hand broadcast and covered with a light discing. Row spaces again vary a great deal from 40 to 150 cm for the same weed control reason as noted for lentil. A local large seeded variety (Turkish) is most commonly planted.

When using such wide row spacing, some farmers use a paired row planting technique.

6.6.6 Weeds and Weed Control Methods

In almost all instances, farmers cited weeds as their most severe production constraint. Only in late planted spring chickpea did late cultivations assist in controlling weeds (see also this report, section 3.7). In the past "Treflan" herbicide was tried by farmers, but they reported unsatisfactory weed control and evidence of residual effects on subsequent cereal crops. Only 30% of the chickpea and 20% of the lentil area are currently treated with herbicides. Before the recent land reform, hand weeding was seldom practiced on large cooperatives, but farmers now appear more prepared to invest in this labor intensive activity. As indicated earlier, many farmers also sow their crops with large inter-row spaces, and control weeds through cultivation.

Sinapis arvensis is the dominant broadleaf weed in the region, leguminous weeds Vicia and Melilotus are also common in the area. Vaccaria pyramidata is also becoming problematic since this weed appeared to be resistant to many herbicides including 2,4-D products used in cereals.

Of the grasses noted in lentil field, Bromus sp. was found at high densities in some fields (100 plants/m^2). Spring chickpea suffers in some locations from the perennial weed Convolvulus arvensis.

6.6.7 Harvesting Techniques

Mechanical harvesting is widely used for both lentil (73%) and chickpea (50%). However, farmers reported unacceptably high levels of yield loss for both crops (average 25%). Since the land reform most farmers indicated that they would return to hand harvesting since the reduction in yield loss would more than cover the extra cost.

6.6.8 Proposals for Priority Areas of Research

- Deep plowing is not needed in such light soils every year, especially when followed by 2 to 3 harrowings. Studies on tillage and seedbed preparation including zero-tillage practice should be carried out.

- Phosphorus is usually applied and incorporated several months before planting. Timing and placement of phosphorus should be compared with existing methods.

- Plant population in lentil appeared to be low even when the seed rate is acceptable. Seeding should be done more precisely. Row spacing is extremely wide in lentil and chickpea. This can be reduced without preventing proper inter-row cultivation.

- Promising herbicides have been identified from existing weed control trials. However they do not solve all weed problems, especially grasses. Herbicide screening should be carried out in both cereals and legumes, aiming at more integrated weed control measures. In this respect .....

- Long term tillage trials which focus on weed control are also needed, since weed problems also result from poor soil management in this area.

6.7 Fertilizer Use On Wheat In Northern Syria 1986/87 and 1987/88. A Two Year Summary

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I. Jabbour, K. El Hajj (SMAAR)

6.7.1 Introduction

The results of this on-going collaborative research for 1986/87 and 1987/88 seasons have been reported in detail elsewhere (Soil Directorate/ICARDA, 1988). The objectives of this cooperative research with the Syrian Soils Directorate are as follows:

- To assess the biological and economic response of wheat to N and P fertilizers through multiple season-multiple location trials on farmers' fields, in the wetter areas (over 300 mm mean annual rainfall) of northern Syria.

- To study the relationship between the available N and P in soils at the time of sowing and to determine the critical level of soil N and P tests beyond which economic responses to N and P fertilization are not expected.

- To establish guidelines to make fertilizer recommendations for wheat, based on soil N and P tests, generating a methodology for similar wheat producing areas in other countries.

In the collaborative project, initiated in 1986/87, 2 replicate, 4x4 factorial fertilizer (NxP) trials on Sham-1 durum wheat were successfully carried out on farmers' fields across Hassakeh, Aleppo, Idleb and Hama provinces during the two seasons. Twenty trials were conducted in each season.

6.7.2 Grain and Straw Responses to N and P

In 1986/87, grain and straw yield responded positively and significantly to N fertilizer at 16 and 19 of the twenty sites respectively. Yield was increased 32-40% in grain, 36-46% in straw by the rates of 40 and 80 kg N/ha respectively over the control (Table 6.23). Responses of grain and straw to P were positive and significant at only 4 of the sites.

In 1987/88, grain and straw yield again responded positively and significantly to N fertilizer at 16 and 20 sites respectively. Mean yield was increased 21-29% in grain, 26-42% in straw by the rates of 40 and 80 kg N/ha respectively over a control. Positive and significant responses to P were again limited to 6 sites for grain yield, and 4 sites for straw yield.

Table 6.23 Summary of mean grain and straw responses to fertilizers at 20 sites for each year in on-farm trials (kg/ha)

	1986/87							
	N, kg/ha				P_2O_5, kg/ha			
	0	40	80	120	0	20	40	80
Northwest Syria								
Grain	2035	2646	2822	2790	2445	2553	2606	2689
Straw	3677	5120	5522	5707	4733	4983	5063	5228
Northeast Syria								
Grain	1066	1504	1574	1483	1392	1392	1355	1489
Straw	3284	4271	4424	4551	3953	3949	4233	4360
Overall Mean								
Grain	1744	2304	2448	2398	2129	2205	2231	2329
Straw	3559	4852	5129	5360	4499	4648	4818	4967
	1987/88							
Northwest Syria								
Grain	3347	4054	4333	4461	3944	4015	4081	4155
Straw	5301	6675	7526	8238	6782	6841	7003	7115

6.7.3 The Effect of Preceding Crop on Nitrogen Fertilizer Responses

The effect of crop sequence on the mean grain and straw yields was significant in 1986/87, the highest yields occuring when wheat followed a summer crop. However this difference did not occur in the 1987/88 growing season due to the high rainfall conditions (Figure 6.7).

In 1986/87, grain yield increases over the control were 29 and 31% following chickpea, 35 and 45% following lentil, 22 and 35% following summer crops from the rates of 40 and 80 kg N/ha respectively. Straw yield increases over the control were 40-49, 40-54 and 31-42% in the same order.

In 1987/88, grain yield increases over the control were 22 and 33% following chickpea, 29 and 40% following lentil, 16 and 21% following summer crops from the rates of 40 and 80 kg N/ha respectively. Straw yield increases over control were 23-38, 36-62 and 22-32% in the same order. Significant response to P in these trials only occured in wheat following rainfed summer crops in 1986/87 (Figure 6.7).

6.7.4 Fertilizer Responses and Rainfall

In the drier year of 1986/87, production levels were clearly related to rainfall totals received at each farm, but the shape of fertilizer response curves were similar. This is illustrated in Figure 6.8 which compares sites receiving more than and less than 400 mm. In the second and much wetter year, many of the farms received between 650 and 900 mm of rainfall, and beyond totals of 600 mm, there was no apparent increase in yield resulting from the extra water supply. Indeed, at several of the wettest locations water logging during the winter months retarded growth severely and caused substantial yield reductions. Figure 6.9 illustrates the general relationship between rainfall totals across the 2 years (up to 600 mm only) and grain yield. Compared with the zero control, optimum levels of N and P fertilizer

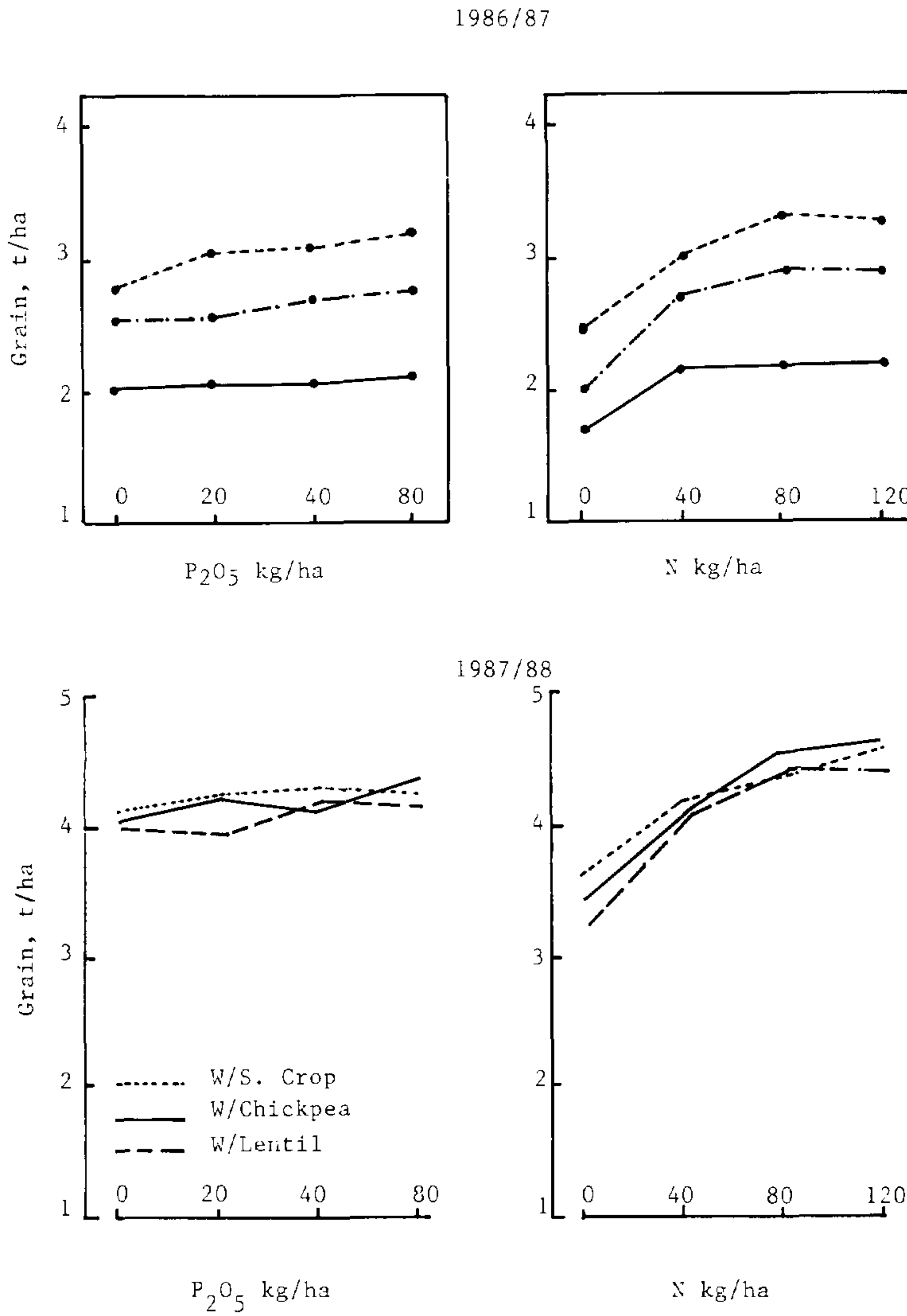

Figure 6.7 Wheat grain responses to P and N fertilizers under different crop sequences. (For significance levels of rotational and fertilizer effects see Soils Directorate/ICARDA 1988.)

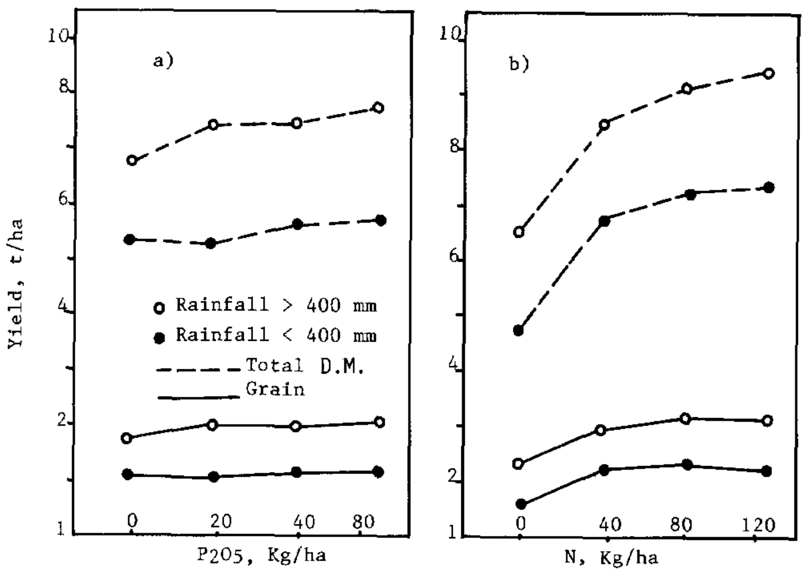

Figure 6.8 Crop responses to P and N fertilizer under different rainfall conditions, 1986/87. (For significance levels of response see Soils Directorate/ICARDA 1988.)

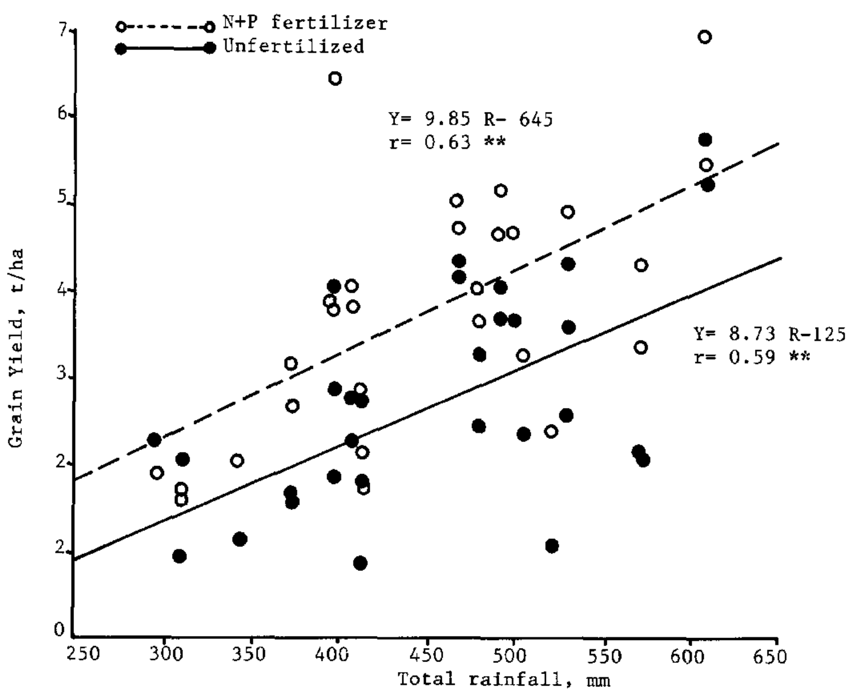

Figure 6.9 Wheat grain yield responses to optimum rates of N and P fertilizer under different rainfall conditions (29 sites) 1986-1988

resulted in approximately a 40% increase in yield, and also an increase in water use efficiency as illustrated by the slopes of the two regression equations.

6.7.5 Soil Test Calibration for Fertilizer Responses

Soil test levels for P requirements of the crop gave reasonable results in 1986/87. The critical level of Olsen-P in soils which gave 80% of maximum TDM was around 5 ppm as determined by both the Cate-Nelson graphical method and the Mitcherlich-Bray equation. However, in 1987/88, it was found that crop response to P according to soil test was erratic. Other research presented in this report has also demonstrated the greater availability of native soil phosphorus in unusually wet years and locations (see section 3.4 of this report).

Various soil tests for N requirements of wheat were also assessed. The mineral-N or NO_3^--N at the top 40 cm of soil were found to be well correlated with the relative response of a durum wheat (Sham-1) to N fertilization in both years (Figure 6.10). Critical levels of NO_3^--N which gave about 80% of maximum yields of TDM were found to be 7 and 8 ppm for the first and the second season respectively. The relative merits of the various soil tests for predicting N availability for wheat are discussed in section 3.6 of this report.

6.7.6 The Economics of Fertilizer Use

Partial budget analyses of fertilizer use is presented in Tables 6.24 and 6.25.

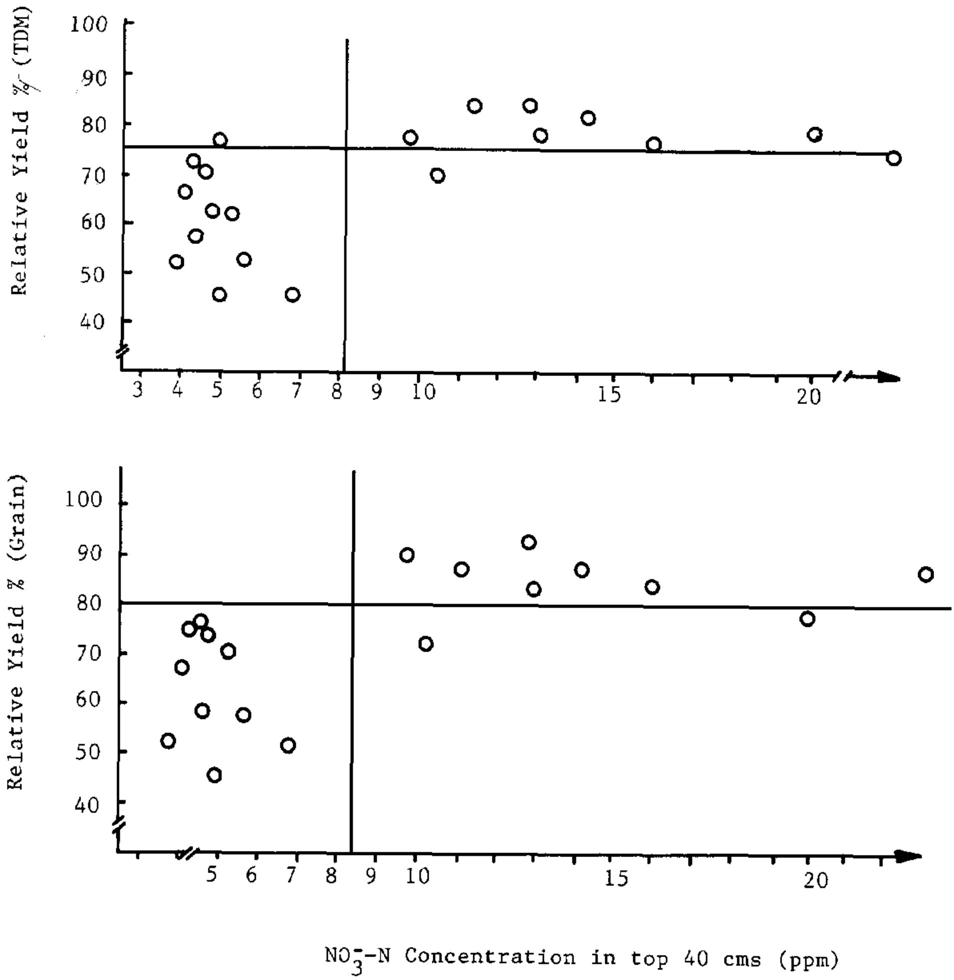

Figure 6.10 Relative yield of wheat total dry matter TDM (upper) and grain (lower) against NO_3^--N in top 40 cm of soil at sowing, 1987/88

Table 6.24 Calculated values of net revenue and marginal net benefit cost ratio for wheat trials by rotation, 1986/87

Previous crop	P_2O_5 kg/ha	Increase in Net Revenue, SL/ha				Net Benefit/ cost ratio			
		0	20	40	80	0	20	40	80
Northwest	N, kg/ha								
Chickpea (4 trials)	0	0	676	113	-288	0.00	5.25	0.94	<0.00
	40	2726	1670	1700	2019	6.12	4.38	3.88	3.47
	80	1997	2050	2148	2461	3.94	3.62	3.41	3.18
	120	2038	2190	2504	2308	3.12	3.03	3.08	2.57
Lentil (4 trials) 439 mm	0	0	1112	1165	593	0.00	6.27	4.92	2.11
	40	2833	2640	3587	3954	6.20	5.40	5.53	4.96
	80	3847	3751	4020	4061	5.40	4.97	4.79	4.72
	120	4236	2898	3427	4795	4.70	3.61	3.75	4.08
Summer crops (5 trials)	0	0	1691	1360	2691	0.00	7.00	5.26	5.23
	40	2471	3994	3880	3928	5.93	6.24	5.70	4.95
	80	2858	4512	5154	4826	5.41	5.37	5.34	4.66
	120	3880	4669	4812	4490	4.50	4.67	4.50	3.94
Northeast									
Chickpea (2 trials)	0	0	-568	-392	-1002	<0.00	<0.00	<0.00	<0.00
	40	1754	1263	2075	2052	5.20	3.76	4.32	3.51
	80	1500	1627	2187	428	3.32	3.13	3.44	0.78
	120	2252	1505	1600	1572	3.33	2.32	2.25	1.93
Lentil (2 trials)	0	0	306	191	609	0.88	3.49	1.48	2.15
	40	1251	956	1095	1654	4.45	3.16	2.95	3.06
	80	923	1120	1461	1487	2.39	2.42	2.64	2.24
	120	1273	1186	925	1976	2.24	1.94	1.45	2.29
Summer crops (2 trials)	0	0	150	395	1152	<0.00	2.12	2.61	3.36
	40	1853	2187	1950	2021	5.32	4.98	4.18	3.47
	80	2678	2868	2039	3553	4.60	4.37	3.30	3.97
	120	982	1557	1176	2879	1.83	2.38	1.77	2.99

Table 6.25 Calculated values of net revenue and marginal net benefit cost ratio for wheat trials by rotation, 1987/88

Previous crop	P_2O_5 kg/ha	Increase in Net Revenue, SL/ha				Net Benefit/ cost ratio			
		0	20	40	80	0	20	40	80
Northwest	N, kg/ha								
Chickpea (6 trials)	0	0	1593	1173	1394	0	6.56	4.47	3.33
	40	3785	4157	3841	5273	6.35	5.91	5.23	5.14
	80	5736	5427	5507	6478	5.86	5.32	5.03	4.85
	120	6526	6669	5446	6934	5.21	5.00	4.31	4.44
Lentil (6 trials)	0	0	866	1929	1078	0	5.43	5.57	2.81
	40	3960	4527	4705	5599	6.34	6.08	5.67	5.27
	80	6608	6299	6319	6394	6.09	5.64	5.33	4.82
	120	6850	6725	7072	6692	5.32	2.02	4.89	4.36
Summer Crop (8 trials)	0	0	38	394	480	0	0.55	2.24	1.51
	40	2710	2301	2645	3336	5.68	4.63	4.40	4.12
	80	2974	3126	4617	3798	4.36	4.09	4.64	3.66
	120	4319	4593	5262	4440	4.29	4.16	4.23	3.46

Fertilizer was in general profitable in all rotations in both years, but the lack of substantial responses to phosphate is reflected in a decrease in net benefit/cost ratios for increasing levels of P-application. Both rotation and year (rainfall) had a significant effect on the profitability of nitrogen fertilizer use on wheat. In the drier year of 1986/87, the greatest benefit of nitrogen was derived in wheat following summer crops, presumably reflecting the added availability of residual moisture from the previous year. In the much wetter year of 1987/88, however, the greatest benefit was found in wheat following legumes. In such a year, moisture would not be a limiting factor, but greater responses would result in the more nitrogen deficient soils following legumes. The effect of year and crop rotation of nitrogen responses of wheat are also examined in section 4 of this report through the use of long-run climatic data and the CERES-N wheat model.

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Thomson, E.F., Bahhady F, and Termanini A. 1985. Production practices and grain yields of barley and wheat at the cultivated margin of the NW Syrian Steppe.

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7. TRAINING AND AGROTECHNOLOGY TRANSFER

M. B. Said

During 1987/88 FRMP staff were involved in a number of training activities. As stated in previous reports, these training activities are directed primarily towards improving the national programs research capabilities. The details of these activities are presented in the following sections.

7.1 Residential Training Course

The third annual residential course in Farming Systems Research and Resource Management at Tel Hadya research station Syria was conducted from 14 February to 31 March, 1988. It consisted of a 2-week general course as an introduction to farming systems research methodology followed by two 4-week specialist courses in (a) crop agronomy and (b) soil moisture studies. Participants chose which of the specialist courses they wished to attend. In the seventh and last week of the course, the participants identified research problems in their own countries and using the knowledge they had learned in the course designed studies to solve those problems. These studies were presented by the participants for group discussion. The course was attended by 18 participants from 8 countries of the region namely Syria, Turkey, Jordan, Morocco, Sudan, Ethiopia, Saudi Arabia and Pakistan.

7.2 Short Courses

Three short courses were conducted by the program during 1987/88 season. The first one was on Research on Effective Use of Fertilizer which was organized, in collaboration with the International Fertilizer Development Center (IFDC), at ICARDA facilities in Aleppo during the period January 10-28, 1988. The course objectives were: (1) to identify and describe the components of a sound national fertilizer program, (2) to review recent advances in soil and crop science and thereby increase the participants' knowledge and understanding of factors influencing crop response to fertilizer, (3) to highlight the problems of soil fertility maintenance at the various cropping systems and socioeconomic conditions of the farmer, (4) to improve participants' ability to test and evaluate new and conventional fertilizer materials and application methods using the latest techniques in field research, (5) to ensure that the necessary techniques for processing, analyzing and interpreting data generated from trials are fully understood and practiced and (6) to improve participants' management and communication skills. The training program dealt with both theoretical and practical aspects of fertilizer use. The course was attended by 14 participants from 11 countries, namely Syria, Jordan, Morocco, Tunisia, Turkey, Kuwait, Iran, China, Malaysia, Nigeria and Zimbabwe.

The second course was a sub-regional training activity on Methods of Farm Surveys organized, in cooperation with INRAT, in Tunisia during the period June 20-29, 1988. The objectives of the course were to provide training in (1) planning for diagnostic farm surveys, (2) Use of relevant field techniques for data collection and (3) evaluation of collected data to identify researchable problems. The training activities included lectures, and practical work on the following topics: (1) farming systems research approach, (2) importance and objectives of farm surveys, (3) use of secondary data, (4) types of surveys, (5) sampling procedures, (6) questionnaire design, (7) data collection techniques, (8) data analysis and (9) interpretation and reporting of results. The course was attended by 11 participants representing Tunisia, Algeria, and Morocco. In order to enhance communication and exchange of information among the participants, country reports were prepared and presented by the participants for group discussion.

The third was an in-country training course on "Agronomy Trials" which was held in cooperation with INRA, in Morocco during the period 31 October - 4 November, 1988. The course was organized for agronomy technicians who are or will be responsible for conducting agronomy trials. The course provided a basic understanding and working knowledge of the principles needed in the implementation and management of agronomy trials. It was attended by 20 Moroccan participants.

7.3 Individual Training

During 1987/88 season FRMP staff, in collaboration with university staff from countries of the region and elsewhere, provided supervision of the thesis research of 8 postgraduate students: 4 M.Sc. and 4 PhD. Names, countries, degrees, cooperating universities and thesis topics of these students are given in Table 7.1 Two other students (one from Syria and the other from Sudan) have been identified to join the program and start their thesis research for M.Sc. during 1988/89 season.

In the individual non-degree category, FRMP offered 14 training opportunities on various research topics during 1987/88. The trainees included both senior and junior scientists and the training period ranged from 1 week to 1 year. Names, countries, subjects and duration of these training programs are given in Table 7.2

7.4 Workshops

Five workshops were held during the season. The first one was a regional consultation on supplemental irrigation and was jointly organized by FAO and ICARDA. The goal of the workshop was to review the literature, examine secondary data sources and administer survey interviews to develop a state-of-the art summary of supplemental irrigation systems for the ICARDA mandate countries. The workshop was held in Morocco during the period 7-9 December 1987 and was attended by 70 participants including 28 national specialists from 17 countries of the region namely Algeria, Cyprus, Egypt, Iraq, Iran, Jordan, Lebanon, Libya, Mauritania, Morocco, Somalia, Sudan, Syria, Tunisia, Turkey, North

Table 7.1 Individual Training, Degree related

Name	Country	Degree	Cooperating University	Thesis Topic
U. Maerz	Germany	PhD	Hohenheim	Multivariate Analysis of Farming Systems
S.A. Magid	Sudan	PhD	Hohenheim	Economics of Faba Beans in New Areas
H. Dahroug	S. Yemen	MSc	Aleppo	Herbicide/ Fertilizer Effect on Wheat
F.J. Mahmoud	Syria	MSc	Aleppo	Soil Test Calibration for Phosphorus
T. Razzouk	Syria	PhD	Aleppo/ Nottingham	Wheat Extension in Syria
A. Ben Achour	Tunisia	PhD	Missouri (Columbia)	Labor and Adoption of Technology
E.K.Al Karablieh	Jordan	MSc	Jordan	Labor and Adoption of Technology
M.S. Issa	Syria	MSc	Aleppo	Variation in Wheat Production in Syria

and South Yemen. It was funded by ICARDA, FAO, Ford Foundation and IDRC. The proceedings of this workshop are currently being edited and will be published in 1989.

During 3-7 April 1988, FRMP organized a workshop in Alexandria, Egypt, which was attended by representatives from ARC Egypt, Alexandria and Cairo Universities, USAID/USDA, GTZ, as well as FRMP, PFLP and FLIP staff from ICARDA. The workshop discussed a report on the first (survey) phase of the Northwest Coast

Table 7.2 Individual Training, Non-degree related

Name	Country	Subject	Duration
A.M. Hussein	Syria	On-Farm Fertility Trials	1 year
W.N. Shehadeh	Syria	On-Farm Fertility Trials	1 year
A.A. Hashim	Sudan	Agric. Economics	2 weeks
M.J. Sirogi	Syria	Data Analysis	2 weeks
W.G. Kidane	Ethiopia	Application of Climate & Crop Models for Land Evaluation	8 weeks
A. Bouaita	Algeria	Survey Data Analysis	4 weeks
M. Laghezali	Morocco	On-farm Trials	1 week
M. Moussaoui	Morocco	On-farm Trials	1 week
A. Herzenni	Morocco	On-farm Trials	1 week
K. Sayyadian	Iran	Tillage/Moisture Conservation	8 weeks
M.B. Rahimi	Iran	Tillage/Moisture Conservation	8 weeks
H. Sengul	Turkey	Socio-economics	9 weeks
M. Direk	Turkey	Socio-economics	9 weeks
M.M. Jendoubi	Tunisia	On-farm Trials	2 weeks

Project: "Evaluation of Farm Resource Management in the Northwest Coast of Egypt" prepared and presented by Drs. El-Naggar, Sheykhoun and Perrier. The participants then toured the region viewing farmers' fields and areas for potential field projects and discussed possible future activities for the second phase of the project. It was sponsored by ICARDA/Egypt.

The third workshop was organized at ICARDA headquarters, Aleppo, 10-14 July 1988 as part of the Agricultural Labor and Technological Change (ALTC) project activities. The purposes of the workshop were: (1) to present the results of the case studies but more importantly to evaluate them, (2) to assess future research priorities for social scientists (3) to recommend a course of action for the institutional aspect of applied social science research in this region. It was attended by participants from national programs, ICARDA, regional organizations and donors. The workshop included presentation of eight case studies, a round table discussion of methodological issues, working groups for the establishment of an agricultural socioeconomic research network and its research agenda, and the form of ICARDA collaboration required by national programs. The eight case studies presented for discussion and evaluation addressed the questions related to labor and employment in rainfed agriculture in countries of the region including Jordan, Turkey, Morocco, Algeria and Tunisia. It was sponsored by Ford Foundation/IDRC/ICARDA.

The fourth was the Third Regional Workshop on Soil Test Calibration which was held in Amman, Jordan from 3 to 9 September 1988 and organized by ICARDA in cooperation with the National Center for Agricultural Research and Technology Transfer (NCARTT), University of Jordan and the Jordan University of Science and Technology. The major objectives of this workshop were: (1) to discuss the results of the joint program of 1987/88 season of the regional network on soil test calibration and (2) to formulate the workplan for regional experimentation and cooperation among countries of the region in 1988/89 season. The workshop was funded by UNDP and attended by 38 participants from Syria, Jordan, Iraq, Turkey, Cyprus, Tunisia, Morocco, N. Yemen, Pakistan and ICARDA.

The fifth workshop held from June 19 through 23, 1988 was an In-House Training activity on Crop Models. The objective of the workshop was to familiarize ICARDA senior scientists with crop growth simulation modelling, with a focus on the CERES barley and wheat models. Drs. Douglas Godwin of IFDC and Susanne Otter-Nacke of Michigan State University, both of whom have been involved in the development of these models, described the methods and rationale used to simulate crop growth, development and yield. Scientists had the opportunity to test the new barley model against their data.

7.5 Miscellaneous Activities

A full draft of the manual "Methods of Crop On-Farm Trials in Farming Systems Adaptive Research" has been completed and distributed to the relevant scientists for further comments. The draft comprises two parts, the first is on Diagnostic Farm Surveys and the second is on Implementation and Evaluation of Farm Trials, which includes farm surveys for trial evaluation and adoption studies. The two parts are preceded by an introductory chapter on the roles of farm surveys and on-farm trials in the research process.

As in previous years the program staff contributed to other programs' training courses through lectures and practicals on approaches to FSR and on weed control principles and methodology. The Program scientists also visited many countries of the region for meetings and discussion with scientists of national programs.

8. PUBLICATIONS

8.1 International Journals 1982-1988

Almost all these articles report research undertaken by staff during their time at ICARDA. However, in some instances, staff have written up research undertaken before they joined the Center. When this research is of relevance to ICARDA's mandate, and when affiliation to ICARDA is indicated by the journal, such articles are included in the list below.

Brown, S., Keatinge, J.D.H., Gregory, P.J., and Cooper, P.J.M. (1987). Effects of fertilizer, variety, and location on barley production under rainfed conditions in northern Syria. I. Root and shoot growth. **Field Crops Research.** 16, 53-66.

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Jones, M.J. (1987). Plant population and sorghum production in Botswana. II. Development of farmer recommendations. **Experimental Agriculture**. 23:349-356.

Jones, M.J. (1987). Soil water and crop production in Botswana. **Soil Use and Management**. 3, 74-79.

Keatinge, J.D.H., and Cooper, P.J.M. (1983). Kabuli chickpea as a winter-sown crop in northern Syria: moisture relations and crop productivity. **Journal of Agricultural Science (Cambridge)**. 100:667-680.

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Wahbi, A., and Gregory, P.J. (1988). Genotypic differences in root and shoot growth of barley (Hordeum Vulgare). II. Field studies of growth and water use of crops grown in N.Syria. **Experimental Agriculture**. Accepted.

8.2 Books and Proceedings

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Youssif, F.S. (1988). Fababean marketing and markets in Sudan. MSc Thesis. Faculty of Economics and Rural Development, University of Gezira, Sudan.

8.3 Conferences, Workshops and Seminars

Cooper, P.J.M. Agro-ecological constraints to crop production in West Asia and North Africa, and their impact on fertilizer use. Presented at the IFDC/UNDP Conference on Fertilizer Sector Development and Agricultural Production for Countries of the Middle East and North Africa. Muscle Shoals, Alamaba. May 1988.

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9. FARM RESOURCE MANAGEMENT PROGRAM

STAFF LIST IN 1988

Peter Cooper	Program Leader - Agronomist/Soil Scientist
Hazel Harris	Soil Water Conservation Scientist
Michael Jones	Barley Based Systems Agronomist
Abdallah Matar	Soils Chemist
Thomas Nordblom	Agricultural Economist
Mustafa Pala	Wheat Based Systems Agronomist
Eugene Perrier	Water Management Agronomist
Mohamed Bakheit Said	Training Scientist
Kutlu Somel *	Agricultural Economist
Dennis Tully *	Coordinator - Agricultural Labor and Technological Change
Thomas Stilwell	Agronomist/Tunisia
Mahmoud Al-Ashram	Visiting Scientist/Economist
Onur Erkan	Visiting Scientist/Economist
Ahmed Mousa El-Ali **	Weed Control
Abdul Bari Salkini	Agricultural Economist
Ahmed Mazid	Agricultural Economist
Wolfgang Goebel	Post-Doc. Fellow/Agro-Climatologist
Ammar Wahbi	Post-Doc. Fellow/On-Farm Agronomy
Richard Tutwiler	Post-Doc. Research Fellow - Anthropologist
Sobhi El-Naggar	Post-Doc. Fellow/Agronomist
Mohamed E. Sheykhoun *	Post-Doc. Fellow/Economist
Hamid Fakki *	Post-Doc. Fellow/Economist
Ciro D'Acunzo	Associate Expert/FAO
Meri Whitaker	Postgraduate Research Student/Economist
Sobhi Dozom	Research Associate I
Mahmoud Oglah	Research Associate I
Andree Rassam *	Research Associate I
Afif Dakermanji	Training Assistant
Sonia Garabet	Research Assistant II
Layth El-Mahdy	Reserach Assistant II
Zuhair Arous	Research Assistant II
Mireille Abdelnour ***	Research Assistant II
Atef Haddad	Research Assistant II
Haitham Halimeh	Research Assistant II
Hassan Jokhadar	Research Assistant II
Samir Masri	Research Assistant II
Shahba Morali	Research Assistant II
Hisham Salahieh	Research Assistant II
Nerses Chapanian	Research Assistant II
Mohamed Tahhan	Research Assistant I
Samuel Abdul Ahad *	Research Assistant I
Pierre Hayek	Senior Research Technician I
Abdul Kader Summakieh	Senior Research Technician I
Sabih Dehni	Senior Research Technician I
Samir Barbar	Research Technician II
Ahmed Nael Hamwieh	Research Technician II

Mohamed Aziz Kassesm	Research Technician II
Mohamed Lababidi	Research Technician II
Hiam Kassar *	Research Technician II
Suleiman Kharboutly	Research Technician II
Samir Baccari	Research Technician/Tunisia
Issam Halimeh	Research Technician I
Dolly Mousalli	Research Technician I
Mohamed Zeki	Research Technician I
Nabil Musattat	Research Technician I
Shereen Baddour	Research Technician I
Ghassan Kanjo	Research Technician I
Kawthar Chehidi *	Assist. Res. Technician I/Tunisia
Hind Bikandi *	Assist. Res. Technician I
Marica Boyagi	Senior Secretary III
Katia Artinian	Secretary II
Bana Rifaii	Secretary I
Zuka Istanbouli	Secretary I
Samir Baradaii	Driver II
Karim Hamou	Farm Labourer
Mohamed Elewi Karram	Farm Labourer
Hayel El-Shaker	Farm Labourer

* Left in 1988
** Transferred to DGO
*** On Leave Without Pay

APPENDIX A

Experiment Number and Title of

FRMP Core Research Program

1987-1988

PROJECT 1. MANAGEMENT OF SOIL, WATER AND NUTRIENTS

Improved Efficiency of Fertilizer Use

SWAN-1 Nitrogen and phosphate soil test calibration for wheat in farmers' fields (cooperative with Syrian Soils Directorate)

SWAN-2 Effect of amount and placement of phosphate on wheat in farmers' fields

SWAN-3 Contribution of the mineralization potential in soils to nitrogen nutrition of wheat (cooperative with FLIP)

SWAN-4 On-farm barley fertilizer research (Cooperative with Syrian Soils Directorate)

SWAN-5 Farmer-managed barley fertilizer trials (cooperative with Syrian Soils Directorate)

SWAN-6 On-farm responses of a vetch/ barley forage mixture to residual fertilizer (cooperative with Syrian Soils Directorate)

SWAN-7 Phosphate soil test calibration with food and forage legumes (cooperative with FLIP)

SWAN-8 Interaction between soil moisture, soil P and applied phosphate on growth, nutrient uptake and yield of lentil (cooperative with Aleppo University, MSc study)

SWAN-9 Rate of change of available-P in soils in relation to residual and applied phosphate under a cereal legume cropping sequence

SWAN-10 P-adsoption isotherms in calcareous soils

Tillage and Stubble Management

SWAN-11 The effect of long term tillage systems on the stability of wheat/lentil rotations

SWAN-12 Tillage method comparison in 3-course wheat/legume/summer crop rotations

SWAN-13 The effect of stubble burning on a wheat/lentil rotation

SWAN-14 The effect of wheat stubble management on the productivity of contrasting farming systems (cooperative with PFLP and FLIP)

SWAN-15 Wheat/medic rotation studies (cooperative with CP, PFLP)

SWAN-16 The effects of sowing method, cultivar and seed rate on wheat production (cooperative with Aleppo University, MSc study)

Weed Control

SWAN-17 Chemical weed control in wheat

SWAN-18 Chemical weed control in food legumes (cooperative with FLIP)

Improved Production Practices for Food Legumes

SWAN-19 On farm assessment of improved production practices for lentil (cooperataive with FLIP)

SWAN-20 On farm assessment of improved production practices for chickpea (cooperative with FLIP)

Fallow Replacement Research

SWAN-21 Fodder legumes potential in dry areas (cooperative with PFLP)

SWAN-22 Vetch utilization trials

SWAN-27 Legume/barley rotation trial (Old Rotation, 9th year)

SWAN-28 Forage/barley rotation trial (New Rotation, 7th year)

SWAN-29 Continuous barley trial (3rd year)

SWAN-30 Barley scale-insect rotation trial (2nd year, cooperative with CP)

SWAN-31 Medic/barley rotation trial year, cooperative with PFLP)

Water Management Studies

SWAN-23 Supplemental irrigation of wheat: nitrogen and variety studies

SWAN-24 Research managed supplemental irrigation of wheat

SWAN-25 Supplemental irrigation of barley: varietal responses (cooperative with CP)

SWAN-26 Supplemental irrigation of chickpea: varietal responses (cooperative with FLIP)

PROJECT 2. AGRO-ECOLOGICAL CHARACTERIZATION FOR RESOURCE MANAGEMENT

Prediction of Crop/Environment Interactions

ACRM-1 Selection and characterization of key sites (cooperative with CP and FLIP)

ACRM-2 Development of spatial climatic model

ACRM-3 SIMTAG

ACRM-4 Simulation of supplemental irrigation farming using a modification of the CERES-N wheat model and ICARDA weather generator

ACRM-5 Development of a CERES compatable model for economic evaluation of nitrogen fertilizer strategies for wheat and barley

ACRM-6 Prediction of crop-environment interactions

ACRM-9 Methods for definition of areas of similar physical production potential and constraints for crops

PROJECT 3. ADOPTION AND IMPACT OF TECHNOLOGIES

ADIM-2 Economic factors influencing adoption of new technology in dry areas. A case study of fertilizer use on barley

ADIM-3 Factors affecting the adoption and impact of supplemental irrigation

ADIM-7 Economic allocation of fertilizer in Syria

ADIM-8 Comparative analysis of barley production in N. Syria and S.E. Turkey

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