FARM RESOURCE MANAGEMENT PROGRAM

Annual Report for 1989

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International Center for Agricultural Research in the Dry Areas

P. O. Box 5466, Aleppo, Syria

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1. INTRODUCTION

1.1 Content of this Report

As in previous years, the format of this report is centred around the four major projects within the program, namely: The Management of Soil, Water and Nutrients; Agro-ecological Characterization for Resource Management; The Adoption and Impact of New Technology and Training and Agrotechnology Transfer. The report contains, in addition to this introduction, seven chapters. Chapter 2 provides an Executive Summary of our research and training in 1988/89. This summary only refers to the content of this report which itself does not attempt to report all our activities. A full listing of all our research activities are given in Appendix B. Chapter 3 contains several important reports within our Project on the Management of Soil, Water and Nutrients. Of these reports, three present a summary of research conducted over the last four seasons. The topics covered are the on-farm evaluation of fertilizer use on barley, the on-farm assessment of improved chickpea production technology and the results from a large scale on-station trial assessing the productivity of contrasting wheat-based farming systems. Chapter 4 presents reports on three contrasting aspects of our research on agro-ecological characterization. Section one illustrates how ICARDA's model for spatial weather generation can be used to identify response domains within which the probability of climatic events, and their impact on technology performance can be identified. The second section illustrates an equally important aspect of characterization, namely the description of different farm types within relatively homogeneous response domains in Jordan. It is the characterization of contrasting farmer strategies within response domains which allows the identification of more specific recommendation domains. The third section demonstrates how long term climatic datasets and a wheat growth simulation model (CERES-

N) can be used to assess the interaction of different levels of N-fertilizer use on soils of varying N-status and their impact on wheat production in Xian Province of China. Chapter 5 contains six reports concerned with the Adoption and Impact of Technology. A wide range of subject matter is covered including the adoption dynamics of winter chickpea in Morocco, an analysis of Syria's current strategy for feeding its expanding National Sheep Flock, an assessment of production functions as descriptors of the impact of technology on barley production in Syria and Turkey, and summaries of eight case studies which assessed the impact of changing technology on agricultural labor in Algeria, Morocco, Tunisia, Jordan and Turkey. Chapter 6 reviews our program of training and workshops during 1989 and Chapter 7 and 8 list our publications and staff respectively.

In summary, whilst not reporting all our activities during the year, our 1989 Annual Report provides a detailed account of a broad range of subjects. These illustrate both the breadth of research undertaken and their multi-disciplinary and integrated nature. As always, it is with great pleasure that we express our sincere appreciation of the dedicated effort of program regional staff and the National Scientists with whom we work.

1.2 Staff Changes

During 1989 we bid farewell to several of our staff, but were delighted to welcome many new additions. Our IDRC funded FSR-Project in Tunisia came to an end in July, and Dr. Thomas Stilwell, our outposted agronomist resigned. Our thanks to him for all the support he provided to the project and also to his research assistant Samir Baccari who also left ICARDA and now works for INRAT. Dr. Thomas Nordblom (Agricultural Economist), who joined the Program in 1981, departed for a well earned sabbatical leave in Australia, and on his return in 1990 will be transferred to ICARDA's Pasture, Forage and Livestock Program.

Mrs. Meri Whitaker (Postgraduate Economist) completed her field work on the design of an economic sub-routine for the Ceres-N Wheat Model and has returned to Stanford University to complete her thesis. Two visiting scientists also returned to their respective countries. Dr. Hamid Fakki (Agricultural Economist, Sudan) completed a training manual on on-farm research, and is now producing an Arabic version in Sudan. Dr. Sobhi Naggar (Agronomist, Egypt) completed six reports on the Farming Systems of the N.W. Coast of Egypt which we hope to publish soon. Our thanks to both Hamid and Sobhi for their excellent work. Mira Abdelnour, after 10 years as one of our senior research assistants, also resigned to devote her attention to her new son. Our congratulations to her and Dr. W. Erskine (FLIP) and our heartfelt thanks for her outstanding work whilst she was with us. We also said a partial goodbye to Miss Bana Rifaii (secretary) who has been transferred to ICARDA's Visitors Services.

Finally, we bid farewell to Messrs Zuhair Masri and Ezzeldine Hassan who joined us for a year from the Syrian Soils Directorate of Aleppo and Hassakeh respectively. We thank them both for the excellent year's work they contributed to our cooperative fertilizer research program.

During 1989, we also welcomed several new visiting scientists. Dr. Shi Zuntong from China joined us to work on our package for Agro-ecological Characterization and to assess its potential for use in the wheat growing areas of Xian Province. Mr. Khazaa El Hajj (Syria's Soils Directorate) also joined us in a collaborative evaluation of our recently developed program for the National Allocation of Fertilizer. Lina Mayda (also Soils Directorate) joined us as a trainee to work with Khazaa on this project. Dr. Nouredine Mona (an ex-postgraduate student) re-joined the Program as a visiting scientist from Aleppo University to assist us in the compilation of a thorough literature review of issues concerned with the ownership and management of marginal lands in West Asia. Finally, another previous colleague, Dr. Elizabeth Bailey, also re-joined the program as a visiting scientist. Elizabeth is an agricultural economist with specialization in risk analysis. She will be working closely with other colleagues at ICARDA on land use strategies in the marginal agricultural areas of West Asia and North Africa.

We were also joined by two postgraduate students. Mr. Maurice Saade (Michigan State University) is working for his PhD in Agricultural Economics with special reference to the allocation of fertilizer, and associated risk analysis. Mr. Elias Afif (Cordoba University) is working for his PhD in Soil Science and is focusing on the dynamics and availability of phosphorus in calcareous soils. Both are making good progress, and are welcome additions to FRMP.

Finally, we welcome Miss Raala El Naeb who joined us as a Research Technician to give added support to our Agroclimatic research.

1.3 The Weather in Syria During the 1988/89 Season

The season of 1988/89 in Syria and Lebanon had two distinct periods: a start with ample, much higher than average rainfall followed by a long, very dry second period.

Substantial and early rainfall amounts were received at all stations, starting the second week of October. Quite heavy rain, in combination with fairly mild temperatures, continued until the end of the year. From the second week of January onward a quite different weather pattern prevailed with very little rainfall (except for a wet spell in March), cold nights and sunny days with high evaporative demand in spring (see Table 1.1). Total seasonal

Table 1.1 Intra-seasonal distribution of rainfall 1988/89

	Period 1 Oct - 8 Jan		Period 2 9 Jan - May	
	Sub total mm	Percent of seasonal total	Sub total mm	Percent of seasonal total
Jindiress	315.9	89	38.3	11
Tel Hadya	195.4	83	38.8	17
Breda	165.0	85	28.8	15
Boueider	154.0	81	32.4	17
Ghrerife	185.5	92	16.0	8
Terbol	232.6	72	75.0	28

rainfall was far below the long term average at all sites. There is only approximately a 1 in 10 chance of receiving the same or less rain than during the 1988/89 season, and one has to go back in history until 1954/55 to find a season with a similar intra-seasonal distribution of rainfall in Aleppo.

The heavy rain in October and November fell in distinct spells which made planting in time possible, as the field surface had sufficient time to dry in between. The good rains up to December enabled early sown crops, cereals and legumes, to develop good stands which managed to withstand the following frost and drought better than one might have expected, yielding up to half of what is harvested in a "normal" season. The reduced weed infestation due to the drought also contributed to this effect. Later sown crops, however, suffered severely from drought and frost, often yielding not more than 10% of the average when harvested. In the barley-livestock areas, most fields were grazed off before harvest time. Even in the wetter, wheat growing areas, grazing of the crops was widespread.

Further details of the weather in 1988/89 are provided in Tables 1.2 to 1.5.

Table 1.2 Monthly precipitation (mm) for the 1988/89 season

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	TOTAL
Jindiress													
1988/89 season	0.0	61.6	125.6	117.1	11.6	1.2	32.1	0.0	5.0	0.0	0.0	0.0	354.2
Long term average (30s.)	1.3	29.5	54.5	99.2	89.5	73.4	64.8	43.4	18.9	3.2	0.0	0.9	478.5
% of long term average	0	209	230	118	13	16	50	0	26	0	n/a	0	74
Tel Hadya													
1988/89 season	0.0	41.2	60.8	83.9	10.0	5.8	17.8	0.0	14.9	0.0	0.0	0.0	234.4
Long term average (11s.)	0.5	27.7	46.3	58.4	62.8	51.6	44.4	28.8	14.4	3.4	0.0	0.1	338.4
% of long term average	0	149	131	144	159	104	40	0	103	0	n/a	0	69
Breda													
1988/89 season	0.0	52.8	45.6	65.4	1.2	2.0	12.6	0.0	14.2	1.0	0.0	0.0	194.8
Long term average (31s.)	1.4	14.5	30.0	52.6	47.2	27.8	32.7	32.5	15.7	1.6	0.2	0.0	256.2
% of long term average	0	364	152	124	3	7	39	0	90	63	0	n/a	76
Boueidar													
1988/89 season	0.0	20.6	56.6	74.2	5.5	0.4	25.7	1.0	2.4	2.6	0.0	0.0	189.0
Long term average (17s.)	1.5	14.3	23.0	36.6	41.3	36.4	27.1	19.0	9.7	0.8	0.2	0.0	209.9
% of long term average	0	144	246	203	13	1	95	5	25	325	0	n/a	90
Ghrerife													
1988/89 season	0.0	72.7	50.0	62.4	0.4	1.8	13.0	0.0	1.2	0.0	0.0	0.0	201.5
Long term average (5s.)	0.0	44.8	36.5	39.6	50.8	36.1	41.8	15.3	19.2	3.5	0.2	0.0	287.8
% of long term average	n/a	162	137	158	0	5	31	0	6	0	0	n/a	70
Terbol													
1988/89 season	0.0	38.2	48.8	145.6	36.2	22.2	39.4	7.2	6.0	0.0	0.0	0.0	343.6
Long term average (9s.)	0.0	29.5	59.3	90.0	122.0	101.8	99.8	24.4	10.9	1.3	0.0	0.0	539.2
% of long term average	n/a	129	82	162	30	22	39	30	55	0	n/a	n/a	64

Table 1.3 Monthly air temperature (°C) for the 1988/89 season

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
Jindiress												
Mean max.	33.1	24.5	14.8	12.2	11.3	15.1	19.8	29.5	31.1	31.6	34.5	33.7
Mean min.	17.1	12.4	6.0	4.4	-2.1	0.9	7.6	11.3	14.4	18.2	21.9	23.3
Average	25.1	18.5	10.4	8.3	4.6	8.0	13.7	20.4	22.8	24.9	28.2	28.5
Abs. max.	38.0	34.3	21.8	18.4	15.9	23.6	24.9	36.1	38.6	37.0	37.9	38.0
Abs. min.	12.1	7.0	-3.9	-3.8	-8.7	-8.1	-0.3	5.8	9.3	14.2	18.9	19.0
Tel Hadya												
Mean max.	34.8	25.5	15.6	12.3	11.9	15.2	20.1	30.8	31.8	33.8	38.0	36.7
Mean min.	17.4	11.5	4.6	2.6	-2.3	-1.4	6.1	9.7	12.8	17.4	21.9	21.6
Average	26.1	18.5	10.1	7.5	4.8	6.9	13.1	20.2	22.3	25.6	30.0	29.2
Abs. max.	40.5	35.5	23.6	18.2	17.0	23.0	24.6	37.1	38.8	39.3	41.7	40.9
Abs. min.	13.2	4.8	-6.6	-4.5	-9.7	-9.9	-1.1	2.9	7.7	12.2	19.9	18.8
Breda												
Mean max.	34.5	25.1	15.2	11.7	11.3	15.0	20.9	31.3	31.9	34.3	38.5	36.9
Mean min.	15.4	10.8	4.3	2.1	-2.4	-0.9	6.0	10.0	12.8	17.2	19.9	20.1
Average	25.0	18.0	9.7	6.9	4.5	7.1	13.4	20.7	22.4	25.7	29.2	28.5
Abs. max.	40.0	35.0	22.9	17.0	16.5	24.0	26.2	36.9	39.0	39.4	42.9	40.5
Abs. min.	12.3	5.7	-5.8	-4.0	-8.8	-9.4	-0.8	4.0	7.7	12.7	16.0	16.2
Boueidar												
Mean max.	33.9	25.4	14.0	8.5	7.8	12.1	17.7	28.9	32.3	35.0	38.7	37.4
Mean min.	14.5	11.6	4.7	1.5	-2.9	-2.1	5.2	9.4	10.9	14.5	17.1	16.5
Average	24.2	18.6	9.4	5.0	2.5	5.0	11.5	19.2	21.6	24.7	27.9	27.0
Abs. max.	39.5	34.2	23.0	15.1	15.0	20.6	23.6	36.0	38.6	39.9	42.3	40.5
Abs. min.	9.0	6.8	-6.3	-3.9	-7.9	-10.0	-1.3	5.4	4.7	10.8	13.9	13.0
Ghrerife												
Mean max.	33.5	24.8	14.7	11.0	10.2	14.0	19.9	30.7	32.1	34.3	38.3	36.9
Mean min.	17.5	12.6	5.0	2.6	-1.6	0.1	6.7	12.5	15.0	17.8	21.4	20.9
Average	25.5	18.7	9.9	6.8	4.3	7.0	13.3	21.6	23.6	26.1	29.9	28.9
Abs. max.	38.9	33.4	23.8	16.7	15.2	23.0	25.7	36.7	38.5	39.3	42.2	40.3
Abs. min.	14.5	8.2	-4.0	-3.0	-8.6	-8.0	-2.5	6.8	10.0	14.3	19.0	18.1
Terbol												
Mean max.	31.0	23.9	16.2	12.2	8.4	13.0	17.2	27.5	27.7	29.9	33.0	33.2
Mean min.	11.2	8.0	2.8	1.6	-3.0	-2.6	2.1	5.9	7.8	10.0	12.8	11.5
Average	21.1	16.0	9.5	6.9	2.7	5.2	9.7	16.7	17.8	20.0	23.0	22.3
Abs. max.	36.5	31.5	23.5	21.5	16.0	23.5	23.5	32.5	34.0	37.0	36.0	36.0
Abs. min.	8.0	4.0	-8.0	-5.0	-8.5	-10.0	-3.5	0.0	2.0	5.0	9.0	7.5

Table 1.4 Frost events during the 1988/89 season

	OCT	NOV	DEC	JAN	FEB	MAR	APR	SEASON
Jindiress								
No. of frost days	-	3	5	25	13	1	-	47
Abs. min. (°C)	-	-3.9	-3.8	-8.7	-8.1	-0.3	-	-8.7
Tel Hadya								
No. of frost days	-	4	5	23	18	2	-	52
Abs. min. (°C)	-	-6.6	-4.5	-9.7	-9.9	-1.1	-	-9.9
Breda								
No. of frost days	-	4	8	22	16	2	-	52
Abs. min. (°C)	-	-5.8	-4.0	-8.8	-9.4	-0.8	-	-9.4
Boueidar								
No. of frost days	-	3	10	26	19	1	-	59
Abs. min. (°C)	-	-6.3	-3.9	-7.9	-10.0	-1.3	-	-10.0
Ghrerife								
No. of frost days	-	4	7	21	15	1	-	48
Abs. min. (°C)	-	-4.0	-3.0	-8.6	-8.0	-2.5	-	-8.6
Terbol								
No. of frost days	-	10	11	27	22	7	1	78
Abs. min. (°C)	-	-8.0	-5.0	-8.5	-10.0	-3.5	0	-10.0

Table 1.5 Frost events at 5 cm above the ground during the 1988/89 season

	OCT	NOV	DEC	JAN	FEB	MAR	APR	SEASON
Tel Hadya								
Frost days	-	5	7	25	19	2	-	58
Abs. min.	-	-8.3	-5.5	-10.5	-11.3	-2.0	-	-11.3

2. EXECUTIVE SUMMARY AND HIGHLIGHTS OF RESEARCH AND TRAINING REPORTS

In this section, we present summaries and highlights of the research results we are reporting this year. Readers are referred to specific sections in which the full and detailed reports are presented. In addition, we provide a full listing of experiments and research activities conducted during the 1988/89 season in Appendix B.

2.1 Project 1. Management of Soil, Water and Nutrients

Four Year Summary of Research on Fertilizer Use on Barley (section 3.1)

Between 1984/85 and 1987/88, 75 on-farm trials were conducted in Zones 2 and 3 of Syria to assess the biological and economic response of barley to nitrogen and phosphate fertilizer. Sites were selected to represent a range of rainfall conditions, soil types, soil depths, soil fertility levels and cropping sequence. At each location, 16 nitrogen and phosphate fertilizer combinations were assessed in factorial design with two replicates. Each site was fully characterized with respect to the range of environmental variables which were thought to have important effects on fertilizer responses. In two seasons, selected fertilizer combinations were also evaluated in parallel farmer-managed trials, and throughout the four seasons surveys were undertaken to determine farmers' current barley production strategies, the associated costs and prices involved and their reaction to the on-farm trials. A thorough analysis has been done on this important and extensive data set, and a summary of this analysis is presented in this year's report.

Agronomic analysis addressed several aspects. The general response of crop growth to site conditions was quantified, and seasonal rainfall, soil type, soil fertility level and crop sequence were all shown to have important effects. Yield (grain and straw) responses of barley to fertilizer were also analysed and several trends were clear. Responses were obtained to N and/or P at 74 out of the 75 sites, but it was noted that:

a) the importance of N increased and that of P decreased with increasing rainfall (and, less clearly, in passing from Zone 2 to Zone 3);
b) N was more important in barley-barley than in fallow-barley rotations, though not by a wide margin;
c) P was most important, and N least important, in gypsiorthid soils; and
d) initial soil contents of available phosphate (Olsen) at 0-20 cm depth and mineral-N at 0-40 cm depth influenced fertilizer response.

Based on the dataset, both descriptive and predictive models were developed which related grain and straw yields to environmental variables and fertilizer application. It was shown that grouping of sites into different recommendation domains improved the predictive power of these models, enabling them to account for between 60 and 77 percent of the observed variability in barley yields. The predictive equations generated were also used to assess both the technical optima and the economic optima fertilizer rates for various contrasting recommendation domains. Fertilizer use on barley was found to be highly economic in these dry areas with marginal rates of return ranging between 125 and 330 percent. It was also observed that the use of fertilizer tended to reduce the variability (as assessed by CV's) of barley yields.

Study on Phosphate of Major Soils
in Syria (section 3.2.1)

A detailed study was made on fifty soils of Syria. Thirty of these soils were sampled from sites where concurrent fertilizer trials were being undertaken on wheat and barley, and twenty other sites, representing irrigated and very high rainfall locations were also sampled. Full physical and chemical soil analysis was performed, and in addition, several extraction procedures of phosphate were evaluated.

Large differences exist in the amount of available phosphorus extracted by various methods used. The smallest amount was obtained with the water extraction and the largest by the citric acid solution of Dyer.

Very high correlation coefficients were observed between the values of $NaHCO_3$-P and the Labile P-extracted by anion exchange resin. Furthermore, the relationships between Olsen-P, oxalic P, citric-P or total-P were found significant.

The strongest relationships between relative yields of barley and wheat and soil P parameters were found first for $NaHCO_3$-P (Olsen-P) and secondly with the water extractable P or resin-P.

Similarly, under greenhouse conditions, the relative yields of ryegrass grown in the wheat soils correlated best with the Olsen-P and resin-P. It was found possible to establish approximate critical levels for four of the soil P tests that divide soils into groups that are responsive and non-responsive to phosphate fertilization.

P-Adsorption Isotherms in Calcareous Soils (section 3.2.2)

To further enhance our understanding of P-dynamics in calcareous soils, the P-adsorption isotherms of twelve contrasting surface soils were studied. Methodology evaluation indicated that equilibrium of phosphate adsorption from a 0.02 M KCl solution containing a range of concentrations of phosphate (KH_2PO_4) was achieved in 6 hours, and was relatively insensitive to the natural fluctuations in laboratory temperature. Both the Freundlich and Langmuir equations were tested for their ability to describe the adsorption curves, and the former was found superior. Phosphate adsorption power of soils was significantly related to the clay content of the soil, but to no other measured soil property. It is noteworthy that there was no relationship between phosphate adsorption and free $CaCO_3$ content, and this supports recent evidence that iron oxides may play a more active role.

Nitrogen Mineralization Potential of
Syrian Soils (section 3.2.3)

Previous reports (see FRMP Annual Report 1988, section 3.6) have presented results showing that a knowledge of the nitrogen mineralization process in soils can assist in predicting responses of cereal crops to nitrogen fertilizer. This year we report an analysis of the relationships of N_o (the size of the pool of mineralizable nitrogen) and K (the mineralization constant) to various soil properties. It was found that as expected, estimates of N_o varied widely amongst soils, being highest for Mollisols and lowest for sandy Entisols. Values ranged from 30 to 325 mg N/kg soil (0-20 cm). N_o values were highly correlated with both organic carbon and total nitrogen content of the soil. However, the mineralization constant K varied only slightly between soils.

Improved Production Practices of Chickpea (section 3.3)

Between 1985/86 and 1988/89, 30 on-farm trials were conducted in Syria which assessed the biological and economic impact of a range factors known to enhance the production of chickpea. These factors were time of sowing, weed control, phosphate application, inoculation and sowing method. The experimental design (replicated 2^n factorial) allowed main effects and first order interactions to be examined. Biological and economic responses to all the factors investigated were observed, but the frequency and magnitude of these responses were variable, depending upon the growing season conditions. However, it was concluded that winter sowing of chickpea (early December) combined with weed control and phosphate application was consistently profitable across all locations and seasons, and always dominated the comparable later sown treatment both in terms of yield and profitability. Across years and locations, the early sowing averaged 1590 kg/ha grain and a net revenue of 13,640 SYL/ha compared with 1170 kg/ha and 9660 SYL/ha for the later sown treatment.

Selection of Barley Genotypes for Systems Using Supplemental Irrigation (section 3.4)

During 1987/88 and 1988/89 (two very contrasting seasons with regard to rainfall) a range of barley genotypes were evaluated for their response to supplemental irrigation. The study was conducted at Boueidar in N. Syria, a site located in Zone 4. Analysis focused on the impact of three levels of supplemental irrigation on grain and straw yield, water use efficiency and protein production. All barleys responded well to additional water, but of these, Rihane-03 was clearly the best. Its increased yield resulted from more grains/head rather than more heads/m^2. In the second season, rainfed grain yield of Rihane-03 increased from 0.22 t/ha to 2.70, 4.75 and 6.72 t/ha as it received supplemental irrigation to replace 33, 66 and 100% of the water balance deficit respectively. Highest water use efficiency was obtained when 66% of the water balance deficit was replaced by supplemental irrigation, with a mean value for all genotypes of 17.8 kg grain/ha/mm of water (rainfall + irrigation applied) compared with a value of 5.4 under rainfed conditions.

Productivity of Crop Rotations (section 3.5)

In 1983/84, we established a large scale rotation (each plot is 0.54 ha) at Tel Hadya to examine the productivity of seven two-course cropping systems. They are: wheat/fallow, wheat/summer crop (water melon), wheat/lentil, wheat/winter sown chickpea, wheat/vetch (Vicia sativa), wheat/medic (Medicago spp.) and wheat/wheat. Additional treatments are imposed in a split-split plot design on the wheat phase of the rotation which examine the effect of contrasting nitrogen fertilizer rates (0, 30, 60, 90 kg N/ha) and three wheat stubble retention strategies. Uniform phosphate (50 kg P_2O_5/ha) is applied to the wheat phase. The trial is a phased entry design with three replicates and occupies an area of 22.7 ha.

Full details of the trial are reported, and an analysis of the productivity of these cropping systems over the last 4 seasons is presented. Although trends are evolving which reflect the impact of the contrasting stubble management treatments, these are not discussed in this year's report. Instead the analysis focuses on the interactions between season, nitrogen response of wheat, the water use and water use efficiency of selected rotations, and the overall biological and economic productivity of the systems.

Mean wheat yields across all rotations varied greatly between the four seasons (0.83 t/ha - 3.62 t/ha), largely due to rainfall, but within seasons, cropping sequence also had a pronounced effect. Wheat yields following fallow $\geq$ melon > vetch $\geq$ lentil > chickpea > medic > wheat. Reasons for these effects are discussed. Responses of wheat to N fertilization were also affected by season, and to some extent by rotation. The productivity of the food legume phase (chickpea and lentil) is also discussed, and it is noted that there is clear evidence of a negative response of these legumes to previous nitrogen application on wheat, largely due to greater water use by the fertilized wheat crop, and hence greater stress in the subsequent legume crop.

The performance of livestock (grazing days, liveweight gain and milk production) grazing the vetch and medic pastures is also presented and discussed. Grazing days/ha for vetch ranged between 1270 and 2212, and for medic 1320 to 2850 days. Full economic analysis of all seven cropping systems was undertaken and the procedures used are presented. Caution is raised with regard to the methodology used to assess the profitability of systems which include livestock. The analysis indicates that systems which include livestock (wheat/vetch, wheat/medic) in general have the highest gross margins with wheat/vetch being superior. Of the other rotations, wheat/lentil was consistently superior, and in contrast, continuous wheat was consistently the poorest and usually provided negative gross margins.

Nitrogen Economy of Barley-Based Rotations (section 3.6)

In last year's report (section 3.2), we presented results on the biological and feed productivity of contrasting barley based rotations. For the last two extreme reasons (1987/88 very wet, 1988/89 very dry), nitrogen analysis of harvest samples was also undertaken which allows us to examine the nitrogen economy of these rotations.

These are long term rotation trials at two locations (Tel Hadya and Breda) which examine the systems productivity of barley in rotation with fallow, vetch, lathyrus, vetch/barley mixtures, lathyrus/barley mixtures, and continuous barley. Several fertilizer management strategies are superimposed on these rotations. The study concludes that:

- As has been reported before, at the same level of fertilization, barley-legume rotations produce more dry matter than barley-barley rotations (in this case, 26-68% more, depending on site and season); but the superiority of the barley-legume rotation in terms of crop nitrogen yield is very much greater (approximately 100-200%).

- Use of legume-barley mixtures in place of pure legumes appears to be disadvantageous. In particular, the use of mixtures reduced crop nitrogen yield by a mean of about 10 kg N/ha in each phase of the rotation.

- Rotations involving Lathyrus sativus consistently outyielded rotations involving Vicia sativa, with means of about 8% more dry matter and about 18% more nitrogen.

2.2 Project 2. Agroecological Characterization for Resource Management

Spatial Rainfall Generation: Examples from A Case Study in the Aleppo Area, N.W. Syria (section 4.2)

Since 1986, a spatial weather generator (SWG) has been under development at ICARDA. The reasons for undertaking this work have been discussed in previous reports. The generator is now operational, and in this year's report we present examples of its output and use. The first part of the report discusses the process of development of the tool in some detail.

During the development of the SWG, it has been found necessary to incorporate a number of measures to compensate for various deficiencies encountered in rainfall records. These are:

- Records of unequal length between different stations and records with gaps,

- Inhomogeneities in station records caused by a relocation of the station, changes in the observation method, or changes to the surroundings of the station which affect the local wind field,

- Varying reliability in reporting rainfall amounts below approximately 2 mm,

- Rounding off values to the closest value divisible by 0.5 or 0.2,

- Outliers, i.e. rainfall amounts with a very low probability of occurrence within the observation period of a station,

- Unreliable stations, which need to be detected and excluded.

The case study area in N. Syria is described, and a series of examples (presented as maps) of the application of the SWG are discussed, using both generated daily and monthly rainfall data.

The examples based on daily generated data are concerned with the influence of temporal and spatial variability of rainfall on crop establishment and survival in early and late sown crops. Early (or dry) sowing on October 1st is shown to be a highly risky. In wheat and barley growing areas, one would expect to wait between three to four and five to six weeks respectively for germination rains to occur one year out of every two. Further maps illustrate the probability of severe drought during the seedling stage following early planting and germination. In wheat growing areas, such a drought has to be expected in 20-40% of the years, while in some barley areas, the risk increases to over 50%.

A similar analysis for later planting shows it to be a more appropriate strategy for risk avoidance. The potential danger of delaying planting, and then being unable to enter the field due to continuous rain is also evaluated.

The second set of examples is based on generated monthly data and utilizes regression equations generated from a set of 75 on-farm barley fertilizer trials (see section 3.1.1). The regressions relate barley yields to October to April rainfall totals and levels of N and P_2O_5 applied in barley-barley and fallow-barley cropping sequences. Maps are generated which show the distribution, at the 80% probability level, of unfertilized and fertilized (60 kg N/ha + 30 kg P_2O_5/ha) barley yields.

Characterizing Dryland Farming Systems of Northern Jordan (section 4.3)

The Jordan University of Science and Technology (JUST) and FRMP began a multidisciplinary cooperative research program in 1988 with the objective of characterizing the agricultural production systems of the so-called "marginal zone" of rainfed agriculture. Approximately 70% of the arable land in the Hashemite Kingdom of Jordan falls into this category and receives between 200 and 300 mm of average annual precipitation. Approximately 41% of the country's population lives in this marginal zone.

In this year's report, we describe the project area (Mafraq), which was chosen to represent the marginal zones of Jordan, and trace the development of agriculture since the early days when it was dominated by nomadic herdsmen. Based on a survey of 114 farmers from 35 villages within the project area, an overview description of current farming systems is presented. Further analysis indicates that four basic farming strategies (or enterprise mixes) dominate within the area, with all but 4 of the 114 interviewed farmers falling within this grouping. They are: cereal/livestock production (CL), cereal/livestock/olive production (CLO), cereal/olive production (CO) and cereal production (C). Cereal production is largely barley, and livestock are dominated by sheep. Preliminary enterprise budgets and farmers' comments clearly show that of all these enterprises, livestock production is the most financially rewarding, and both CL and CLO farmers rely far less on off-farm employment to meet their family needs. When asked to identify their principal problem, almost all farmers with livestock said an adequate feed supply. Perhaps more importantly, they said they desired to increase the productivity of their land with the specific intention of lessening their dependence on external sources of livestock feed.

Using the interrelations among the variables examined the report concludes that a preliminary target farmer population would display the following minimum characteristics: (1) mean farm size of 20 ha, (2) mean combined sheep and goat flock of 90 head, and (3) mean annual area planted to barley of 8.5 ha. Such a group would be geographically concentrated in Zone 2 (200-250 mm) and would depend on on-farm sources for the bulk of its household income. It would also be a fair assumption that this group would have a reasonable level and flexibility of disposable income. Improved technologies and cultural practices targeted to this population would seek to raise the amount of livestock feed which the farmer could produce from his land.

<u>CERES-Wheat Model and Strategic Planning for Nitrogen Fertilization - A Framework (section 4.4)</u>

CERES-wheat model was applied to the question of wheat yield responses to N fertilization under various conditions in Xian region of P.R. of China. Grain yield data obtained by applying the CERES-wheat growth model are examined, for strategic planning of N fertilization. This study was undertaken to examine the feasibility of using tools such as this model to improve fertilizer recommendations and to develop long term policies for the maintenance of soil productivity. Soil parameters, the necessary crop coefficients required by CERES, and nine seasons of daily climatic data where used to predict wheat responses to levels of nitrogen fertilizer ranging between 0 and 210 kg N/ha on four soils of contrasting nitrogen status. Model output confirmed that responses to nitrogen are sensitive to initial soil nitrogen levels and amounts and distribution of seasonal water supply. Further analysis indicated seasonally dependent economically optimum rates of N application ranging between 0 and 150 kg N/ha in the driest and wettest years respectively. Timing of fertilizer application was also evaluated, and the model output confirmed that split applications at sowing and at the start of stem elongation was superior, and on average gave a 10% increase in yield over a single application at sowing.

Crop/soil nitrogen balances were also assessed, and it was concluded that in order to avoid long term depletion of soil nitrogen reserves, 120 kg N/ha should be added annually to wheat crops in Xian Province.

2.3 Project 3. Adoption and Impact of Technology

Adoption Dynamics of Winter Sown Chickpea in Morocco (section 5.2)

In 1985/86, the demonstration of winter sown chickpea in farmers' fields started in Morocco, and in 1987/88 two varieties ILC 482 and ILC 195 were released and the demonstration program was expanded. During 1989, ICARDA cooperated with Moroccan scientists in conducting a major survey to evaluate the adoption dynamics of winter chickpea. A total of 112 farmers were interviewed. Four categories of farmers were identified:

i) Non-adopters — farmers who had participated in previous demonstrations but had decided not to grow winter chickpea

ii) Trial farmers — farmers in the process of evaluating winter chickpea through current demonstrations

iii) Adopters — farmers who had started growing winter chickpea independent of the demonstration program

iv) Neighbours — farmers who had never grown winter chickpea, but had seen nearby demonstrations

The design and objectives of the survey are discussed in detail and the results of the analysis are presented. The economic performance of winter sown chickpea was assessed, and a wide range of gross margins (from -1213 DH/ha to +4667 DH/ha) was reported. Reasons for this large range are discussed. Trends in the farming systems were evaluated, and it was confirmed that the area under food legume production was declining. 56% of the farmers reported a decrease in the land sown to legumes, and only 22% said they were growing more. Farmers cited several reasons for reducing their area, but disease and high labor costs of legume production were outstanding. High market prices were the major reason some farmers had increased their area.

Farmers were asked about the major advantages they associated with winter chickpea compared with spring sown varieties. Good plant stand, high grain and straw yields, less risk of crop failure and resistance to disease were all frequently cited as advantages. On the other hand, when asked about problems, farmers were concerned about the small seed size (hence market value) of the currently released varieties and also their apparent susceptibility to disease. Additional problems with weeds were also frequently mentioned. When asked about possible constraints to further adoption of winter sown chickpea; small seed size, more technical information and greater availability of seed were frequently mentioned.

Based on the results of this survey, the report concludes with a section describing how the adoption process may be enhanced and indicates the positive actions already being put into practice.

An Assessment of Risk Associated with
Increasing Sheep Feed Supplies in Syria.
Current and Alternative Strategies (section 5.3)

Rising demand for livestock products has resulted in a dramatic increase in National Sheep Flock size (3.1 to 13.3 million) in the last 35 years. The derived demand for barley grain and straw has caused an equally dramatic increase in the area sown to barley which has risen from 0.75 million in 1960 to 2.9 million ha in 1988/89, but yields/ha have largely stagnated. Analysis of secondary data of area, yield and production in terms of sheep feed equivalents (SFE) showed that thirty years ago, Syria would have expected a sheep feed equivalent deficit of 3.0 million SFE only once in ten years, whereas now, it would be expected that this deficit would exceed 4.0 million SFE nine years out of ten. This is reflected in our analysis of barley trade figures which indicate that Syria has moved from being a frequent exporter to a frequent importer of barley in the last 25 years.

The data indicate that the rapid expanse of the area under barley has been achieved by expanding cultivation into more and more marginal environments, and through the adoption of barley monoculture. National average yields have not increased, but clear indications of increased yield variability are present. Currently, barley cultivation occupies two thirds of the arable land in Zones 2 to 5. The implications of this apparent strategy on sustainable production and resource conservation are discussed.

Other possible strategies are examined through the utilization of some of our research results on improved barley production practices and improved cropping systems.

The analyses indicates that alternative strategies are possible. Reducing the area under barley in the marginal areas of Zones 4 and 5 and improving production on the remaining area through the introduction of simple improved practices such as seed dressing, drill sowing, the use of nitrogen and phosphorus fertilizer and the maintenance of the barley/fallow rotation, has the potential to meet national flock feed requirements in 75% of years and, at the same time, will increase the stability of production over time. In addition, the introduction of forage legumes would further enhance the national feed supply in all but the driest years.

<u>Changes in Lentil Production Technology in Syria: A Comparative Study (section 5.4)</u>

In 1978/79 and 1979/80, ICARDA scientists conducted a Lentil Production Survey in N. Syria. Ten years later, as part of an on-farm survey training course at Tel Hadya, ICARDA scientists and trainees conducted a similar survey. Although the geographical areas covered differed slightly in the two surveys, and in spite of the fact that the raw data from the first survey was not available, some interesting observations on the evolution of lentil production practices over ten years are possible.

In general, farmers have increased the number of land preparation cultivations with the bulk of farmers (65%) now cultivating twice.

Over a ten year period, farmers have also increased their seed rates substantially from an average of 144 to 185 kg/ha, but seeding method (70% manual, 30% mechanical) has remained largely unchanged. Similarly, the varieties used are also the same (80% local small red, 20% local white large). Farmers are also tending to sow their lentils several weeks later than 10 years ago.

Average rate of phosphate application has increased enormously (from 64 to 145 kg P_2O_5/ha), and whereas 10 years ago 50% of farmers applied no P, now only 13% use no fertilizer. This increase in fertilizer use is almost certainly due to the relative price of fertilizer. In 1979, the farm gate price of 1 kg of Triple Super Phosphate was equivalent to 1 kg of lentil grain, whereas now it is equivalent to only 0.35 kg of lentil grain. All farmers interviewed still harvest by hand.

In monetary terms, production costs of lentils have increased sharply, but relative production costs have declined dramatically. The average production costs of 1 ha of lentils in 1979 had an equivalent value of 1218 kg of lentil grain, but this has fallen to 667 kg grain in 1989.

<u>Stubble Burning in N.W. Syria.
An Interim Report (section 5.5)</u>

Cereal straw and stubble (particularly barley) are traditionally viewed as a valuable livestock feed. Stubbles are extensively grazed during the summer months and straw is often stored on farm for supplemental feeding during the late Autumn and Winter. The 1987/88 and 1988/89 seasons in N. Syria represented the 3% most productive and 3% least productive of years. Very different stubble management strategies were observed in the two respective summers.

Farmer surveys were conducted in both seasons to gain greater insight into how farmers make decisions on stubble management, and a short summary is presented on the information gained in the first survey conducted in the highly production season 1987/88. In spite of the value they place on stubbles, many farmers burnt them after only a partial grazing. In fact, 38% of the farmers were burning their stubble for the first time. When asked why they were burning their stubbles, 63% of the farmers stated that they did this because (a) it eased cultivation and seedbed preparation or (b) it was an effective rodent control measure. 23% said they needed to remove the stubble as fast as possible in order to plant an irrigated summer crop. In general, farmers felt they had more stubbles than were desired or needed that year.

A more detailed comparative analysis will be presented next year.

Barley Production Functions as Descriptors of the Impact of Technology on Yield in S.E. Turkey and N. Syria (section 5.6)

Similar surveys on barley production practices were undertaken in N. Syria (1981/82) and in S.E. Turkey (1984/85). Comparative analysis of these surveys has been undertaken, and we reported some results in last year's Annual Report (section 6.4). This year we present an across country analysis of the use of production functions as descriptors of factors affecting barley yields. It was shown that six variables recorded in the survey, namely average rainfall, seed rate, seed variety, amount of phosphate applied, amount of nitrogen applied and soil depth accounted for 62% of the variability in reported barley yields.

The authors argue that such analysis of diagnostic survey data is a useful tool in determining important topics for future research. They emphasize that such production functions are almost certainly specific to the project area surveyed.

Agricultural Labor and Technological Change (section 5.7)

During 1987/88, as part of our Regional Agricultural Labor and Technological Change Project, we coordinated eight case studies within the region. These studies (conducted by national scientists in Algeria, Morocco, Tunisia, Jordan and Turkey) were presented and discussed at a workshop at ICARDA in July 1988. They have subsequently been compiled into a book which will be published in 1990. In this section we present summaries of the principal findings of these eight case studies.

2.4 Project 4. Training and Agrotechnology Transfer (section 6)

- Our Residential Training Course (February 26 to March 30) focused on the design, conduct and analysis of farmer surveys. It was attended by 11 trainees from Syria, Turkey, Morocco, Algeria, Sudan, Ethiopia, North Yemen and Pakistan. (See also section 5.4 of this report for the results of the trainees' practical survey work.)

- We held three short courses: (i) Soil and plant analysis (February 5-16) attended by eight trainees from Syria, Algeria, Tunisia, North Yemen and Ethiopia. (ii) A sub-regional course held in Algeria (June 17-26) on Farm Survey Methods which was attended by 15 trainees from Algeria, Morocco, Tunisia and Libya. (iii) A course on the Scheduling of Supplemental Irrigation (November 7-9) attended by 10 Extension agents from Aleppo Province, Syria.

- We jointly supervised 4 MSc and 5 PhD students, and provided individual non-degree training to 8 trainees.

- We held five meetings: (i) Jointly with Cukurova University, Turkey an International Seminar on Farming Systems Research (October 31 - November 3, 1988). (ii) A travelling workshop in Tunisia and Morocco (March 11-18) to visit and discuss activities in Soil Test Calibration. (iii) Jointly with WMO, an International Symposium on the Agrometeorology of Barley-Barley Based Systems held in Tunisia (March 6-10). (iv) Jointly with MAAFRA (Turkey) and CIMMYT an International Workshop on Soil and Crop Management for Improved Water Use Efficiency in Rainfed Areas, held in Ankara, Turkey (May 15-19). (v) Jointly with the Syrian Soils Directorate, a meeting to provide an overview of our fertilizer research on barley and to develop extension/demonstration plans for 1990, held at Tel Hadya (June 11-12) and attended by Extension personnel from the major barley producing provinces.

- We worked with four visiting scientists and two postdoctoral fellows in studies on the generation of barley production functions, the application of climate and crop models, the allocation of fertilizer at the National level, land tenure and management of marginal land, the finalization of reports on the farming systems of the N.W. Coastal Region of Egypt and the production of a training manual on on-farm surveys and trials.

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

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. Such collaboration fosters a systems perspective in national research structures and helps 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 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 not easy and by necessity requires that environmental interaction with technology and 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.

3.1 Four Year Summary of Fertilizer Research on Barley in N. Syria (1984 - 1989)

Barley is an important feed crop in semi-arid, winter-rainfall regions. Its major advantage is that it will grow in areas of low rainfall where other crops, such as wheat and legumes often fail.

Under such dry conditions, efficient water use is essential. Not only is the rainfall low and unreliable, but there is a high evaporative demand and, where severe deficiencies of soil nutrients occur, up to 80% of the seasonal rainfall may be evaporated directly from the soil in farmers' fields and only 20%

of total water used by plants. However, extensive research at ICARDA has shown that application of fertilizer to barley results in a substantial increase in transpiration of water by the crop and reduced losses due to evaporation from the surface under the crop. Fertilizer thus promotes a better water use efficiency by the barley. However, according to the results of a survey of barley producers in Northern Syria, less than 15% use fertilizer, even though deficiencies in the major soil nutrients P and N are widespread in their soils.

These findings were discussed by members of the ICARDA Farm Resource Management Program and of the Soils Directorate (the Syrian Government agency responsible for determining fertilizer requirements and recommendations) at a workshop in March 1984. Based on the deliberations and recommendations of that workshop, a Collaborative Project on Fertilizer Use on Barley was initiated in 1984/1985 jointly by the Soils Directorate and the Farm Resource Management Program. This cooperative research project ran for 5 seasons and was brought to a successful conclusion in 1989.

The object of the project was to assess the biological and economic effects of the use of nitrogen and phosphorus fertilizer on barley, through multiple-season multiple-location trials on farmers' fields in the agricultural stability zones 2 and 3 of Northern Syria. The range of locations and seasons allowed environmental variability to be taken into consideration in our analysis. At each site, soils were characterized and sampled for subsequent nutrient analysis. Rainfall was measured weekly, so that the critical parameters of available N and P and rainfall could be incorporated into the interpretation of results. Soil profile descriptions were undertaken at each location.

Between the season 1984/85 to 1987/88, 75 researcher managed on-farm fertilizer trials were successfully harvested. The agronomic analysis of this extensive and unique four year data set is reported in section 3.1.1., and an economic assessment is reported in section 3.1.2.

During the 1987/88 and 1988/89 seasons, we also evaluated corresponding farmer managed fertilizer trials in order to assess if the responses we observed would also be obtained by farmers when soils, fertilizer and crops were managed entirely by them. The comparison of responses obtained in scientist managed and farmer managed trials is reported in section 3.1.3.

In addition to the above studies, we have also undertaken nutrient analysis of grain and straw samples from selected treatments over the four year period. Initial analysis of these data has shown large variability in the protein content of both grain and straw and has illustrated that both environmental factors (seasonal rainfall and soil fertility status) and management factors (application of N and P fertilizer) have pronounced effects on total protein production and % protein content. The full analysis of these results is on-going and will be reported next year.

3.1.1 Researcher Managed Trials: an Agronomic Summary, 1984-1988

M.J. Jones

3.1.1.1 Introduction

The series of researcher managed barley fertilizer trials conducted on farmers' fields across northern Syria is now complete. In the four seasons, 1984-1988, a total of seventy-five trials were successfully harvested. Trial sites are indicated in Figure 3.1.1.

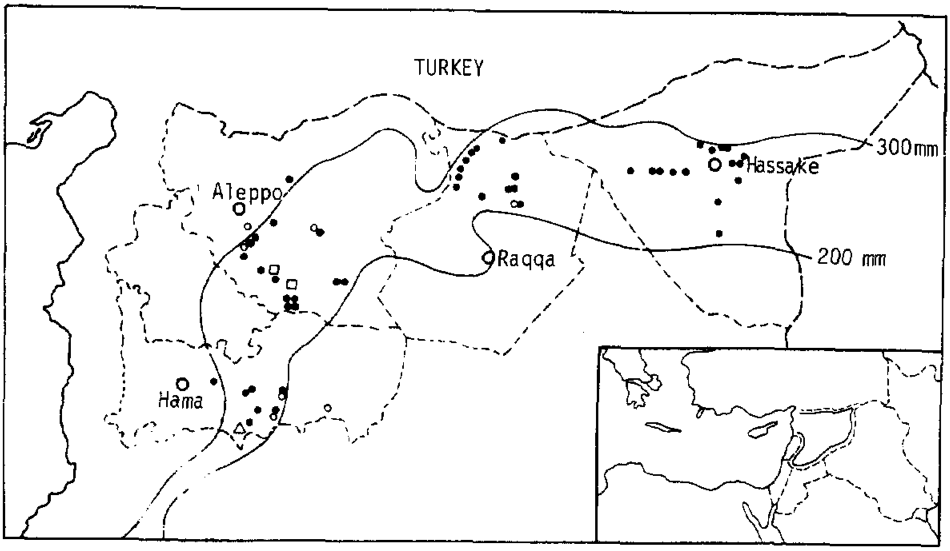


Figure 3.1.1 Distribution of trials in northern Syria: locations used in one (•), two (o), three (Δ) or four (□) years.

The experimental procedure was uniform throughout. Sites were selected each year to represent: the main soil types used by farmers for barley; the range of natural fertility found in those soils; and the two predominant crop rotations, barley following fallow (F-B) and barley following barley (B-B). Each trial comprised two replicates of a randomized complete block with four rates of nitrogen (0, 20, 40 and 60 kg N/ha, supplied as ammonium nitrate) and four rates of phosphorus (0, 30, 60 and 90 kg P_2O_5/ha, supplied as triple super phosphate), 32 plots in all (each 12.5 m x 2.1 m).

The initial cultivation was done by the farmer, usually with a "ducks-foot" cultivator to moderate depth (10-15 cm); but final seedbed preparation (with a spiked-tooth harrow), sowing and all subsequent operations were conducted by a mobile research team. Barley seed (var. Arabic Aswad) was treated with fungicide (Vitavax) and sown at a rate of 100 kg/ha using a 12-row Øyjord plot drill set at 17.5 cm row spacing. Mean sowing date was 15 November ± 8.1 days. The phosphorus fertilizer and half of the nitrogen were drilled with the seed, the remaining nitrogen being top-dressed at the tillering stage. Weeds were controlled with Brominal Plus (240 g brominal/ha), applied once or twice as necessary during February and March. Harvest was usually in the first half of May.

Soils were sampled in 20 cm increments down to 100 cm (or bed-rock, if shallower) at planting time for the determination of mineral-N and (Olsen) available-P. Rainfall was recorded on a weekly or two-weekly basis at each site, starting about 2-3 weeks before planting and continuing until harvest. Yields were determined by cutting, at ground level, eight or ten 1-meter lengths of row in each plot at maturity. These samples were oven-dried at 80 C for 24-36 hours, weighed to determine total dry matter, then threshed to determine grain weight.

The present report attempts to summarize the main agronomic findings and demonstrate the main trends.

3.1.1.2 Crop response to site conditions

A major concern of this study was the effect of highly variable environmental conditions on barley response to fertilizer. We therefore start here with a summary of conditions at the experimental sites and the broad effect of those conditions on crop performance.

Most soils were classified as either xerochrepts, calciorthids or gypsiorthids. The gypsiorthids occurred mainly in the East (Hassakeh and Raqqa provinces) and almost entirely in the drier Zone 3, while calciorthids were more common in the West. Out of 75 sites, 57 had soils at least 1 m deep, 14 0.5-1.0 m deep and 4 less than 0.5 m deep. This distribution almost certainly under-represents the use of shallow soils for barley by farmers, but sites with shallow soils suitable for experimentation were difficult to identify.

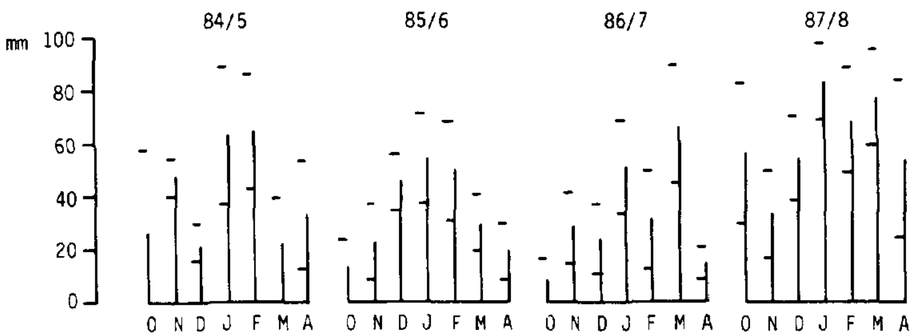
Soil mineral-N and available-P contents at planting time were mostly low but with a few scattered high values in both cases (Table 3.1.1). Mineral-N values tended to be higher at F-B sites and also in the drier Zone 3 and gypsiorthid soils; but available-P values were apparently unrelated to rotation, zone or soil type.

Table 3.1.1 Distribution of (a) soil Olsen available-P contents (0-20 cm depth) and (b) soil mineral-N contents (0-40 cm depth) at planting time among the 75 experimental sites

a) Available-P, ppm:	0-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11
Number of sites:	1	15	19	18	11	5	1	1	3	1

b) Mineral-N, ppm:	0-5	5-10	10-15	15-20	20-25	25-30	30-35	≥100
Number of sites:	2	31	23	10	6	0	1	2
F-B sites:	1	18	19	9	5	0	0	1
B-B sites:	1	13	4	1	1	0	1	1

Seasonal rainfall totals varied widely between sites over the four years, with a mean of 283.7 (± 100.2) mm and an extreme range, 135.9-567.8 mm. (These values omit any rain falling between the beginning of May and the middle of October and will therefore, in some cases, be less than the corresponding 12-month totals.) The distribution of totals is skewed: 48 sites (32 out of 42 in Zone 3; 16 out of 33 in Zone 2) had rainfall less than 300 mm, but there was a long tail of higher values. Most of these arose in 1987/88, which was an unusually wet season. Of the other three seasons, 1985/86 and 1986/87 were rather dry, whereas 1984/85 could be described as average. However, although each season had certain features general across most sites, there were also wide differences between sites in both seasonal and monthly rainfall totals (Figure 3.1.2).



Total rain, mm:-	84/5	85/6	86/7	87/8
Mean	271.8	228.2	220.2	423.9
Range	208.0-338.9	135.9-288.5	151.3-333.0	342.6-567.8
No of sites	10	22	23	20

Figure 3.1.2

Pattern of rainfall in each experimental year: monthly means (± s.d.) and seasonal totals, means and ranges. [Values for October were for less than a full month in most cases.]

Barley yield was strongly, positively and linearly related to total seasonal rainfall in each of the first three seasons. For example, in 1985/86, linear regression on rainfall accounted for 74% of the variance of site mean yields of grain. In the much wetter 1987/88 season, however, yield showed little relation to rainfall; and over the four-year data set the general yield-rainfall trend is better described by a quadratic expression.

Equations fitted to mean data from F-B and B-B rotation sites separately indicate dry-matter yield maxima for both rotations somewhere between 400 and 500 mm, although yields in B-B rotation were generally lower at all rainfall levels. Use of mean data disguises quite large yield differences, at all rainfall levels, between fertilizer treatments; but comparison of regressions fitted to data from the two extremes, zero-fertilizer control and the 60N:90P treatment, shows the general trend of the yield-rainfall relationship to be unaffected by fertilizer in either rotation (Figure 3.1.3).

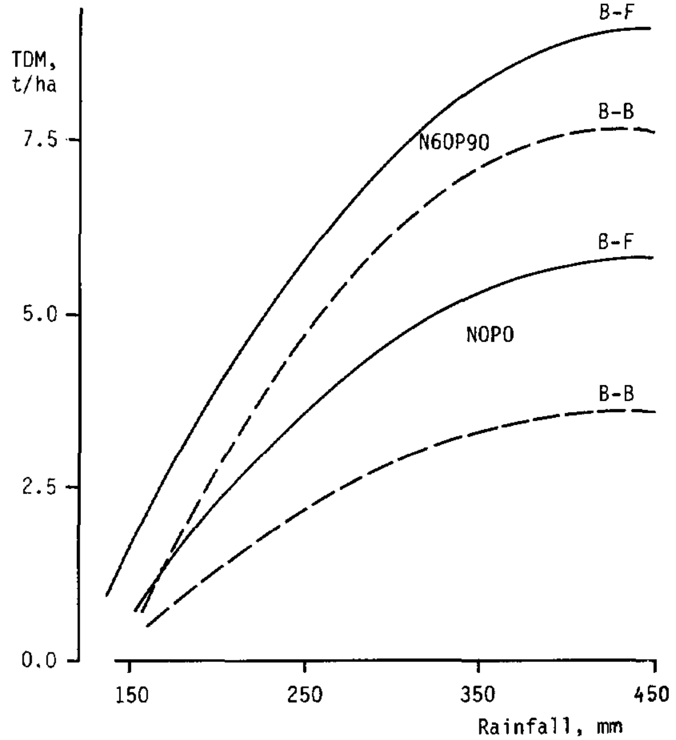


Figure 3.1.3 Relationship of total dry matter yield to rainfall under zero and high fertilizer regimes in F-B and B-B rotations separately. Fitted equations:

			R^2, %
B-F	N60P90:	$Y = 74.21Q - 0.08274Q^2 - 7583$ (kg/ha)	67.3
	NOPO:	$Y = 52.17Q - 0.05868Q^2 - 5792$	51.4
B-B	N60P90:	$Y = 79.67Q - 0.09282Q^2 - 9455$	65.9
	NOPO:	$Y = 34.60Q - 0.03931Q^2 - 4016$	43.7

Regressions on total seasonal rainfall take no account of the distribution of that rainfall. To examine the importance of this, we have compared the equation used so far (I) with an equation in which the linear component of the regression is divided over the monthly rainfall subtotals. This example is for grain yield (kg/ha) across all 75 sites:

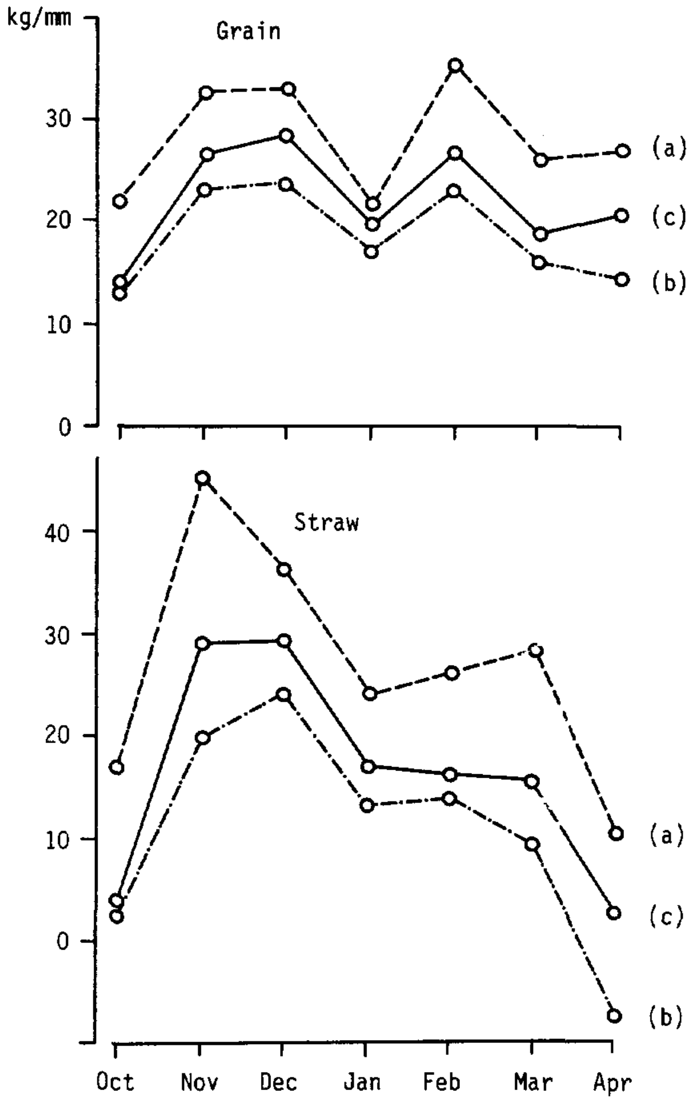
$$Y = 25.45\ Q - 0.0294\ Q^2 - 2740 \qquad \text{.... Eqn I } (R^2 = 53.4\%)$$

$$\begin{aligned} Y = 14.09\ Q_{oct} &+ 26.62\ Q_{nov} + 28.56\ Q_{dec} \\ &+ 19.81\ Q_{jan} + 26.84\ Q_{feb} \\ &+ 19.05\ Q_{mar} + 20.80\ Q_{apr} \\ &- 0.0224\ Q^2 - 2500 \qquad \text{.... Eqn II } (R^2 = 59.1\%) \end{aligned}$$

where Q is total seasonal rainfall, October-April, and Q_{oct}, Q_{nov}, etc., are the monthly subtotals. [All terms in each equation are statistically significant at the 1% level.]

Increasing the complexity of the equation gives some increase in the variance accounted for. Although not particularly large, this increase implies that rain made a greater or smaller contribution to crop yield according to when it fell.

Given the limitations of the data set and the single quadratic term, it is almost certainly unjustified to place too precise meaning on the individual values of the linear coefficients for each month; but their general trend, illustrated in Figure 3.1.4 is probably meaningful. Coefficients for grain were moderately constant, implying that rain at any time had approximately equal utility for grain production; but corresponding values for straw showed larger differences, the peaks in November and December suggesting that early rain had greatest effect on production. These trends appear to be broadly independent of fertilizer rate. Absolute differences between the coefficients for zero-fertilizer and high-fertilizer treatments for most months were quite large, but the pattern of their values across the sequence of months was remarkably similar.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Mean rain	24.1	29.8	37.3	61.5	50.5	52.1	28.5
S.D. (±)	27.7	15.8	18.6	22.2	24.4	28.9	24.3

Figure 3.1.4 Coefficients for monthly rainfall terms in regression equation III for grain and straw yields in (a) high fertilizer treatments, N60P90, (b) zero fertilizer treatment, N0P0, and (c) mean of 16 fertilizer treatments, in each case at 75 sites. [All values plotted are statistically significant at the 0.01% level in their respective equations.]

However, appreciable differences appeared when data were separated according to rotation. In the B-B rotation, the linear effect of November rainfall was between 1.5 and 4 times greater for both grain and straw production than that of rainfall in subsequent months, whereas, in the F-B rotation, coefficient values remained approximately constant from November to March. We may hypothesize cautiously that this arises from a greater dryness of the soil profile in land previously cropped to barley, which makes the volume of early rain more critical for the performance of the new crop.

Effects of soil type were much smaller than those of rainfall. Over all treatments, calciorthids gave the highest mean yields of grain and straw, despite having a lower mean rainfall than that of the xerochrepts (Table 3.1.2). Mean rainfall and

<u>Table 3.1.2</u> Summary of mean site and yield data on the three main soil types

		Xerochrepts	Calciorthids	Gypsiorthids
Number of sites		36	18	14
Means across sites:				
Total seasonal rainfall, mm		294.5	273.4	259.1
Mineral-N (0-40 cm depth), ppm		10.4	13.2	44.2
Available-P (0-20 cm depth), ppm		4.4	4.9	4.0
Harvest yields, t/ha:				
N_0P_0 treatment -	grain	1.42	1.69	1.04
	straw	1.71	2.05	1.30
$N_{60}P_{90}$ treatment -	grain	2.19	2.38	1.75
	straw	3.60	3.37	2.66
16-treatment mean -	grain	1.83	2.02	1.32
	straw	2.58	2.70	1.84

mean yield were lowest for gypsiorthids, a predominantly Zone-3 soil. Higher yields on calciorthid soils appeared to arise from a greater responsiveness to rainfall on those soils (Figure 3.1.5). The reasons for this are not known.

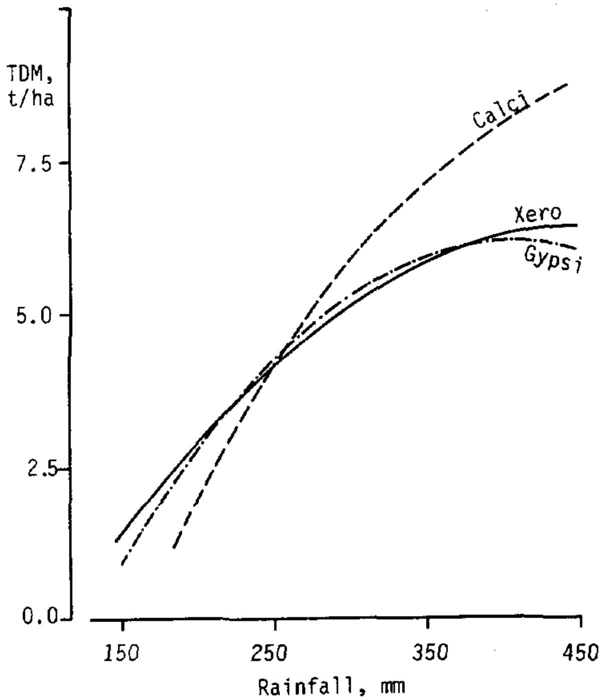


Figure 3.1.5 Effect of soil type on the response of total dry matter yield to rainfall. Equations based on values from all 16 treatments:

Calciorthids: $Y = 74.45Q - 0.07517Q^2 - 10007$ (kg/ha)
Zerochrepts: $Y = 48.21Q - 0.05274Q^2 - 4616$
Gypsiorthids: $Y = 64.53Q - 0.07930Q^2 - 6980$

[Variance accounted for, 62.1%, 43.9%, and 67.0 respectively.]

Effects of soil mineral-N and available-P contents on yields (site means or individual treatments) were much smaller than those of rainfall and were also partly confounded with them, since soil mineral-N values tended to be lower and available-P values slightly higher where mean rainfall was higher (e.g. Zone 2 compared with Zone 3). For these reasons, it is difficult to identify site yield differences (even in the zero-fertilizer control treatment) attributable to initial soil fertility differences. Nevertheless, as we show below, the effect of such differences on crop response to fertilizer can be demonstrated.

One further site difference was that of rotation. As noted above, yields and values of yield/mm of rainfall were generally lower in B-B than F-B rotation; and, as the means show (Table 3.1.3), this cannot easily be attributed to differences in measured site factors. Nor can it be attributed to any substantial difference in response to fertilizer. Regressions of total dry matter on rainfall show similar discrepancies between rotations in both zero-fertilizer and high-fertilizer treatments (Figure 3.1.3). Part of the difference may have been of biological origin (i.e. rotations differing in pest and disease incidence) and part, at least in some cases, due to differences in the amount of stored water in the soil profile at planting time.

Table 3.1.3 Mean site conditions and mean yields (16 treatments) in F-B and B-B rotations

Rotation	Rain, mm	Mineral-N, ppm	Available-P, ppm	Yields, t/ha		
				Grain	Straw	Total
F-B	286.4	18.4	4.3	1.99	2.79	4.78
B-B	277.0	15.4	4.9	1.40	1.95	3.35

3.1.1.3 General pattern of yield response to fertilizer

Mean yields of grain and straw across the 75 trials showed highly significant responses to both N and P fertilizer (Table 3.1.4). Increases over the control treatment were rather greater for straw than for grain (88% compared with 48%, at the highest fertilizer rate, $N_{60}P_{90}$), resulting in a reduction in harvest index with increasing fertilizer rate (from 45.5% in control to 38% in $N_{60}P_{90}$). Fertilizer effects on 1000-grain weight were small, especially in the case of phosphate, but significant. Values tended to decrease with increasing fertilization.

Table 3.1.4 Mean effect of fertilizer treatment over 75 sites on barley grain and straw yields (t/ha) and 1000-grain weight (g)

	N-fertilizer, kg N/ha	P-fertilizer, kg P_2O_5/ha 0	30	60	90	Mean
						***
GRAIN	0	1.48	1.56	1.68	1.71	1.61
	20	1.57	1.82	1.93	1.93	1.81
	40	1.63	1.88	2.02	2.09	1.91
	60	1.64	1.98	2.08	2.19	1.97
			***			
	Mean	1.58	1.81	1.93	1.98	1.82
						***
STRAW	0	1.83	1.99	2.15	2.24	2.05
	20	2.02	2.47	2.66	2.71	2.47
	40	2.22	2.67	2.93	3.14	2.74
	60	2.33	2.86	3.22	3.44	2.96
			***			
	Mean	2.10	2.50	2.74	2.88	2.56
						***
1000-GRAIN WEIGHT	0	33.5	33.3	33.2	33.2	33.3
	20	32.7	32.4	32.3	32.2	32.4
	40	32.0	31.6	31.6	31.7	31.7
	60	31.6	31.1	30.9	31.0	31.2
			***			
	Mean	32.5	32.1	32.0	32.0	32.1

Standard errors (±) of main treatment means: grain, 0.015; straw, 0.042; 1000-grain weight, 0.083. Analyses did not test for significance of N x P interactions.

Analysis of the same data on a trial-by-trial basis shows that barley grain or straw or both responded positively and significantly (at 5% level or better) to N and/or P fertilizer at

74 of the 75 sites. Significant responses were more numerous to P than to N but not by a wide margin: 50 to 53 for straw and 45 to 36 for grain. Again, we see the somewhat greater responsiveness of the straw. Examination of the frequency of significant responses to fertilizer in relation to site factors (Table 3.1.5) shows that:

a) the importance of N increased and that of P decreased with increasing rainfall (and, less clearly, in passing from Zone 2 to Zone 3).

b) N was more important in barley-barley (B-B) than in fallow-barley (F-B) rotation, though not by a wide margin.

c) P was most important, and N least important, in gypsiorthid soils.

d) initial soil contents of available phosphate (Olsen) at 0-20 cm depth and mineral-N at 0-40 cm depth influenced fertilizer response.

Significant interactions between N and P fertilizers were relatively few -- 14 sites for grain, 18 for straw -- but this under-values the extent to which one nutrient had a synergistic effect on the other. There were very few sites at which response to P was not enhanced by the presence of at least a low rate of N. [See also the positive NP terms in the equations given in Table 3.1.6.]

These analyses show that, in a general way, barley responds well to fertility but that the size and statistical significance of that response may depend on environmental conditions-- rainfall, soil type and preceding crop. However, for better understanding and for practical application, further analysis is

Table 3.1.5 Summary of the percentage distributions of significant responses to N and P fertilizer as affected by main site factors

Factor		Number of sites	Grain N	Grain P	Straw N	Straw P
Rainfall	< 225 mm	24	21	88	50	96
	225-300 mm	29	52	52	76	79
	> 300 mm	22	73	41	86	59
Zone	2	31	61	45	74	74
	3	44	39	70	68	82
Rotation	F-B	54	44	65	65	81
	B-B	21	57	48	86	71
Soil Group	Gypsiorthid	14	21	86	36	100
	Xerochrept	36	64	53	89	72
	Calciorthid	18	39	61	72	89
Available P	< 5.0 ppm	50	46	68	64	88
	5.1-8.0 ppm	19	37	53	79	68
	> 8.0 ppm	6	100	17	100	33
Mineral-N	< 8.0 ppm	22	68	55	91	68
	8.1-16.0 ppm	36	50	64	72	86
	> 16.0 ppm	17	18	59	41	76

Rainfall values are totals from mid-October to end of April.

required to express these relationships quantitatively as equations or models. There is no single correct way to do this. We have chosen a direct regression approach. We have looked for simple models that express yield in terms of the rate of applied fertilizer and rainfall, for alternative sets of environmental conditions, and in doing this, we have recognized two different aims:

i) Descriptive -- to improve our understanding of the separate and interacting effects of fertilizer and various environmental factors on crop performance.

ii) Predictive — to indicate how barley will respond to fertilizer on future occasions.

The first facilitates scientific interpretation of the results. The second is essential to the practical target of developing fertilizer recommendations. The two methodologies differ, because not all the information available for retrospective description is available for prediction. This is obviously true for rainfall but may also apply in many cases to soil parameters.

3.1.1.4 Descriptive models

The descriptive model used has the general form:

$$Y = aN + bP + cNP + dN^2 + eP^2 + fQ + gQ^2 + hQN + iQP + const \quad \text{..... Eqn III}$$

where N and P represent rates (kg/ha) of fertilizer N and P_2O_5 applied, Q is total seasonal rainfall, and a, b, ... i are derived coefficients different for each version of the equation. This allows for the large linear and quadratic effect of rainfall on general yield level; yield response, linear and quadratic, to fertilizer; and the first order interactions of rainfall on fertilizer response. Further complexity has been found to give only marginal increases in the variance accounted for.

Coefficients for the above equation for various set or subsets of the data are given in Table 3.1.6. In all cases, caution is needed in interpreting the meaning of individual terms. For instance, a negative value of the coefficient for the linear N term does not mean that yields are generally depressed by applied nitrogen. Rather, the response to N is strongly rainfall-dependent, and this is covered by the positive QN interaction

Table 3.1.6 Coefficients for terms in equation III for ten different data sets

Data set		Number of sites	N	P	NP	N^2	P^2	Q	QQ	QN	QP	Const.	Adj. R^2 %
a. All grain		75	-1.320	7.035	0.0528	-0.0854	-0.0497	24.351	-0.0294	0.0353	0.00094	-2891.8	59.0
b. F-B grain		54	-2.037	7.556	0.0632	-0.0752	-0.0532	22.459	-0.0263	0.0299	0.00130	-2394.2	60.5
c. B-B grain		21	0.289	6.047	0.0263	-0.1117	-0.0408	24.945	-0.0310	0.0506	-0.00013	-3238.1	65.6
d. F-B straw		54	-4.892	7.960	0.1510	-0.1211	-0.0762	30.058	-0.0344	0.0654	0.01432	-3416.5	58.3
e. Xerochrept	tdm	36	9.463	11.333	0.1862	-0.2509	-0.1084	45.021	-0.0527	0.0860	0.01360	-4968.4	58.4
f. Calciorthid	tdm	18	-7.101	26.669	0.1422	-0.2812	-0.1261	72.644	-0.0752	0.1192	-0.01710	-10457.3	70.9
g. Gypsiorthid	tdm	14	-28.499	12.448	0.2301	-0.0594	-0.1389	59.049	-0.0793	0.1272	0.03700	-6474.7	77.4
h. "napa"	tdm	23	4.093	12.791	0.2533	-0.2705	-0.1242	51.513	-0.0620	0.0850	0.01777	-6184.0	61.9
i. "NApa"	tdm	22.5	-19.302	23.265	0.1969	-0.1371	-0.1019	77.527	-0.0976	0.1191	-0.01421	-9580.4	69.7
j. "NAPA"	tdm	19.5	-22.064	15.617	0.1461	-0.1489	-0.1446	49.687	-0.0549	0.1471	0.01792	-5401.5	63.8

For equations h, i and j, upper and lower case print for NA and PA (available N and P in soil) indicate high and low values, viz. NA>10 ppm>na and PA>4.5 ppm>pa. Non-integral site numbers arise from one site having replicates with available-P value above and below 4.5 ppm.

term. Such effects are most easily represented graphically: for example, the grain and straw yields in F-B rotation (Figure 3.1.6). At the highest fertilizer rate, the calculated grain yield improvement over control rises from 483 kg/ha at 150 mm to 961 kg/ha at 400 mm (an increase of 478 kg/ha or 99%), while corresponding figures for straw are 967 and 2270 kg/ha (an increase of 1303 kg/ha or 135%).

There are other ways of representing the relationships described by such equations. For instance, isoquants for grain yield increases over zero-fertilizer control have been derived from the equations for F-B and B-B rotations at three rainfall values, the seasonal mean of the 75 trials and one standard deviation above and below that mean (Figure 3.1.7). For F-B rotation, except at the lowest rainfall, isoquants are approximately equidistant from both N and P axes; but for B-B rotation, with increasing rainfall they become increasingly orientated parallel to the P-axis. This demonstrates the increasingly greater importance of N fertilizer for continuously cropped barley under increasing rainfall.

Alternatively, we may look at the effect of soil nutrient content at planting time on barley response to applied fertilizer. This is illustrated for total dry matter production at three standard rainfall values in Figure 3.1.8 in respect of three different states of soil nutrient availability: "napa" (low available N and P), "NApa" (high available N, low available P) and "NAPA" (high available N and P). The state "naPA" is omitted, because it includes too few sites. In fact, the dividing value between high and low available P, 4.5 ppm, is already rather low. Other work suggests that the "critical" Olsen-P value above which fertilizer responses rapidly decline is around 6-7 ppm. This would have made a more appropriate dividing line, but one which put most soils in the low available-P category.

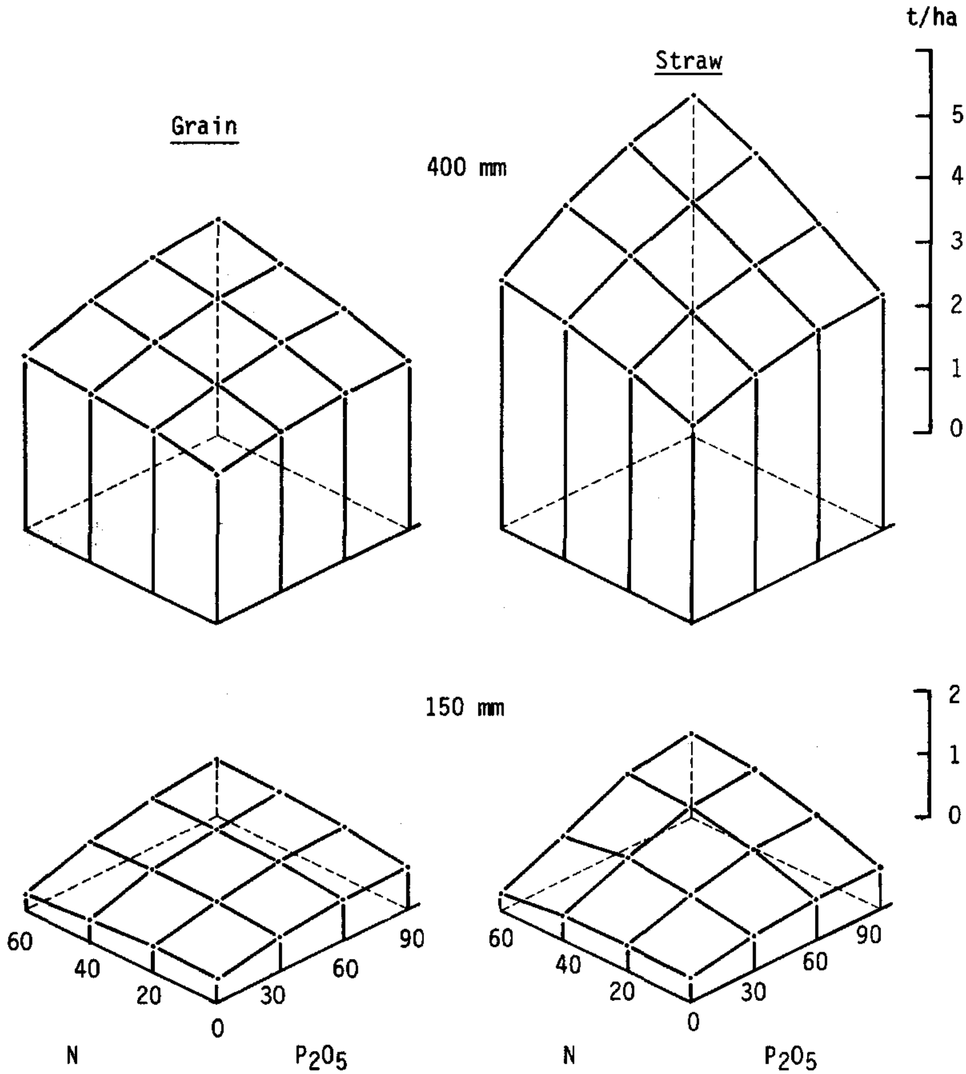


Figure 3.1.6 Effect of rainfall on the differential responsiveness of grain and straw to N and P fertilizers in F-B rotation (drawn from equations b and d in Table 3.1.6).

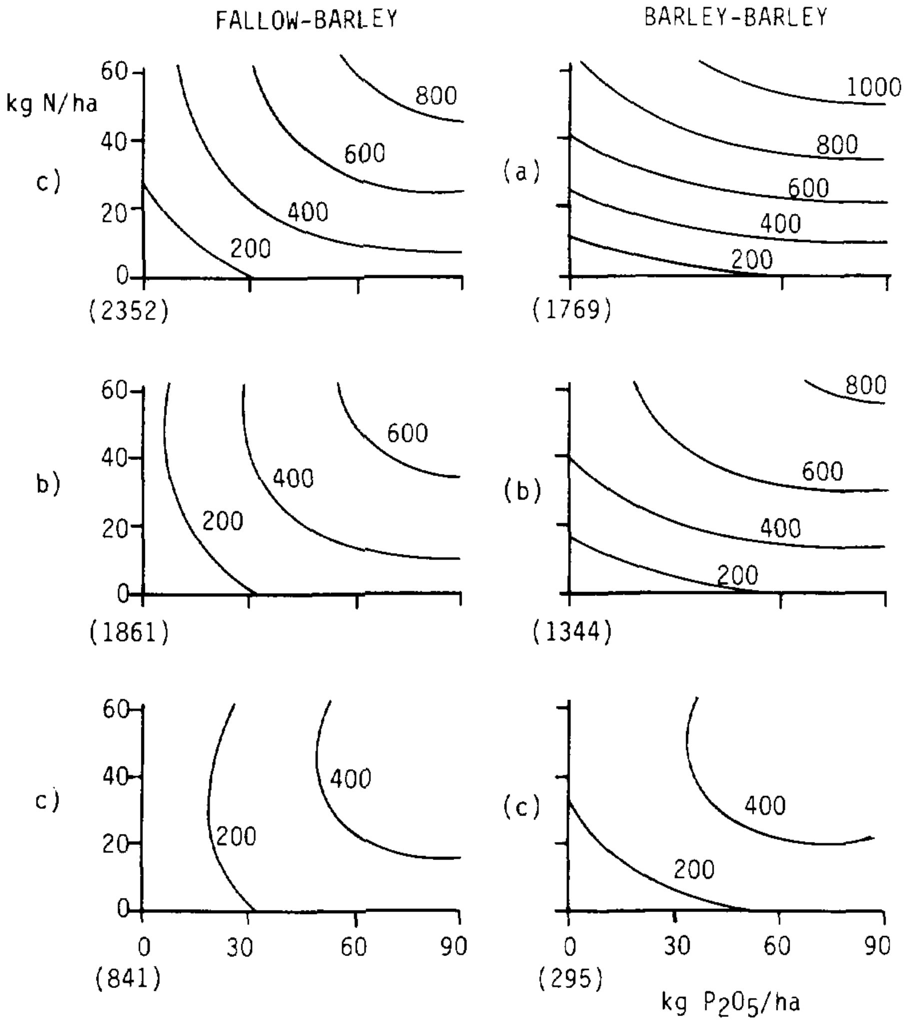


Figure 3.1.7 Isoquants for grain yield increase (kg/ha) over zero-fertilizer control in F-B and B-B rotations at three different seasonal rainfall values: (a) 183.5 mm; (b) 283.7 mm; (c) 383.9 mm (i.e. 75-site mean ± 1 standard deviation). Numbers in brackets indicate zero-fertilizer control yields (kg/ha) in that rotation for that rainfall value. (Plotted lines calculated from equations b and c in Table 3.1.6).

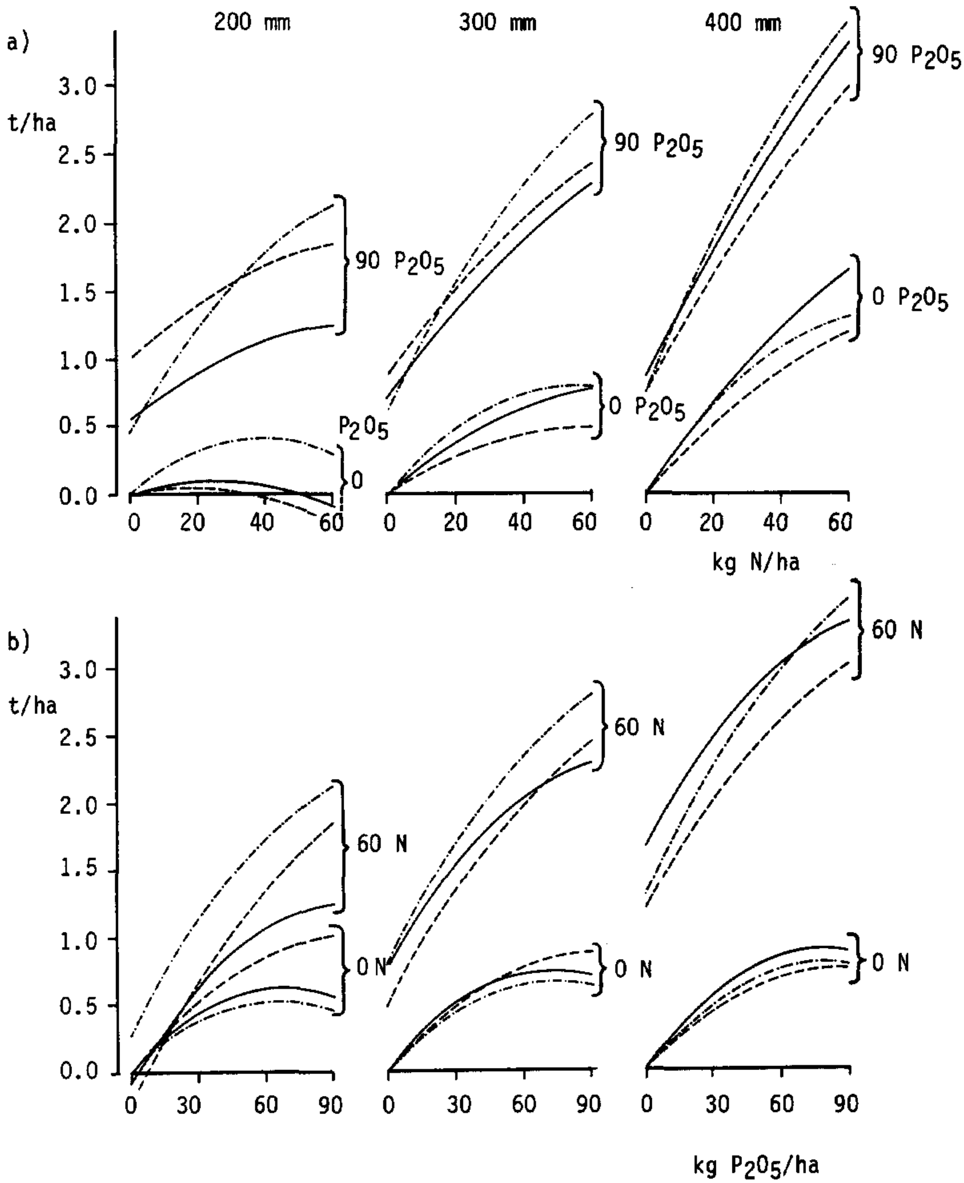


Figure 3.1.8 Effect of initial soil nutrient content on total dry matter response to applied fertilizer at three rainfall levels: increases (t/ha) over zero-fertilizer control (a) from N-fertilizer at two rates of P-fertilization and (b) from P-fertilizer at two rates of N-fertilization, for napa (-.— .— .—), NApa (- - - -) and NAPA (———). (Drawn from equations h,i and j in Table 3.1.6).

Nevertheless, the three equations show some interesting differences. With the single exception of response to P on NApa soils in the absence of added N, all fertilizer responses increase with increasing rainfall. But they also converge. That is, the higher the rainfall, the less critical the effect of initial soil fertility on yield response to fertilizer. At 200 mm, yield increases from the highest fertilizer rate on napa, NApa and NAPA soils are, respectively, 2.12, 1.85 and 1.25 t/ha; but at 400 mm, 3.47, 3.03 and 3.34 t/ha.

Where differences occur, that is at low rainfall (exemplified by the values calculated for 200 mm), they conform largely to expectation. Thus, response to fertilizer N is greatest in napa soils; in fact, in NApa and NAPA soils it is negative in the absence of added phosphate. Response to fertilizer P is also greatest in napa soils but only in the presence of added N. When no N is added, greatest response is in NApa soils.

Many other equations, and ways of representing them, can be derived to represent the information in the 75-site data set. However, there are limitations. For example, we may compare yield response to rainfall and fertilizer on three different soil types or in two different rotations but not in each of the six different combinations of soil type and rotation separately. Site numbers are too few to give six reliable equations. Nevertheless, in general, the regression approach adds greatly to our understanding of the pattern of yield response to fertilizer provided by standard analysis of variance (Tables 3.1.4 and 3.1.5). Among the points that stand out are:

a) The divergence between rotations in crop response to applied N. That response intensifies with increasing rainfall more strongly in B-B than in F-B rotation, to an extent that appears disproportionate to any initial difference in soil mineral-N content.

b) The convergence, with increasing rainfall, between soils of different initial nutrient content in crop response to applied N and P.

Such effects should be seen in the context of the very large, curvilinear response to rainfall that occurs irrespective of soil type, nutrient status or rotation. Between 150 and 450 mm, with or without applied fertilizer, the biomass increases three- or even four-fold with, presumably, approximately proportionate increases in the demand for nutrients. There is thus a remarkable dependence on rainfall in the apparent efficiency with which nutrients are utilized.

For instance, under 200 mm rainfall, a soil with 3-4 ppm available P and 10-15 ppm mineral-N might yield 1t barley grain/ha without fertilizer and perhaps 1.5 t/ha with fertilizer ($N_{60}P_{90}$); but under 400 mm, the same soil, might produce as much as 2.0 t/ha without fertilizer and 3.5 t/ha with fertilizer. In particular, yield response per unit of fertilizer nutrient--"fertilizer efficiency" -- varies widely (Figure 3.1.9). As well as declining with increasing rate of application and taking a higher value where both nutrients are applied together, this efficiency differs

a) between rotations, for both N and P (e.g. in the presence of 60 kg N/ha, 50 kg P_2O_5 increases grain yield by 6.3 kg/kg P_2O_5 in F-B rotation but by only 3.5 kg/kg P_2O_5 in B-B rotation);
b) according to rainfall amount, for N (e.g. in the presence of 90 kg P_2O_5/ha, 35 kg/ha increases grain yield by 5 kg/kg N at 200 mm but by 15.1 kg/kg N at 400 mm).

3.1.1.5 <u>Predictive models</u>

The above points underline the difficulty of making reliable and economic fertilizer-rate recommendations in a highly variable rainfall environment. In the search for a useful model to achieve the predictive aim, but accommodating rainfall unpredictability, two approaches have been compared:

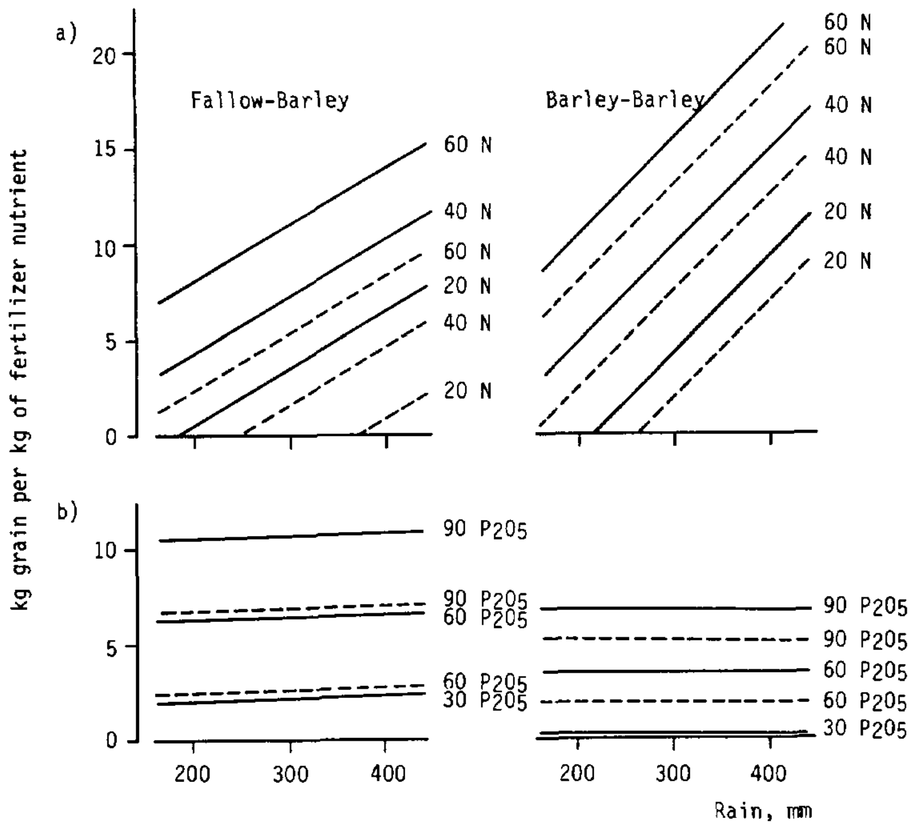


Figure 3.1.9 Effect of rainfall and rotation on grain-yield production per unit of fertilizer nutrient: (a) response to N at three rates of application in the presence of 90 kg P_2O_5 (——) and in the absence of applied P (-----); (b) response to P at three rates of application in the presence of 60 kg N/ha (——) and in the absence of applied N (-----). (Based on equations b and c in Table 3.1.6).

I. The calculation of simple equations representing yield increase over zero-fertilizer control, quadratic with respect to N and P fertilizer rates but omitting rainfall terms.

II. The application of historical rainfall data to some of the descriptive models already described to look at the long-term probabilities of response to different fertilizer rates.

We also recognize two different recommendation objectives:

a) general recommendations, for broadly-defined environments, which any farmer growing barley in that environment could expect to use with the minimum of risk;
b) recommendations that take account of known values of available N and P in the soil.

For the general recommendations under approach I above we have used equations representing the increase in grain yield due to fertilizer use, over zero-fertilizer control, of the form:

$$\triangle Y = aN + bP + cNP + dn^2 + eP^2 \qquad \text{..... Eqn IV}$$

where N and P represent the rates of fertilizer N and P_2O_5 applied (kg/ha) and a, b, c, d and e are derived coefficients.

Such equations have been derived from subsets of the data specified, for ease of subsequent prediction, in terms of easily identified site parameters: geographical location (province, region); crop rotation (barley after fallow, F-B, or barley after barley, B-B); and agricultural stability zone. Comparisons between actual mean yield increases and those generated by these equations make it quite clear that "subset" equations give a much better fit than does the "general" equation based on the full data set (Table 3.1.7). Although this is not true validation, since the equations are being tested only against the data from which they were derived, there is a strong implication here that appropriate subgrouping would give better prediction.

Table 3.1.7 Comparisons between actual increases in mean grain yield for three fertilizer treatments and estimates calculated from fitted equations (given below)

	Fertilizer treatment, N : P_2O_5					
	0 : 90		60 : 0		60 : 90	
Sites	Actual	Calc'd	Actual	Calc'd	Actual	Calc'd
All	234	217	160	177	717	728
Zone 2, F-B	153	163	218	197	720	733
Zone 2, B-B	463	391	712	744	1113	1085
Zone 3, F-B	338	297	-83	-35	684	689
Zone 3, B-B	16	36	254	245	539	581

(Based on the following equations:

Sites		Coefficients for Equation IV					Adj R^2, %
		a	b	c	d	e	
All	75	7.520	6.517 ****	0.0617 ****	-0.0762 ****	-0.0456 **	41.03 ****
Zone 2, F-B	25	6.733	5.797 ****	0.0691 ****	-0.0576 **	-0.0442 *	38.18 *
Zone 2, B-B	8	24.759	7.882 ****	-0.0148 **	-0.1976	-0.0393 **	70.43
Zone 3, F-B	29	3.517	7.892 +	0.0792 ****	-0.0683 ***	-0.0511 +	40.19 **
Zone 3, B-B	13	7.352	3.994 **	0.0556 *	-0.0546 *	-0.0399	38.01 +

Significance levels of coefficients:
**** 0.01%; *** 0.1%; ** 1%; * 5%; + 10%

Zone 3 group includes a few Zone 4 sites.)

From a practical standpoint, the question is, which system of subdividing the data gives the best predictive equations. There are considerations of both reliability and field applicability involved here. One weakness of the division into two zones and two rotations shown above is that the "Zone 2, B-B" subgroup comprises only 8 trials, hardly an adequate sample. One alternative division, of similar field practicality and having more equal partitioning of trials between subgroups, is that into two zones and two geographic regions, West (Aleppo and Hama Provinces) and North-East (Raqqa and Hassakeh Provinces). Equations for these subgroups also generate treatment values that fit well to the actual experimental means (Figure 3.1.10).

For situations where soil available N and P values are known, equations have been developed for four states of preplanting soil fertility: "napa" (low available N and P); "NApa" (high N, low P); "naPA" (low N, high P); and "NAPA" (high available N and P). As observed previously, the (Olsen) available-P value, 4.5 ppm, used to separate "pa" from "PA", is itself rather low (because the distribution of experimental soils was rather overweighted towards low available-P contents). Here, an "naPA" equation is included-- for completeness -- but, based on only 10 trials, it may be less reliable for predictive purposes than the other three.

Isoquants derived from these equations demonstrate that initial soil fertility status produces substantial differences in the fertilizer needed for a specific mean yield increase (Figure 3.1.11). For instance, on a per hectare basis, an extra 400 kg grain requires just 20 kg N in "naPA" soils; 20 kg N and 40 kg P_2O_5 in "napa" soils; 20 kg N and 60 kg P_2O_5 in "NApa" soils; and 40 kg N and 60 kg P_2O_5 in "NAPA" soils. If the soil is already relatively rich in available nutrients, a greater input of fertilizer is required to give the same yield increment. For "NAPA" soils, there is a fairly low limit on the yield increase

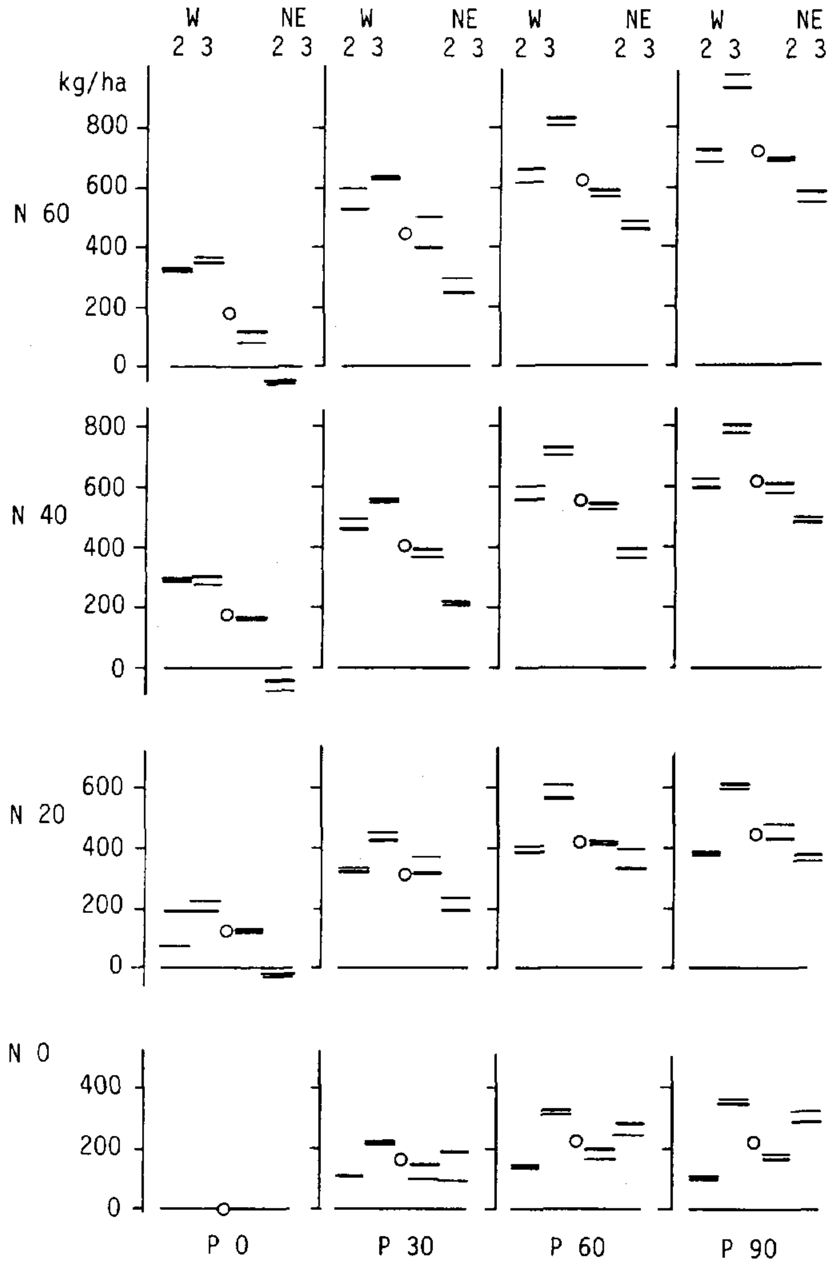


Figure 3.1.10 Values of grain yield increase over control under fifteen fertilizer regimes: comparisons of actual means (———) and values calculated from subgroup equations (———) for four geographical situations with values calculated from the general 75-trial equation (o).

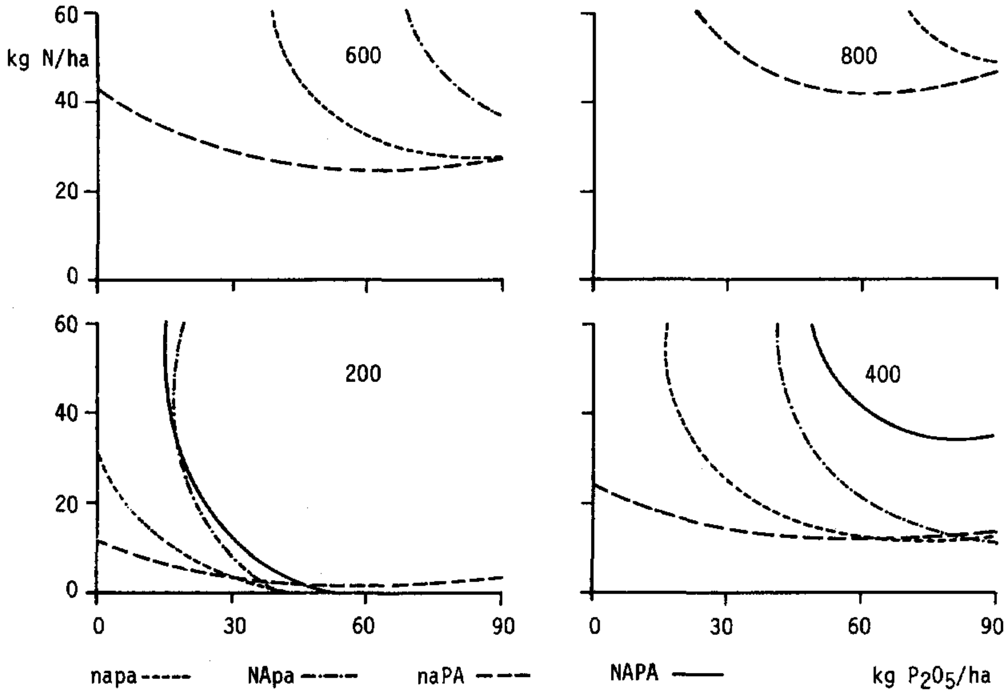


Figure 3.1.11 Isoquants indicating the amounts of fertilizer required to give mean grain-yield increases over control of 200, 400, 600 and 800 kg/ha under four different initial conditions of soil fertility

that can be achieved; no fertilizer rate within the ranges tested, will give a mean grain-yield increase of 600 kg/ha.

All the above predictive equations contain no rainfall term but, instead, "assume" a rainfall that is, in fact, the mean of the rainfall totals recorded in the trials contributing to the data set upon which the equation is based. The equation for, say, F-B rotation in Zone 2 assumes an October-April rainfall total of 315 mm, and that for F-B rotation in Zone 3 262 mm, these being the mean values, respectively, for the 25 and 29 trials in those subgroups. Given that these means are reasonably representative of the zones concerned and that "next season's rainfall" is always

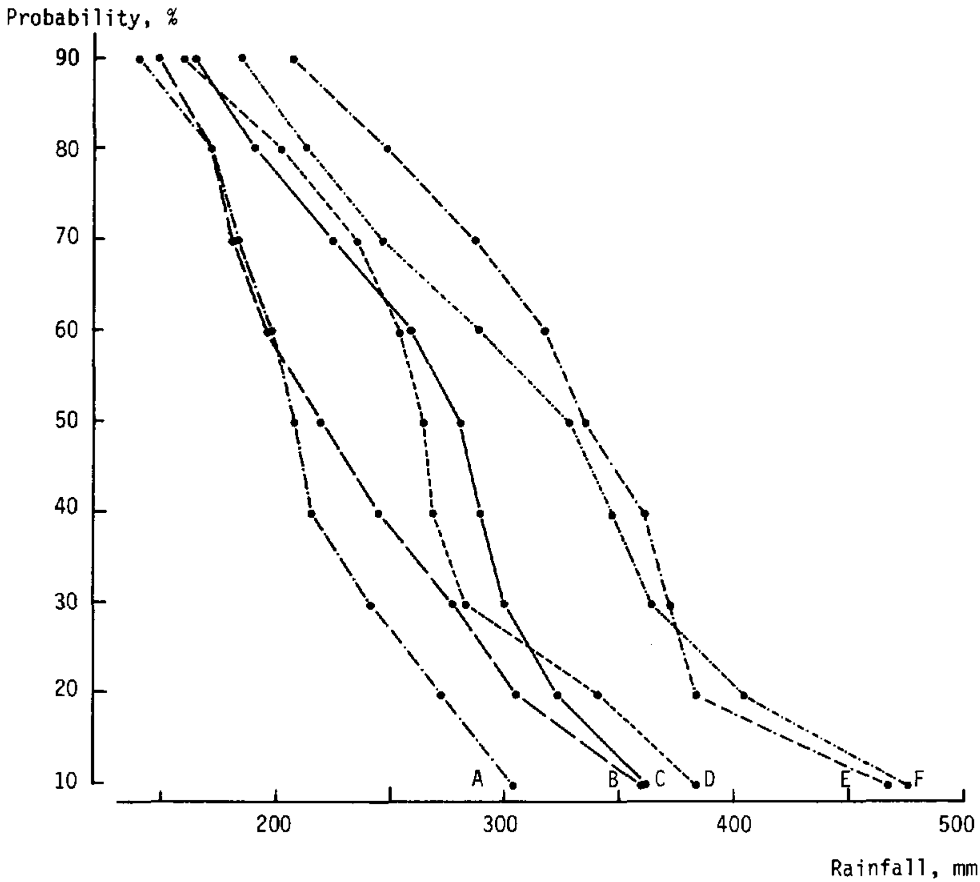


Figure 3.1.12 Probabilities of October-April rainfall totals at six sites in north-west Syria (based on 23-28 years of records since 1960). Sites: A: El Khafseh; B: Abudhu; C: Munbuj; D: Breda; E: Saraqeb; F: Qadi

unpredictable, such an assumption may seem unavoidable. However, where long-term rainfall records are available, it is possible to improve on this. Accepting that previous rainfall records may be taken as a reliable guide to future rainfall probabilities, descriptive equations that express yield in terms of both fertilizer rate and rainfall can be used to make statements about future yield responses to fertilizer in probabilistic terms.

For example, Figure 3.1.12 shows October-April rainfall totals at probabilities of 10 to 90% for a range of meteorological stations in north-western Syria (based on 25 ± 3 years data from the period, 1960-1989). From these, it is possible (using the appropriate equation in Table 3.1.6) to calculate yield increases at the same probability levels for any chosen fertilizer treatment. An example compares four fertilizer treatments applied to barley in F-B rotation at a moderately wet station, Munbuj, and a relatively dry station, El Khafseh (October-April mean totals, 264 ± 79 mm and 215 ± 61 mm, respectively) (Figure 3.1.13).

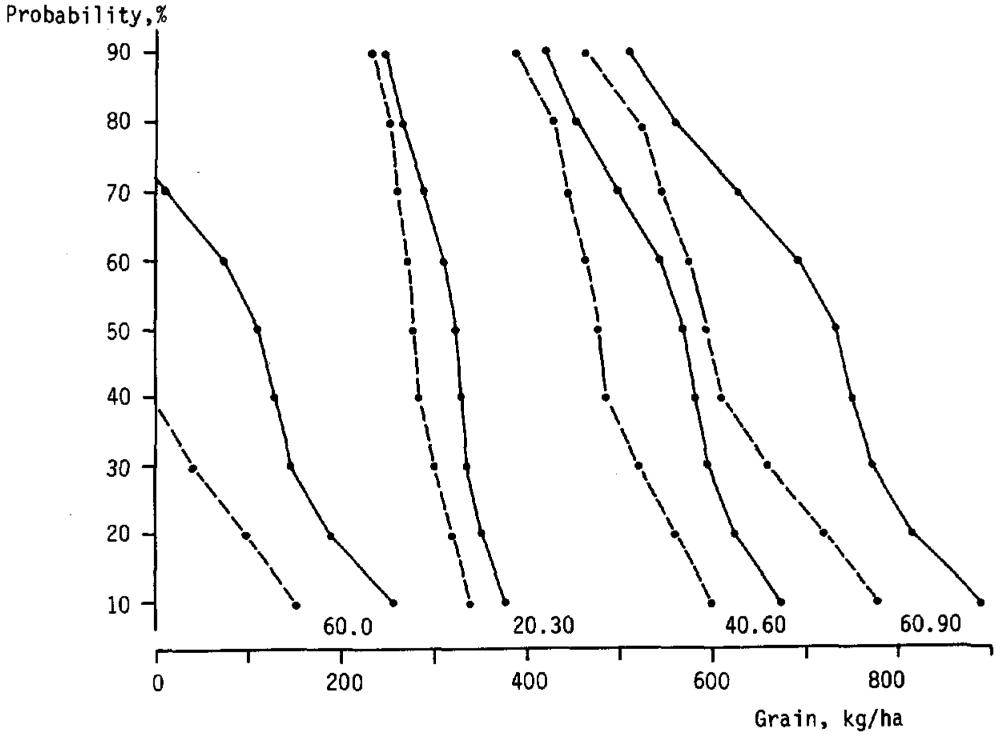


Figure 3.1.13 Probability of grain yield increases over control from four fertilizer treatments applied to barley in F-B rotation, at Munbuj (——) and at El Khafseh (—.—.—)

Given a sufficient density of stations with long-term rainfall records, one may take this process one step further and translate maps of rainfall probability into maps of fertilizer response probability. Figure 3.1.14 illustrates the potential but also two

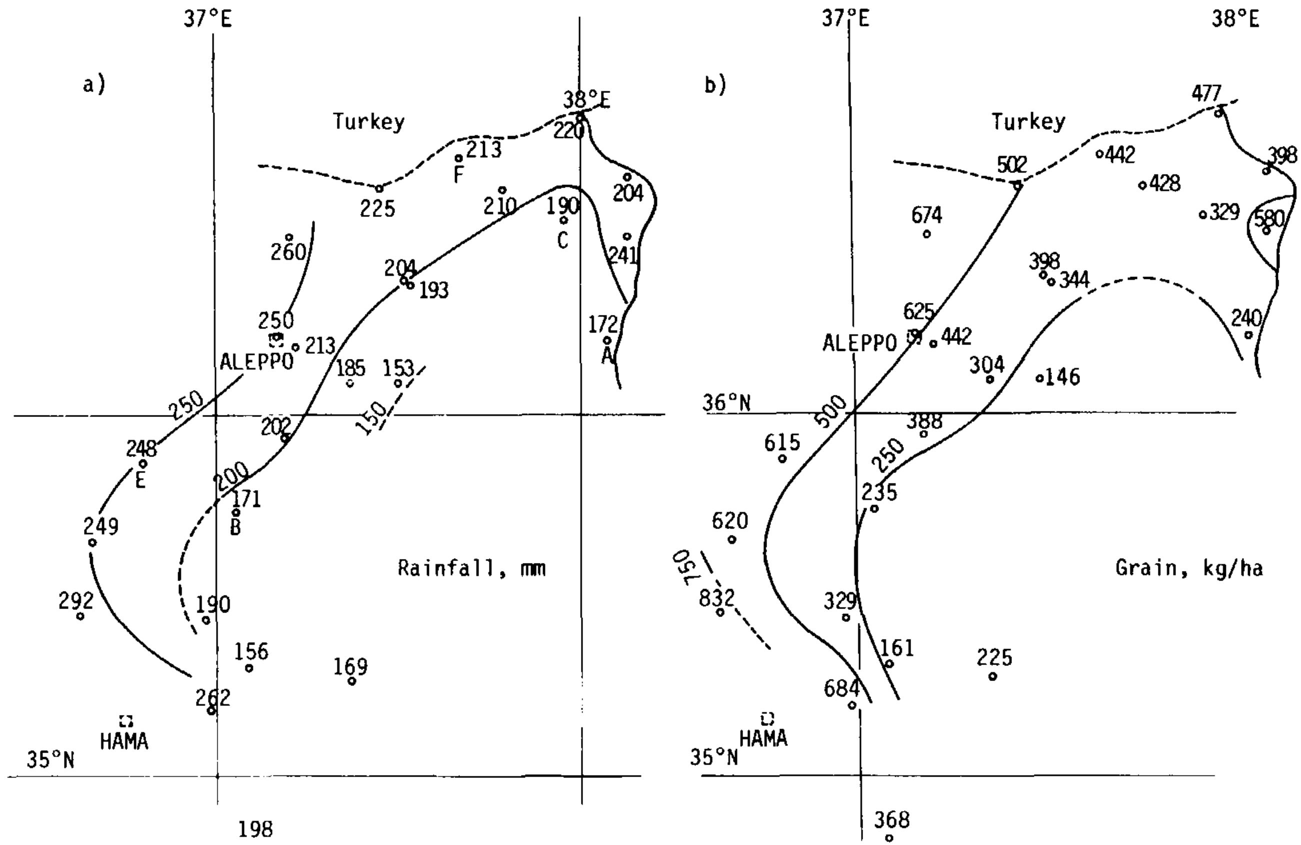


Figure 3.1.14 North-west Syria: (a) October-April rainfall totals at 80% probability; (b) calculated barley grain-yield increases in B-B rotation from 60N:30P205 at 80% probability. (In each case, point values at 25 meteorological stations and interpolated isovalues.)

of the current limitations of this method. First, the density of stations decreases rapidly towards the drier areas; and, unfortunately, it is these areas where the question of the reliability of barley response to fertilizer becomes most critical. Secondly, there is the problem of inconsistencies between neighbouring stations, arising mainly from small differences in the time spans of the available data. In a record of only 25 years, the presence or absence of one or two years' data can make a substantial difference to the probabilities indicated for a particular rainfall condition. However, the development of reliable statistical techniques, currently in progress, for the generation from existing records of long-term rainfall data sets on a regular map-grid basis would appear to promise much scope for refinement of this method.

3.1.2 Economic Analysis of Researcher Managed Trials

A. Mazid

Four years' results from the collaborative SMAAR/ICARDA on-farm barley fertilizer trials are now available and allow a detailed economic analysis of fertilizer use on barley in zones 2 and 3 of N. Syria to be conducted.

3.1.2.1 Partial Budgets

In a partial budget analysis of the four-year data set (Table 3.1.8), values of net revenue and marginal net benefit/cost ratios were compared, for each fertilizer treatment, between three groups of trials using 1988/89 prices of grain, straw and fertilizer:

F-B rotation in Zone 2
F-B rotation in Zone 3
B-B rotation in Zones 2 and 3 together

Table 3.1.8 Calculated mean values of net revenue and marginal net benefit:cost ratio for F-B rotation, zones 2 and 3 separately, and B-B rotation

		Net revenue SYL/ha				Net benefit:cost ratio			
kg P_2O_5/ha:		0	30	60	90	0	30	60	9 0
	kg N/ha								
F-B Zone 2	0	0	-66	545	71	0	<0	1.04	0.10
(25 sites)	20	-123	1076	1418	1168	<0	1.91	1.75	1.71
	40	455	1468	1992	2138	1.11	1.92	1.93	1.69
	60	653	1537	2180	2547	1.10	1.64	1.79	1.74
F-B Zone 3	0	0	335	609	893	-	1.17	1.15	1.16
(29 sites)	20	69	1269	1363	1448	0.33	2.18	1.69	1.41
	40	-54	897	1542	1898	<0	1.26	1.56	1.53
	60	-532	1205	1767	2315	<0	1.33	1.51	1.60
B-B (All)	0	0	216	133	214	-	0.78	0.28	0.30
(21 sites)	20	977	1171	1648	1335	3.27	1.05	1.98	1.31
	40	1278	1913	2046	2091	2.59	2.36	1.97	1.66
	60	1562	2572	2597	2576	2.28	2.48	2.07	1.75

Net revenue values indicate that fertilizer use on barley is profitable in all treatments except (i) the low rate of phosphate without nitrogen ($P_{30}N_0$) and the low rate of nitrogen without phosphate (P_0N_{20}) in F-B rotation in Zone 2; and (ii) all rates of nitrogen without phosphate (except P_0N_{20}) in F-B rotation in Zone 3.

3.1.2.2 Technical and Economic Optima

Technical and economic input optima were calculated for thirteen different defined environments, by taking partial derivatives of the relevant estimated response function for grain yield (see section 3.1.1).

$$Y = aN + bP + cNP + dN^2 + eP^2 + const$$

Technical optima (i.e. yield maxima) were found by equating the partial derivatives to zero and solving the two resulting simultaneous equations for N and P:

$$\frac{dY}{dN} = a + cP + 2dN = 0 \qquad \frac{dY}{dP} = b + cN = 2cP = 0 \qquad (1)$$

For the economic optima, the partial derivatives were equated to the relative prices of fertilizer and gain and, again, the two resulting equations solved for N and P :

$$\frac{dY}{dN} = \frac{\text{Price, N-fert}}{\text{Price, grain}} \quad ; \quad \frac{dY}{dP} = \frac{\text{Price, P-fert}}{\text{Price, grain}} \qquad (2)$$

The prices of barley grain and fertilizer used were the Government prices for the 1988/89 season. In the case of N fertilizers, two different compounds, ammonium nitrate (33.5% N) and urea (46% N), have been compared. Throughout, the assumption is made that the farmers' objectives are: (a) to maximize grain yield, (b) to protect themselves against the risk of loss of revenue; for these reasons, the calculations take no account of straw value and set a threshold for adoption equal to a marginal rate of return of 40 percent.

The calculated values of the fertilizer rates that maximize yields (technical optima) are high (Table 3.1.9). In almost all circumstances they lie above the highest rates tested experimentally, and for this reason they must be regarded as only approximate and unreliable indicators. Moreover, the calculation for model 7 appears anomalous and probably should be disregarded.* However, the technical optimum is never a practical target, and it is the economic optimum that is of importance here.

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* It should be noted that those technical optima are specific to the response model formulated, in this case a quadratic. Alternative formulations of the response function would produce different technical optima.

Table 3.1.9 Model specification and calculated mean technical optima (fertilizer rates maximizing yields)

Model specification	At yield optimum (max yield) Fertilizer, kg/ha N	P_2O_5	Grain yield kg/ha	Net revenue increase over zero fert. in grain equiv. kg/ha
1. F-B, Zone 2	100	119	2837	892
2. F-B, Zone 3	101	147	2185	837
3. B-B, Zones 2 and 3	75	94	1767	806
4. F-B, Zone 2, West	72	94	2655	809
5. F-B, Zone 3, West	77	120	2044	760
6. F-B, Zone 2, North-East	100	130	2719	1054
7. F-B, Zone 3, North-East	0	0	1019	0
8. F-B, Zone 2	63	102	2255	1058
9. B-B, Zone 3	99	103	1532	709
10. Low NA, Low PA	92	131	2144	869
11, Low NA, High PA	64	63	2023	843
12. High NA, Low PA	114	186	2572	960
13. High NA, High PA	76	94	2091	486

NA and PA refer to available nitrogen and phosphate in soil at planting time overall rotations, all zones, nutrient levels dividing "high" and "low": NA 10 ppm, PA 4.5 ppm.

Tables 3.1.10 and 3.1.11 present the economic optimum N and P_2O_5 rates, derived for each model using the relative prices, per unit weight, of fertilizer nutrients and barley grain. The following values were also calculated:

a. the predicted mean grain yield at the optimum N and P_2O_5 rates;

b. the resulting increase in net revenue (expressed in kg grain/ha) over that from zero-fertilizer control;

c. the marginal benefit:cost ratio, as a percentage. This is equivalent to the rate of return from applying fertilizer at the optimal rate compared with no fertilizer use.

Table 3.1.10 Calculated mean economic optima, assuming a marginal rate of return of 40 per cent and the use of ammonium nitrate as nitrogen source

Model	At yield optimum fert, kg/ha N	At yield optimum fert, kg/ha P	Grain yield kg/ha	Increase in net revenue as grain equivalents kg/ha	Marginal benefit:cost ratio %
1	66	78	2733	502	175
2	53	90	2039	410	146
3	57	56	1691	503	221
4	55	60	2585	510	223
5	50	76	1947	414	166
6	71	90	2623	640	202
7	0	0	1019	-	-
8	55	62	2191	762	329
9	63	57	1409	356	149
10	60	84	2035	476	168
11	54	37	1974	610	332
12	57	110	2387	450	139
13	29	54	1968	201	125

Calculations are based on relative prices of fertilizer N and P_2O_5 to barley grain of 2.13 and 1.86, respectively.

Table 3.1.11 Calculated mean economic optima, assuming a marginal rate of return of 40 per cent and the use of urea as nitrogen source

Model	At yield optimum fert, kg/ha N	At yield optimum fert, kg/ha P	Grain yield kg/ha	Increase in net revenue as grain equivalents kg/ha	Marginal benefit:cost ratio %
1	71	80	2751	534	197
2	59	94	2064	439	158
3	60	57	1700	529	251
4	57	61	2594	535	251
5	53	78	1961	438	184
6	75	92	2638	673	224
7	0	0	1019	-	-
8	56	62	2195	785	368
9	67	59	1428	387	170
10	63	87	2052	505	186
11	56	37	1979	633	382
12	63	115	2417	482	149
13	36	56	1992	221	133

Calculations are based on relative prices of fertilizer N and P_2O_5 to barley grain of 1.74 and 1.86, respectively.

Little difference between the economic optima is indicated for the two forms of fertilizer nitrogen, ammonium nitrate and urea. Because it is slightly cheaper per unit of N, urea shows slightly higher benefit:cost ratios for all models.

Calculations of marginal benefit:cost ratio were extended for each of the 13 models to cover a range of relative fertilizer prices. Price variability and sensitivity analyses showed that fertilizer use would still be beneficial and the benefit:cost ratio would still exceed 40%, for N and/or P prices up to 5 times higher than that of grain.

3.1.2.3 Yield Variability

A further point, with a particular bearing on the economic risks associated with fertilizer use, is that fertilization appears to reduce yield variability. Coefficients of variation of grain yield decreased with increasing fertilizer rate (especially phosphate) in each of the three main sub-groups of trials tested: F-B Zone 2, F-B Zone 3 and B-B (Table 3.1.12). Further and more detailed analysis of fertilizer use, yield variability and risk in currently underway.

3.1.3 A Comparison of Farmer Managed and Researcher Managed Barley/Fertilizer Trials (1987/88, 1988/89)

A. Wahbi and M.J. Jones

To relate the 4 year results of researcher managed trials (see section 3.1.1) to farmers' conditions, it was necessary to compare the barley responses to fertilizer obtained in our researcher managed trials with those obtained under the farmers' own managed practices. In 1987/88 and 1988/89, we coupled a farmer managed trial (FMT) to each of our researcher managed trials (RMT). In these farmer managed trials, the farmer himself applied several fertilizer combinations (N_{40}, P_{90} and $N_{40}P_{90}$ kg/ha in 1987/88 and in 1988/89 an additional treatment of $N_{20}P_{45}$ kg/ha) and grew the barley crop according to his usual practices without researcher influence.

Table 3.1.12 Effect of fertilizer rate on mean grain yield and coefficient of variation in F-B rotation, Zones 2 and 3 separately, and B-B rotation

	Fertilizer, kg/ha		F-B, Zone 2			F-B, Zone 3			B-B, all		
No.	N	P_2O_5	Grwt	SD	CV%	Grwt	SD	CV%	Grwt	SD	CV%
1	0	0	2018	826	41	1372	726	53	971	552	57
2	0	30	2037	809	40	1493	673	45	1088	619	57
3	0	60	2231	875	39	1617	707	44	1108	639	58
4	0	90	2171	857	39	1710	787	46	1157	646	56
5	20	0	2015	815	40	1411	793	56	1248	702	56
6	20	30	2332	903	39	1747	901	52	1315	695	53
7	20	60	2436	871	36	1799	775	43	1497	826	55
8	20	90	2411	773	32	1873	878	47	1439	774	54
9	40	0	2148	855	39	1390	793	57	1313	811	62
10	40	30	2442	906	37	1658	852	51	1510	758	50
11	40	60	2572	868	34	1850	839	45	1594	808	51
12	40	90	2623	855	33	1958	860	44	1625	890	55
13	60	0	2236	980	44	1289	726	56	1399	819	59
14	60	30	2487	898	36	1762	934	53	1670	1024	61
15	60	60	2610	915	35	1910	909	48	1695	894	53
16	60	70	2737	911	33	2057	1026	50	1729	907	53

Grwt = grain weight, kg/ha; SD is the standard deviation of that grain weight; and CV is the coefficient of variation calculated from them.

1987/88 and 1988/89 seasons were very different in terms of rainfall (Figures 3.1.15 and 3.1.16), the first (87/88) being very wet with an average rainfall of 422 mm across locations and the second (88/89) very dry with an average rainfall of 174 mm. In both seasons, the probability of receiving such wet and dry seasonal totals was approximately one in thirty years. Indeed

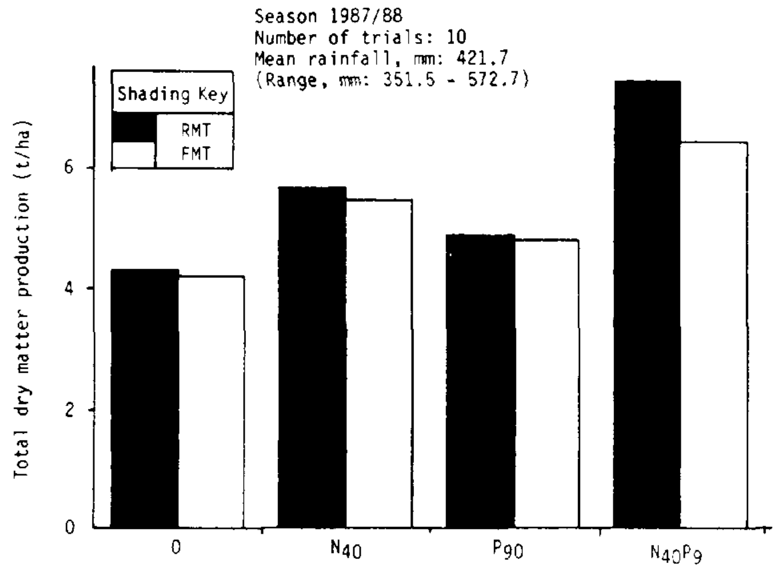

Figure 3.1.15 Total dry matter production of barley for four fertilizer treatments in Researcher Managed Trials (RMT) and Farmer Managed Trials (FMT) in N. Syria (1987/88).

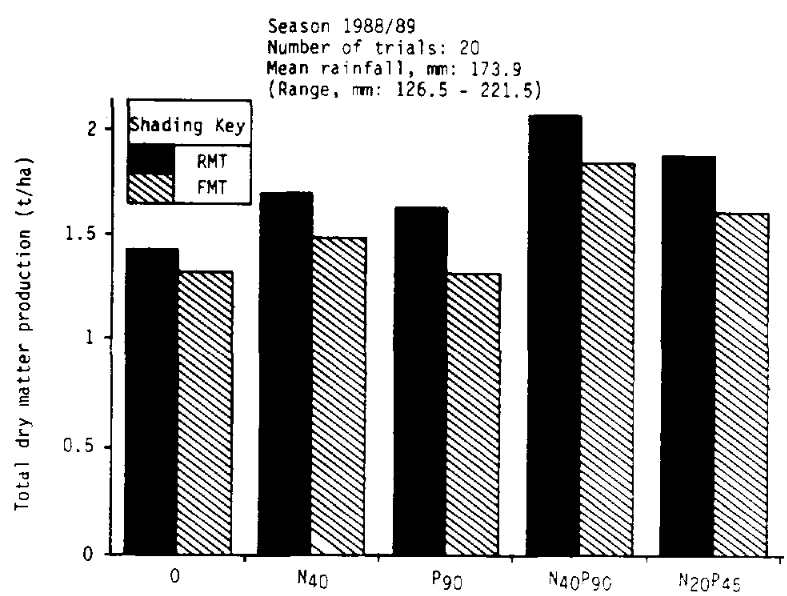

Figure 3.1.16 Total dry matter production of barley for four fertilizer treatments in Researcher Managed Trials (RMT) and Farmer Managed Trials (FMT) in N. Syria (1988/89)

these two years were so extreme that this series of trials contained no sites that received rainfall between 250-350 mm, although in terms of expected mean rainfall this range defines the major barley growing areas and is the major focus of our work. However, in spite of this, the trends of yield responses to fertilizer were similar in both years and in both types of trial. However, as Figure 3.1.15 shows, in the wet season, RMT slightly outyielded the FMT in each treatment, but in Figure 3.1.16 (dry season), RMT outyielded the FMT to a greater extent. In spite of the unusual rainfall totals associated with the two year trial, the results allow us to conclude that even under extreme and opposing conditions, farmers will also obtain the same pattern of fertilizer responses as we observed in our researcher managed plots. We see no reasons to suppose that this would not also be true in more "average" seasons.

As a result of the work reported in sections 3.1.1 to 3.1.3, we have been able to formulate provisional fertilizer recommendations that could be tested further in demonstration fields. A meeting was held at ICARDA, between the Soils Directorate and Extension Directorate on 11 and 12 June 1989 to familiarize the Extension Directorate with our results of the past five years and to discuss the initiation of a collaborative program between the two Directorates. The meeting was a success. A provisional fertilizer recommendation was by accepted by all parties and both Soils Directorate and Extension Directorate agreed to carry out a series of demonstration trials over the next two years in five provinces (Dara'a, Hama, Aleppo, Raqqa and Hassakeh). These will be financed jointly by the Syrian Ministry of Agriculture and Near East Foundation. ICARDA will also participate in this activity by continuing to carry out social-economic studies which will monitor farmers' reaction to the demonstrations and assess factors associated with fertilizer adoption and impact.

3.2 Studies on Basic Soil Properties and Soil Nutrient Dynamics

Soil analysis for assessment of native fertility levels in farmers' fields is a useful tool in guiding the formulation of targeted and efficient fertilizer recommendations, and yet we must also be aware that they are only spot measurements in time. In reality, soil fertility levels are not static, but undergo continuous changes, both within and between seasons. They are influenced by the weather, the activity of soil microfauna and flora, chemical and physical reactions associated with basic soil properties and of course by the crops themselves and the sequence in which these crops are grown. It is therefore not surprising that simple soil analysis at a given moment in time does not always provide the desired prediction of the "seasonal" nutrient supplying power of soils. In this section we report current progress in some of our more basic soil fertility research which is aimed at gaining a greater understanding of such nutrient dynamics, and the factors which affect them. Much still remains to be done,and previous world-wide experience of such research has served to emphasize the complexity of the bio-physical processes involved. Progress is slow. Nevertheless, without such qualitative and quantitative description and analysis of these processes, the efficiency of fertilizer use will continue to suffer from the limitations imposed by empirical relationships.

3.2.1 Study on the Phosphate Status of Major Soils in Syria

A.E. Matar, M.J. Jones and P. Cooper

In successive field and laboratory studies of Syrian soils it has been repeatedly found that phosphorus availability in native soils is generally low, and responses of rainfed crops to P fertilization have been demonstrated on barley, wheat, food and forages legumes.

Within the framework of project on phosphate status in the Mediterranean soils being carried out by the Institut Mondial des Phosphates (IMPHOS) in Casablanca (Morocco) and the Societe Agricole de Services au Maroc (SASMA), a joint study between ICARDA, IMPHOS and SASMA, was conducted to study the phosphorus status of the major Syrian soils.

The present work represents a detailed study of the phosphate status of the soils where thirty fertilizer trials on wheat and barley were conducted in farmers' fields during the 1985/86 season; with the addition of soils from 20 other sites representing irrigated and high rainfall areas outside the ICARDA mandate with no concurrent field experiments. The barley experiments were part of a collaborative research project between the Soils Directorate of Syria and the Farm Resource Management Program (FRMP) at ICARDA and aimed to study the biological and economic response of barley to nitrogen and phosphate fertilizers. The experiments on wheat represent the FRMP effort to relate soil testing for available-P to crop response to phosphate fertilization. The field work in Syria was carried out by staff from ICARDA and the Soils Directorate of the Ministry of Agriculture. The concurrent laboratory work was conducted by IMPHOS-SASMA.

The present report summarizes and integrates the results from agronomic field and soil laboratory studies.

Twenty sites were chosen within agricultural stability zones 2 and 3 of the four provinces, Aleppo, Hama, Hassakeh and Raqqa, to represent the dominant soil groups used for growing barley. At each site a fertilizer trial on barley was conducted comprising two replicates of a complete randomized factorial design with four levels of N (0, 20, 40 and 60 kg N/ha) and four levels of phosphorus (0, 30, 60 and 90 kg P_2O_5/ha). Detailed information on management, soil classification, the grain and straw yields obtained and the economic analysis have been published elsewhere (SD/ICARDA Research Report 1986, see also section 3.1.1. of this report). All soils were classified according to the USDA Soil Taxonomy systems.

To represent wheat, ten sites were chosen in Aleppo province, with soils ranging in $NaHCO_3$-P content between 2 and 24 parts per million at sowing. All were classified as vertic xerochrepts or vertic chromoxererts. At each site a P-fertilizer trial was conducted on wheat (Sham 1 variety), with 4 levels of P (0, 50, 100 and 150 kg P_2O_5/ha) and 3 replicates. A basic dressing of 60 kg N/ha was added to all plots, split, with 30 kg added at sowing and the rest at tillering. Concurrently, P-response trials were conducted in the greenhouse for the wheat soils. The results obtained, soil P test values and wheat responses to P fertilization, have been published elsewhere (Matar et al. 1987).

To complete the representation of major agricultural soils in Syria, soils were sampled from twenty irrigated and high rainfall sites in various provinces.

3.2.1.1 Soil Studies

Basic physical and chemical properties were determined for the top 0-20 cm soil layer. These included organic matter content, active calcium carbonate, cation exchange capacity, and exchangeable K. Total N was determined by the Kjeldahl method, and particle-size distribution by the pipette method after removal of the calcium carbonate and organic matter fractions. Soil pH was measured in soil suspension, with a soil to solution ratio of 1 to 2.5.

More detailed studies were conducted on soil phosphorus. These included the determination of total P, Organic P and water-soluble P. Available P was determined by several different methods: (a) Citric acid extraction, (b) oxalic acid extraction, (c) anion resin desorption, (d) water extraction, and (e) $NaHCO_3$ extraction. Finally, P fixing power was determined as the amount of P that must be added to the soil to achieve an equilibrium soil solution of 2 mg l^{-1}.

3.2.1.2 Soil Classification of the Sites

All sites were classified according to the U.S. Soil Taxonomy System (Table 3.2.1). Most fell within three main soil classes:

Table 3.2.1 Classification of sites into various soil sub-orders in Syria

Soil Group	Class	Soil Sub-Order	Sites Numbers
1	Inceptisols	Typic Xerochrept	31
		Lithic Xerochrept	34
		Ruptic-Lithic "	35
		Petrocalcic "	15 16 17
		Lithic-Vertic "	48
		Calcixerollic "	6 9 11 12 18
		Vertic	49
2	Vertisols	Entic Pelloxerert	32
		Typic Chromoxerert	21 22 23 24 25
			26 27 28 29 30
			36 46 50
		Entic Chromoxerert	46
3	Aridisols	Typic Calciorthid	1 2 19 20 38
		Xerollic "	4 10 13 14
		Typic Salorthid	43 44
		Typic Gypsiorthid	7 8 41 42
		Calcic "	3
		Petrogypsic "	5
4	Entisols	Typic Xeropsamment	33
		Typic Torrifluvent	39 40 45
5	Mollisols	Typic Haploxeroll	37

thirteen inceptisols, fifteen vertisols and seventeen aridisols. There were also a few entisols and millisols.

The soils differed widely in their basic characteristics. Calcium carbonate contents ranged between 0 and 68 percent, and the active fraction of $CaCO_3$ between 0 and 14.5 percent. Organic matter contents ranged between 0.7 and 5.60%, although most soils contained between 1 and 2%. Total nitrogen content was generally very low, with 80 percent of soils having less than 0.1%. Soils tended to be of medium texture, but over all, clay contents ranged between 9 and 68%, and cation exchange capacities between 11 and 62.5 milliequivalents per 100 gram.

3.2.1.3 Comparison of various parameters for characterizing soil phosphorus availability on all soil groups combined

Amounts of soil phosphorus extracted differed greatly according to the extraction method used. Lowest values were those of water-soluble P; highest values were those of total P, extracted by strong acid (Table 3.2.2).

Table 3.2.2 Means and range of extractable phosphorus by various solutions from all sites

Variable	Means	Range
P-Olsen	8.4	1.3 - 69.2
P-Oxalic	57.9	4.0 - 2025.0
P-Citric	244.8	12.0 - 2452.0
P-Organic	83.8	5.0 - 1239.0
P-H_2O	0.4	0.0 - 0.9
P-Resin	9.8	2.2 - 61.8
P-Fixing Power	60.9	18.3 - 107.4
P-Total	689.2	333.0 - 1574.0

The water extractable-P represents, on average, 0.05 percent of the total P in the soil, and the organic fraction 13.9 percent of total P. This low figure is to be expected, because soil organic matter contents are low as a result of the arid climate and low return of biological material to the soil.

The citric acid extractable-P (P-Dyer) and oxalic acid extractable-P (P-Joret Hebert) both represent a larger fraction of total P than that extracted by $NaHCO_3$ solution (P-Olsen) or anion desorption (P-resin). This probably accounts for the good correlation observed between total P and P-Joret Hebert (r = +0.65) (Figure 3.2.1).

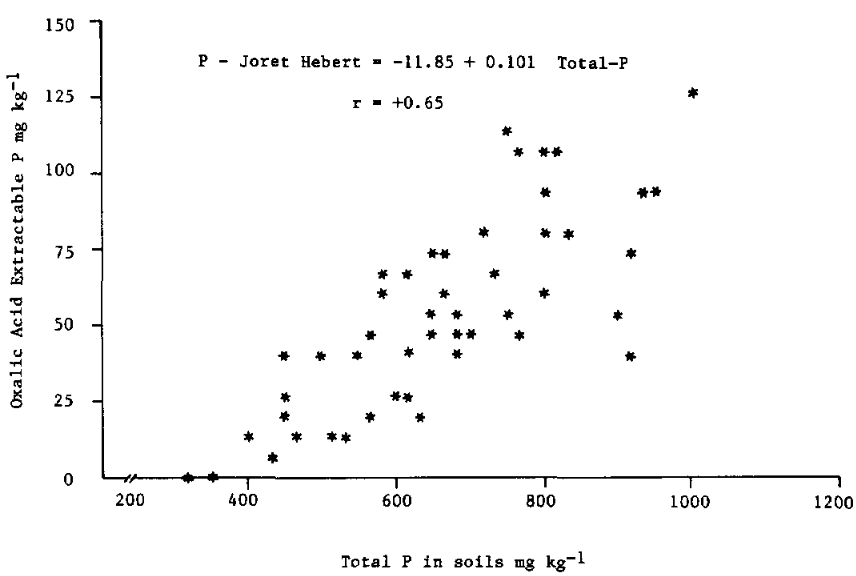

Figure 3.2.1 Relationship between total P in Syrian soils and the available P in soils as extracted by the oxalic solution of Joret Hebert method.

The relationship between resin-P and $NaHCO_3$-P (Olsen-P) was found to be very significant with r = +0.97 (Figure 3.2.2). This supports the previous results of Agbani et al. (1983) and Matar et al. (1988).

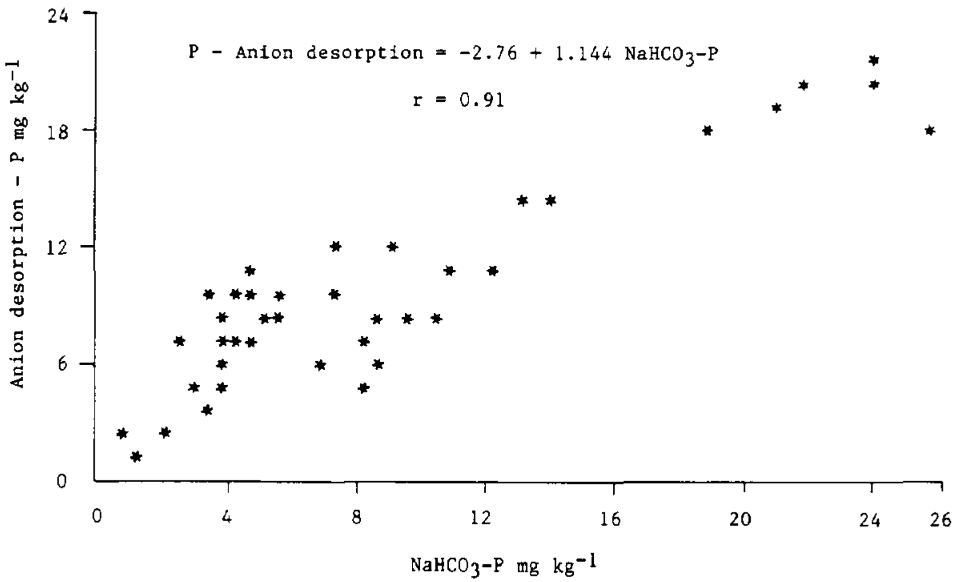

Figure 3.2.2 The relationship between the $NaHCO_3$ extractable-P (Olsen-P) and Anion desorption P in Syrian soils

3.2.1.4 Relationships between parameters for characterizing soil phosphorus and soil physico-chemical characteristics

The organic matter content (OM) and/or the total nitrogen (TN) contents of soils were found the only soil characteristics that correlated moderately well with the various parameters used for characterizing the available P in soils (with r = 0.45 for both OM or TN). This could be the result of the extraction of part of the soil phosphorus associated with the organic component of soil. Both the acid extraction solutions of the Dyer (citric-P) and Joret Hebert methods (Oxalix acid) or the $NaHCO_3$ solution of the Olsen method could lead to a solubilization or dispersion of the humic fractions of soils.

Soil phosphorus fixing power (PFP) correlated positively with cation exchange capacity, (r = 0.67) and less with the clay content (r = 0.43). This indicates that phosphorus fixation tends to increase with increasing soil contents of fine surface-charged particles (see also section 3.2.2). However, various inorganic colloids have quite different adsorption capacities. Juo and Fox (1977) found a highly significant correlation at 1% level between PFP and free iron (Fe_2O_3), clay content and clay surface area. Similar results were obtained in Luvisols. But on the other hand, PFP is negatively correlated with the organic matter content of the soils (r = -0.40). However, Greaves and Webley (1965) showed that soils with high levels of OM (hence organic-P) maintained high levels of available-P due to a gradual process of mineralization of organic-P.

3.2.1.5 Relationships between parameters characterizing soil phosphorus and response of cereals to phosphatic fertilization in the field and greenhouse

The relative yields (RY) of wheat and barley (percentage ratio of yields without P to yields with optimum P applied) were calculated for the first 30 sites where NP fertilizer experiments were conducted. When the RYs for grain (GY) and total dry matter (TDM) at harvest were correlated with various soil phosphorus parameters (Table 3.2.3), it was found that $NaHCO_3$ gave a better correlation coefficient than any other soil P parameter: r = +0.49 for GY and r = +0.46 for TDM. No significant relationships were found between Oxalic-P or Citric-P and relative yields.

For comparison of various soil P tests under controlled greenhouse conditions, the relative yields of ryegrass obtained from pot tests with the same soils, published elsewhere (Matar et al. 1988) were correlated with the values of the four major soil P tests at planting and plotted in Figure 3.2.3. Using the Cate-Nelson graphical method as modified by the analysis of variance method of Nelson and Anderson the relative yields of ryegrass (Yo/Ymax x 100) against soil test values for P, the 10 soil types

Table 3.2.3 The linear correlation coefficients between soil phosphorus parameters and relative yields of grain (GY) and total dry matter (TDM) in the barley and wheat experiments

Soil P Parameters	Barley + Wheat	
	GY	TDM
P-Olsen	+0.49	+0.46
P-Jeret Hebert	-0.02	0.0
P-Dyer	-0.23	-0.19
P-Organic	-0.28	-0.23
P-H_2O	+0.35	+0.24
P-Resin	+0.26	+0.18
P-Fixing Power	+0.16	+0.29
P-Total	0.09	0.07

could be subdivided into major groups: responsive and non-responsive to P application. The critical response levels of soil test for P for which R^2 is maximum were equivalent to 11.5, 13.5, 38.5 and 0.5 mg/kg for $NaHCO_3$, anion resin, oxalic acid (J-H), or water soil tests, respectively. Although the $NaHCO_3$ test procedure was superior to other tests in predicting responses to P application, the R^2 values were also sufficiently good for the oxalate, water and resin tests to separate soils into responsive and non responsive to P application.

3.2.1.6 Summary and Conclusions

Three major soil groups dominate the soils of barley and wheat growing areas in Syria: Aridosols, Vertisols, and Inceptisols.

Large differences exist in the amount of available phosphorus extracted by various methods used. The smallest amount was obtained with the water extraction and the largest extracted by the citric acid solution of Dyer.

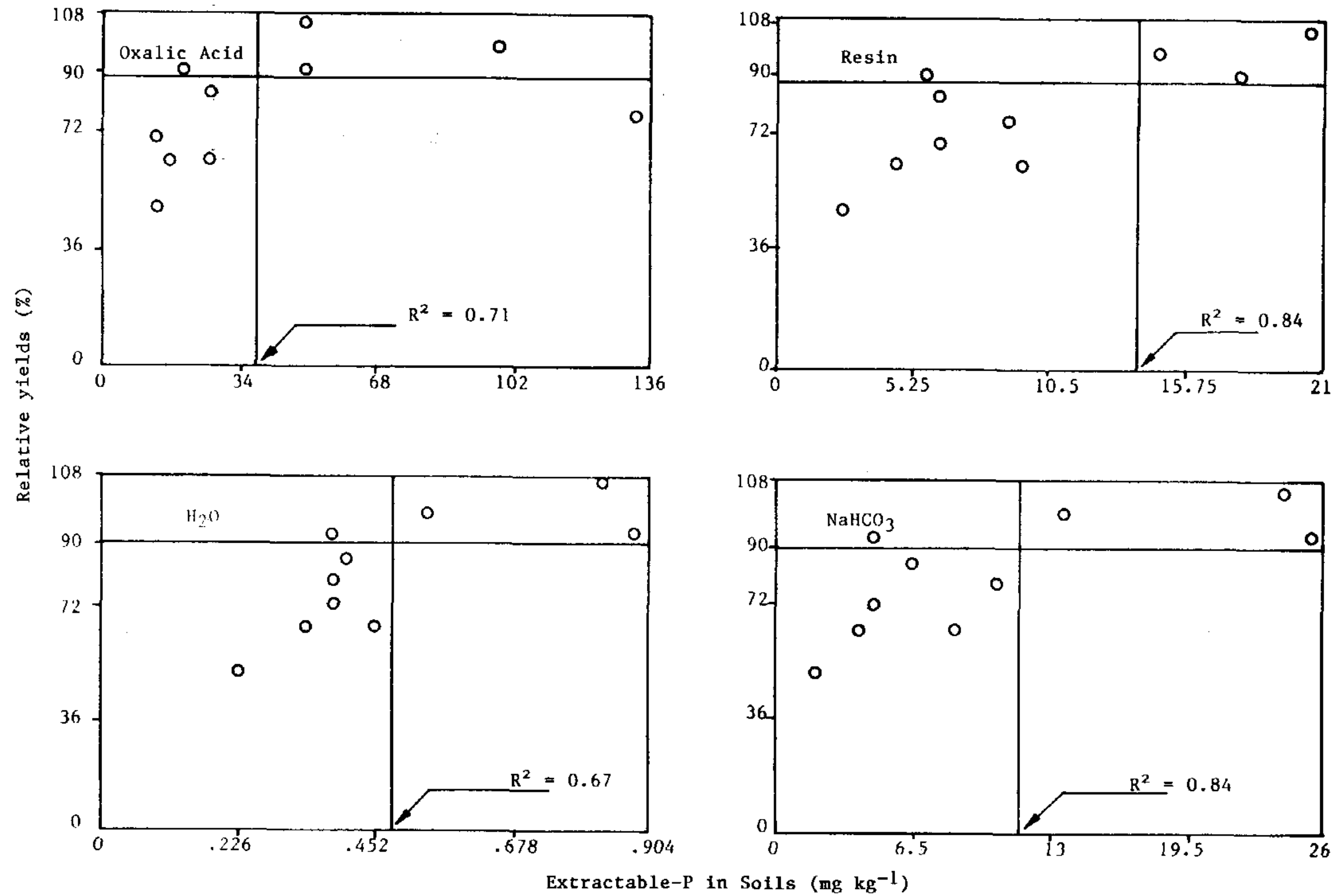

Figure 3.2.3 Scatter diagrams of relative dry weights (%) of both cuts of ryegrass, as related to available P in soils determined by four different tests for P.

Very high correlation coefficients were observed between the values of $NaHCO_3$-P and the Labile P-extracted by anion exchange resin. Furthermore, the relationships between Olsen-P, oxalic P, citric-P or total-P were found significant.

The strongest relationships between relative yields of barley and wheat and soil P parameters were found first for $NaHCO_3$-P (Olsen-P) and secondly with the water extractable P or resin-P.

Similarly, under greenhouse conditions, the relative yields of ryegrass grown in the wheat soils correlated best with the Olsen-P and Resin-P. It was found possible to establish approximate critical levels for four of the soil P tests that divide soils into groups that are responsive and non-responsive to phosphate fertilization.

3.2.1.7 References

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3.2.2 P-Adsorption Isotherms in Calcareous Soils

M. Bakheit Said

3.2.2.1 Introduction

Information obtained from experimental work carried out in Syria has shown that calcareous and phosphate-fixing soils are deficient in phosphorus. Annual applications of phosphate fertilizer gradually increase the level of available P. The availability of the applied P is controlled by the sorption and desorption characteristics of the soil. The reactions involved in these phenomena are influenced by soil properties and environmental factors as well as the amount of phosphorus added. The major soil properties that influence these reactions include: the amount and type of clay, amounts of iron and aluminum oxides, organic matter, pH and Calcium Carbonate (Solis and Torrent 1989; Bennoah and Acquaye 1989). The influence of these factors is, at present, little known. For example there is increasing evidence that in calcareous soils iron oxides play a significant role in phosphate sorption (Ryan et al. 1984). This influence may be either by direct reaction, or indirectly through a modifying effect of coating the $CaCO_3$ phase. The objectives of this study are to determine and characterize the P adsorption isotherms of these soils, to study the soil properties affecting adsorption and to use this understanding to explain and estimate the need for phosphate fertilizer.

3.2.2.2 Soil Samples

12 surface soil samples (0-20 cm) of varying properties, collected from some of ICARDA's barley and wheat on-farm trials, were used in this study. The samples were air-dried and passed through a 2 mm sieve for subsequent analysis. Table 3.2.4 shows some physical and chemical properties of these soils.

3.2.2.3 P-Adsorption Studies

Reaction time was studied by equilibrating duplicate 2 g samples of two soils of widely varying properties in 40 ml of 0.02 M KCl containing 5 and 20 ppm P as KH_2PO_4. A few drops of toluene were added to inhibit microbial growth and the suspension was shaken for periods of contact ranging from 1 to 48 hours at room temperature and then centrifuged. The amount of P sorbed was calculated by subtracting the amount of P in the supernatant solution from the amount of P initially added. P was determined colorimetrically by the ascorbic acid method. P adsorption is known to increase with increasing temperature, but room temperature variations in this study had little effect. Ideally, such studies should be conducted under controlled temperature conditions. A portion of the data obtained for the

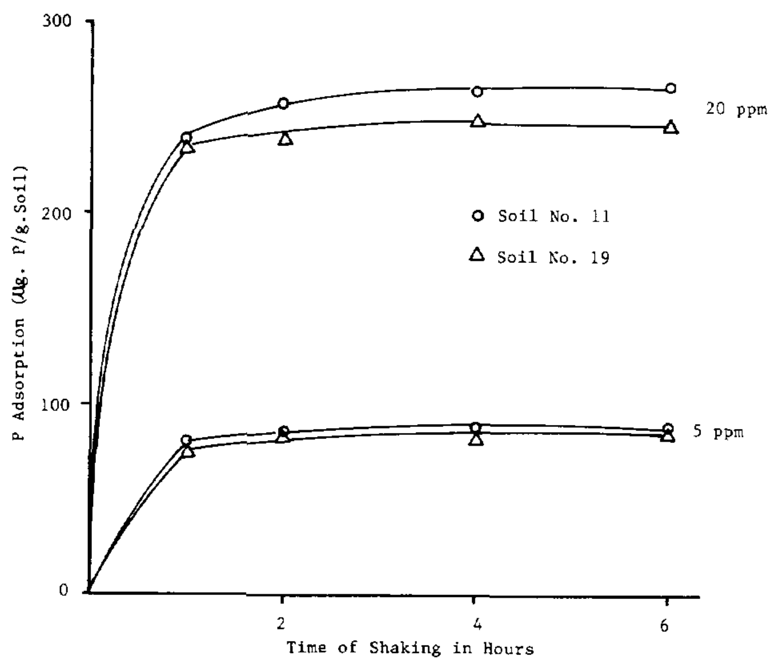

Figure 3.2.4 Time Adsorption Curves For Two Soils (No. 11 and No. 19) And Two Initial P Concentrations (5 and 20 ppm)

time/adsorption curve is given in Figure 3.2.4. The data indicate that a 4-6 hour shaking time is adequate to complete the adsorption reaction. A 6-hour shaking time was used in all subsequent P adsorption studies.

The phosphate adsorption data of the 12 soils were obtained using 2.5, 5.0, 10.0, 20.0, 30.0 and 40.0 ppm initial P concentrations. Figure 3.2.5 gives the adsorption isotherms for these soils. The data obtained were plotted according to the linear forms of both the Freundlich and Langmuir equations and gave consistently better and highly significant correlation with the former than the latter equation. For comparison as to the goodness of fit in the linear form of the equations, R^2 exceeded 0.977 in each case for the Freundlich equation and 0.834 in each case for the Langmuir equation. This finding is in agreement with that obtained by Polyzopoulus <u>et al.</u> (1985) and Berigari (1988). They found that the Freundlich isotherm fitted the phosphate sorption data better than the Langmuir isotherm, however, its drawback is its inability to estimate the adsorption maximum. The importance of the adsorption maximum is that it can be related to various soil properties and hence supply information about the nature of the reaction between the soil and the phosphate fertilizer. However, the assumption of the Langmuir equation of "no lateral interaction among the sorbed phosphate species and constant free energy of adsorption does not fit well with the present knowledge that sorbed phosphate carries charges and that surface charge and potential decrease as more phosphate is sorbed on oxide mineral or in soil systems" (Kuo 1988). The plots according to the Freundlich equation are illustrated in Figure 3.2.6 where x = g P adsorbed per g of soil and c = equilibrium P concentration in g P per ml of solution. Ideally the adsorption would be determined in a system in which the surface is free of adsorbed phosphate or a correction is made for the initial surface phosphate. This correction is small in soils of low fertility.

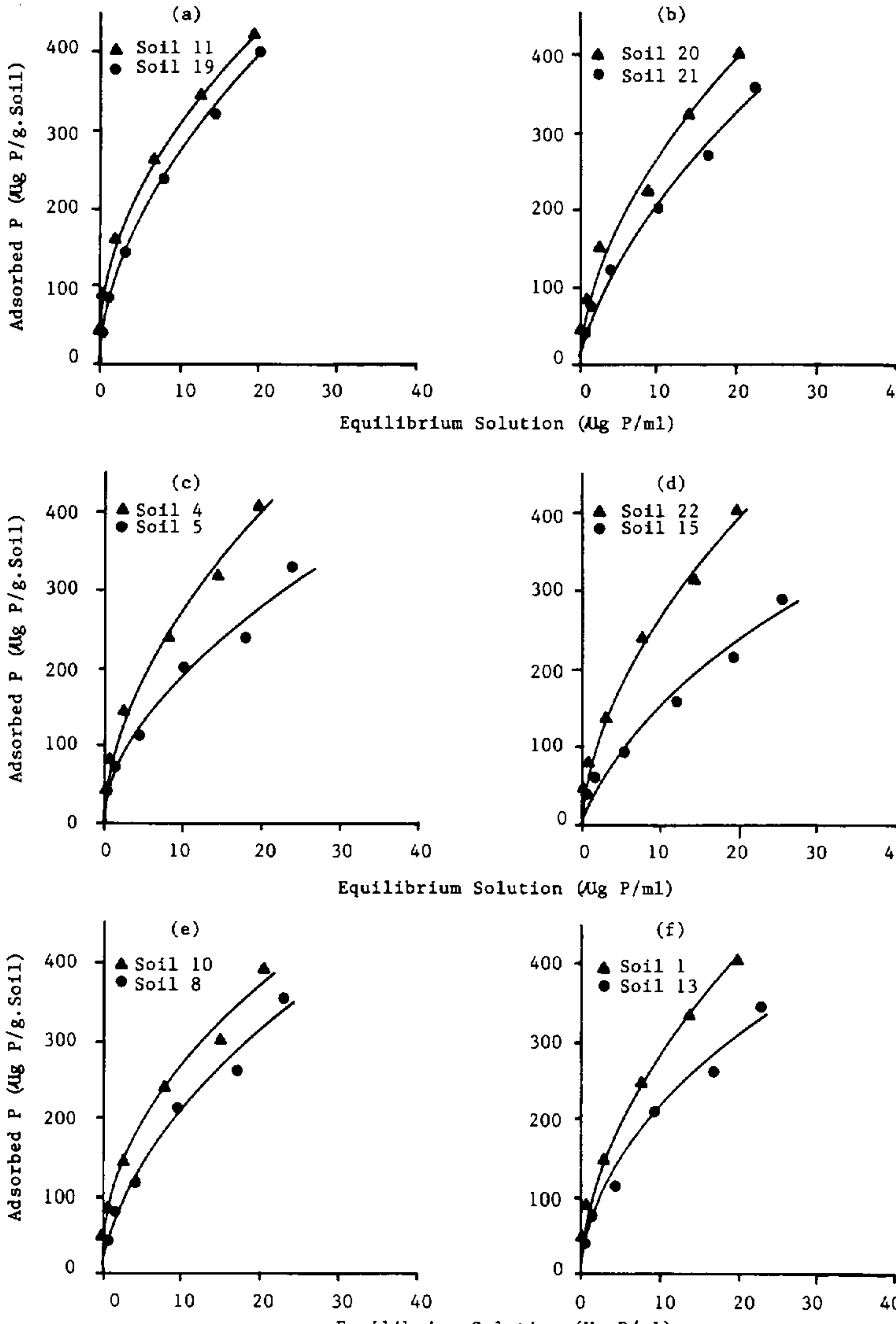

Figure 3.2.5 Phosphate adsorption isotherms of soils.

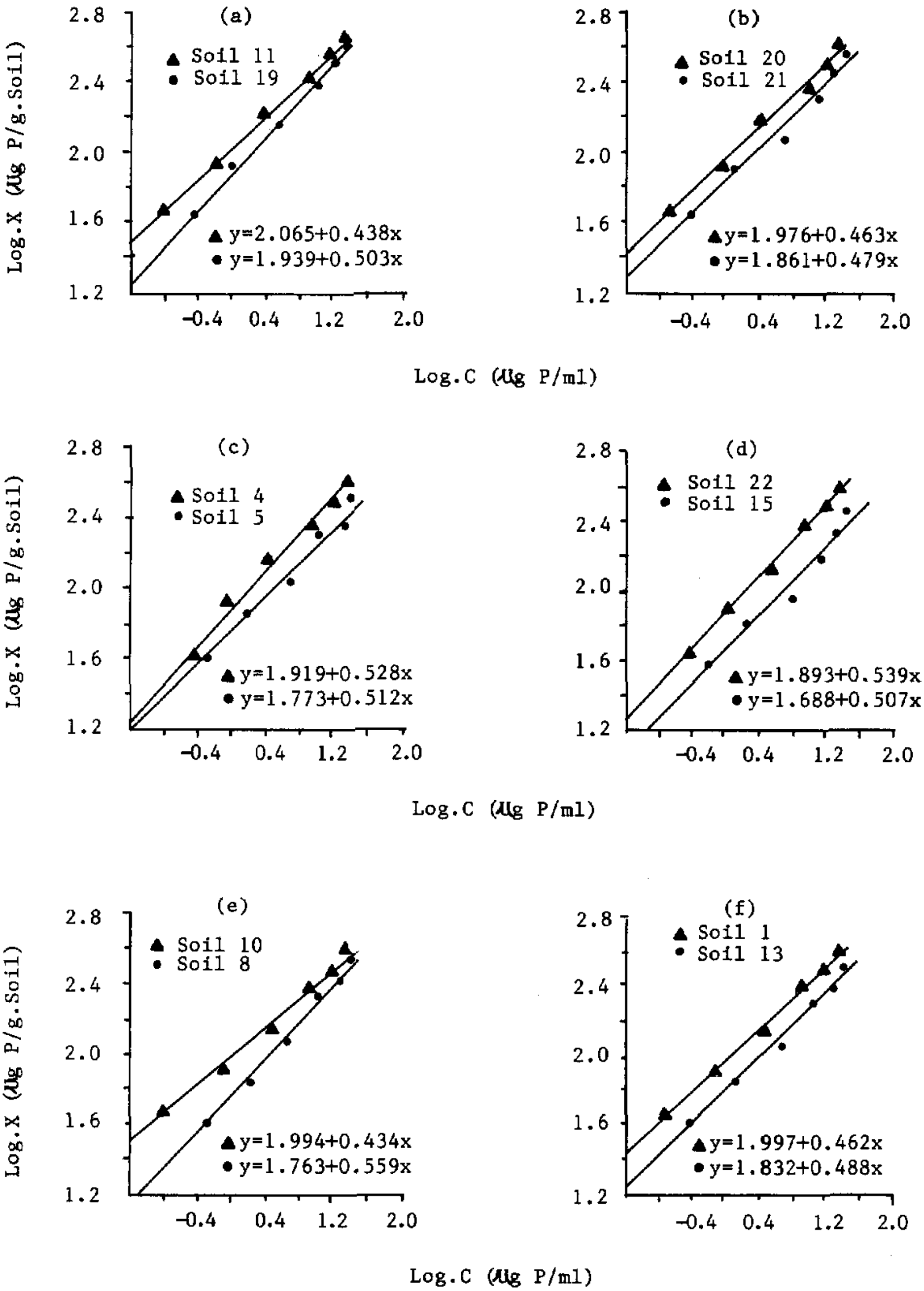

Figure 3.2.6 Phosphate Adsorption Data Plotted According to the Linear Form of the Freundlich Equation.

The importance of this linear relationship is that it can be used for the determination of P fertilizer requirements of soils using an adsorption isotherm from only two data points (Berigari 1988).

3.2.2.4 Soil Properties Affecting P Adsorption

Unlike the Langmuir equation, the Freundlich equation does not allow the calculation of a phosphate adsorption maximum, (Olsen and Watanabe 1957). As a result of this the soil P adsorption from the highest P concentration (40 ppm in this case) was used to relate adsorption to various soil properties. However, because of the interacting effect of these factors it is difficult to evaluate the effect of each property properly and independently. Of all the soil properties studied (Table 3.2.4) only the clay content influenced phosphate sorption in these soils significantly so that 69.2% of the variation in adsorption can be regarded as associated with variation in clay content. Olsen and Watanabe (1957) found a close relationship between the phosphate adsorption maximum and surface area for both alkaline soils (R^2 = 0.960) and acid soils (R^2 = 0.922). The observed relationship between the clay content and phosphate adsorption is attributed to the high

Table 3.2.4 Some physical and chemical properties of the soils

Soil No.	Locality	pH (1:1)	$CaCO_3$ %	Clay %	Organic matter %	Available P, ppm	E.C. mS/cm	Kjeldahl N, ppm
1	T.H. P_0 - Aleppo	8.2	25.7	63.4	0.83	3.6	0.25	631
4	T.H. P_{60} - Aleppo	8.2	25.5	62.5	0.95	12.9	0.25	677
5	Breda P_0 - Aleppo	8.3	25.2	31.6	0.98	2.8	0.24	708
8	Breda P_{60} - Aleppo	8.3	23.8	39.3	1.14	12.3	0.28	731
10	Afes - Idleb	8.2	31.1	66.2	0.86	2.8	0.22	574
11	Teoum - Idleb	8.2	26.2	71.8	0.78	3.5	0.21	544
13	Um El Kubar - Hassakeh	8.0	24.3	41.3	1.08	3.5	1.02	823
15	Sayed Ali - Hassakeh	8.2	26.6	35.6	1.31	2.7	0.26	888
19	Souha - Hama	8.4	1.8	46.1	1.24	11.1	0.25	916
20	Sheikh Ali - Hama	8.0	2.3	58.4	2.04	8.4	0.41	1301
21	Tel El Dura - Hama	8.3	49.1	56.2	1.28	6.3	0.32	778
22	Alqamiyeh - Aleppo	7.9	11.8	74.3	1.12	8.3	0.21	762

surface area the clay provides for phosphate adsorption. It is noteworthy that there is no significant correlation between adsorption and $CaCO_3$ (R^2 = 0.106) although $CaCO_3$ content in these soils ranges from 1.8 to 49.1%. Ryan <u>et al.</u> (1984) studied the significance of iron oxides and calcium carbonate particle size in phosphate sorption by calcareous soils using correlation and regression coefficients with actual P retention from solution. This research indicated an involvement of Fe (as extracted by oxalic acid) but there was no effect of $CaCO_3$ particle size. Holford and Mattingly (quoted by Ryan <u>et al.</u> 1984) reported that the reactivity of $CaCO_3$ is dependent on specific surface, which is related to carbonate particle size distribution, rather than to total chemically determined $CaCO_3$. Thus, P sorption characteristics of calcareous soils may not be well related to total $CaCO_3$. The absence of relationship between adsorption and either pH (R^2 = 0.019) or organic matter (R^2 = 0.016) is likely to be due to the samples having a very narrow pH range (7.9 - 8.4) and a low content (1.41 ± 0.63%) in the case of organic matter. Further work is needed on factors influencing phosphate sorption in these soils with emphasis on iron and aluminum oxides, calcium carbonate and specific surface area.

3.2.2.5 <u>References</u>

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3.2.3 Nitrogen Mineralization Potential of Syrian Soils

A.E. Matar, D. Beck, M. Pala, S. Garabet

Amounts of residual NO_3 in soil reflect management and N fertilization practices, and influence amounts of N fertilizer required for wheat. The remainder of soil derived N is supplied through mineralization of soil organic N. Evaluation of effects on crop available N of a pool of readily mineralizable N representing a small proportion of the total soil N, which is mineralized at a rate proportional to the size of the pool, necessitates measurement of residual nitrogen from previous fertilization and estimation of soil N actually mineralized between harvest and planting and during crop growth.

This pool of mineralizable N can be estimated to be of size N_o, and its magnitude is approached asymptotically by N_t, the cumulative N mineralized in time t, according to the equation $N_t=N_m\ (1-e^{kt})$, where k is the mineralization constant. Through measurement of Nm over time using laboratory incubations, N_o and k can be estimated by an iterative procedure using a non-linear, least squares procedure in a first-order model. Nitrogen mineralization is known to be influenced by such environmental variables as temperature and moisture and by soil characteristics, but the technique whereby potentially mineralizable nitrogen fractions are measured using successive laboratory incubations has proved the least empirical method available for estimating the nitrogen-supplying power in widely varying soils.

In order to gain a better understanding of N availability in Syrian soils, 18 soil samples were selected from dominant soil groups for study of their N mineralization potentials (Table 3.2.5). Several different approaches to calculate N_o and k were

Table 3.2.5 Classification and chemical properties of surface (0-20 cm) soils used in the N mineralization study.

Site	Classification	Surface soil properties(%)				N-Mineralization potential (N_o) * mg/kg soil	
		$CaCO_3$	Organic	Total	Clay		
		----- % -----				1	2
1	Mollisol 1	26.7	1.82	0.165	67.4	172	172
2	Mollisol 2	53.0	6.38	0.596	46.1	291	297
3	Mollisol-3	9.1	1.41	0.153	57.1	213	210
4	Mollisol-4	7.4	1.69	0.217	56.7	324	325
5	Entisol-1	36.8	0.19	0.036	7.2	23	30
6	Entisol-2	28.1	0.88	0.096	53.5	135	139
7	Entisol-3	21.2	0.49	0.045	25.1	99	102
8	Gypsiorthid	12.2	0.34	0.044	-	63	63
9	Vertisol-1	24.3	0.53	0.061	63.9	63	58
10	Vertisol-2	20.4	0.71	0.073	74.9	103	111
11	Vertisol-3	25.1	0.51	0.052	72.6	65	62
12	Vertisol-4	25.6	0.49	0.056	70.1	69	60
13	Vertisol-5	37.7	0.96	0.094	58.1	134	127
14	Vertisol-6	24.6	0.52	0.054	74.4	102	85
15	Vertisol-7	13.2	0.65	0.071	76.4	98	74
16	Vertisol-8	6.2	0.56	0.059	75.8	110	112
17	Inceptisol-1	16.8	0.67	0.083	63.7	89	89
18	Inceptisol-2	62.6	0.45	0.042	45.1	38	46

* The (N_o) values cited represent the N mineralization potential estimated from (1) the exponential equation suggested by Stanford and Smith (1972) and (2) the empirical equation:

$$N_o = 6.5\ (\triangle N_t / \triangle t^{1/2}$$

utilized, including hyperbolic and exponential equations based on first-order kinetics, with the aim to provide researchers in the region with a simple but accurate model for calculation. Results using the various models were highly correlated, enabling use of the simpler empirical linear equation relating N_o to the slope of N mineralized (N_t) with the square root of time (t) as: $N_o = 6.5 (\triangle N_t / \triangle t^{1/2})$.

It was found that: (1) estimates of N_o varied largely among Syrian soils, being highest for Mollisols and lowest for a sandy Entisol (Figure 3.2.7); (2) difference between N_o values estimated by various mathematical models were not significant; 3) the rate of mineralization constant (k) for the test soils varied only slightly, with an average value of 0.0376 $week^{-1}$. The average time required for half of N_o to mineralize under laboratory conditions (25°C) was 18.5 weeks; and 4) estimates of N_o correlated well with both organic carbon content (OC) and total N, with R^2 values of 0.78 and 0.90, respectively. No other soil properties correlated with N_o values, e.g. $CaCO_3$ of clay content.

Understanding the contribution by nitrogen fertilization and rotation practices to magnitude and stability of this potentially mineralizable N in various soils could lead to a more sustainable production in the wheat-based farming systems of the region. Short-term laboratory incubations (6-8 weeks) coupled with interpretation using the empirical equation provide a simple practical tool for estimating mineralizable N in Mediterranean soils in evaluation of the long-term effects of soil and systems management. Ongoing work in this area at ICARDA will assess relationships between various soil N tests, including N_o, plant N uptake and N fertilizer responses.

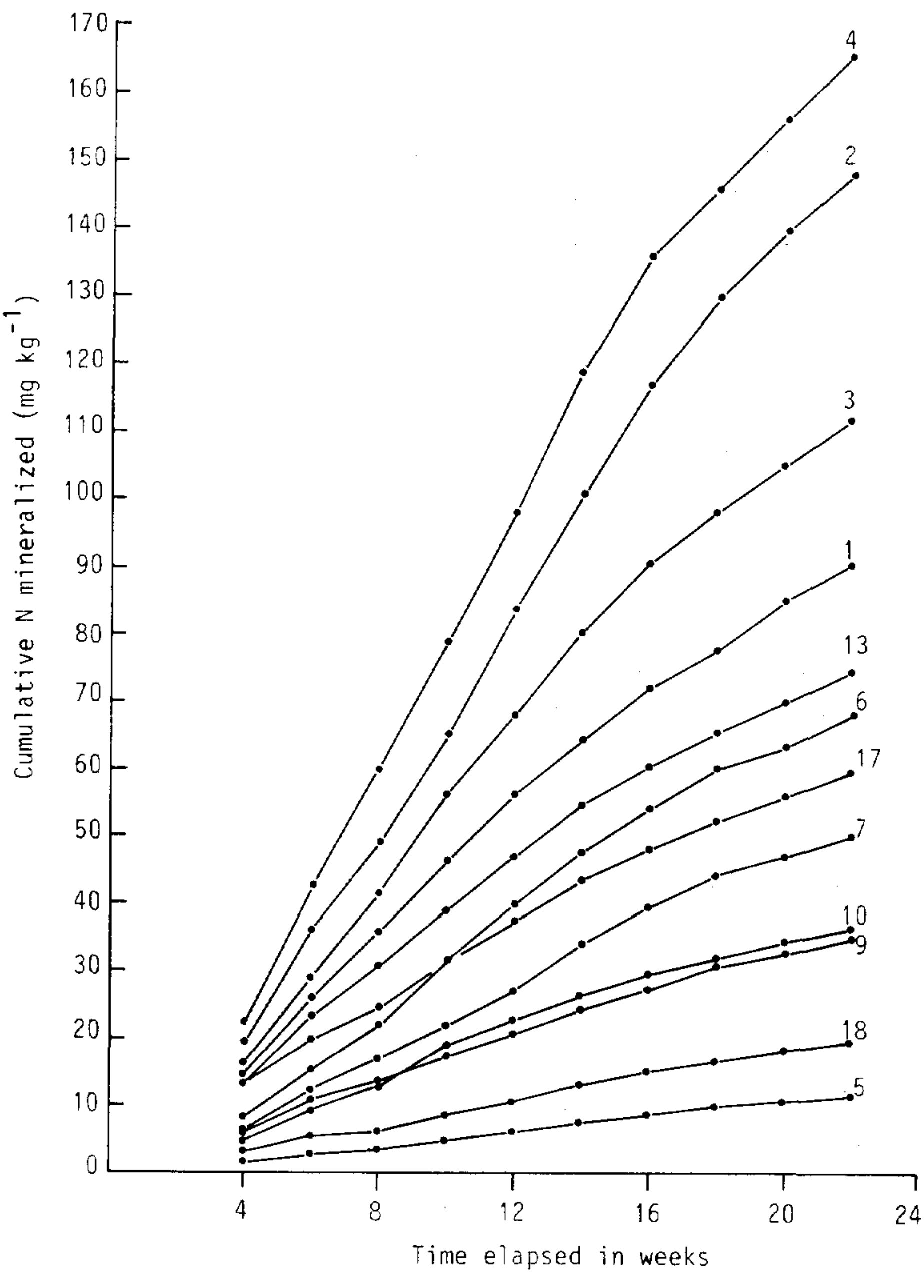

Figure 3.2.7 Cumulative N mineralized with time for selected soils from various groups in Syria.

3.2.3.1 References

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3.3 Improved Production Practices for Chickpea: On-Farm Assessment in Syria

M. Pala and A. Mazid

3.3.1 Introduction

Wheat consumption per capita in ICARDA region is higher than anywhere in the world except East Europe and the USSR, and three times the average for developing countries. Wheat provides most of dietary energy and protein but lacks certain essential amino-acids which food legumes are able to supply. They are thus important to a nutritionally well balanced diet, especially for lower-income people who cannot afford much meat, and, in addition, provide variety to the menu. In terms of protein production per hectare/day, four of the world's top ranking crops are legumes, all being cool season species, and they are also the cheapest source of protein (Oram and Belaid 1989).

Among the cool season food legumes which provide the bulk of pulse supply in the WANA region, chickpea occupies first place overall.

About 8.7 million hectares are sown to chickpea in the world as a whole (FAO 1988), representing only 1.1% of the total cereal plus pulses area. However, chickpea accounts for 13% of the total world area of pulses, and 24% of the total chickpea area is found in ICARDA region (Tables 3.3.1 and 3.3.2). The increase in chickpea area in West Asia and North Africa from 1981 to 1988 results mainly from fallow replacement in Turkey.

Table 3.3.1 Chickpea status in North Africa and West Asia region compared with cereals and pulses

Country	Arable Crops (x 1000 ha)	Total Cereals (x 1000 ha) 1979/81	Total Cereals 1988	Total Pulses (x 1000 ha) 1979/81	Total Pulses 1988	Chickpea (x 1000 ha) 1979/81	Chickpea 1988	Chickpea yield (kg/ha) 1979/81	Chickpea yield 1988
Algeria	6970	2968	2871	121	161	42	58	389	379
Libya	1800	538	427	8	10	1	1	669	714
Morocco	7930	4411	5406	388	486	53	73	633	766
Tunisia	3155	1416	513	159	86	67	31	441	654
Egypt	2390	2007	2018	141	189	7	9	1538	1765
Ethiopia	13200	4890	4750	905	940	154	182	829	714
Sudan	12420	4541	8367	76	98	2	2	1104	1045
North Africa	**47865**	**20771**	**24352**	**1798**	**1970**	**326**	**356**	**736**	**691**
Iraq	5250	2159	2732	46	32	20	10	633	750
Jordan	359	154	101	13	16	2	2	601	833
Lebanon	208	34	16	10	11	2	2	1150	1325
Syria	5013	2642	3011	220	279	65	83	722	662
Pakistan	20320	10693	10865	1502	1222	1065	817	372	440
Iran	14100	7663	9659	241	569	48	115	1092	694
Turkey	24964	13499	13670	717	2043	213	665	1149	1169
West Asia	**78124**	**36844**	**40038**	**2772**	**4197**	**1414**	**1694**	**525**	**758**
Total/mean	125989	57615	64390	4570	6167	1740	2050	564	747
World	1373200	719497	702083	60333	68536	9530	8650	624	671

Source: FAO Production Yearbook, 1988

Table 3.3.2 Area and yield of chickpea in the world and in ICARDA region (FAO 1988)

Region	Chickpea status: Area harvested in 1000 ha 1981	Area harvested 1988	% of the World 1981	% of the World 1988	Yield in kg/ha 1981	Yield in kg/ha 1988
World	9530	8650	-	-	624	671
- North Africa	326	356	3	4	736	691
- West Asia	1414	1694	15	20	525	758
Total	1740	2050	18	24	564	747

Since there has only been a slight increase in the area under chickpea in the region during the last decade, production per unit area must also be substantially increased to meet the rising demand for food legume. In this respect, recent research at ICARDA has produced encouraging results. It has clearly demonstrated that low yields of chickpea in West Asia and North Africa can be increased through the use of newly developed crop genotypes and improved agronomic practices. Yields of about 4000 kg/ha have been frequently obtained in research trials (Saxena 1984, Hawtin and Singh 1984, Keatinge and Cooper 1984, ICARDA 1985, FLIP 1984, 1986, 1987, Saxena 1987).

Chickpea is grown in the more favourable environments where annual rainfall exceeds 350 mm. However, local varieties of chickpea are susceptible to cold damage and severe infestation of Ascochyta Blight, a disease which is most prevalent under cold and moist winter conditions. As a result, chickpeas are traditionally planted in the spring (late February-May depending on the locality) are largely dependent on moisture which has been stored in the soil during the winter months. Under such circumstances, the entire plant development takes place under conditions of increasing temperature, day length and aridity with diminishing soil moisture supply, and a low probability of any significant precipitation during the growing period. In addition, low moisture levels in the seedbed at the time of germination of spring sown chickpea results in poor crop stands in most areas of the region. This poor crop stand is accompanied by further reduction in yield due to increasing water stress during flowering and pod filling stages.

3.3.2 Winter Sowing

A potential breakthrough in increasing the productivity of chickpeas in West Asia and North Africa is possible however through a shift in the date of sowing from spring to early winter thus providing better use of the available moisture by crop and earlier harvest (Hawtin 1975; Saxena 1980, 1984). By matching the vegetative and reproductive phase of the crop with more favourable thermal and moisture supply regimes than are possible when the crop is sown in spring, winter planting results in the development of plants with a larger vegetative frame capable of supporting a bigger reproductive structure, leading to greater water use efficiency and increased productivity (Keatinge and Cooper 1983, 1984). For example it was reported by Saxena (1984) that the yield of ILC 482 chickpea cultivar increased by 69, 155 and 250% respectively with progressive advancement of the sowing date from March 11 to February 13, December 19 and November 20. Averaged over all the genotypes, the winter sowing (November 20) resulted in a 118% higher yield than from the spring sowing (March 11).

3.3.3 Weed Control

However, associated with this increased yield potential, it is also true that the winter sown crop is likely to face a more serious weed problem than the spring crop as most of the weeds that would have competed with the spring crop are killed by the preparatory tillage. In the winter sowing, most of the weeds emerge with the crop and create serious competition for water, nutrients and light because of low competitive ability of chickpea crop specifically during the early stages of crop growth. Depending upon dominant weed species, and the level of infestation, chickpea yield losses due to weeds have been recorded in the range of 23 to 54% in West Asia (ICARDA 1981; Saxena 1984).

The choice of weed control methods depends on the available technology , the type of crop culture and farmers' resources. The traditional methods of controlling weeds in the region involve hand hoeing during the early crop stage, hand weeding for fodder, or a combination of both (ICARDA 1978). All of the weeding systems have been shown to lead to larger yields, but rising labor costs and also unavailability of labor in time impose increasing limitations on hand weeding in the region.

Inter-row cultivation is a feasible alternative, but requires special and carefully set equipment such as ducksfoot cultivator, as well as improved crop sowing geometry. Because of this, chemical weed control merits appropriate consideration. Several herbicides have been tested in different countries as well as at the ICARDA research stations for weed control and crop tolerance. Some of them have been identified as effectively controlling weeds. The combination of pre-emergence applications of cyanazine, or terbutryne with pronamide has proved to be quite promising for broad-spectrum weed control with a slight susceptibility depending on the locality.

3.3.4 Nutrient Supply

The amount of major nutrients that accumulate in the crop is generally proportional to the total dry matter yield due to the small variations in the nutrient concentration (Saxena 1984a). Since the yield levels of a winter sown crop are much higher than those of the spring sown crop, it might be expected that the nutrient requirement of the former would also be considerably higher than that of the latter. Soils with a poor fertility status may create a significant constraint to the realization of the larger yield potential of a winter sown crop. Chickpea is capable to meet a major part of its nitrogen requirement by symbiotic N fixation, provided the suitable Cicer rhizobium is present in the soil and no other mineral nutrient is limiting the functioning of the symbiotic association. Although chickpeas seem to have a much lower critical value for the available soil phosphorus than other grain legumes, their growth and yield can be remarkably restricted in the soil with deficient phosphorus supply. Phosphorus is also needed for nodulation response.

3.3.5 Sowing Method

Drill use for sowing should replace farmers' method of broadcasting to provide uniform seeding depth, a uniform stand of the crop, efficient use of seeds and fertilizers and a more favorable effect of herbicides. It would also allow the possibility of using of inter-row cultivation for mechanical weed control.

3.3.6 Chickpeas On-Farm Trials (1985-1989)
Trial Description

During 4 seasons, starting from 1985/86, a series of 30 on-farm trials were undertaken in NW Syria which examined the main effects and interactions of several management practices discussed in the previous section which were thought to be important in improving chickpea production.

Treatments imposed in all years are given in Table 3.3.3. In the first year, experiments were sown according to farmers' practice of hand broadcasting seed and fertilizer over ridged land, and subsequent splitting the ridges to cover the seed with a one-set ducksfoot cultivator (row spacing is about 45 cm). In subsequent years a single pass mechanical planter was compared with the farmers' method. Details of the construction and modus operandi of this planter have been reported previously.

Results obtained from these trials have been fully analysed and also subjected to economical evaluation. Firstly, the highlights of chickpea yield responses to agronomic practices are presented through a summary examination of pooled data across locations for each season. In the second part concerning the economic analyses, grain responses of each treatment combination and their associated variability, both between sites and years is

Table 3.3.3 Treatments imposed in on-farm chickpea trials in NW Syria, 1985/86 to 1988/89

	1985/86	1986/87	1987/88	1988/89
Number of sites	8	6	6	10
Trial design	2^4	2^5	2^4	2^4
Replicates/site	2	1	2	2
Cultivar	ILC 482	ILC 482	ILC 482	ILC 482
Treatment imposed:				
a) Time of sowing	Winter .v. spring	E. winter .v. L. winter	E. winter .v. L. winter	E. winter .v. L. winter
b) Rhizobium inoculation	+ .v. 0	+ .v. 0	NA	+ .v. 0
c) Weed control	Chemical[1] .v. 0	Chemical .v. h. weeding	Chemical .v. h. weeding	Chemical .v. h. weeding
d) P_2O_5 (kg/ha)	50 .v. 0	50 .v. 0	50 .v. 0	50 .v. 0
e) Sowing method[2]	N.A.	SPP[3] .v. BOR[4]	SPP .v. BOR	SPP .v. BOR

1. Chemical weed control, Terbutryne + pronamide, 2.0 + 0.5 kg ai/ha
2. 100 kg/ha seed rate used in all years.
3. BOR: Farmers' method of sowing (broadcast)
4. SPP: Single pass planter (40 cm row spacing)

discussed. The analyses focuses on a comparison of net revenues for each treatment combination, and their associated variability. Finally we conclude with a discussion of the implication of these results for our future research strategy for improved chickpea production.

3.3.7 Pooled analysis

The main effects, first order interactions and levels of significance for grain yield responses of chickpea are presented for each year as pooled analyses in Table 3.3.4. Because of the low economic value of chickpea straw as animal feed, straw yields are not considered in the analyses. However, the straw yield responses to treatment combination were similar to those of grain.

Advancing the date of sowing to early winter resulted in substantial and quite consistent yield increases in all years across locations, with 23 out of 30 trials giving significant positive responses. The response to early sowing was reduced in the 1985/86 season due to a severe infestation of Heliothis spp. at the podding stage in winter sown chickpeas. In the 1988/89 season, again the response to early sowing was lower because of 40-50 days very low temperatures which adversely affected the development of the winter sown crop. However, overall increases in chickpea grain yield by early winter sowing was 32% over late sowing for the last 3 seasons.

Effects of inoculation were small and inconsistent: in the first season only 2 out of 8 trials showed a positive response, whereas in the second season no significant response was obtained. This treatment was dropped in the last two seasons, and instead soil samples were collected to find the most appropriate Rhizobium strains for the respective sites of the trials.

Table 3.3.4 Main effect and first order interaction of chickpea grain yield responses in NW Syria (kg/ha), 1986-1989

Treatment		1985/86		1986/87		1987/88		1988/89	
Time of sowing	(Early)	E. Dec 85	1409**	E. Dec 86	1797**	M. Dec 87	1519**	E. Dec 88	972**
	(Late)	E. Mar 86	1108	M. Jan 87	1335	M. Feb 88	997	M. Jan 89	822
Weed control	(Chem.)		1400**		1498**		1221**		855**
	(Other[1])		1198		1634		1294		938
P_2O_5 (kg/ha)	50		1360**		1660**		1307**		889
	0		1237		1471		1208		904
Inoculation	(+)		1332*		1538*		N.A.		N.A.
	(0)		1265		1594				
Sowing method	(SPP)		N.A.		1641**		1315**		940**
	(BOR)				1490		1200		853
LSD (0.05)			67		54		49		36

First order interactions

		Weed Control		Sowing method		Sowing method		Sowing method	
		+	-	SPP	BOR	SPP	BOR	SPP	BOR
		**		**		**		**	
Time of sowing	(Early)	1572	1246	1933	1661	1498	1449	1033	910
	(Late)	1227	1149	1350	1320	1101	915	848	796
LSD (0.05)		94		76		69		51	

1. See Table 3.3.3 for details

* P<0.05 ** P<0.01

Significant and consistent responses to chemical weed control were observed in the first season in 6 out of 8 trials. Because weeds pose a more serious threat in winter sown chickpea there was a significant interaction between time of sowing and herbicide use. Weed infestation was 5 times greater in winter sown chickpea compared with the spring sown crop (1174 vs. 274 kg/ha of weed dry matter across all locations). Herbicide thus had a greater effect in winter sown crops which only achieved their greatest advantage when weeds were controlled. However, since the effect of herbicide use over the control was clear, the question then arose as to the effectiveness of hand weeding as an alternative, since there is always a slight crop sensitivity to the herbicides used. The results showed that hand weeding gave significantly greater yields than chemical control at only 7 out 22 sites in last 3 years. The relative merits of the two methods are discussed further in the section on economic analyses.

Crop responses to phosphate application were significant only in the first 3 years, but the response was erratic with only 7 out of 30 trials showing positive responses. Significant interactions (not shown in Table 3.3.4) indicated that in the first year the effect of phosphate fertilizer was greater in the absence of weed control, presumably due to preferential stimulation of chickpea growth allowing better competition with weeds. Again in the first year, a significant second order interaction indicated that phosphorus was clearly effective in winter sown chickpea without herbicide where it gave a 30% yield increase. In the second and third seasons, significant interactions were also obtained between phosphorus and time of sowing. Responses to phosphorus were greater in early sown chickpea than in later sown crop. This is most probably due to a higher nutrient requirement of the early sown crop.

Other research on barley has indicated clear relationships between native levels of available Olsen-P and responses to phosphate (Cooper et al. 1988). Such a clear relationship was not found for wheat. Twenty years of continuous application of phosphate and in the wheat based systems has radically changed the P-status of these soils (SMAAR/ICARDA 1988, 1989). Chickpea is commonly grown in these areas in rotation with wheat, thus similar results would probably be expected for chickpea. Indeed, a critical level of 7 ppm Olsen-P was reported for chickpea as well as other food legumes in trials conducted in Tel Hadya research station where the original Olsen-P level was very low. In the light of such findings it is not clear why similar relationships were not obtained in farmers' fields in the wheat based farming areas since in several instances native Olsen-P levels were 5 ppm or less, and yet no responses were obtained. Phosphorus dynamics of these soils are being further studied.

In the last three years, method of sowing was also studied. Drilling the seed with the single pass planter (SPP) gave substantial yield increases over broadcasting (farmers' method) with 12 significant response out of 22 trials across all seasons. However as indicated in Table 3.3.4 there was a strong interaction between time of sowing and method of sowing with larger responses to drilling in the early sowing in 1986/87 and 1988/89 and in late sowing in 1987/88.

In 1986/87 and 1988/89 seasons, excellent soil conditions occurred during early sowing. Early rains were well distributed with sufficient dry spells to allow soil drainage and the effective operation of the mechanical single pass planter (see Figure 3.3.1). But in 1987/88 season, such dry spells did not occur so frequently, and early sowing had to be done under wet soil conditions. As a result, the efficiency of the planter was greater in late spring planting when better soil conditions occurred. These results show that the timing of planting

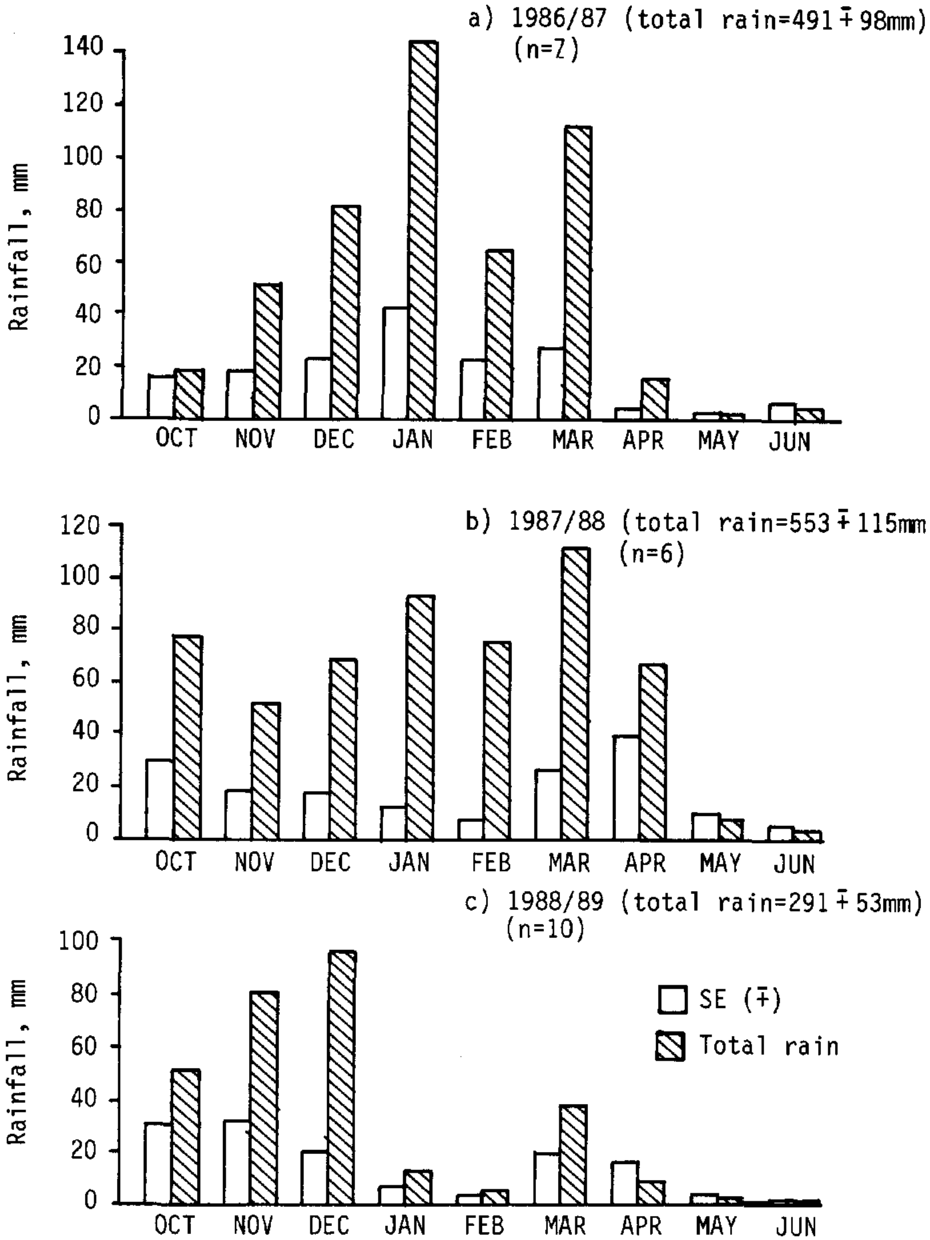

Figure 3.3.1 Mean monthly rainfall amounts and their associated standard error in on-farm chickpea trials in NW Syria

operations is important on the heavy clay soils if the planter is going to give its maximum benefit.

3.3.8 Economic Analysis

Pooled co-variance analysis were used to evaluate the economic feasibility of improved production practices for chickpea. In each season the base treatments for economic analysis were those with the lowest levels of inputs.

The overall effects of treatment combination on grain yield and their associated variabilities are presented in Table 3.3.5 and partial budget analysis of respective treatment combinations are given in Table 3.3.6. The parameters utilized in the analyses are given in Table 3.3.7. The inoculum application treatment was discounted in the analyses in 1986/87 since there was no significant response. As a result, the last 3 years became consistent in treatment combination.

Table 3.3.5 The overall effects of treatments on grain yield and their associated standard deviation in on-farm chickpea trials in NW Syria

	1985/86		1986/87		1987/88		1988/89		Mean of last 3 years	
Treatment No. [1]	Grain kg/ha	SD	Grain kg/ha	SD	Grain kg/ha	SD	Grain kg/ha	SD	Grain kg/ha	SD
1	1051	359	1206	790	886	499	831	367	948	556
2	1178	387	1361	859	885	516	811	345	981	605
3	1191	350	1324	733	865	465	749	328	937	547
4	1171	428	1389	845	925	509	794	371	992	611
5	1167	587	1274	926	1142	674	847	453	1044	680
6	1201	391	1325	750	977	533	860	342	1019	554
7	1209	402	1346	722	1189	772	783	378	1048	642
8	1336	337	1454	750	1102	662	902	379	1106	611
9	898	533	1522	742	1336	630	875	416	1177	634
10	1266	713	1578	588	1543 (3)	738	998	398	1305	615
11	1644 (1)	691	1663	655	1455	814	767	323	1199	701
12	1496	537	1879 (3)	495	1704 (2)	766	1002 (3)	370	1433 (2)	660
13	1405 (4)	572	1691	681	1396	729	971	472	1283	670
14	1415	706	1814 (4)	526	1496	692	1042 (2)	469	1376 (4)	633
15	1557 (3)	623	1957 (2)	782	1501 (4)	713	1021 (3)	472	1407 (3)	736
16	1592 (2)	644	2270 (1)	621	1717 (1)	710	1098 (1)	487	1586 (1)	760

Table 3.3.6 The overall effects of treatment on net revenue and increase in net revenue in on-farm chickpea trials in NW Syria

Treat. No.	1985/86 Net Rev. (SYL/ha)	1985/86 Increase Net Rev. (SYL/ha)	1986/87 Net Rev. (SYL/ha)	1986/87 Increase Net Rev. (SYL/ha)	1987/88 Net Rev. (SYL/ha)	1987/88 Increase Net Rev. (SYL/ha)	1988/89 Net Rev. (SYL/ha)	1988/89 Increase Net Rev. (SYL/ha)
1	5498	-	11707	-	6456	-	9424	-
2	6068	576	13289	1582	6482	26	9548	124
3	5659	167	12812	1105	6132	-324	7974	-1449
4	5464	-28	13463	1756	6677	221	8968	-455
5	5976	484	12480	773	8740	2284	9759	335
6	6065	573	12984	1277	7364	908	10326	902
7	5632	140	13113	1406	9003	2547	8552	-872
8	6205	713	14209	2502	8285	1829	10516	1092
9	4692	-800	15004	3297	10309	3852	10010	586
10	6522	1030	15563	3856	12105 (3)	5649	12031 (3)	2607
11	8026 (1)	2534	16361	4654	11170	4713	8209	-1215
12	7163	1671	18581 (3)	6874	13328 (2)	6872	11735 (4)	2311
13	7219 (4)	1727	16836	5129	10917	4461	11405	1982
14	7181	1689	18093 (4)	6386	11799 (4)	5343	12739 (2)	3315
15	7452 (3)	1960	19498 (2)	7791	11666	5210	11719	2295
16	7542 (2)	2050	22730 (1)	11023	13542 (1)	7086	13128 (1)	3705

Table 3.3.7 Parameters used in the economic analysis for each season

	1985/86	1986/87	1987/88	1988/89
Seed price (SYL/kg)	5.5	11.0	9.0	14.0
Broadcasting method (SYL/ha)	-	165	190	215
Planter method (SYL/ha)	-	230	288	338
Hand weed control (SYL/ha)	-	700	800	900
Chemical weed control (SYL/ha)	563	670	832	1290
Fertilizer costs (SYL/ha)	121	121	148.5	360
Harvesting cost (as percentage from Total Rev.)	5%	5%	5%	5%

In general economic results reflect the results for grain yields because the costs of all treatments were relatively low compared to crop values.

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 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 spring sowing with no inoculum, herbicide or phosphate application. In the last three seasons, the base treatment for economic analysis was the late winter sowing with farmers' method of planting, herbicide application and no phosphate.

For risk analysis, average net revenues for each treatment combination were plotted against their associated standard deviation. These are presented in Figures 3.3.2, 3.3.3, 3.3.4 and 3.3.5 for the four seasons. Each treatment combination is assigned a number for reference in the subsequent text. These are indicated in each of the above figures.

In 1985/86 all treatments with winter sowing dominated the comparable spring sowing treatments in terms of higher average net revenues for the same costs except treatment No. 9. The lowest average net revenue of the winter sown treatments (No. 10) was greater than that of the highest average net revenue among the spring sown treatments (No. 8) (Figure 3.3.2). No treatment consistently gave positive effects on net revenues across the 8 locations, however, as indicated above, the worst treatment was No. 9 (winter sowing with zero level of other treatments) which gave 5 negative cases out of 8. Treatment No. 11 with winter sowing combined with only weed control was further distinguished as giving the highest average net revenue. However, average net revenues also needs to be considered in light of the variations from location to location. It is notable that variations among the winter sowing treatments were greater than those among the spring sown treatments (Figure 3.3.2).

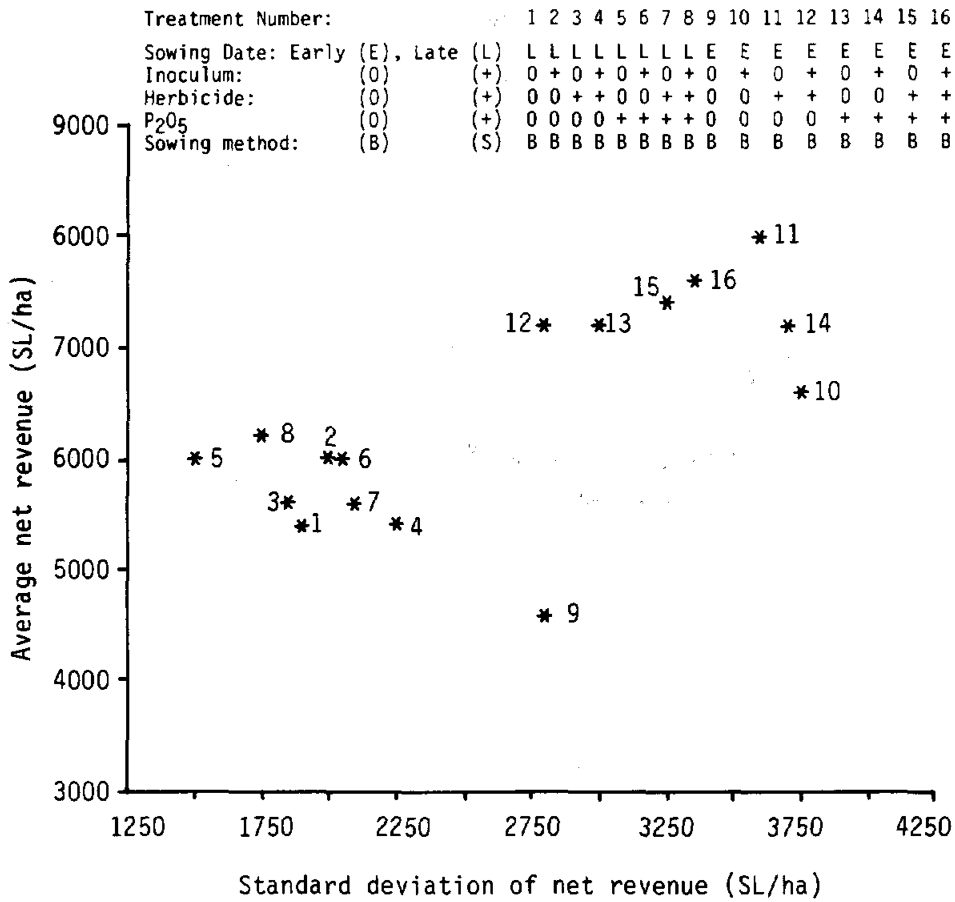

Figure 3.3.2 Risk analysis of chickpea agronomy treatments at 8 locations in NW Syria, 1985/86.

In 1986/87, all treatments with early winter sowing dominated the comparable late winter sown treatments in terms of higher average net revenues (Figure 3.3.3). Consistently positive effects on net revenues, across the 6 locations, were found in only five treatments (11, 12, 14, 15 and 16), while all other treatments gave negative results at some locations. It is notable that all these treatments were under winter sowing. Treatments 12, 14, 15 and 16 were also distinguished as giving the highest

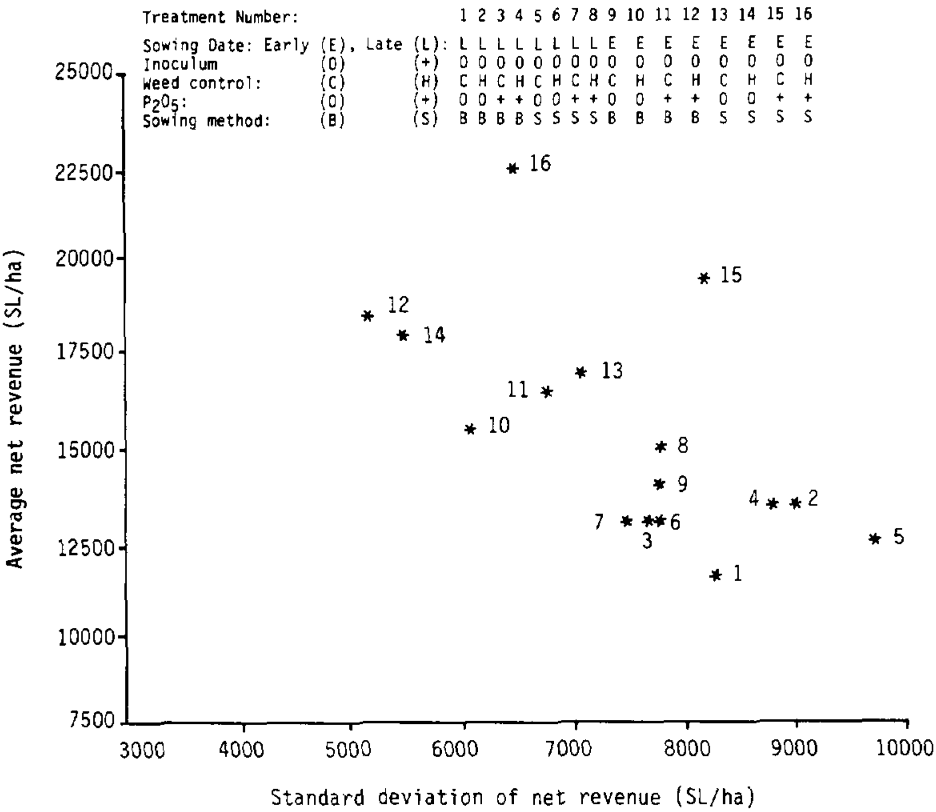

Figure 3.3.3 Risk analysis of chickpea agronomy treatments at 6 locations in SW Syria, 1986/87.

average net revenues. Among these treatments 12, 14 and 16 had the lowest standard deviation in net revenue in contrast to the previous season.

In 1987/88, all treatments with early winter sowing again dominated the comparable late winter sown treatments in terms of higher average net revenues (Figure 3.3.4). In addition, all of the winter sown treatments gave consistently positive effects on net revenues across all the 6 locations, while all late sown treatments gave negative results at some locations. Treatments 10, 12, 14, 15 and 16 gave the highest average net revenues.

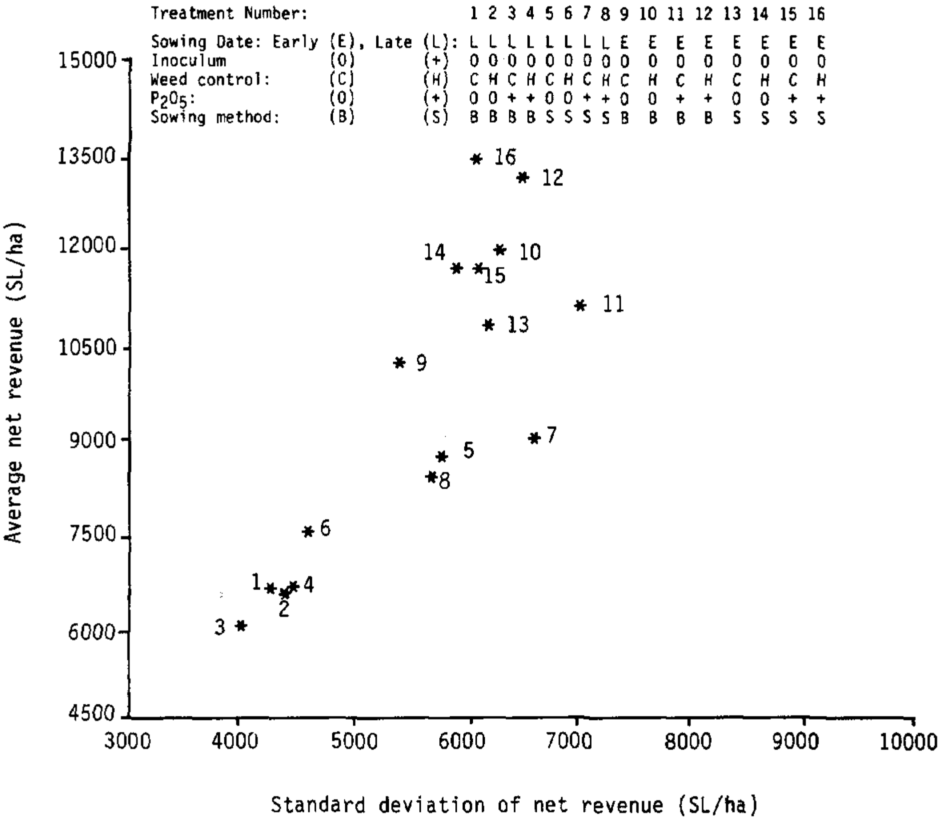

Figure 3.3.4 Risk analysis of chickpea agronomy treatments at 6 locations in NW Syria, 1987/88.

In 1988/89, which was the driest year with many frost days, all treatments with early sowing again dominated the comparable late sowing treatments except treatment 9 (Figure 3.3.5). However no treatment consistently gave positive effects on net revenue across the 10 locations. Treatments 10, 12, 14, 15 and 16 as in previous season provided the highest average net revenues. Similarly standard deviations of these treatments were in the same range of comparable late sown chickpea treatments.

Variability in crop yield is unavoidable even in the same agroecologic zone due to day-to-day or month-to-month or year-to-year variability in rainfall and temperature.

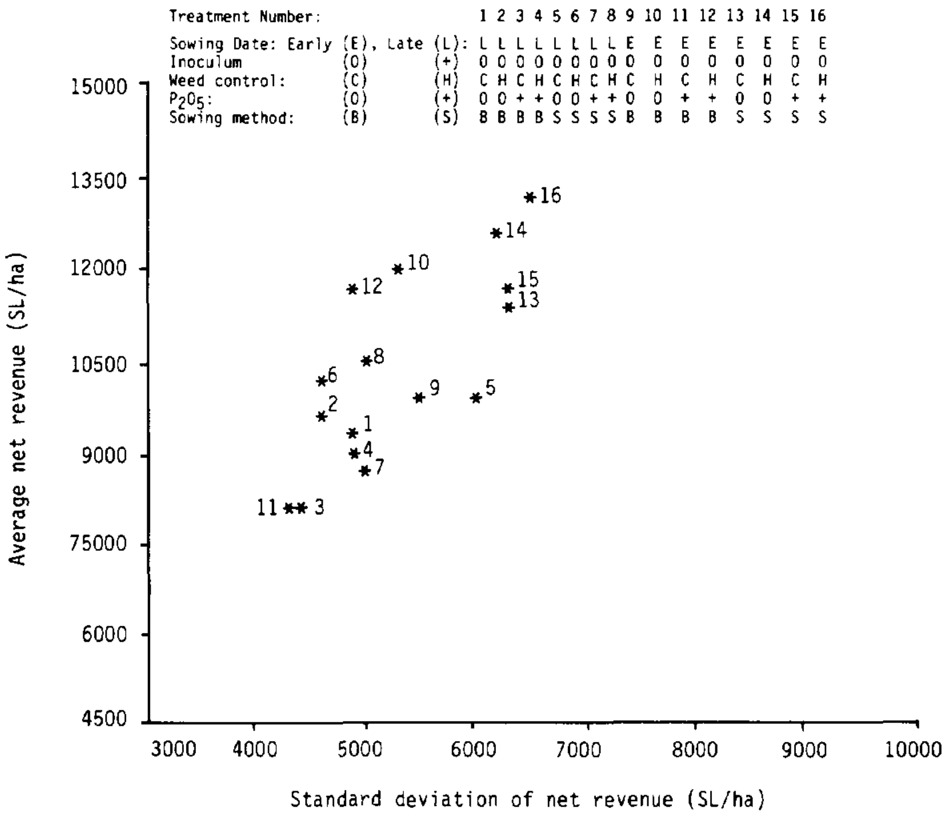

Figure 3.3.5 Risk analysis of chickpea agronomy treatments at 6 locations in NW Syria, 1988/89.

As mentioned earlier in the first season, the greater variations among the winter sown treatments were due to a severe damage of Heliothis spp., in spite of being sprayed with insecticides. In the following seasons, due to timely application of insecticides using feromone traps to monitor Heliothis population, variations among the early sown treatment combinations were kept within quite narrow boundaries and net revenues became substantially higher.

In spite of the variations across locations, there were some consistent trends over the four years. First, there was a substantial boost in net revenue resulting from winter planting in early December with a new cultivar tolerant to cold and to Ascochyta Blight. In addition, weed control provided higher net revenues in combination with early winter sowing in all seasons, with hand weeding being more profitable than chemical weed control in last three seasons. Although hand-weeding was more effective than chemical weed control, the availability of labor is likely to be deciding factor and is expected to vary from place to place. Therefore it is wise to continue the research on chemical weed control in the future.

Rhizobia inoculation did not give sufficient yield increases to cover the cost of this operation. However, if chickpea cultivation is expanded to drier areas where this crop has not been grown in recent decades and populations of _Cicer rhizobium_ are not present, inoculation may become profitable.

In all seasons, phosphate fertilizer was most profitable for the chickpea crops sown in early winter. Results were less consistent in the cases of spring or late winter sowing.

The use of the planter (in this case a single pass planter) compared to the farmers' traditional sowing method of broadcasting over the ridges gave a strong boost to net revenues especially in the case of early winter sowing especially in 1986/87 season, but the results were also positive in the last two years irrespective of sowing date. We can conclude that local cereal drills can economically replace traditional broadcasting methods.

3.3.9 Conclusion

Early winter drill sowing of chickpea (early December) combined with weed control and phosphate application has proved to be consistently profitable in these on-farm trials. The next step must now involve the wider testing and demonstration of the most profitable and stable treatment combinations in farmer managed trials. Such work would most properly be undertaken by the national research and extension systems. Such an initiative should clearly start in Syria, the country in which these trials were conducted, but the results of this study should also be tested, and where necessary adapted, in other major chickpea growing areas within the region.

In Morocco, such an initiative is well underway, and in section 5.2 of this report we highlight the findings of a study of the adoption dynamics of winter sown chickpea.

3.3.10 References

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3.4 Selection of Barley Genotypes for Systems using Supplemental Irrigation

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E.R. Perrier

3.4.1 Introduction

About 6000 years ago, supplemental irrigation started in the uplands and foothill regions near many small rivers and streams in the Near East. These efforts were devoted to the production of cereal grains; mainly barley and wheat. Even now supplemental irrigation continues to be indigenous to the region. Whereas conventional irrigation supplies the entire plant-water need because rainfall cannot be relied upon during all or a large part of the growing season, supplemental irrigation occurs in an area where a crop can be grown by natural rainfall alone but additional water stabilizes and improves yield. In addition, irrespective of seasonal rainfall, supplemental irrigation can provide conditions suitable for using high inputs, such as high yielding varieties, fertilizers, herbicides, etc., as well as more intensive cropping.

The use of supplemental irrigation can alleviate climatic risk factors in semi-arid regions by increasing choices for soil and crop management which can stabilize yields. The magnitude and

1. The first year, 44 barley genotypes, selected at the Boueidar station and suggested by the Barley Breeders of the Cereal Improvement Program of the ICARDA, were entered into the design; and,

2. The second year, only 16 of those genotypes which showed a response to supplemental irrigation were selected to be entered in the second seasons's trials.

They were mainly barley lines from advanced trials being 6 out of the original 44 genotypes barley varieties already grown on farm; their names or crosses are reported in Table 3.4.1.

All plots were fertilized with 50 and 80 kg/ha of P_2O_5 in the form of triple superphosphate at the beginning of the 1987/88 and 1988/89 seasons respectively. Nitrogen fertilizers were not applied in either season. In Table 3.4.2 the results of both chemical and mechanical analyses are reported for every layer of the soil profile up to the depth of 1.2 m.

The profile was more than 1.5 m deep. The Total Available Water was 227 mm/m.

Rainfall at sowing time was adequate for germination for both seasons. Scheduling of supplemental irrigation was by water balance methods (Perrier and Salkini 1989) employing the Class A pan evaporation measurements, and verified using gravimetric soil samples and neutron probe measurements.

3.4.3 Weather Conditions 1987-89

Figure 3.4.1 shows mean temperatures on a 10-day basis for both seasons from the first period of November to the end of May.

Table 3.4.1 Names or crosses of the genotypes composing the pool under test at the Boueidar station during the 1987/88 and 1988/89 seasons

Name of Cross	Reference 1987/88	Reference 1988/89
Apm/PI 000046//Line 251-11-2	1	
Lignee 131/Arabi Abiad	2	
Menuet//Apm/PI 000046	3	
Arizona 5908/Aths//Lignee 640 (ICB81-0210-1AP-4AP-0AP)	4	
5604/1025//Arabi Abiad	5	
Arizona 5908/Aths//Lignee 640 (ICB81-0210-1AP-9AP-0AP)	6	1
Ctn/RM1508//10876-2/3/70-22423/B1	7	2
WI2198/Harmal-02	8	
Nacta/Arabi Abiad	9	
Sawsan/Lignee 527//Arar	10	3
Mv46/WI2198	11	
Arizona 5908/Aths//Asse/3/F208-74	12	4
Harmal-02/Arabi Abiad//ER/Apm	13	
Lignee 527/Sawsan//Bc	14	5
Lignee 1242/Arabi Abiad	15	
CN100/DC23//Fun*3/3/Tra/4/10925-1/5//Bco.Mr/As/6/Seed Source 72-S"	16	
WI2269/3/Mari/Roho//Row 134-73	17	
Mari/Aths*2/3/Apm/IB65//B6	18	6
Roho/Arabi Abiad	19	
INRA35-56-4/NK1467	20	
Esp/1808-4L//Harmal-02	21	
WI2269//CI 08887/CI05761	22	
Api/CM67//Mzq/3/Arabi Abiad*2	23	
Cr. 115/Por//Bc/3/Api/CM67/4/Man//Api/CM67	24	7
DL71/Beacon//Ore's'/3/11016-2/EB-OBS-E-72	25	
Aths/Lignee 686	26	8
NK1616/Comp.Cr.89	27	
Apm/DwII-1Y//Apm/IB65/3/Gitane	28	
SP(Gh)/Apro//Cal.mr/3/Apm/IB65//4/DL71/Strain 205	29	9
Aths/Bc	30	10
BKF Maguelone 1604/Badia//Arar	31	11
Bgs//MD ATL/CM-B-4-2-2-B-B/3/Arar	32	
Arizona 5908/Aths//H272/11012-2	33	
Mari/Aths*2//Ky63-1294	34	12
Bonus*2/Arabi Abiad	35	
Mari/Aths*2//Kantara	36	
Roho/Harmal-02	37	
WI 2291	38	13
WI 2269	39	
Arar	40	14
Rihane-03	41	15
Harmal	42	
Arabi Aswad	43	
Arabi Abiad	44	16

Bold names and crosses mean that the genotype has been selected for the second season

Table 3.4.2 Results of nitrate-nitrogen, extractable phosphorus and mechanical analysis of eight combined samples from the experimental field at Boueidar, 1988/89 season

Depth cm	NO_3 ppm	P (Olsen) ppm	Mechanical analysis % Clay	% Silt	% Sand
0-15	22.8	3.5	46.9	39.1	14.0
15-30	29.5	6.8	46.6	41.4	12.0
30-45	18.2	4.0	50.7	37.0	12.3
45-60	24.8	2.0	55.4	32.8	11.8
60-75	38.3	1.2	58.6	30.2	11.2
75-90	33.8	1.2	58.2	31.4	11.6*
90-105	32.6	1.2	88.4		11.6*
105-120	35.8	1.0	85.2		14.8*

* Presence of gypsum

Note: Sampling was carried out after ploughing.

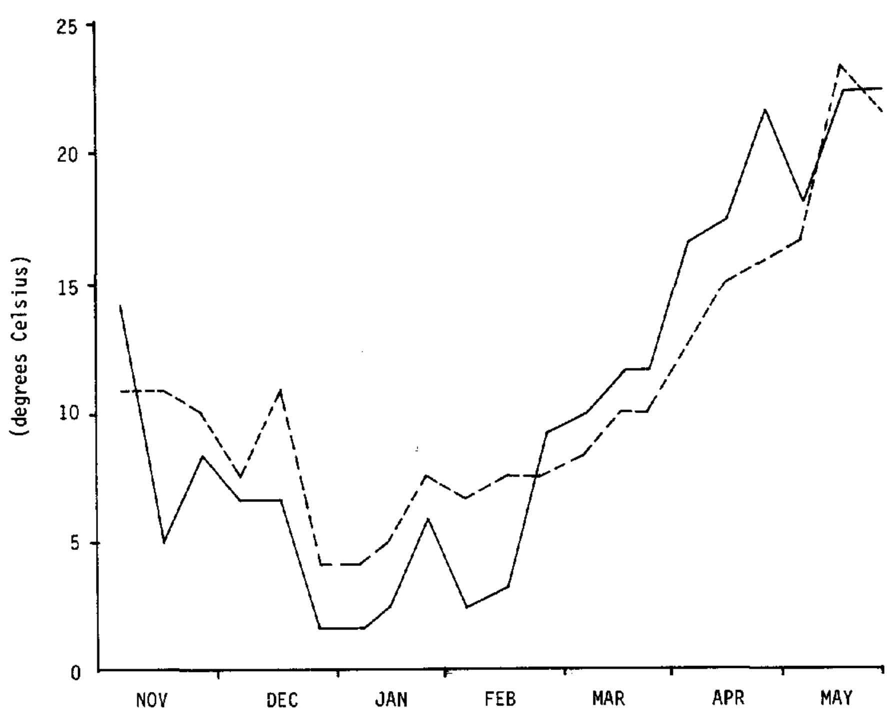

Figure 3.4.1 Mean temperatures during 2 seasons at Boueidar, N. Syria, 1987/88 (----), 1988/89 (——).

During the 1987/88 season relatively cloudy weather with the consequent reduction of irradiation caused relatively mild temperatures. Only 20 frost events were recorded and the crop developed rapidly. Ground cover occurred early in the season by the end of February.

The 1988/89 season was much colder with temperatures dropping below freezing point 59 days of which 53 were recorded during the period of December 19 to February 21. The cold season along with drought hindered normal plant growth. Full ground cover occurred only by the end of March.

Figure 3.4.2 shows the root:shoot pattern of growth relative to the 1988/89 season. This pattern is somewhat different to that described by Perrier (1989) for wheat at Tel Hadya, and is probably largely due to the cold season and the resulting delay of plant growth.

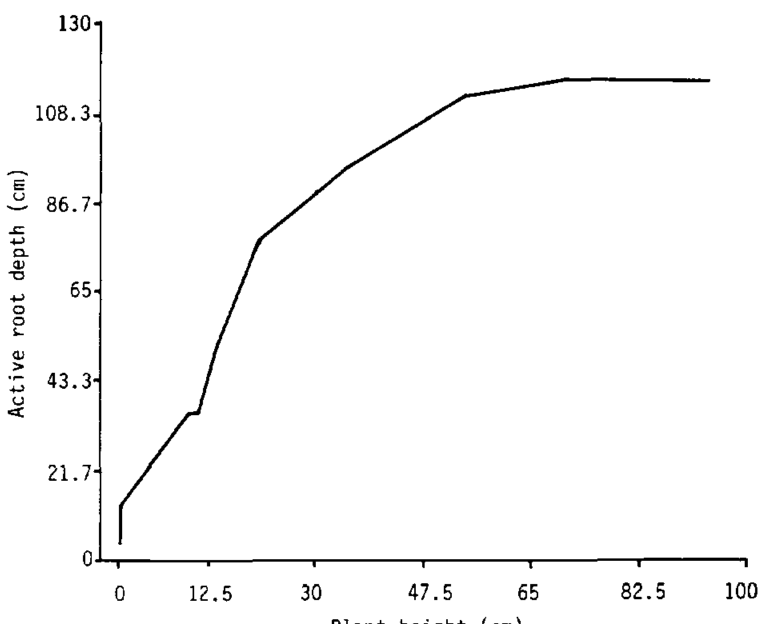

Figure 3.4.2 Relationship between active root depth and plant height of barley at Boueidar, N. Syria, 1988/89.

Monthly accumulated rainfall for both seasons is shown in Figure 3.4.3. This confirms that rainfall distribution is erratic in the region. The 1987/88 season totalled 385.7 mm of rainfall whereas the following season was only 186.4 mm. In the first season the rainfall distribution was good during both January and February and soil water availability, with relatively mild temperatures allowed the plants to grow without soil moisture stress. Rainfall started to decline during March and, the following months, two supplemental irrigations were needed to replenish the soil moisture in the active root zone.

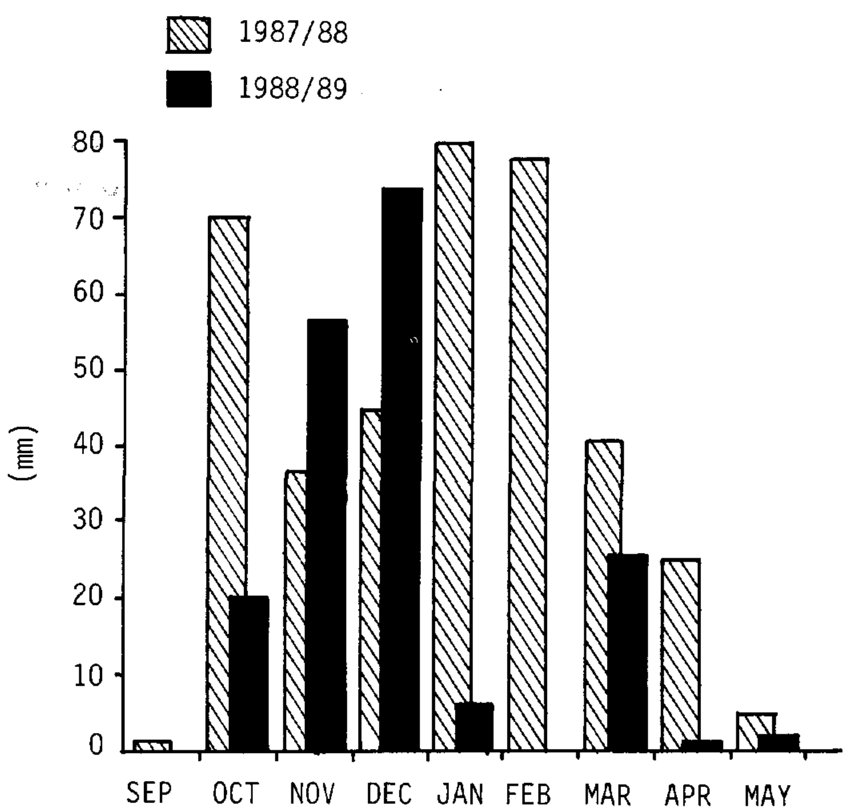

Figure 3.4.3 Monthly rainfall totals at Boueidar, N. Syria, over 2 seasons.

The following season was different: the rainy season started in October and ceased towards the end of March. However, two pronounced dry spells occurred. The first, a 23 day dry spell from November 20 to December 13 (7 mm accumulated rainfall) and the second a long drought from the beginning of January to March 12 (just 5.9 mm accumulated rainfall). These unusual droughts caused many failures of rainfed barley fields managed by farmers in the region. The experimental plots had to be supplementally irrigated early in the season. Five irrigations were applied starting as early as December. Table 3.4.3 shows the quantity of water applied and seasonal rainfall for each supplemental irrigation treatment during both seasons.

Table 3.4.3 Quantity of water (mm) applied and rainfall for the supplemental irrigation treatments for the 1987/88 and 1988/89 growing seasons at Boueidar

Irrigation levels	Rainfall	Supplemental irrigation	Total
1987/88			
Rainfed	385	0	385
1/3 replenishment	385	125	510
2/3 replenishment	385	125	510
3/3 replenishment	385	125	510
1988/89			
Rainfed	186	0	186
1/3 replenishment	186	177	363
2/3 replenishment	186	353	539
3/3 replenishment	186	523	709

During the first season and because of problems of water distribution, we were forced to irrigate balancing the volumes of water applied. Thus, the treatments I-1, I-2 and I-3 received respectively 30, 60 and 90 mm of water on April 29-30 and 95, 65 and 35 mm on May 10-11. In so doing, with the two irrigations the treatments received 125 mm each but scheduling of applications differed.

The pattern of water demand, relative to Class A pan evaporation and to the 1988/89 season, is shown in Figure 3.4.4, where the Crop Coefficient (kc) is plotted against days after emergence. This illustrates the increase in water demand that follows stem elongation.

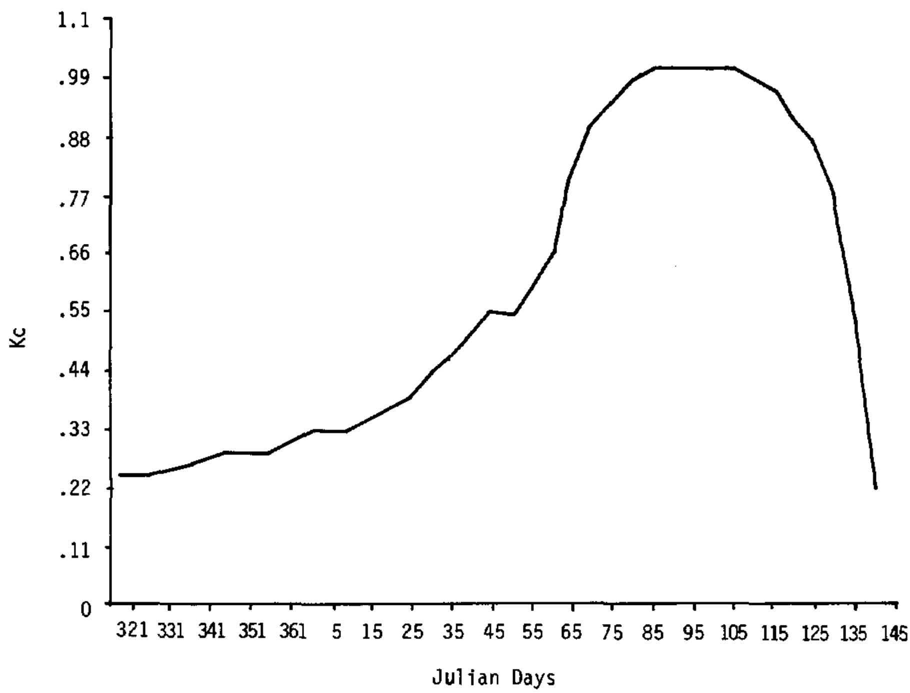

Figure 3.4.4 Seasonal variation of the barley crop coefficient (Kc) during 1988/89 at Boueidar, N. Syria.

3.4.4 Results of The First Season

The 1987/88 season was not a typical one at the site. The weather, problems of personnel and project management made it impossible to have reliable data concerning yields. Nonetheless, some data were collected about agronomic aspects that influence grain yield, such as the capacity to not lodge under higher water regimes, the weight of 1000 grains, the weight of seeds/ear, etc. These measurements allowed a first selection aimed at reducing the number of genotypes in the second year's experiment.

Those genotypes which were selected showed an appreciable response to supplemental irrigation and significant increases in the weight of seeds per ear and/or the weight of 1000 grains. Then, all which exhibited a high rate of lodging were also discarded. This characteristic results in a mechanical resistance to water flow in the stem and to a reduction in yield and quality (Briggs 1978; Day 1957). In addition lodging genotypes cannot utilize the irrigation water efficiently because of hindered photosynthesis. The remaining genotypes selected were those showing trends of increased yields and/or other factors that increase yield. A total of 16 genotypes were entered in the following season's trial.

3.4.5 Results of The Second Season

After harvest all the data needed to estimate the effects of the different supplemental irrigation treatments were measured (Biomass, no. of ears/m^2, weight of the ears, grain yield, 1000 grains weight, absolute protein and lysine contents) or calculated (Straw weight, no. of fertile spikelets/ear, water use efficiency).

The ANOVA calculations were carried out according to the following table:

Source of variation	D.F.
Replications	3
Supplemental irrigation	3
Error A	9
Barley entries	15
Interaction s.irr.*barley entries	45
Error B	180

Statistical analysis showed that all the supplemental irrigation treatments had a positive effect. The factors of yield, no. of ears/m2, no. of fertile spikelets/ear, and weight of 1000 grains, were related to the level of water applied (Figure 3.4.5). These characteristic increased yields accordingly. In Table 3.4.4 the mean yields for the different genotypes are reported for each supplemental irrigation treatment.

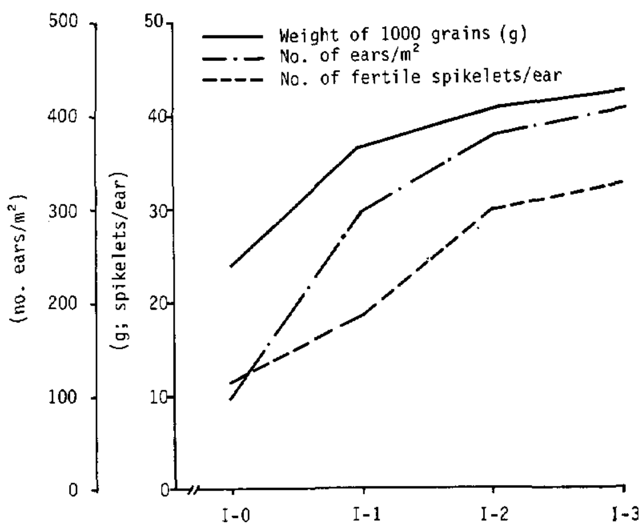

Figure 3.4.5 Determinants of barley grain yields at different levels of supplemental irrigation (see text) at Boueidar, N. Syria, 1988/89.

Table 3.4.4 Mean yields (t/ha) of the genotypes at different supplemental irrigation levels; weights are at field moisture content

Entry		Irrigation			
		I-0	I-1	I-2	I-3
1		0.17	1.48	4.25	5.89
2		0.21	1.60	3.71	4.32
3		0.27	1.66	4.00	4.92
4		0.18	1.75	5.00	5.65
5		0.19	1.54	4.22	4.73
6		0.19	1.36	3.99	5.04
7		0.22	1.74	3.73	4.55
8		0.30	1.98	4.69	5.41
9		0.30	1.83	3.91	4.77
10		0.26	1.61	4.55	5.37
11		0.18	2.13	3.94	4.93
12		0.31	2.11	4.27	5.00
13	WI 2291	0.29	1.81	4.39	5.42
14	Arar	0.23	2.45	4.29	4.37
15	Rihane-03	0.22	2.70	4.75	6.72
16	A. Abiad	0.54	2.12	3.98	5.11
Mean		0.26	1.89	4.25	5.17

LSD 0.05 = 0.74 between two irrigation means for the same entry mean
LSD 0.05 = 0.61 between two entry means at the same level of irrigation
LSD 0.05 = 0.45 between two irrigation means

These dramatic results was caused by the unusual drought during the year, and the consequent necessity of applying a greater volume of water than is normally required for supplemental irrigation at this location.

Grain yields of each genotype were increased significantly from I-0 to I-3 at the 5% significance level. However, genotypes 2, 4, 5, 8 and Arar did not respond to the highest level of irrigation.

The highest yielding genotype was Rihane-03. It recorded 0.22 t/ha under rainfed conditions all the way up to 6.72 t/ha for full replacement of the water deficit in the soil profile. Other good yielding genotypes were 1, 4, 8, 10 and WI 2291. Other genotypes had good responses to supplemental irrigation, but the magnitude of their yields was significantly different from higher yielding genotypes.

Differences between genotypes at the same level of irrigation are less recurrent and the analysis of the regressions of variable grain yield vs. total amount of water received (Figure 3.4.6) showed that only Rihane-03 had a significantly different behaviour in 5 comparisons out of 15. This means that the group of barley genotypes is nearly homogeneous with regard to supplemental irrigation response which is attributed to the first years selections. Another point was that all genotype materials were selected at the same site and all were selections from rainfed barleys.

The water use efficiency, WUE, (Bolton 1981; Cooper 1983) was computed as:

$$WUE = \frac{\text{Biomass (kg/ha)}}{\text{Total water (mm)}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (1)$$

where biomass is the total weight of the harvested plants (not including roots and crowns) and where the total water is the sum of the seasonal rainfall and the water applied by means of supplemental irrigation.

The WUE's are reported in Table 3.4.5 for each genotype and for all the supplemental irrigation levels.

In general WUE increases significantly from I-0 to I-2 where it reaches its maxima; then, it reduces significantly in I-3 where its value is similar to that of level I-1.

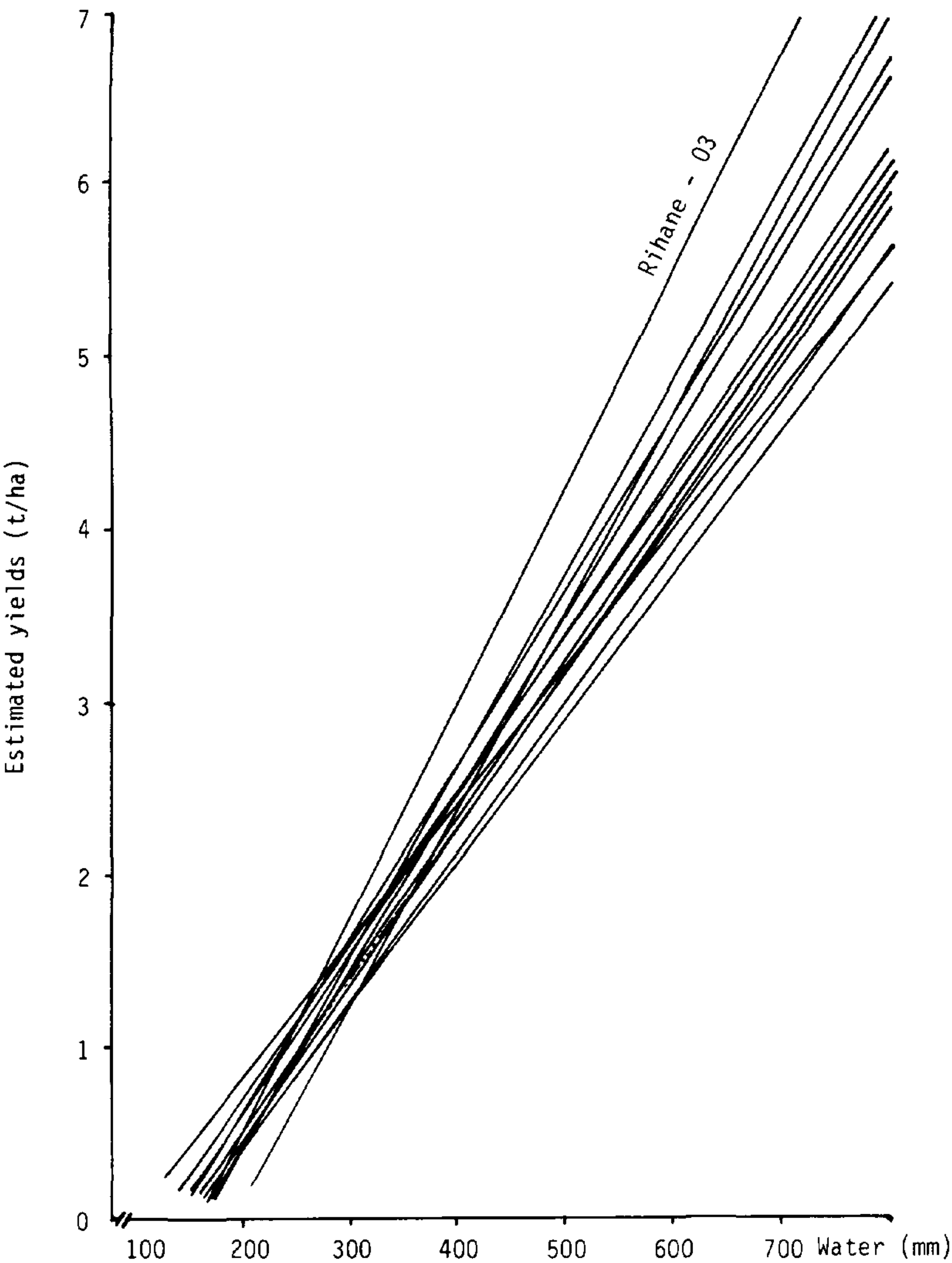

Figure 3.4.6 Linear regression of grain yield vs. total water.

Table 3.4.5 Water use efficiency indexes (kg/ha/mm) for the different genotypes and supplemental irrigation treatments

		Irrigation			
Entry		I-0	I-1	I-2	I-3
1		4.84	16.12	17.79	17.82
2		4.50	15.83	18.56	17.18
3		5.65	13.09	15.62	16.39
4		4.39	15.52	18.13	16.05
5		5.09	13.77	18.55	16.56
6		4.94	12.36	15.63	12.53
7		5.25	14.16	16.57	14.28
8		6.32	15.76	18.38	15.87
9		6.38	13.48	14.99	13.96
10		7.09	16.55	18.74	17.79
11		5.18	19.42	20.05	14.93
12		5.75	18.55	17.42	16.14
13	WI 2291	5.65	19.53	20.17	17.71
14	Arar	4.28	13.67	14.50	12.64
15	Rihane-03	5.61	17.51	19.81	17.72
16	A. Abiad	4.80	15.38	18.73	16.81
Mean		5.36	15.67	17.75	15.90

LSD 0.05 = 2.82 between two genotype means at the same level of supplemental irrigation;
LSD 0.05 = 2.93 between two supplemental irrigation means for the same genotype
LSD 0.05 = 1.08 between two irrigation means

The highest WUE were achieved by the genotypes 2, 4, 5, 8, 10, 11, 12, WI 2291, Rihane-03 and Arabi Abiad in irrigation I-2. However, Rihane-03 utilized the water to produce more grains than straw whereas the other genotypes had a different behaviour. In fact, computing

$$WUE = \frac{\text{Grain yield (kg/ha)}}{\text{Total water (mm)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

shows that Rihane-03 produced 1.18, 7.47, 8.84 and 9.57 kg/ha/mm of grain for the treatments I-0, I-1, I-2, and I-3, respectively. The difference between its WUE index in I-3 (computed according to equation (2)) and those of the other genotypes at the same level of irrigation are significant (i.e., LSD 0.05 = 1.43 between two means at the same level of irrigation), and shows that the last supplemental irrigation increased the grain yield factors more than straw weight. The number of fertile spikelets per ear was the main factor responsible for the yield increase, as it changed from 30 in I-2 to 39 in I-3 whereas the number of tillers/m^2 (no. of ears/m^2) and the weight of 1000 grains did not increase between I-2 to I-3.

Absolute grain protein content decreases with supplemental irrigation treatment from I-0 to I-3. In Table 3.4.6 the mean percentages of both protein and lysine contents are reported for each supplemental irrigation treatment.

<u>Table 3.4.6</u> Absolute contents of both protein and lysine in grains (%) (Mean of all genotypes)

Treatment	Protein %	Lysine %
I-0	17.68	0.65
I-1	16.19	0.61
I-2	14.60	0.56
I-3	14.55	0.56

LSD 0.05 = 0.49 between two irrigation means for protein
LSD 0.05 = 0.01 between two irrigation means for lysine

Protein quality is stable with a slight tendency to increase from I-0 to I-2.

The lysine to protein ratios are reported in Table 3.4.7 for the supplemental irrigation treatments. Both protein and lysine absolute contents decrease with increasing application of supplemental irrigation, but lysine changes at different rate then protein, in other words, its rate of reduction is less.

Table 3.4.7 Lysine to protein rations (%). (Mean of all genotypes)

Treatment	%
Rainfed	3.68
1/3 replenishment	3.78
2/3 replenishment	3.87
3/3 replenishment	3.86

LSD 0.05 = 0.05 between two means

Even if the absolute protein content decreases, a big increase in the total weight of protein yielded occurs, resulting, of course, from increased yields. Table 3.4.8 reports the mean kilograms of protein yielded for each supplemental irrigation treatment.

Table 3.4.8 Weights of grain protein yielded (kg/ha). (Mean of all genotypes)

Treatment	Protein
Rainfed	44.69
1/3 replenishment	302.29
2/3 replenishment	617.40
3/3 replenishment	747.40

LSD 0.05 = 66.34 between two means

Straw is an important agricultural by-product especially in those areas were barley straw provides a resource to feed livestock. In Table 3.4.9 the tonage of straw harvested is reported for each genotype and supplemental irrigation treatment.

Table 3.4.9 Mean straw yields (t/ha) of the genotypes at different supplemental irrigation levels

Entry		Irrigation			
		I-0	I-1	I-2	I-3
1		0.47	2.92	3.96	5.67
2		0.45	2.90	4.77	6.34
3		0.55	2.30	3.74	5.50
4		0.44	2.48	4.01	4.95
5		0.56	2.66	4.74	5.73
6		0.39	1.94	3.32	3.71
7		0.42	2.31	3.76	4.78
8		0.41	2.42	4.06	5.00
9		0.59	2.03	3.50	4.68
10		0.68	2.79	4.44	6.41
11		0.55	3.82	4.83	5.18
12		0.39	2.75	3.65	5.25
13	WI 2291	0.55	3.27	5.05	6.26
14	Arar	0.31	2.07	3.34	3.96
15	Rihane-03	0.56	2.99	4.51	5.34
16	A. Abiad	0.19	2.31	4.30	5.62
Mean		0.47	2.62	4.12	5.27

LSD 0.05 = 0.77 between two irrigation means for the same entry mean
LSD 0.05 = 0.73 between two entry means at the same level of irrigation
LSD 0.05 = 0.30 between two irrigation means

These results are similar to those for grain yields. The increase in straw production is due to the height of the plants and to the increased number of tillers per square meter.

The increase in straw weight does not match the trend of the grain yield, i.e., Rihane-03 was the top yielding genotype concerning grain, however, it produces a lower quantity of straw with supplemental irrigation.

Absolute protein content of straw (Table 3.4.10) decreases significantly from I-0 to I-2, but the further small decrease is observed in I-3 was not significant.

Table 3.4.10 Absolute protein content in straw (%). (Mean of all genotypes

Treatment	Protein
Rainfed	10.83
1/3 replenishment	7.61
2/3 replenishment	6.27
3/3 replenishment	5.74

LSD 0.05 = 0.77 between two means

Thus, absolute protein content decreases also in straw; but, due to the remarkable increase in straw yield, the total weight of protein yielded clearly increased as a result of supplemental irrigation.

3.4.6 Conclusions

Drawing conclusions from the data collected during the second year of experimental work should be done with some caution as the results are of course affected by the characteristics of the season which in this case was particulary dry. However, we can observe the following:

- All the barley genotypes responded well to additional water applied by supplemental irrigation treatments.

- Rihane-03 gave the best response to water. Its increased yield was due to the increased number of grains per head and not to the number of tillers per square meter. This means that, in selecting barley's genotypes for supplemental irrigation research, the criterion of taking only good tillering genotypes could result in some potential material being lost.

- The other genotypes all responded to the different levels of supplemental irrigation but, having all been selected at the same site (Boueidar), they did not show differences in responses. Thus, introduction of new genetic materials coming from sites where rainfall ranges are different should be taken into consideration and it could be much more advantageous to increase barley yields in the considered region.

3.4.7 References

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3.5 Productivity of Crop Rotations

H. Harris

ICARDA is developing technologies for the improvement of food production in the dry winter rainfall areas of North Africa and West Asia. Of necessity, much of its work is organized along lines of commodity and disciple. However it is a feature of the Center that it is recognized that there is a need to draw together work on individual commodities and of individual disciplines and to evaluate research findings in relation to the farming systems with which the Center works. This is particularly important in the light of the variability of environmental conditions, especially those which relate to seasonal weather. It was thus felt that it was necessary that new technologies should be tested by the Center, over time, to determine their potential productivity.

To achieve this objective two-course rotations were established in the 1983-84 season on land that had been under cereal-based rotations from 1977-78. Seven cropping sequences, namely wheat following fallow (W/F), summer crop (W/SC) (water melon), lentil (W/L), chickpea (W/C), vetch (Vicia sativa) (W/V), medic (Medicago spp.) (W/M), and wheat (W/W), are replicated three times, and both phases of the rotations are included each year. Individual plot size is 0.54 ha, and each rotation therefore covers 3.24 ha. These rotations provide the opportunity for new systems to prove their worth in the variable conditions of the region.

The soil is a Calcic Rhodoxeralf (Harmsen 1980) and the trial is sited on sloping land. In most of the area the soil is 1 to 2 m or more deep, but there are areas where the depth is variable with some patches with less than 0.5 m of soil.

In the first two years no inputs were used, but from the 1985-86 season fertilizer, and weed, pest and disease control measures have been applied, and improved cultivars introduced. Two experimental treatments are superimposed in a split-split plot design. Four levels of nitrogen (0, 30, 60, and 90 kg N/ha) are applied to sub-plots in the wheat phase for the dual purpose of assessing the long term reliability of nitrogen responses and evaluating the capability of the legumes to supply nitrogen to the systems. The wheat stubble is subject to three management treatments - heavy grazing, moderate grazing or stubble retention - which form the sub-sub-plots.

Here we report findings on the performance of the rotations and on the effects of nitrogen in four crop seasons, 1985-86 to 1988-89 inclusive. Some trends appear to be emerging in the stubble treatments, but we prefer to defer discussion of these until they are more clear.

3.5.1 Trial Management

Tillage. Since 1987-88, primary tillage in the wheat phase is carried out with a tyned cultivator after the first rain of the season, and this is followed by a pass with a spike-toothed harrow for seed bed preparation.

Planting. In the first two seasons (1985-86 and 1986-87) the traditional method of broadcasting seed on to ridged land and covering it by splitting the ridges was used. However this results in poor crop geometry with widely spaced (48 cm), dense bands of plants giving insufficient ground cover, especially early in the season. Therefore in the last two seasons seed has been drilled, wheat with a locally built seed drill at 17.5 cm row spacing following seed bed preparation as above, and legumes (vetch, lentil and chickpea) with a zero till planter directly into wheat stubble at 30 cm row spacing. Medic seed was broadcast in 1983 and 1984 and now pastures regenerate annually. Water melon, which is grown in the summer on water stored in the profile during winter, is established as single plants on a 3 x 3 m grid according to local practice.

Wheat and the legumes normally are planted in the second half of November and early December respectively, following the opening rains, and water melon is sown in mid-April on land that is fallowed to that time. Seeding rates are: wheat, chickpea and vetch, 120 kg/ha; lentil, 100 kg/ha; melon, 1.5 kg/ha.

Cultivars. The improved durum wheat, Sham 1, has been used throughout the four years. ILC 482, a cold tolerant chickpea cultivar with tolerance for aschochyta blight, now released in Syria as Ghab 1, was selected for the early sowing strategy used in the trial. Syrian local small lentil, used for the first two years, was replaced by a newly released cultivar, Idleb, in

1987-88. The vetch and water melon are both strains used locally. A mixture of medic species and cultivars was sown originally, with the objective of studying their population dynamics. The pastures are now dominated by Medicago polymorpha and M. rigidula (P.S.Cocks, personal communication).

Fertilizer. Phosphate fertilizer was broadcast over the whole area in the first two years at 60 and 90 kg P_2O_5/ha respectively to raise the fertility level. It is now drilled with the wheat at 50 kg P_2O_5/ha. The nitrogen is hand broadcast, half at planting and the remainder at the tillering stage of wheat growth.

Crop Protection. Weed Control. In the wheat phase bromoxynil + MCPA and diclofop-methyl are applied when necessary at the tillering stage to control broadleafed and grassy weeds respectively. Pre-emergence herbicides are used for the food legumes, terbutryn and cyanazine for chickpea, and pronamide and cyanazine for lentil, following, if necessary, a contact herbicide (paraquat) to control cereal volunteers prior to planting. Vetch and medic are grazed and no other weed control is imposed. Fallows are maintained weed-free either by cultivation with a tyned implement or by the use of paraquat and/or glyphosate.

Crop Protection. Pest and Disease Control. Seed dressing is used routinely for all species, and furadan is drilled with lentil to control sitona weevil lavae. Insect and rodent populations are monitored and controlled as necessary. An outbreak of aschochyta blight in chickpea in 1987-88 was treated with the fungicide, chlorothalonil.

Grazing Management. Medic pastures are grazed throughout the year for as long as they will support 8 to 10 ewes (and lambs) per hectare. Vetch is also grazed and is used to fatten weaner lambs in the spring.

Yield Determination. Approximately 20% of the plot area of wheat and chickpea is harvested with a plot combine to determine grain yield, usually in the first half of June. The harvest index is estimated from 20 x 1 m row samples per sub-plot and total dry matter and residue yields are estimated from the grain yield and the harvest index. The same proportion of lentil plots is hand harvested (late April/early May), dried and threshed and seed and residue yields are measured. All yields are reported as oven-dry weights. The 'yield' of the vetch and of medic pastures is estimated as grazing days per year (number of days x stocking rate) and as animal products.

3.5.2 Seasonal Conditions

Total seasonal rainfall in the first two years was equal to the long term average (Figure 3.5.1), while in the third and fourth years it approached the upper and lower extremes, respectively, for the area. The intra-seasonal distribution was more favourable in 1985-86 than in the following year, with rain in April and May. In 1986-87 the rain which fell in September and October was followed by a six week dry spell and was largely ineffective. In both years crops did not fully establish until rain in late December promoted final germination. Excellent October rain in the next two seasons allowed early establishment of wheat and medic, and of the other legumes in 1988-89. However in 1987-88 sowing of vetch, lentil and chickpea was delayed by wet conditions until early January. In 1988-89 there was only one effective rain event after December, and the January and February rainfall total was estimated to be a 1 in 200 years low (W. Goebel, personal communication). Rainfall in May was too late to have any effect on yields.

The most significant temperature events on the four years were the long cold spell, associated with low air humidities, in

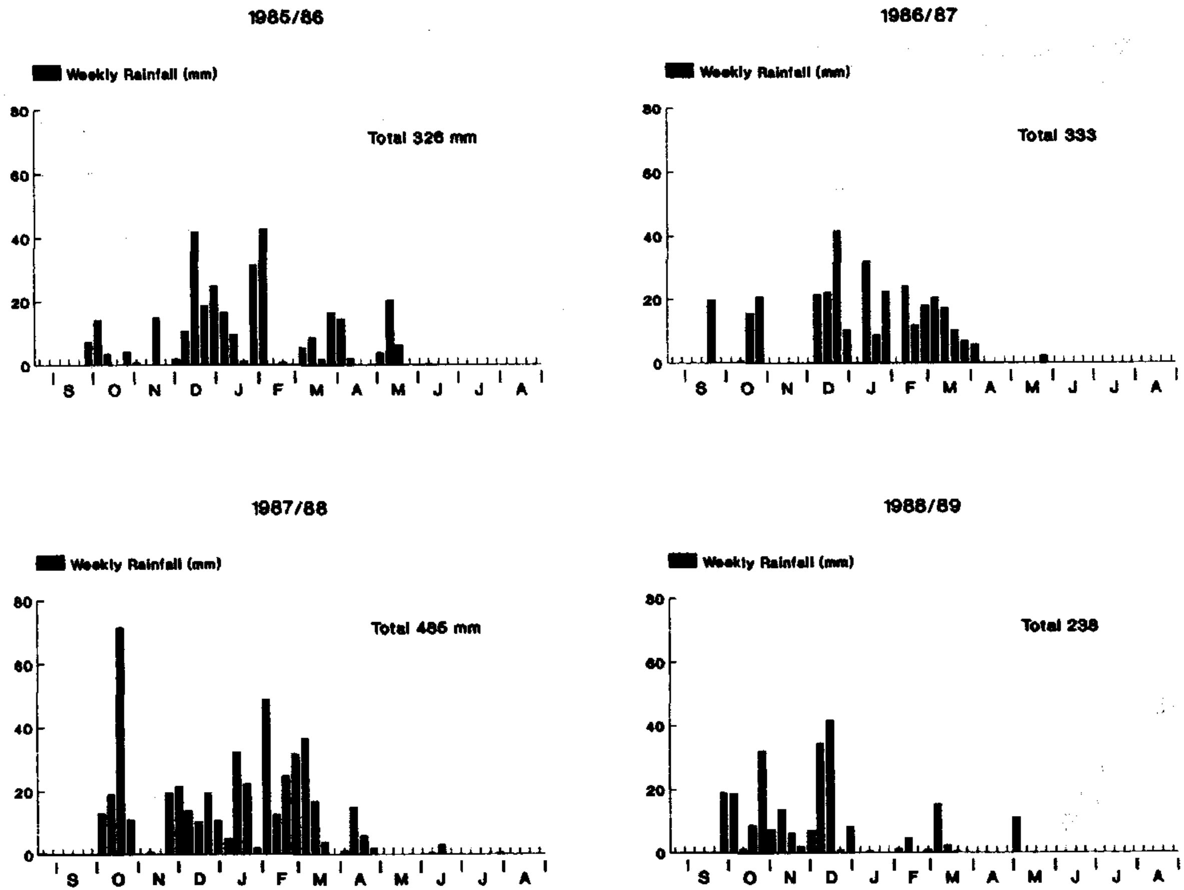

Figure 3.5.1 Weekly and total seasonal rainfall (mm) on Block C, Tel Hadya, 1985-86 to 1988-89.

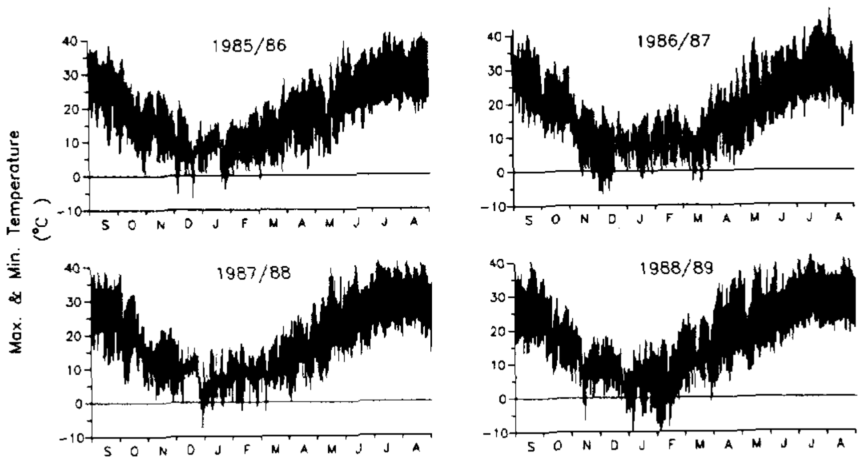

Figure 3.5.2 Daily maximum and minimum temperatures at Tel Hadya Meteorological Station, 1985-86 to 1988-89.

January and February of 1989, and a relatively cool period in May of 1986 (Figure 3.5.2).

3.5.3 Crop Yields

Wheat. Mean wheat grain yields have varied with seasonal conditions from 0.83 t/ha in the dry year to 3.62 t/ha in 1987-88 (Figure 3.5.3). The difference between 1985-86 (2 t/ha) and 1986-87 (1.5 t/ha) was due to rain in May in the first year which not only relieved water stress in some measure, but also was accompanied by relatively cool temperatures. Growing conditions were excellent for most of the season in 1987-88. Although temperatures above 35°C in mid-May (Figure 3.5.2) no doubt shortened the grain-filling phase of crop growth, the yields of 4.5 to 5 t/ha of fertilized crops following fallow, melon, vetch and lentil can be considered as approaching the potential of the cultivar for rainfed conditions in the environment. The extreme drought of 1988-89 was somewhat mitigated by the fact that the previous year was exceptionally wet, and the yield of several rotations was, in fact, better than the conditions of the season could otherwise have produced.

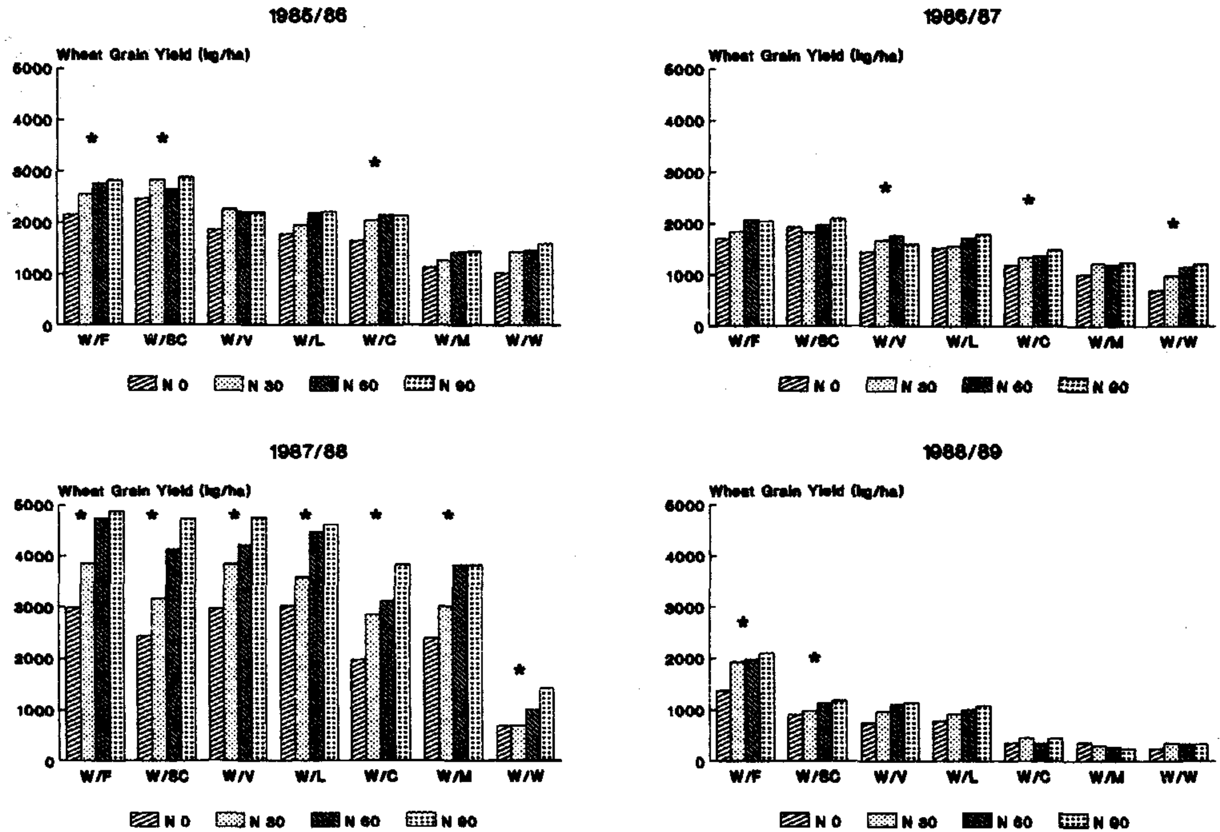

Figure 3.5.3 Grain yields of durum wheat (kg/ha) in seven two-course rotations at Tel Hadya, 1985-86 to 1988-89. See text for key to x axis legend. * signifies a statistically significant effect of nitrogen within the rotation ($P \leq 0.05$).

The crop sequence has a strong and virtually consistent influence on the yield of total biomass and grain. The ranking according to the preceding phase is fallow $\geq$ melon > vetch $\geq$ lentil > chickpea > medic $\geq$ wheat (Figures 3.5.3 and 3.5.4). Exceptions occurred only in the wet year, 1987/88, when grain yields following vetch and lentil did not differ from those after fallow, and those following medic and chickpea were equal. In the same year the continuous wheat plots were decimated in January by a severe infestation of lavae of the wheat ground beetle, Zabrus tenebroides. The plots were resown when the weather permitted in early March and yielded poorly.

As the results for the wet year indicate, some of the ranking can be explained almost entirely by the water balance of the rotations. More detail on this is given in the next section. It is now recognized that there has been a build up of root knot nematodes in the wheat-chickpea rotation and joint studies with FLIP to be commenced in the 1989-90 season will attempt to quantify their impact on wheat yields. Wheat following medic or wheat lacks vigour, but the reasons for this remain obscure. The suspicion that root pathogens may be the cause of the decline in the continuous wheat was not confirmed by critical studies (Krause 1988). Detailed growth analyses of wheat following medic (Smith 1989; Harris, unpublished data) show that from the outset of growth plants are smaller and have fewer tillers than when the crop is preceded by fallow. Further work to try to identify the cause is planned for the 1989-90 season.

Total dry matter of wheat following fallow or summer crop (water melon) has been increased by nitrogen application (Figure 3.5.4) in each year. There has also been a response following all of the legumes in three of the four years, although not always in the same year. There is nothing in the data that would suggest that the legumes contribute significant amounts of nitrogen to the

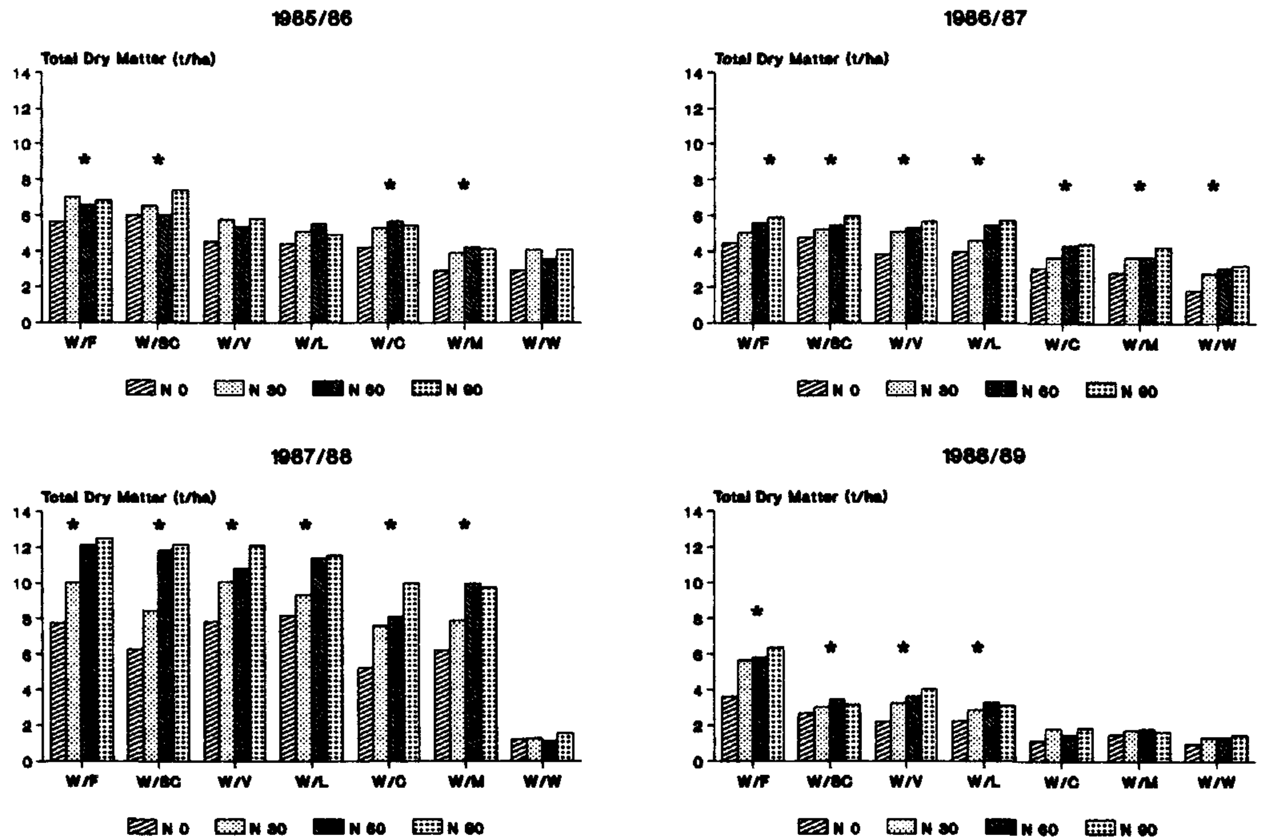

Figure 3.5.4 Total dry matter (t/ha) of durum wheat in seven two-course rotations at Tel Hadya, 1985-86 to 1988-89. See text for key to x axis legend. * signifies a statistically significant effect of nitrogen within the rotation ($P \leq 0.05$).

following wheat crops. However, in the winter of 1988-89 wheat after medic showed no N deficiency symptoms whereas deficiencies were clearly visible in all of the other rotations at zero and low N application rates. This suggested that there may have been a buildup of N following the third cycle of medic pasture but the effect was negated by the drought. Nitrogen balance studies with ^{15}N were begun in 1988-89 (D. Beck, personal communication) and what is hoped will become routine start-of-season soil sampling will be implemented from 1989-90.

There was an overall response of grain yield to 30 kg N/ha in 1985-86 and 1989-90, and to 90 kg N/ha in 1988-89. Crops following fallow, melon and chickpea most consistently show a statistically significant response in grain yield (Figure 3.5.3). In the first two of these rotations undoubtedly greater availability of water allows the response to be expressed in grain yield. Trends following the other legumes are similar to those after chickpea, and it is perhaps by chance that only those for chickpea reach statistical significance. Coefficients of variation for the trial are quite high, due mainly to the variable soil depth and hence variable water availability in some plots. Because of the location of plots the results for 1986-87 and 1988-89 are most affected.

It is apparent from these data that the yield depression in the wheat/medic and continuous wheat rotations is not due to nitrogen nutrition as the response is proportionally no greater in these than in other rotations. Soil phosphate concentrations in the trial area are above the critical level at which a response can be expected (A. Matar, personal communication).

Food Legumes. Seed yield of the legumes has been relatively stable, except in the drought year (Figure 3.5.5). Failure of these crops to respond to the good season in 1987-88 was due to

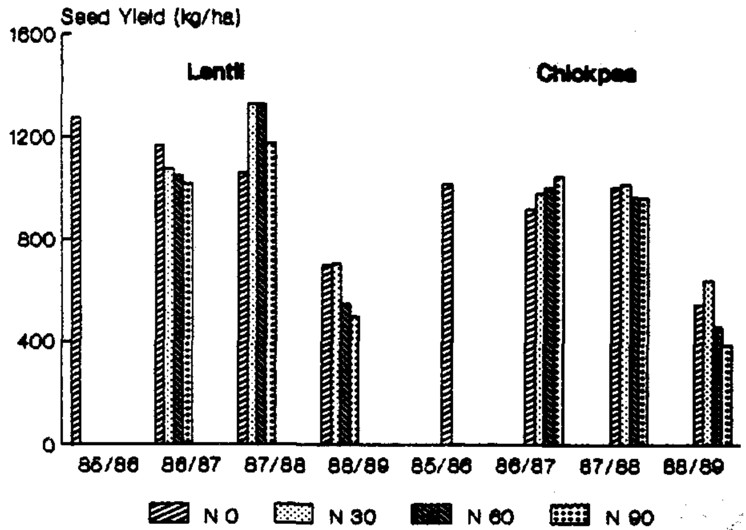

Figure 3.5.5 Seed yield (kg/ha) of lentil and chickpea grown in rotation with wheat at Tel Hadya, 1985-86 to 1988-89. (Indicated N levels were applied to previous wheat crop.)

the delayed sowing. Cold and very wet conditions during establishment lead to inferior plant stands and this is reflected in yields.

Lentil has responded negatively to nitrogen applied to the preceding wheat crop in each year, although in 1987-88 there was first a positive response to the residue of 30 and 60 kg/ha. The most likely explanation is that crops following heavily fertilized wheat suffer more moisture stress (see next section). Similar trends are apparent in the seed yield of chickpea but here the nematode infestation noted above also has affected yield to an unknown degree. Plans are in hand to quantify losses due to nematodes in the next season.

Vetch. Grazing of vetch normally begins in early March when lambs are weaned, and continues for as long as the lambs are gaining weight. At stocking rates of 25 to 30 head per hectare the period of grazing has varied from 7 to 13 weeks depending on the season. Total liveweight gain has varied from about 250 to 350 kg/ha (Table 3.5.1).

Table 3.5.1 Grazing days and live weight gain (kg/ha) of lambs grazing forage vetch in two course rotations at Tel Hadya, 1985-86 to 1988-89

Season	Grazing Days [1]	Liveweight Gain kg/ha
1985-86	2212	292
1986-86	2165	350
1987-88	1510	361
1988-89	1270	246

[1] Number of lambs x days of grazing

It is not normal farmer practice to use vetch in this way. It is normally harvested at maturity and both the seed and residue are stored for feeding in the late autumn and winter which is the main period of feed deficit. However its potential for the fattening of lambs was identified by farmers during farmer-managed on-farm trials in the drier areas (Thomson 1988).

Medic. Medic pastures have established well in each year and since uniform grazing management has been introduced have fully supported sheep for periods of from 4.5 to 9.5 months (Table 3.5.2).

Grazing has normally begun in late November or early December and except for short, very cold and wet periods, has continued into the late spring and summer. In 1988 sheep grazed throughout the summer. Early grazing comprises largely volunteer wheat and

Table 3.5.2 Grazing days, liveweight gain of lambs (kg/ha) and milk production of medic pastures in two course rotations at Tel Hadya, 1986-97 to 1988-89

Season	Stocking rate (ewes/ha)	Grazing days		Liveweight gain of lambs (kg/ha)	Milk production (kg/ha)
		Ewes	Lambs		
1986/87	10	1410	-	na [1]	na
1987/88	10	2850	980	258	200
1988/89	8	1320	448	113	104

[1] Not available

weeds, providing effective weed control, and by about early February the stands comprise virtually pure medic.

Water melon. The harvested yield of water melon ranged from 2.0 to 3.5 t fresh fruit/ha in the first three seasons. However, this cannot be taken to represent the productivity of the crop as we harvest only those fruit not stolen by workers on Tel Hadya. There was insufficient stored water to plant in 1988/89.

3.5.4 Water Balance of Rotations

Neutron probe access tubes are installed permanently in the N_0 and N_{90} treatments in two replicates of the wheat/fallow, wheat/chickpea and wheat/medic rotations to monitor the water balance.

The data are illustrated as 'stored soil water' or water use. Stored soil water is calculated as the change from the amount of water present at the first sampling of the season. Negative values therefore indicate either water stored in the profile throughout the summer that is subsequently taken up by a crop, and/or that there was rain before the first sampling. This treatment of the data avoids the ever present problem in soil water measurement of inherent apparent differences in the water content of profiles due to highly localized soil variability (Harris 1989).

Cumulative water use and the pattern of stored soil moisture accumulation and use during the three seasons are shown in Figure 3.5.6. Maximum storage occurred in mid-February in 1987, at the end of March in 1988, and in mid-January in 1989. The maximum quantity stored in 1988/89 was not much less than in 1986/87, but in 1986/87 the maximum was maintained for much longer. Fallow-stored water used by the following wheat crop ranged from 25 mm in 1986-87 to 40 mm in 1987-88 and 170 mm in 1988-89 or 8, 12, and 35 percent of the rainfall of the previous season. The amount of water available from the fallow for 1987-88 probably was not of significance to the final yield as there was also drainage through the profile in that year (Figure 3.5.7). However in 1988-89 almost half of the total amount used by the crop was stored water (Figure 3.5.8). The efficiency of fallows is quite variable and is largely related to the depth of wet soil, storage being much more efficient below 30 cm in the soil profile.

Nitrogen application increased the total amount of water used by the wheat. This is illustrated by soil water profiles for wheat in 1987/88 after fallow at the two levels of N (Figure 3.5.7). Fertilized crops extracted more water from greater depth in the profile due no doubt to improved root growth (Brown et al. 1987; Cooper et al. 1987).

Both of these legumes dry the profile to about the same extent as wheat, with the medic apparently extracting a few more millimeters than chickpea (Figure 3.5.6). This is further illustrated for the two extreme seasons in Figure 3.5.8. In rotations with these legumes therefore the crops of each phase

A)

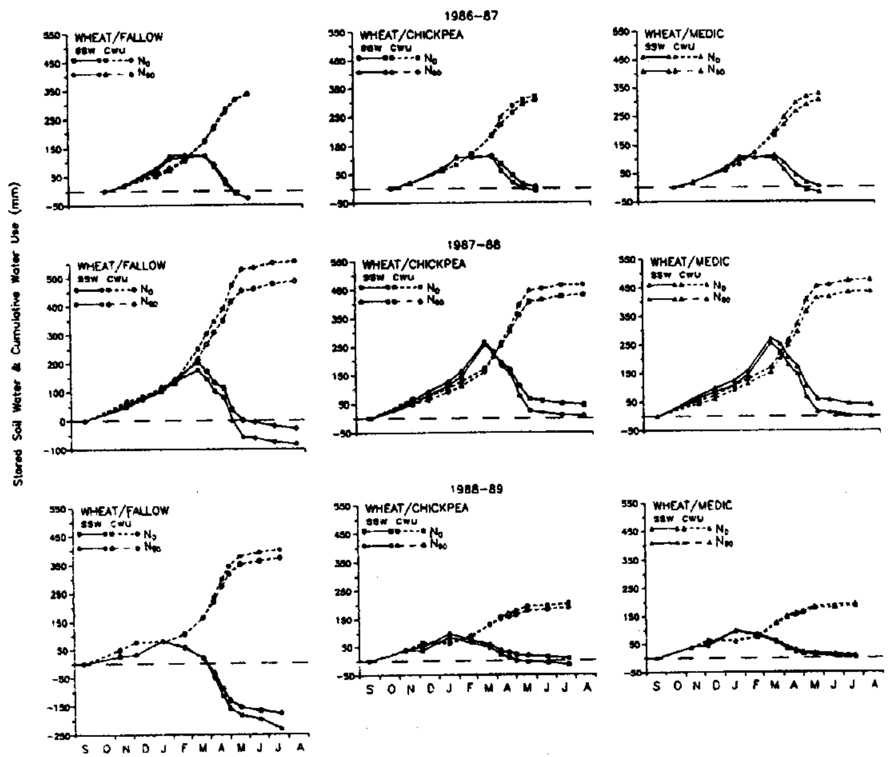

Figure 3.5.6a Seasonal patterns of stored soil water (SSW) and cumulative water use (CWU) at two nitrogen fertilizer levels (0 and 90 kg N/ha) in three rotations at Tel Hadya, 1986-87 to 1988-89. See text for explanation of negative values of stored soil water. A) Wheat phase B) Non-cereal phase. Cumulative rainfall is shown on the central plot of Fig. 3.5.6B.

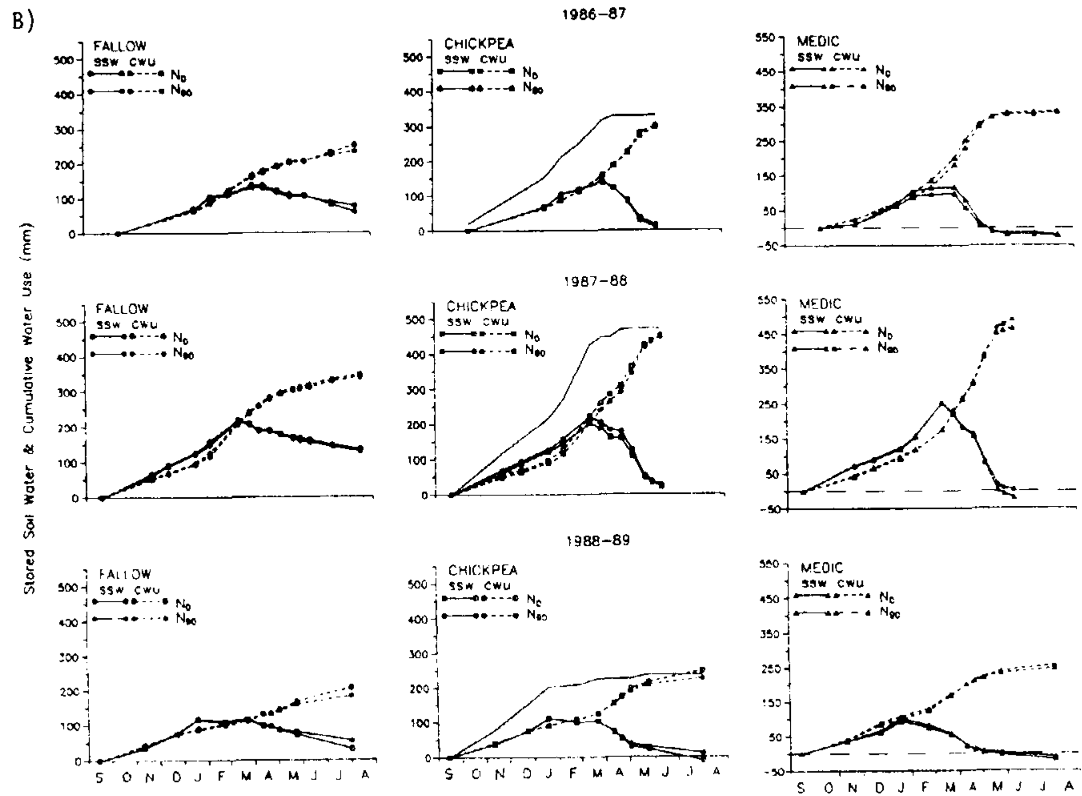

Figure 3.5.6b Seasonal patterns of stored soil water (SSW) and cumulative water use (CWU) at two nitrogen fertilizer levels (0 and 90 kg N/ha) in three rotations at Tel Hadya, 1986-87 to 1988-89. See text for explanation of negative values of stored soil water. A) Wheat phase B) Non-cereal phase. Cumulative rainfall is shown on the central plot of Fig. 3.5.6B.

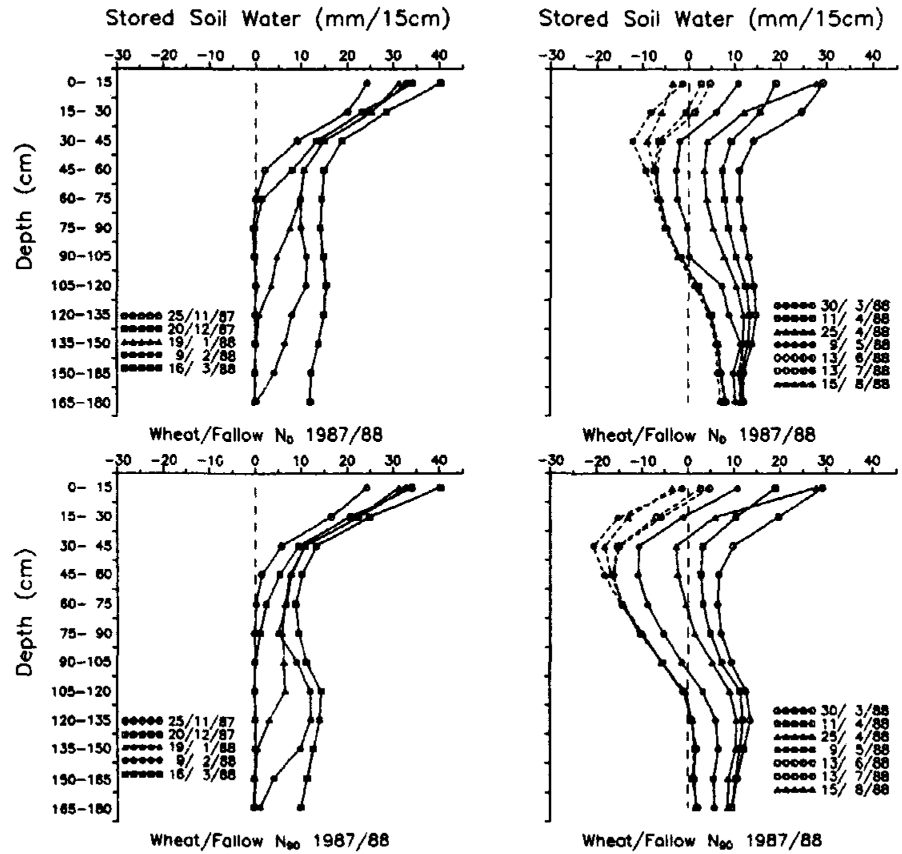

Figure 3.5.7 Soil water profiles during recharge (left) and discharge (right) under a durum wheat crop grown with two levels of nitrogen fertilizer (0 and 90 kg N/ha) in 1987-88 following fallow.

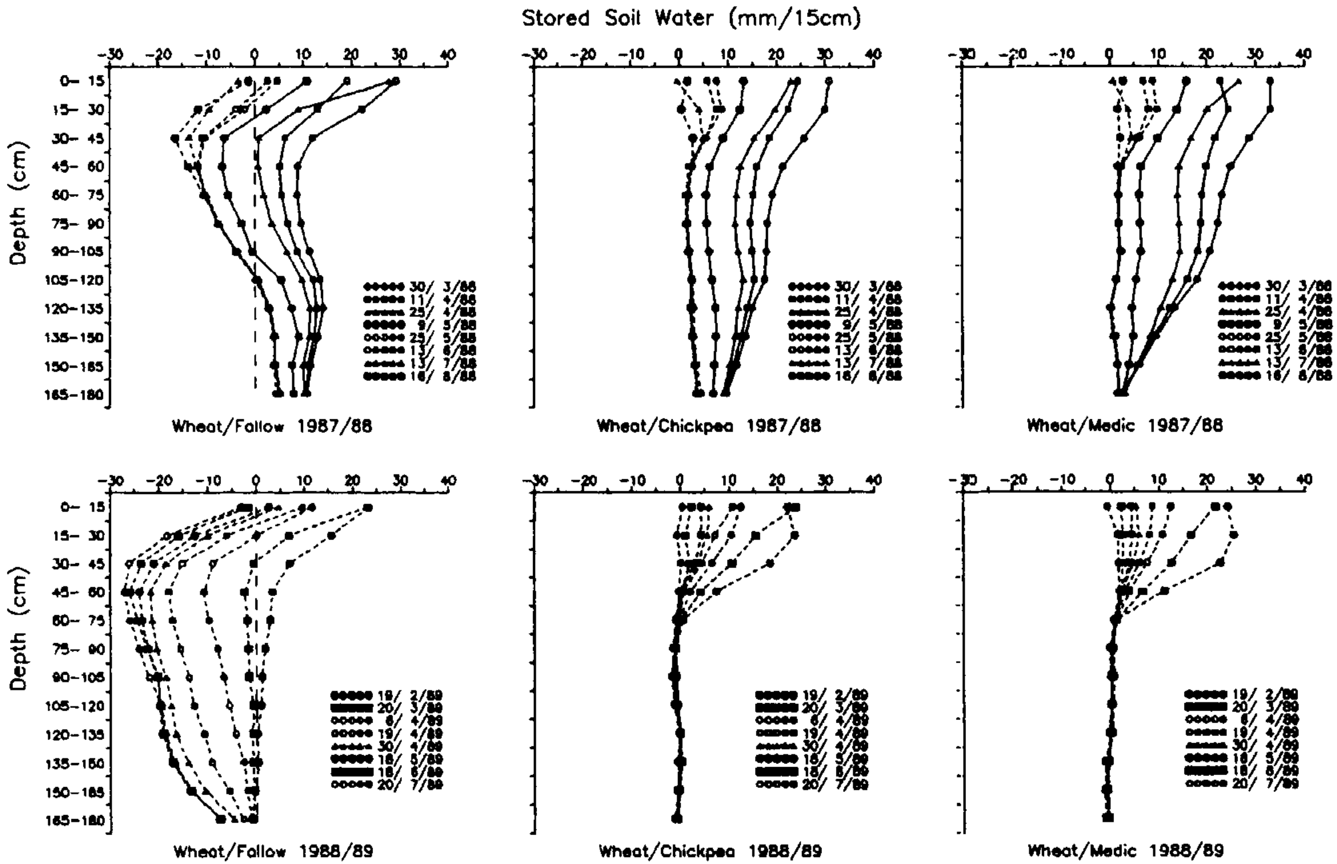

Figure 3.5.8 Soil water profiles during discharge in two contrasting seasons. The line on the right in each plot is the maximum storage profile for the season. The crop is durum wheat.

have available to them only the water from the current season's rainfall. This contrasts with our observations in a wheat/lentil rotation trial elsewhere on Tel Hadya (Harris and Pala 1988) which show water remaining in the profile after short season lentil crops that is used by the following wheat crop. The relative yields of the rotations in this trial lead us to infer that here too a similar situation exists after lentil, vetch and water melon.

The water use efficiency (WUE, kg/ha/mm) of wheat was greatest in the wet year, is greater for W/F than for either the W/C or W/M rotations, and is increased by N fertilization (Table 3.5.3). However it must be borne in mind that in a W/F rotation land is cropped only every second year.

Table 3.5.3 Water use efficiency (kg/ha/mm) of above ground biomass and grain production of durum wheat as influenced by rotation, nitrogen fertilizer application and season

Season	Nitrogen (kg/ha)	Wheat/Fallow		Wheat/Chickpea		Wheat/Medic	
		WUE_B[1]	WUE_G[1]	WUE_B	WUE_G	WUE_B	WUE_G
1986/87	0	13.3	5.1	10.0	3.9	9.2	3.3
	90	17.6	6.1	13.8	4.6	13.0	3.8
1987/88	0	16.8	6.5	12.7	4.8	14.9	5.7
	90	23.3	9.1	21.6	8.4	21.2	8.3
1988/89	0	10.3	3.9	6.0	1.8	8.5	2.0
	90	16.8	5.5	10.3	2.5	8.8	1.4

1. WUE_B, Biomass; WUE_G, Grain.

Above ground biomass and grain yields are closely related to total water use, which, in both parameters, accounts for 85% of the variation across rotations, nitrogen treatments and seasons

(Figure 3.5.9). The difference in the slope of the line for fallow from those for the other rotations reflects the differences in water use efficiency of Table 3.5.3, but is not statistically significant, the lines each being based on only six data points.

The water use of the remaining rotations (W/SC, W/V, W/L, and W/W) predicted from the relationship for fallow in Figure 3.5.9, together with estimates of water use efficiency are shown in Table 3.5.4. These data suggest that from 60 to 100 mm of extractable water remained in the soil after melon, vetch and lentil in 1987-88, which seems quite feasible from our measurements in other trials. However, the estimates for the other two years are generally lower than would be expected, and the data need to be treated with considerable caution.

Table 3.5.4 Estimated crop season water use (mm) and water use efficiency (kg/ha/mm) of total biomass production of durum wheat in wheat/water melon (W/SC), wheat/vetch (W/V), wheat/lentil (W/L), and wheat/wheat (W/W) rotations

Season	Nitrogen (kg/ha)	W/SC WU	W/SC WUE	W/V WU	W/V WUE	W/L WU	W/L WUE	W/W WU	W/W WUE
1986/87	0	329	14.6	296	13.1	299	13.3	222	8.2
	90	369	16.0	361	15.7	362	15.8	273	11.9
1987/88	0	382	16.4	438	17.8	450	18.1	-	-
	90	595	20.4	592	20.4	571	20.1	-	-
1988/89	0	253	10.6	236	9.4	238	9.5	190	5.0
	90	271	11.8	302	13.4	269	11.7	208	7.0

3.5.5 Profitability of Rotations

For technology to be adopted, the first requisite is that it must offer the farmer greater profitability, and in all probability

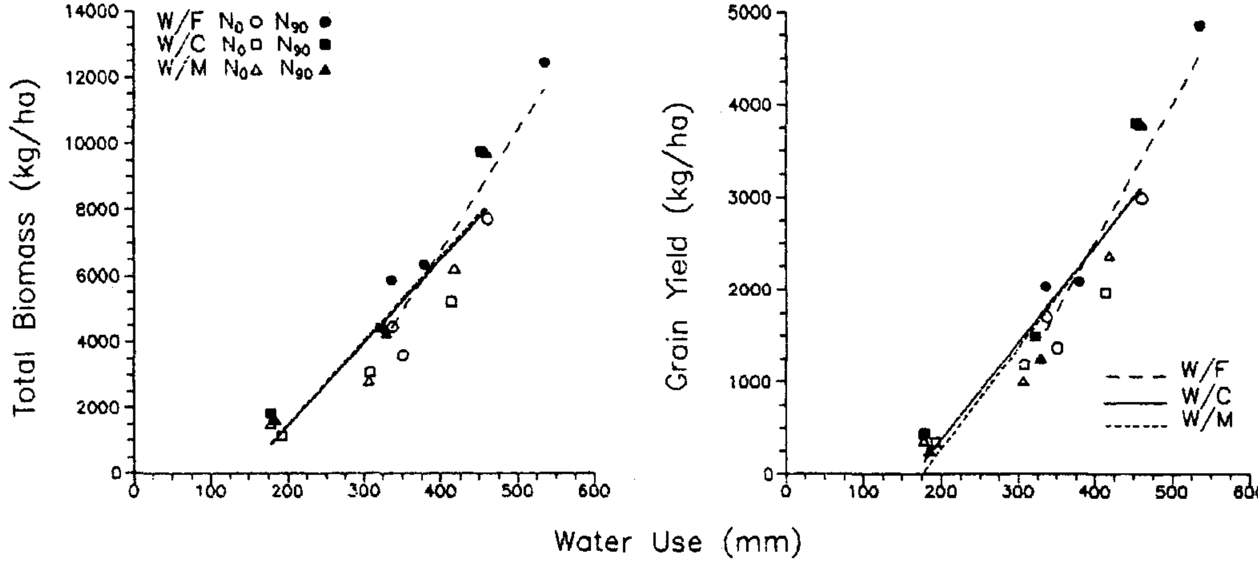

Figure 3.5.9

The relationship between water use (mm) of durum wheat and total above-ground biomass production (kg/ha) and grain yield of durum wheat in three rotations at Tel Hadya, 1986-87 to 1988-89.
Line Key: W/F - long dash; W/C - solid; W/M - short dash.

	TDM		Grain		F (for slope)
	b	R^2	b	R^2	
W/F	36.3	0.84	15.0	0.88	2.2
W/C	25.3	0.78	10.5	0.81	
W/M	25.6	0.85	11.0	0.86	

must do so in all years as for resource-poor farmers reliable cash flow is possibly more important than the maximization of income over several years. Partial budgets therefore have been carried out for all of the rotations. Local values of the inputs and outputs have been used, or where, as for some chemicals no local market exists, values have been converted to Syrian Lira (SYL) at the prevailing international rates.

Costs. The costs have been divided into two groups; those for crop establishment and crop protection which, for wheat, are common to all rotations; and harvest costs which vary with the yield and therefore are unique to each rotation and treatment. Farming is widely mechanized in Syria. Few farmers own equipment, so hiring is standard practice and the costs are readily identified.

Items included in the first group (Table 3.5.5) are: machinery hire for tillage and/or planting; seed and seed broadcasting; and fertilizer, herbicides, insecticides and fungicides and their application. Of these, chemicals are the major component. The costs of harvest (Tables 3.5.6 and 3.5.7) include: the cost of combine harvesting of wheat (10% of grain yield) and chickpea (5% of seed yield); wheat straw collection (assumed also to cost 10%

Table 3.5.5 Costs (SYL/ha) of crop establishment and crop protection in two course rotations from 1985/86 to 1988/89

Season	Wheat				Melon	Vetch	Lentil	Chpea	Fallow
	N_0	N_{30}	N_{60}	N_{90}					
1985/86	585	691	797	903	558	640	1270	1292	299
1986/87	2222	2328	2434	2540	993	1057	2850	3055	3196
1987/88	1694	1824	1954	2084	1493	4932	6065	7272	3100
1988/89	4269	4494	4719	4944	600	1900	4570	4903	3300

Table 3.5.6 Costs of harvest (SYL/ha) of wheat in two course rotations from 1985/86 to 1988/89

Season	N Tment	W/F	W/SC	W/V	W/L	W/C	W/M	W/W
1985/86	0	785	852	648	623	586	398	380
	30	941	961	797	704	727	454	500
	60	958	898	764	776	773	522	530
	90	984	1027	789	742	756	515	557
1986/87	0	921	1020	786	830	639	551	381
	30	997	1008	949	871	728	693	535
	60	1121	1073	999	976	774	697	630
	90	1133	1239	944	988	827	704	674
1987/88	0	1940	1597	1970	2000	1292	1598	416
	30	2503	2086	2553	2363	1893	2081	416
	60	3065	2197	2769	2929	2057	2688	616
	90	3184	3103	3095	3009	2511	3047	688
1988-89	0	2514	1712	1450	1578	670	740	486
	30	3524	1906	1943	1880	947	813	701
	60	3614	2159	2179	1977	727	661	693
	90	3848	2250	2380	2096	983	705	722

of its value); labor costs for hand harvesting of melon and lentil, and lentil threshing; bags, and loading and transport to market.

All costs have escalated appreciably in the four year period. This is due to a greater reliance on herbicides with the introduction, from 1986/87, of stubble management treatments and a fall in the value of the Syrian Lira. In 1987-88, wet conditions at the critical time prevented application of herbicide for grassy weed control, so the cost of crop protection was reduced (Table 3.5.5). Rain immediately after planting in the same year prevented the use of pre-emergence herbicides on the legumes, and more costly post-emergence chemicals were used later in the season. High costs for vetch in the same year were due to a need to control summer growing weeds which became a problem because of the moisture available in this year. The cost of hand harvesting is reflected in the harvest costs for lentil (Table 3.5.7).

Table 3.5.7 Costs of harvest (SYL/ha) of crops in the non-cereal phase in two course rotations, 1985/86 to 1988/89

Season	N Tment	Melon	Lentil	Chickpea	Wheat
1985/86	0	500	1202	334	192
1986/87	0	500	2200	529	168
	30		2102	552	138
	60		2082	561	194
	90		2029	578	205
1987/88	0	920	2143	668	305
	30		2397	675	324
	60		2397	653	301
	90		2250	650	405
1988/89	0	-	2377	1289	486
	30		2377	1360	701
	60		2130	1317	693
	90		1988	1172	722

Table 3.5.8 Value of the outputs (SYL/kg) of the individual rotations

Season	Wheat		Melon	Lentil		Chpea	Meat	Milk
	Grain	Straw		Seed	Straw	Seed		
1985/86	1.75	0.8	1.2	3.8	2.5	4.0	24.5	-
1986/87	2.5	0.8	1.25	6.2	2.5	7.5	40.2	-
1987/88	3.75	0.5	2.17	8.0	1.1	9.0	66.2	20
1988/89	5.75	2.5	-	9.0	4.0	10.0	52.2	20

<u>Gross output</u>. Gross output (Tables 3.5.9 and 3.5.10) for the crops has been calculated from the yield and the value of outputs (Table 3.5.8). It has been Government policy to increase the prices paid for grain and seed as costs have increased. Straw prices respond to seasonal demand. In estimating the value of wheat straw it has been assumed that part of it is collected and therefore has a market value but the remainder, the stubble, will be grazed and has a lower value on a per kilogram basis. Straw values have been scaled by 0.75 to allow for this.

<u>Table 3.5.9</u> Gross output (SYL/ha) from durum wheat in two course rotations from 1985-86 to 1988-89

Season	N Tment	Rotation W/F	W/SC	W/V	W/L	W/C	W/M	W/W
1985/86	0	5892	6395	6259	4717	4429	3022	2937
	30	7139	7161	7750	5332	5538	3786	3769
	60	7161	6689	7396	5857	5907	3162	4049
	90	7370	7788	7654	5502	5734	4122	4171
1986/87	0	5925	6522	5096	4839	4100	3644	2425
	30	6523	6613	6255	5734	4761	4554	3509
	60	7288	7050	6564	6529	5214	4495	4207
	90	7422	7547	6451	6658	5489	4947	4414
1987/88	0	12507	10568	12939	13246	8610	10299	2809
	30	16401	13851	16691	15531	12463	13009	2820
	60	20108	17839	18242	19313	13539	16418	4003
	90	21036	20511	20411	19828	16476	16343	5646
1988/89	0	11224	10125	7011	7221	4097	4217	2721
	30	14913	11128	9804	9170	5972	4444	3803
	60	15200	12853	11013	10045	4669	4459	3716
	90	17080	13856	12021	10261	6328	4016	4007

It is difficult to know how best to value the output from the grazed legumes. For the vetch, it is assumed that a farmer would own lambs that could be fattened on the crop and the gross value has been calculated from liveweight gain and the market value of

Table 3.5.10 Gross output (SYL/ha) of the non-cereal phase of two-course rotations from 1985-86 to 1988-89

Season	N Tment	Rotation SC/W	V/W	L/W	C/W	M/W	W/W
1985/86	0	2435	7154	11737	4080	na	2117
1986/87	0	3270	14070	12343	6900	na	1702
	30			11665	7350		1540
	60			11185	7538		2104
	90			11180	7875		2261
1987/88	0	7638	23898	9969	9045	21148	1974
	30			12646	9180		2162
	60			12585	8730		1933
	90			11145	8685		2702
1988/89	0	0	12915	11740	5450	6180	2721
	30			11751	6400		3803
	60			9530	4600		3761
	90			9020	3900		4007

sheep (SYL/kg of liveweight). If, however, a farmer did not own lambs he would need to either buy them in or, probably more likely, agist them. There would be costs associated with both of these options that would reduce the value of the output. As this use of the crop is not currently farmer practice there are no market values on which to base estimates of gross output. It has also been argued that costs such as shepherding should be accounted (Nordblom 1989), but as this is often done by family members and therefore does not entail a cash outlay it has not been considered.

Animal products (liveweight gain and milk) were also used in the estimation of gross output from the medic pastures. In the first two years lambs were not grazed, but they now are included as part of the system. However the value of medic lies not only in these direct products, but also in the substitution of grazing for the feeding of stored grain and straw and concentrates such as cotton seed cake and wheat bran during the winter. In the past 4 years sheep grazing natural pastures at 2.3 hd/ha received supplementation, on average, of 40 kg/hd of each of hay and barley grain in December, January and February (F. Bahhady, personal communication) at an average cost of SYL 200/hd.

Again there may be additional management costs, such as shepherding or fencing, which should be included. However, such costs are also incurred when sheep graze native pastures. The whole question of how to assess the economics of animal production in integrated systems is currently under study (T.L.Nordblom, personal communication), and better ways of reporting should be available in the future.

Because of the assumptions used in estimating the returns from grazing the gross output must be regarded with caution.

<u>Gross margins</u>. It is assumed that half of the land in the rotations is in each phase in each year. The gross margins (Table 3.5.11) have therefore been calculated as: 0.5 ((gross output for wheat + gross output for non-cereal) - (costs for wheat + costs for non-cereal)).

Comparisons should not be drawn among all the rotations because of the questions related to the methods for estimating returns for the grazed treatments. It does seem valid, however, to comment on the relative returns of the other rotations. Among these wheat/lentil stands out as being consistently superior to the others. The demand for lentil residue for animal feed, especially in dry seasons, contributes to the stable income from this rotation. It should be recognized that, with an average rainfall of approximately 330 mm, Tel Hadya is very marginal for the production of chickpea and this is reflected in the gross margins. The other feature is the very poor performance of continuous wheat. This is obviously not a practice to be recommended.

Table 3.5.11 Gross margins (SYL/ha) of seven two-course rotations from 1985-86 to 1988-89

Season	N Tment	W/F	W/SC	W/V	W/L	W/C	W/M	W/W
1985/86	0	211	3168	4860	6387	2856	na	1656
	30	2604	3443	6055	6601	3287		1959
	60	2554	3186	5746	6775	3396		2018
	90	2592	3618	6004	6561	3265		2025
1986/87	0	-207	2529	6096	4540	2278	na	-433
	30	1	2527	6255	4624	2724		-87
	60	269	2660	6564	4686	2964		415
	30	277	2773	6451	4716	3182		517
1987/88	0	2892	6251	14121	5656	3365	17580	-1763
	30	4487	7583	15650	7903	4990	15126	-1738
	60	5995	9457	16243	9277	5167	16462	-1415
	90	6334	10275	17099	8783	6332	16180	-362
1988/89	0	1044	1154	6154	3117	-853	2694	-2034
	30	2438	1408	7191	3832	139	2660	-1392
	60	2410	1924	7565	3121	-1118	2630	-1696
	90	3194	2249	7856	2873	-949	2274	-1659

Acknowledgements. Many people contribute to this trial. General management: Mr. R. Makboul assisted by M. Lababidi, M. Karram (FRMP); Soil water measurements: Mr. H. Jokhadar assisted by I. Halimeh, M. Zaki, A.H. Dibo (FRMP). Sheep and medic pasture management: Drs. P.S. Cocks and E. Thomson and Mr. F. Bahhady and sheep unit staff (PFLP); Cultivars: Drs. M. Nachit (CP), K.B. Singh, W. Erskine (FLIP) P.S. Cocks (PFLP); Pathology: Dr. O. Mamluk (CP); Entomology: Drs. S. Weigand (FLIP) and R. Miller (CP); Weed control: Dr. M. Pala and Messrs A. Haddad and S. Dozom (FRMP); Nutrition: Drs. A. Matar (FRMP) and D. Beck (FLIP); Interpretation is the responsibility of the author.

3.5.6 References

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3.6 The Nitrogen Economy of Barley-Based Rotations

M.J. Jones

3.6.1 Introduction

The barley-based rotation trials at Tel Hadya and Breda are concerned with arable/sheep-feed production systems for drier areas and the year-to-year variability and long-term sustainability of such systems. Previously we have assessed the biological yield of different treatments in these trials in terms either of dry-matter yield or "sheep equivalent", i.e. sheep-feed values based on estimates of either metabolizable energy or crude protein content (FRMP 1989; Jones 1989). However, crude protein estimates have depended on assumed average values for the nitrogen contents of the harvested crop components (barley grain and straw, legume hay), values that we know in fact vary considerably with season and management treatment. Given that feed value increases with increasing nitrogen content, that the inclusion of legumes in rotations is often justified on the grounds of anticipated benefits to 'soil fertility' (nitrogen availability), but that hard data on the magnitude of such benefits are scarce, it appeared urgent to re-examine the above rotation trials in terms of crop nitrogen output.

For two trials, designated 'New Rotation, Tel Hadya' and 'New Rotation, Breda', both established in 1982/3, we now have crop nitrogen data on a per plot basis for the two seasons 1987/8 and 1988/9. These data are used here to compare different two-year barley rotations and different fertilizer regimes imposed on those rotations in terms of 'nitrogen productivity'. Although these comparisons are intended primarily to augment earlier ones based on dry matter production and sheep-feed value (FRMP 1989; Jones 1989), because they derive from the two most recent seasons they have two advantages over those given previously:

i) as the rainfall receipts in 1987/8 and 1988/9 represent almost the extreme ends of the ranges expected, the data from those seasons seem likely to define approximate upper and lower limits for dry matter and crop nitrogen production at the two sites;

ii) since, respectively, one or two cropping seasons now intervene, all crop data may be assumed to be clear of any ambiguity arising from two earlier changes in management: a change in legume harvest time from the hay stage to crop maturity, introduced in 1985/6; and a change from peas to lathyrus introduced in 1986/7. The new data thus cover a new practice and a new crop, each believed to be better fitted to the climate and farming practices in the area for which we are working.

3.6.2 Rotation Effects

Both trials compare three basic rotations, barley-legume (B-Leg), barley-fallow (B-F) and barley-barley (B-B); but the B-Leg rotation occurs in four forms, distinguished by differences in the nature of the legume-phase crop: lathyrus sativus (lathyrus, Lath), vicia sativa (vetch, V) and mixtures of each of those legumes with barley (B/Lath, B/V). However, we compare here first the B-F and B-B rotations with just those two B-Leg rotations which include pure legume crops, B-Lath and B-V, in each case with two fertilizer regimes: zero-fertilizer control and N and P applied biannually to the barley phase [40N:60P_2O_5 at Tel Hadya and 20N:60P_2O_5 at Breda].

Total dry matter and total crop N production are summarized in Figure 3.6.1. For each rotation, yield and nitrogen content (for barley grain and straw + legume grain and straw, where appropriate) has been summed across both phases of the rotation on a per hectare basis (0.5 ha per phase). The high yield levels (of dry matter and N) in 1987/8 were very similar at Tel Hadya and Breda despite an approximately 100 mm difference in rainfall; but the low yields of 1988/9 showed a much greater reduction over those of 1987/8 at Breda than at Tel Hadya (Table 3.6.1), presumably due to the 40 mm difference in rainfall. Particularly

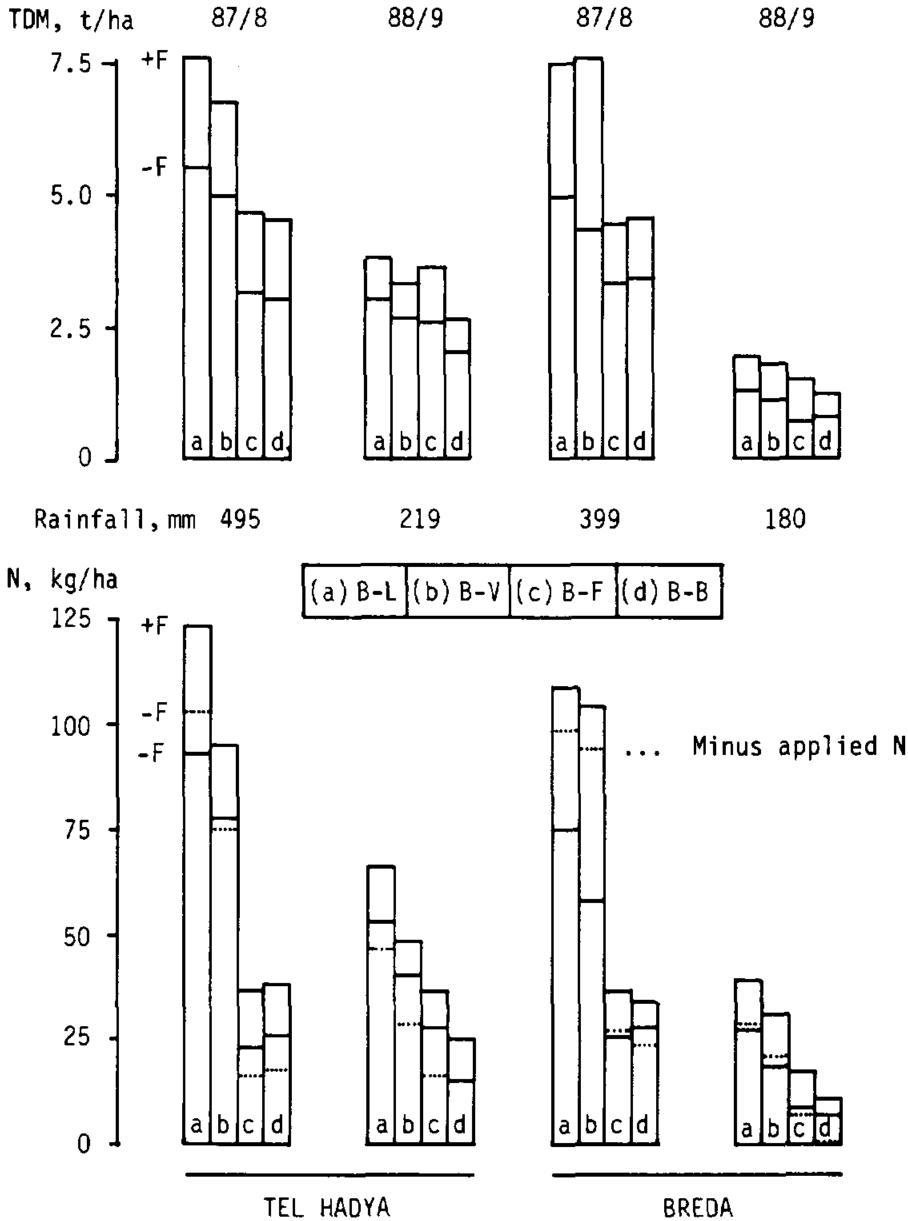


Figure 3.6.1 Rotation effects on mean yields of total dry matter and crop nitrogen under fertilized (+F) and unfertilized (-F) management, New Rotation Trials, Tel Hadya and Breda, 1987/8 and 1988/9. Rainfall values are October to April totals. Rotations are of barley with lathyrus, vetch, fallow and barley, respectively.

Table 3.6.1 Mean yields of dry matter and crop N harvested in 1988/89 trials expressed as a percentage of yields of the same rotations in 1987/88 (data for both phases and fertilizer regimes pooled)

		Rotation				
		B-Lath	B-V	B-F	B-B	Mean
TDM	Tel Hadya	52.1	51.1	79.5	61.1	61.0
	Breda	25.8	24.5	28.6	24.6	25.9
N	Tel Hadya	55.1	51.2	109.8	67.1	70.8
	Breda	35.8	30.3	41.3	28.0	33.9

at Tel Hadya, B-F was the most conservative rotation; halving the rainfall reduced dry matter production by only about 20 per cent and actually increased the N yield slightly. At both sites and in all rotations, N yield tended to be more conservative than dry matter yield. In other words, the smaller mass of plant material produced under drier conditions was usually richer in nitrogen, as is well demonstrated by the figures for barley in Table 3.6.2. At the extreme, the mean percentage N-content of barley straw at Breda was 76% greater in 1988/9 than in 1987/8 (see also section 3.1.4 for further discussion on this).

Quite clearly, in 1987/8, the two rotations that include legumes produced much more dry matter than the two rotations with no legumes (Table 3.6.3). The mean differences exceeded 2t/ha (around 60%) at both sites. Under the much lower-yielding conditions of 1988/9, differences were much smaller both absolutely and, at Tel Hadya, as percentages as well. However, in terms of crop N yield, the differences that were very large (around 200%) in 1987/8 remained large in 1988/9. Even when one allows for the fertilizer nitrogen applied to barley in fertilized treatments, the net yield of crop N in B-Leg rotations was around

75-100 kg N/ha in 1987/8 and 20-45 kg N/ha in 1988/9, compared (respectively) with 5-28 kg N/ha and 0-28 kg N/ha in the non-legume rotations. Relative to the B-B rotation, which yielded the least nitrogen, mean additional crop N produced by the other rotations amounted to:

B-F rotation	-	3.2 kg N/ha/annum
B-V rotation	-	35.9 kg N/ha/annum
B-Lath rotation	-	50.1 kg N/ha/annum

Table 3.6.2 Year and site effects of N-content(%) of barley grain and straw (means of four rotations, with and without fertilizer)*

	Tel Hadya		Breda	
	87/88	88/89	87/88	88/89
Grain	1.44	1.85	1.37	2.05
Straw	0.35	0.48	0.37	0.65

* Values were lower in the absence of fertilizer (except for straw at Breda), but their pattern in relation to site, year and rotation was similar.

Table 3.6.3 Comparison of legume rotations with non-legume rotations in respect of dry matter and nitrogen production (means of fertilized and unfertilized rotations)*

		Total dry matter (t/ha)				Crop N (kg/ha)			
		+Leg	-Leg	Diff.	Incr.	+Leg	-Leg	Diff.	%Incr.
Tel Hadya	87/88	6.21	3.85	2.36	61	97	30	67	219
	88/89	3.21	2.71	0.50	18	52	27	25	95
Breda	87/88	6.08	3.91	2.17	56	86	31	55	180
	88/89	1.53	1.04	0.49	47	29	11	18	168

* Rotations: +Leg is the mean of B-Lath and B-V;
-Leg is the mean of B-F and B-B

3.6.3 Legume/Barley Mixtures and the Timing of Phosphate

Dry matter and N yield data from all four B-Leg rotations (i.e. including legume/barley mixtures as well as pure legumes), each grown under four fertilizer regimes, are summarized in Figure 3.6.2. Generally, the effect of phosphate timing was small, and any differences were inconsistent between sites and years and statistically non-significant; but, unsurprisingly, differences between the three regimes supplying N and P and the unfertilized control were quite large and consistently significant.

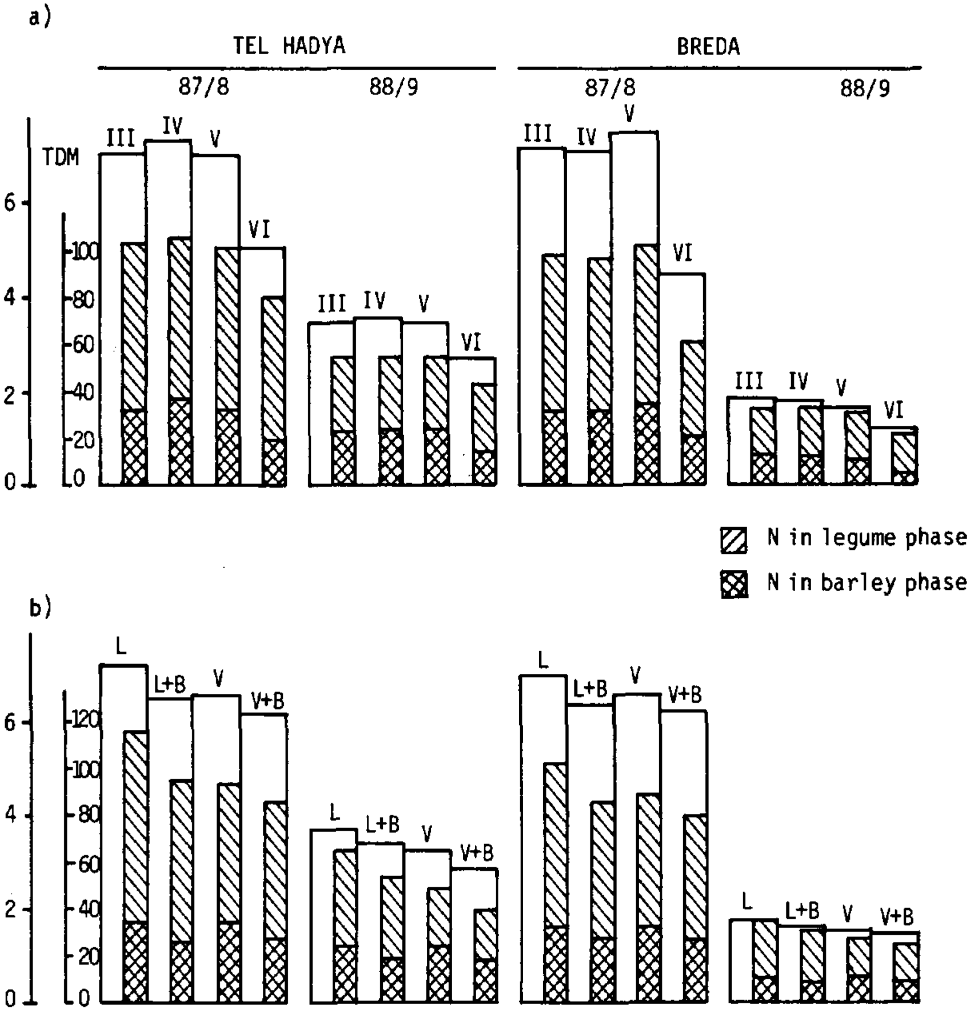
Rotation differences were also consistent and, in many cases, also significant. The general trends are clear:

i) the B-Lath rotation always outyielded the B-V rotation in both dry matter and N; and the same pattern existed where pure legumes were replaced by legume/barley mixtures;

ii) rotations involving pure legumes always outyielded those having legume/barley mixtures instead, in both dry matter and N production.

In respect of nitrogen yield, differences between legume species arose entirely within the legume phase of the rotation: as Figure 3.6.2 shows, amounts of N harvested in the barley were almost identical (in the two pure legume rotations and in the two legume/barley mixture rotations) at any particular site/year. Differences between pure-legume rotations and legume/barley rotations, however, arose in both phases (Table 3.6.4). That is, the yield of N in a mixed legume/barley crop was less than that in a pure legume (by an average of 10.7 kg N/ha or 11.1%) and the yield of N in the barley following a mixture was also reduced (by an average of 10.2 kg N/ha or 19.4%).

Figure 3.6.2 Effect of fertilizer regime and legume on crop total dry matter and N yield in four B-leg rotations in New Rotation trials, Tel Hadya and Breda, 1987/8 and 1988/9.



a) Fertilizer regimes:

III - 60P to barley phase

IV - 30P to barley phase; 30P to legume phase

V - 60P to legume phase

VI - No fertilizer control

(all means across 4 rotations)

b) Rotations:

L - barley - lathyrus

L+B - barley - lathyrus/barley mixture

V - barley - vetch

V+B - barley - vetch/barley mixture

Table 3.6.4 How the use of legume/barley mixtures decreases N yield in both phases of B-Leg rotations relative to pure legumes (kg/N and %)

	Tel Hadya		Breda	
	87/8	88/9	87/8	88/9
Legume-Phase N:				
Lath/bar -Lath	-25.6 (15.8%)	-12.1 (14.9%)	-23.5 (16.8%)	-6.2 (12.6%)
Vetch/bar-Vetch	-2.3 (1.9%)	-7.1 (14.4%)	-6.5 (5.7%)	-2.1 (6.5%)
			Mean: 10.7 (11.1%)	
Barley-phase N:				
Lath/bar -Lath	-16.6 (24.3%)	-11.8 (24.11)	-9.0 (14.0%)	-3.0 (14.0%)
Vetch/bar-Vetch	-14.6 (21.0%)	-10.4 (21.8%)	-12.5 (19.2%)	-3.8 (16.9%)
		Mean: 10.2 (19.4%)		

3.6.4 Continuous Barley

Each year, continuous barley (B-B) is grown under four different fertilizer treatments, comprising 3 different regimes (or fertilizer 'rotations'):

1. No fertilizer at all (none since start of trial) 0-0

2. Fertilizer every 2 years
   - a. last year, not this year F-0
   - b. this year, not last year 0-F

3. Fertilizer every year (since trial started) .... F-F

Rotations 1 and 2 were used above as, respectively, unfertilized and fertilized B-B in the comparisons with B-Lath, B-V and B-F. Here we compare them with the annually-fertilized rotation 3. Presentation in Figure 3.6.3 is as single phases, but for both 1 and 3 the picture for the whole rotation would be the same (since both rotations consist essentially of one phase, the same each year). For rotation 2, it would be the mean of 2a and 2b.

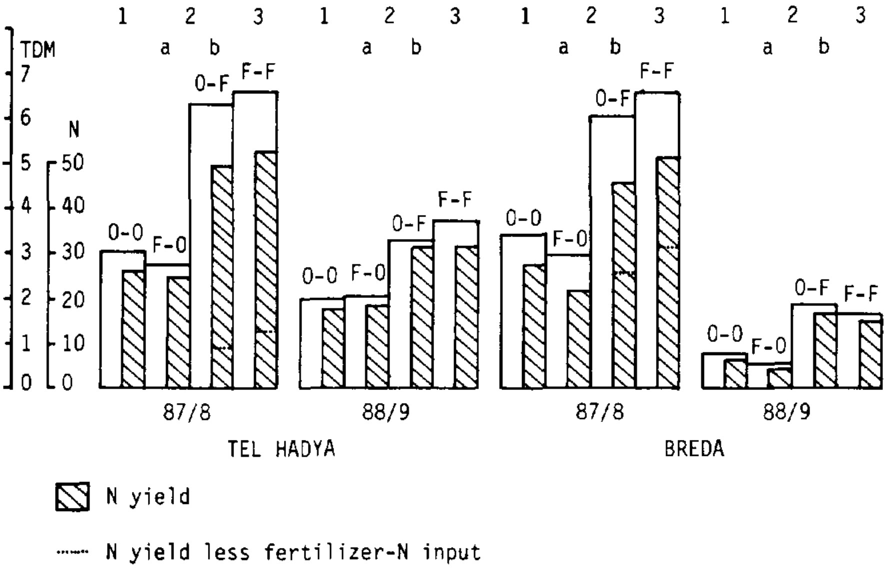


Figure 3.6.3 Yields of total dry matter (t/ha) and crop nitrogen (kg/ha) in single phases of barley-barley rotation under different fertilizer regimes (for details, see text).

We see

i) that the response of dry matter and, to a lesser extent, crop nitrogen yield to fertilizer applied in the current season is quite large (compare 2b and 3 with 1); but response to any residual effects of previous fertilization is either small (compare 3 with 2b) or even slightly negative (compare 2a with 1).

ii) that, if the applied fertilizer-N is discounted, actual yields of nitrogen in continuous barley are small, and they are largest (average around 20 kg N/ha) in the unfertilized rotation, 0-0 (Table 3.6.5).

Table 3.6.5 Effect of fertilizer regime on the net crop nitrogen yield (crop-N minus fertilizer-N) in continuous barley rotation, B-B

	Rotation:	1	2a	2b	3
	Fertilizer:	0-0	F-0	0-F	F-F
Tel Hadya	88/8	25.9	24.6	9.0	12.6
			17.8		
	88/9	17.6	18.6	(0.0)	(0.0)
			9.3		
Breda	87/8	27.6	21.6	25.7	30.9
			23.7		
	88/9	6.6	4.6	(0.0)	(0.0)
			2.3		

(0.0) implies a net loss of nitrogen.

3.6.5 Conclusions

1. As has been reported before, at the same level of fertilization, barley-legume rotations produce more dry matter than barley-barley rotations (in this case, 26-68% more, depending on site and season); but the superiority of the barley-legume rotation in terms of crop nitrogen yield is very much greater (approximately 100-200%).

2. Use of legume/barley mixtures in place of pure legumes appears to be disadvantageous. In particular, the use of mixtures reduced crop nitrogen yield by a mean of about 10 kg N/ha in each phase of the rotation. [Corresponding reductions in dry matter production do not conflict with the earlier results of Osman and Nersoyan (1986). Their positive endorsement of legume/barley forage mixtures was largely in relation to barley grown after previous cereal; and a (hay-stage) forage yield greater from legume/barley mixtures than for pure legumes was achieved in only one out of two experimental years.]

3. Rotations involving lathyrus sativus consistently outyielded rotations involving vicia sativa, with means of about 8% more dry matter and about 18% more nitrogen.

3.6.6 References

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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.

Homogeneous recommendation domains are defined as areas, not necessarily contiguous, in which the combined effects of topography, soils, climate and socio-economic conditions are such that any given recommendation will have an equal probability of success within the boundaries of the domain. The level of specificity at which one defines such domains will be dependent upon the technology or "packet" of technologies for which they are developed, and also upon the detail of information available.

In this year's report we illustrate how two very different types of information can be used. One example illustrates how historical daily and monthly climatic data sets, through the application of both temporal and spatial weather generation can be used to define domains in which the probability of climatic events and their effect on technology performance can be determined.

A second example uses farm level survey data, obtained from a relatively small project area, to identify four distinct types of farms. The contrasting production strategies and their implication for the possible targeting and adoption of new technology are discussed.

A third section illustrates the application of CERES-N wheat model in the evaluation of contrasting nitrogen fertilizer strategies for rainfed wheat in Xian Province of China.

4.2 Spatial Rainfall Generation: Examples from a Case Study in the Aleppo Area, NW Syria

W. Goebel

4.2.1 The Tool

Since 1986 a Spatial Weather Generator (SWG) has been under development in FRMP. The reasons for undertaking this work have been summarized in the Program's Annual Reports for 1986 and 1987.

Weather generators are useful tools for estimating the frequencies of climatic events which are of significance for crop production, like dry or wet spells, frosts etc. In combination with crop models of various types, from simple regression models to complex simulation models, they can provide information on the expected distribution of yield and on the effects of management alternatives. A weather generator consists of two main parts: a parameter estimation part reduces the original weather data to a set of coefficients for each weather station; a generator part in the strict sense stochastically reproduces synthetic sequences of data from the sets of coefficients. In a spatial weather generator, a third part, the interpolation of the coefficients between the stations, is added between parameter estimation and data generation. This permits questions to be answered on expected frequencies of events, crop yield distributions, and effects of alternative crop management for all locations, independent of their distances from meteorological stations, and to present the results in the form of maps.

The SWG used in this study can generate rainfall, maximum and minimum temperatures and solar radiation. This report, however, is concerned with the generation of rainfall only. This part of the SWG is constructed to work on a daily or on a monthly time-step depending on the requirements of the task and the availability of data. If rainfall data are available from some stations in daily form and only in monthly form from others, the monthly data, totals and, where available, information on the number of rainy days per month, are used to improve the parameter estimation and the spatial interpolation of the coefficients for the generation of daily data. When working on a daily time-step, generator coefficients are estimated by taking all days of a particular calendar month from all years on record of a station as one population. This increases the number of data values for the estimation of each coefficient by a factor of 30 compared to separate estimation for each calendar day. This approach is particularly suitable for the estimation of coefficients for rainfall during the drier parts of the year and when working on data from stations with short records. This procedure results in one set of coefficients for each calendar month. Before generating daily data from them, the coefficients are smoothed across the year with the help of polynomial splines in such a way that monthly totals and averages are preserved (for details on this and other computational procedures see Appendix 1, section 4.2.4), which is not necessarily the case if a Fourier series is used for coefficient smoothing as is frequently done (Woolhiser, Hanson and Richardson, 1989; Stern, Dennett and Dale 1982).

The approach which the SWG uses to simulate rainfall is similar to that of many other rainfall models (e.g. Buishand 1977, Katz 1977, Stern, Dennett and Dale 1985, Richardson and Wright 1984, Woolhiser, Hanson and Richardson 1988) in having two steps, separating the probability of receiving rain from the amount of rainfall received.

When working on a monthly time-step the straightforward, unconditional probabilities of each of the calendar months having at least one rainy day are used to determine whether a dry or a wet month is more likely to be generated. On a daily time-step, however, the conditions on the previous days influence the probability whether the next day will be wet or dry. Therefore the SWG uses a second-order Markov chain with two states, wet and dry, to model the sequence of wet and dry days, i.e. whether a wet or a dry day is more likely to be generated depends on the status of the preceding two-day period. The use of a second order Markov chain is a compromise between the need to keep the numbers of coefficients (i.e. the transition probabilities) manageable for the spatial interpolation and the desire for accurate modelling of the dependence structure of daily rainfall. Frequently a first order Markov chain, characterized by only two independent transition probabilities, is used (e.g. Woolhiser, Hanson and

Richardson 1988, Richardson and Wright 1984). Chin (1977), Bishnoi and Saxena (1979), Dennett, Rodgers and Keatinge (1983) and others have, however, found that this is an inadequate model in certain climates. The added accuracy from using a third or higher order Markov chain is, however, very small and does not warrant the extra coefficients involved (Hutchinson 1987). Therefore, a second order model characterized by four independent transition probabilities has been chosen for this SWG, which is intended to be used with data from diverse climates.

For modelling the amount of rainfall received during a wet day or a wet month, a Gamma-distribution is used. Since Das' pioneering work (Das 1955), this has been demonstrated to be an adequate model over a wide variety of climates (Kotz and Newmann 1963, Katz 1977, Garbutt, Stern, Dennett and Elston 1980, Dennett, Rodgers and Keatinge 1983). The flexibility of the Gamma-distribution makes it possible to use one model for both daily rainfall, where it takes on the shape of an inverse J, as well as for monthly data, where it resembles a skewed Normal-distribution.

A Gamma-distribution is defined by three parameters, slope parameter, scale parameter, and a third parameter which defines the point below which the value of the density function is zero. Slope and scale parameters are estimated by the maximum likelihood method from arithmetic and geometric means of the rainfall values. The SWG uses total monthly rainfall and unconditional probability of a day (or the month) being wet, from which the arithmetic mean of rainfall on a wet day (or month) is derived, as well as the ratio of geometric and arithmetic means as coefficients, since these are more readily mapped than the shape and scale factors themselves. The third parameter of the Gamma-distribution is set to zero, as evidently there is no negative rainfall. This is not without problems, since rainfall values below about 0.1 mm are not measured quantitatively, if at all, i.e. a truncation occurs somewhere between 0.05 mm and 0.1 mm. The Gamma-distribution is quite sensitive to this and ignoring this problem causes severe distortion of the generated data, especially when the distribution has an inverted J-shape (daily data). Unfortunately, the theory of Gamma-distribution truncated near the origin does not seem well enough developed to offer an easily implemented solution. The use of censored Gamma-distributions, which below a certain threshold require only the frequency of such small rains rather than their values (Das 1955, Buishand 1977, Stern, Dennett and Dale 1982) does not really help because the frequency of these small rainfalls is also not often known. The SWG overcomes the problem with the help of a table of the effects of the truncation on shape and scale parameters.

During the development of the SWG, it has been found necessary to incorporate a number of measures to compensate for various deficiencies encountered in rainfall records. These are:

- Records of unequal length between different stations and records with gaps,

- Inhomogeneities in station records caused by a relocation of the station, changes in the observation method, or changes to the surroundings of the station which affect the local wind field,

- Varying reliability in reporting rainfall amounts below approximately 2 mm,

- Rounding off values to the closest value divisible by 0.5 or 0.2,

- Outliers, i.e. rainfall amounts with a very low probability of occurrence within the observation period of a station,

- Unreliable stations, which need to be detected and excluded.

As these problems and the methods used to rectify them have already been described before (Farm Resource Management Program 1989) it is not necessary to go into detail here. (For more details on the computational aspects also see Appendix 1 to this contribution.)

The spatial interpolation of the generator coefficients is mainly done by hand, guided by topography, satellite imagery where available, and information on typical weather situations during the course of the year. If exercised with proper care, this method presently is still superior to all automatic mapping of rainfall (Bartels 1986). In spite of encouraging progress during the last years in developing objective spatial interpolation methods for rainfall, these methods, so far, either ignore all influences of topography on rainfall (Woolhiser, Hanson and Richardon 1988) or they incorporate only an average effect of altitude (Hutchinson and Bishop 1983), and therefore require a quite dense network of rainfall stations for satisfactory results in hilly terrain. Manual interpolation on the other hand is extremely flexible with regard to data availability; whatever is known can be incorporated into the maps and in all situations, the best possible estimate can be obtained. The major drawback of manual interpolation is that it is very time consuming, since the maps of all coefficients must be free of mutual contradictions at any point. This adjustment is facilitated if regionally valid regressions of some coefficients on others can be established. Such relationships may be particularly helpful during the construction of maps of the Markov transition probabilities from maps of the unconditional probability of rainy days (for first order Markov chains, this has been demonstrated by Hershfield, 1970).

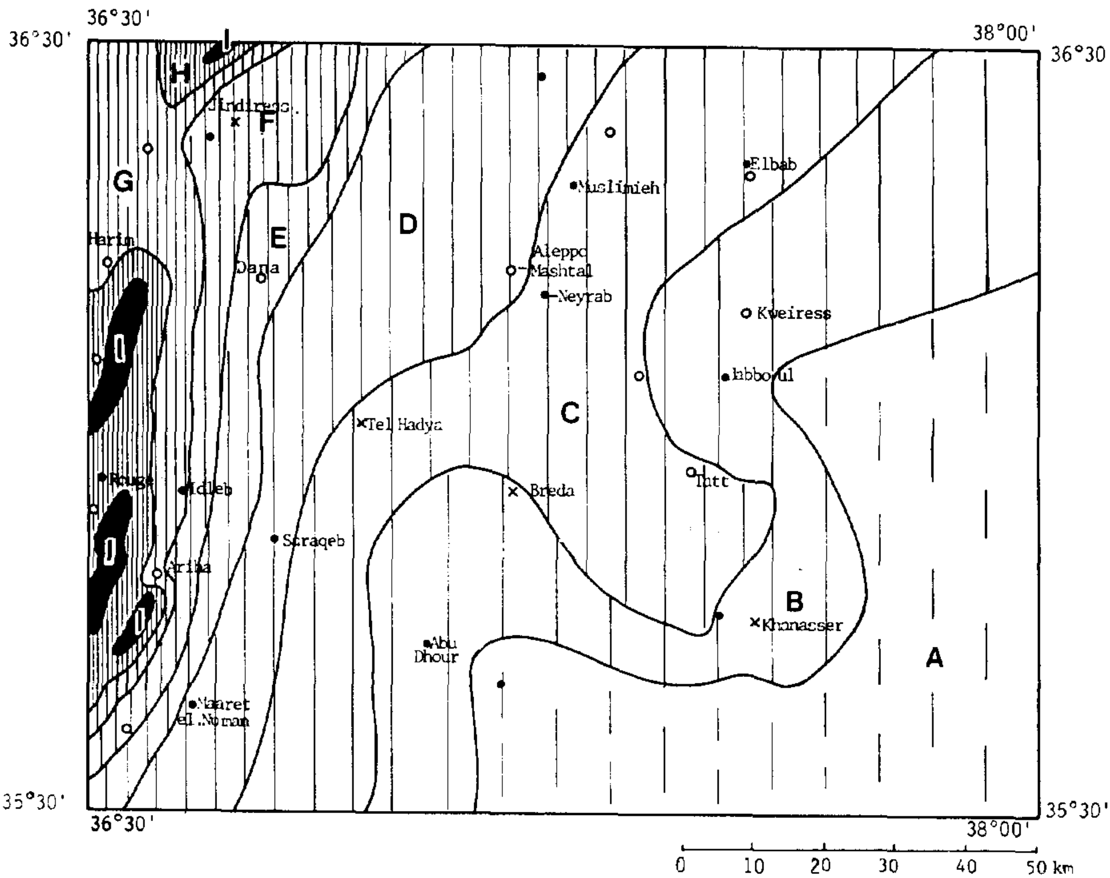
Although the individual subroutines of the SWG have been validated independently with data from West Asia, East Africa and East Asia, the results presented in this contribution still have to be viewed with caution, as the model as a whole so far has not been properly validated due to the lack of suitable datasets which have to be sufficiently large and of high quality. Comprehensive validation is underway as part of a newly started collaborative project with NARS and Meteorological Services in the WANA region.

4.2.2 The Case Study: Location and Input Data

The study region is located between 35°30′ and 36°30′ North and between 36°30′ and 38°00′ East in Northwestern Syria, its center about 20 km south of Aleppo. It stretches from the mountain ridge forming the eastern escarpment of the Ghab in the west not quite to the Euphrates River in the east, and from near the Syrian-Turkish border in the north to a range of more elevated land extending eastwards from Maaret-el-Numan in the south. Roughly in the middle of the area, there is a range of hills extending from near Aleppo to Khanasser in the southeast. Except for this range of hills and the mountains in the west, the area is largely composed of vast agricultural plains and rangeland occupying the driest part in the south-east. Within the last few years, much of this traditional rangeland has been planted to barley. The area transects all Syrian agricultural stability zones (cf. section 5.3, Figure 5.3.4 in this report) from Zone 1a in the west to the Zone 5 in the southeast. In the wetter western and northwestern part, wheat-based farming systems dominate, whereas the drier part is occupied by barley-livestock systems (for convenience, the areas of wheat-based farming systems will be referred to as wheat growing areas, those of barley-livestock systems as barley areas).

Annual rainfall totals in the area drop quickly from up to

600 mm in the west to 400 mm as one moves eastward out of the mountains on the western side. Across the flat land rainfall continues to decrease gradually to around 200 mm in the southeast and 300 mm in the northeast of the area. In general, rainfall shows a tendency to decrease from west to east in the south of the area and from northwest to southeast in the north of the area. This trend is interrupted by the hills southeast of Aleppo which receive higher rainfall than the surrounding plains (cf. Figure 4.1).



A 200-250 mm B 250-300 mm C 300-350 mm D 350-400 mm
E 400-450 mm F 450-500 mm G 500-550 mm H 550-600 mm
I 600-650 mm

Figure 4.1 Mean annual rainfall in the study area in NW Syria and network of meteorological stations. Circles: stations with monthly data, dots: stations with daily data, crosses: ICARDA stations before 1985 (data not used)

Rainfall data from 49 meteorological and rainfall stations were used in the study*. For 19 of these, daily data were available, and for the other 30, only monthly totals and the number of rainy days per month were available. 27 of the stations used (14 with daily and 13 with monthly data) are located inside the study area itself, the others are situated within a perimeter of up to about 30 km around the area, facilitating the interpolation of coefficients right up to the borders of the area. As far as possible, records from a standard period of 26 years, 1960-1985 (data for earlier or later years were not available for many of the stations at the time the dataset was assembled) were used. Incomplete records were corrected to represent the full standard period as described in Appendix 1. One station in the northeast outside the area had to be dropped because of irreconcilable differences between its data and those from other stations. ICARDA stations were not used, since less than 7 complete years are available for them up to 1985. Although the density of the network of stations is quite adequate in parts of the study area, there are a few gaps and places, where the interpolation of rainfall coefficients depends heavily on the disputable interpretation of data from a single station:

- There is no station in the summit region of the mountains in the west of the area; coefficients are based on extrapolation of data from stations located at the foot of the range and on the slopes.

- There is no station in the hills on the east side of the Afrin valley and in their eastern hinterland. The shielding effect of the hills on the other side of the valley is difficult to estimate, as is the effect of these hills on their hinterland.

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* The data were kindly supplied by the Meteorological Department of the Syrian Arab Republic.

- There is no station between Saraqeb and Breda in the south and Dana and Aleppo in the north. Dana, for which only monthly data were available, therefore gets a very high weight in determining the gradient across the flat land with Tel Hadya in its center.

- There is only one station, Tatt, for which only an incomplete monthly dataset was available, situated in the hills southeast of Aleppo. On the evidence of that station, it is assumed that the hills receive significantly more rain than the surrounding plains.

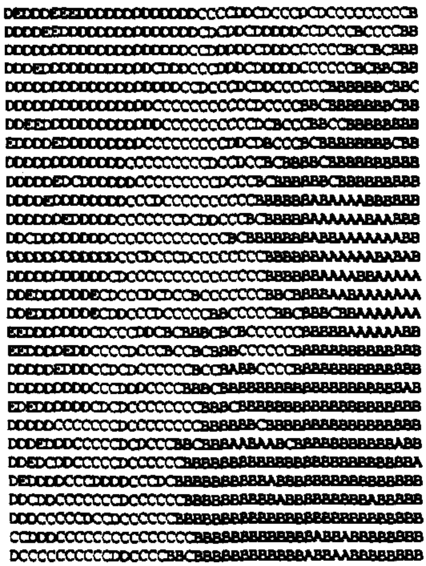
- The rainfall gradient across the plain east of Aleppo to some extent depends on the interpretation of the somewhat contradictory datasets from Jabboul and Kweiress, Maskaneh and El Khafse (beyond the eastern border).

4.2.3 Results and Examples of Generated Maps

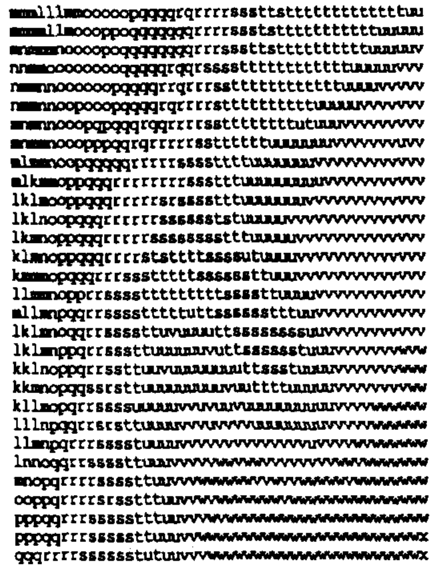
500 years of daily rainfall data and 1000 years of monthly rainfall totals were generated for the central points of 2′ by 2′ large rectangles of land, i.e. for a regular grid of 30 by 45 cells of about 11.1 km^2 each.* Figure 4.2 gives examples of the raw, character-oriented output (the maps are the same as reproduced in Figures 4.4 and 4.10) Each character represents one 2′ by 2′ large grid cell (due to the fixed line spacing and type face of the printer, the maps are compressed in east-west direction).

The raw output maps still show a certain amount of noise, which is eliminated after a comparison with the coefficient maps

* 2′ (2 minutes) correspond to approximately 3.7 km in north-south direction and 3.0 km in east-west direction at 36° latitude.



A = 50%-59%   B = 40%-49%   C = 30%-39%
D = 20%-29%   E = 10%-19%



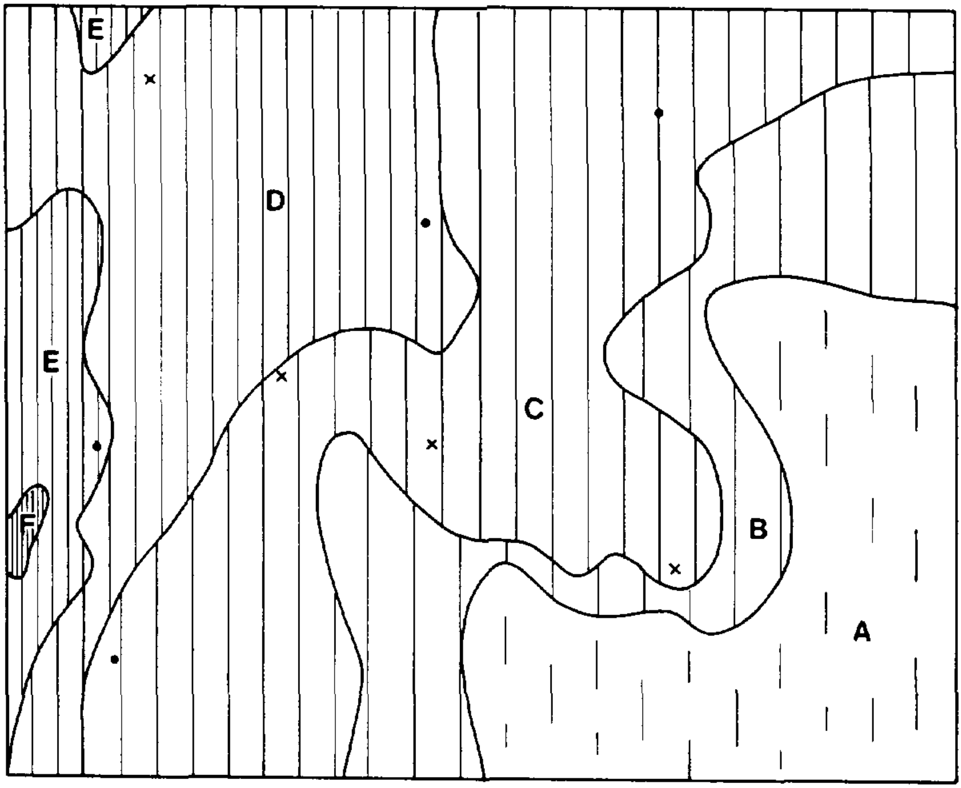
x = 50- 99 kg   w = 100–149 kg   v = 150–199 kg
u = 200–249 kg   t = 250–299 kg   s = 300–349 kg
r = 350–399 kg   q = 400–449 kg   p = 450–499 kg
o = 500–549 kg   n = 550–599 kg   m = 600–649 kg
l = 650–699 kg   k = 700–749 kg

Figure 4.2 Examples of raw output from the SWG. The map on the left shows the risk of a 20 day-long drought 1 Nov. to 10 Dec., based on 500 years of generated daily rainfall (cf. Figure 4.4). The map on the right shows the yield increase of barley from 60 kg N and 30 kg P_2O_5 expected in 4 years out of 5 in a fallow-barley rotation, based on 1000 years of generated monthly rainfall totals (cf. Figure 4.10)

and a topographic map. This noise is caused by defects of the coefficient maps (isolines not dense enough or remaining inconsistencies between different coefficient maps) and the limited number of generated years. At the cost of time spent on the careful construction of more detailed coefficient maps, and computing time used to generate longer runs, this noise can be reduced. From a comparison of the two maps in Figure 4.2 it is evident that output maps based on daily generated data are more prone to noise. This is due to the larger number of coefficients involved compared to monthly data and also the higher demand on computing time restricting the length of generated runs.

The examples based on daily generated data (Figures 4.3 to 4.7) are concerned with the planting and crop establishment phase. Keatinge, Dennett and Rodgers (1985, 1986) have found that 10 mm or more of rain over 3 days is likely to cause germination of cereals even when the soil is rather dry before the event. Early planting is desirable especially in the drier areas as it extends the effective growth period of the crop thereby conferring a yield advantage which is further increased by a higher water use efficiency, as early planted crops develop a closed canopy more rapidly, reducing evaporation from the soil surface (Cooper, Keatinge and Hughes 1983). In the wetter areas, early germinating rains can be used to cultivate volunteer cereals before planting the field to legumes. The major drawback of early planting of cereals is the risk of a severe drought in the early vegetative phase, causing cessation of growth and possible seedling mortality. Such a risk can be defined as a 20 days or longer dry spell within 40 days after germination (Keatinge, Dennett and Rodgers 1986). On the other hand, late planting not only reduces yield because of the reasons stated above. In addition, since the probability of long, uninterrupted wet spells increases throughout the planting period, so does the risk of not being able to enter the field because of the wet surface, thereby causing even more delay.

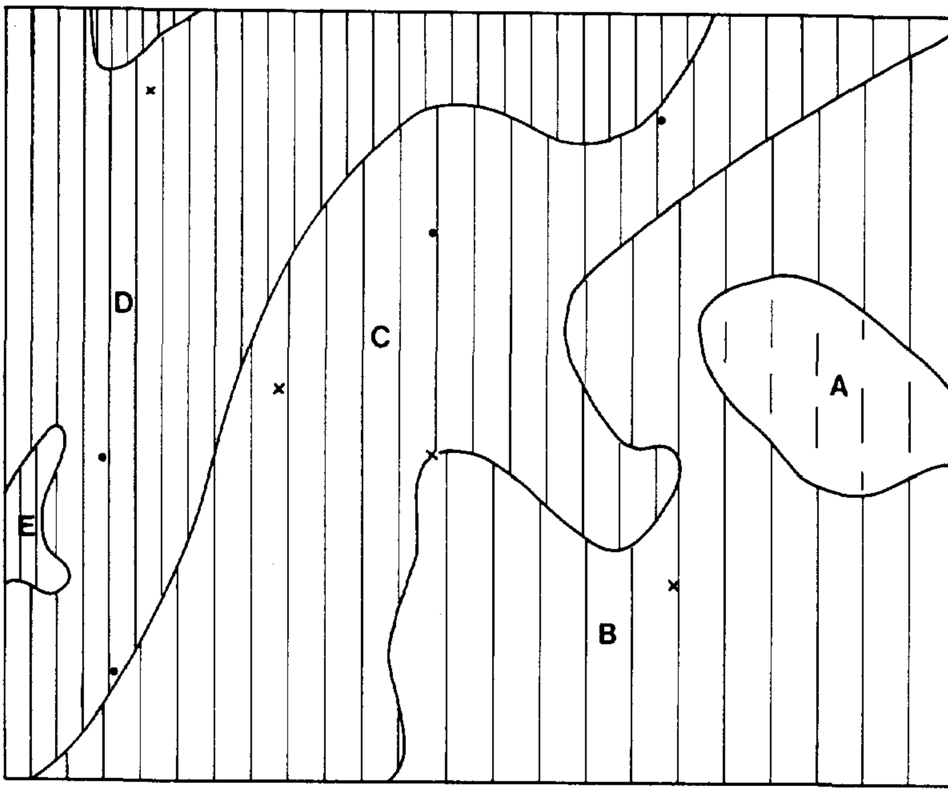
Figure 4.3 is a map of the median date of the start of the first germinating rain, expressed as days elapsed since 1 October. Even in the wettest areas, one has to wait two to three weeks for such an event in one year out of two. In the major wheat producing areas, this span is three to four weeks, increasing to five and six weeks in the barley areas. Assuming germination had occurred by 1 November, Figure 4.4 gives the probability of a severe drought during the seedling stage. In the wheat growing areas, such a drought has to be expected in 20 to 40% of the years, while in some of the barley areas, the risk increases to



A 36-45 days B 31-35 days C 26-30 days D 21-25 days
E 16-20 days F 14-15 days

Figure 4.3 Median number of days after 1 October to receive $\geq$ 10 mm rainfall within 72 hours (for scale and place names see Figure 4.1)

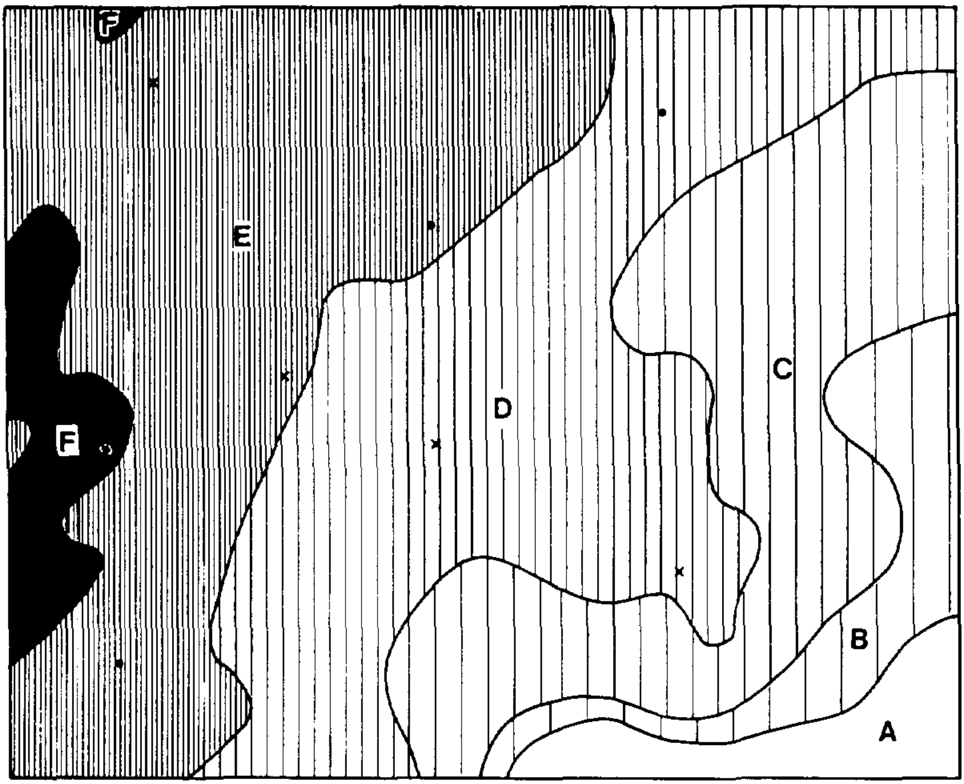
over 50%. From these two maps it is evident that dry planting in early October is not an advisable proposition anywhere in the study area. A more realistic scenario is depicted in Figures 4.5, 4.6 and 4.7. The median date of germinating rains, assuming planting on 1 December, is shown in Figure 4.5. It is less than a week in most of the wheat growing areas, and only in the driest of the barley areas on the map does one have to wait more than two weeks for germination in one year out of two. The risk of early



A 50%-60%   B 40%-50%   C 30%-40%   D 20%-30%
E 10%-20%

Figure 4.4 Probability of a $\geq$ 20 days long period with < 5 mm rainfall during 40 days starting 1 November (for scale and place names see Figure 4.1)

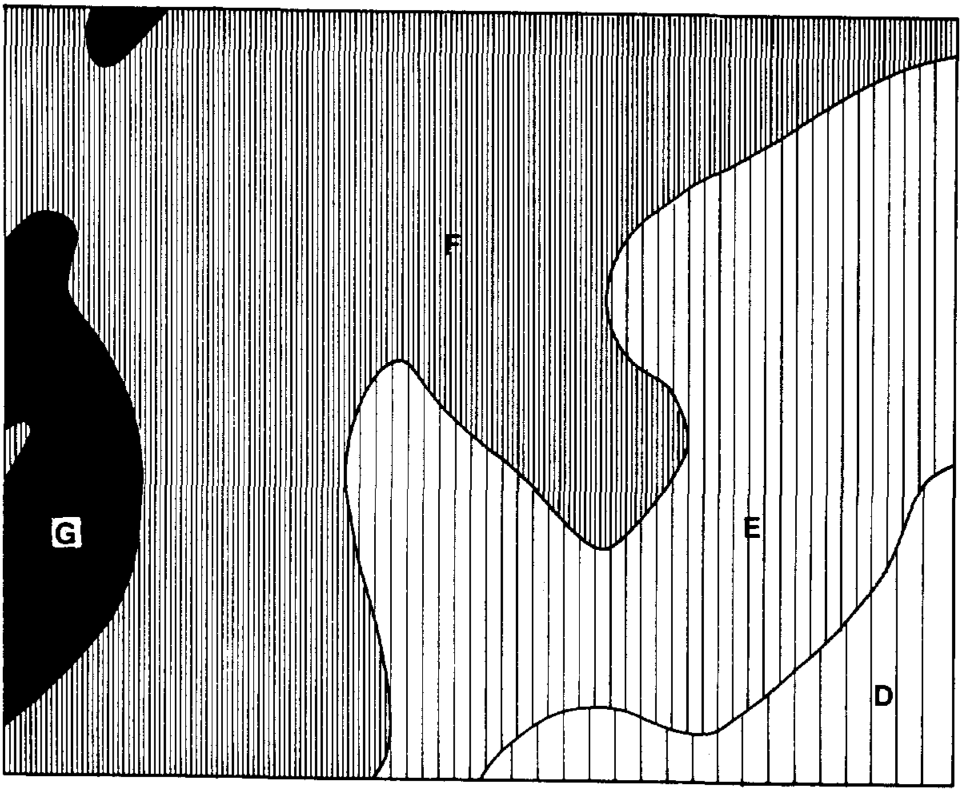
drought is markedly decreased during the 40 days following the first of December (Figure 4.6). With less than a 10% chance, it is nearly negligible all across the wheat growing areas and only in the dry southeastern corner of the map does it increase to over 20%. Figure 4.7 gives the probabilities of not being able to enter the field for two weeks starting 1 December. This would be caused by 10 or more days of rain, not interrupted by more than three days with no or only light (< 2 mm) rain, assuming that the



A 16-21 days B 13-15 days C 10-12 days D 7-9 days
E 4-6 days F 1-3 days

Figure 4.5 Median number of days after 1 December to receive $\geq$ 10 mm rainfall within 72 hours (for scale and place names see Figure 4.1)

soil surface takes three days to dry out sufficiently. Even during the first half of December it turns out that this risk is negligible all over the barley areas and below 20% in the wetter of the wheat growing areas. From Figures 4.5 and 4.6 it would seem that dry planting of cereals during the second half of November is a valid option across the whole area; however in the wetter half of the wheat growing part, earlier planting during the first half of November or in late October may be a superior



D 20%-30% E 10%-20% F 4%-10% G < 4%

Figure 4.6 Probability of a ≥ 20 day long period with < 5 mm rainfall during 40 days starting 1 December (for scale and place names see Figure 4.1)

strategy. In the driest part in the southeast, any rainfed crop production is a risky undertaking.

The second set of examples is based on generated monthly rainfall totals. Regression equations of barley responses to October-to-April rainfall totals and nitrogen and phosphate fertilizer obtained by Jones and Wahbi from on-farm trials and described in section 3.1.1 of this report were used to obtain

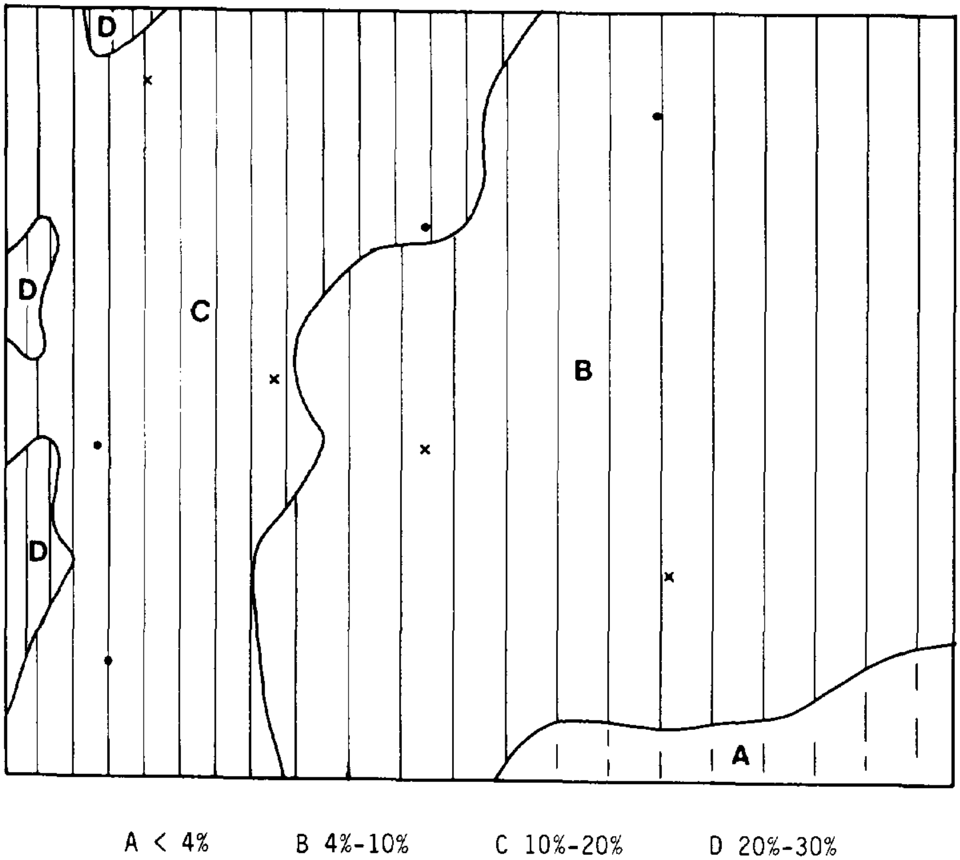
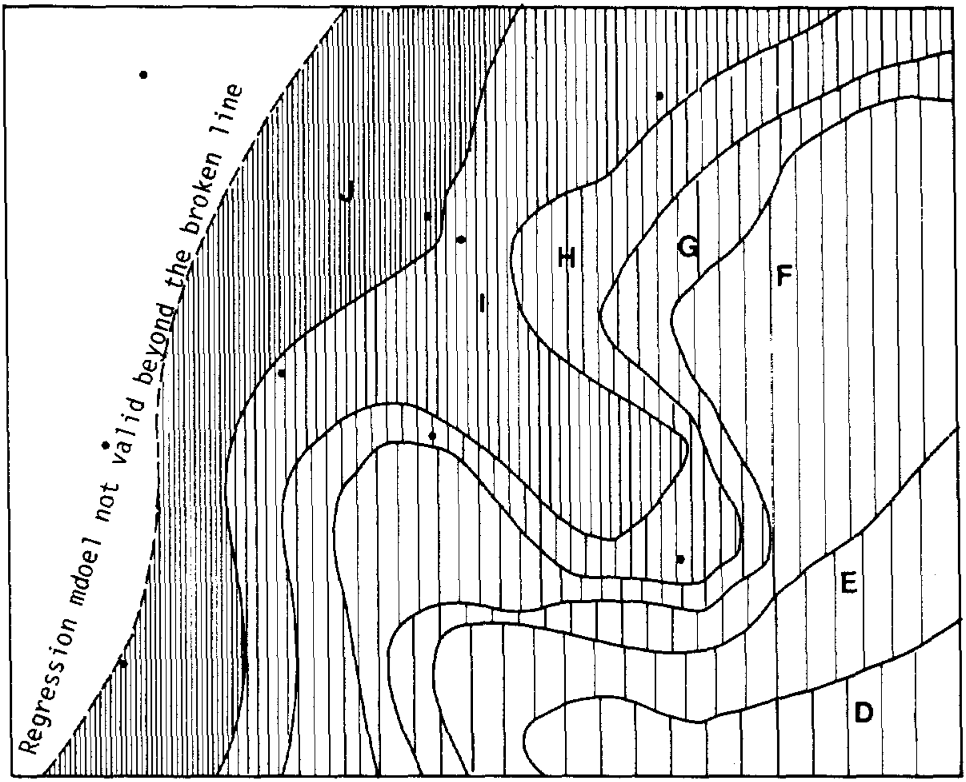


Figure 4.7 Probability of a 2 week long period of continuously wet soil surface starting 1 December. The soil surface is assumed to be dry after 72 hours with < 2 mm rainfall (for scale and place names see Figure 4.1)

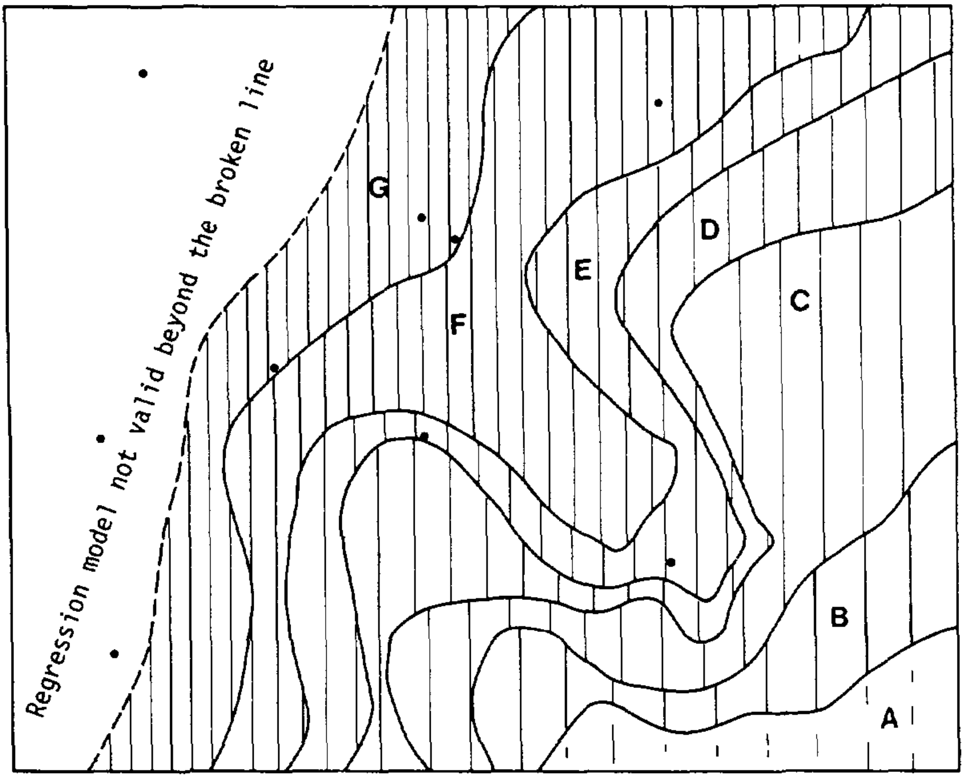
maps of mean unfertilized barley yields in fallow-barley and barley-barley rotations (Figures 4.8 and 4.9), as well as maps of barley response to 60 kg/ha N and 30 kg/ha P_2O_5 expected in four years out of five in the same rotations (Figures 4.10 and 4.11). The maps assume the same "average" soil types and conditions as existed at the sites of the trials, thereby overpredicting yields in areas of shallow and degraded soils, such as encountered in hilly and degraded areas southeast and west of Aleppo. The



D 800-1000 kg/ha E 1000-1200 kg/ha F 1200-1400 kg/ha
G 1400-1600 kg/ha H 1600-1800 kg/ha I 1800-2000 kg/ha
J 2000-2200 kg/ha

Figure 4.8 Mean barley yield in an unfertilized fallow-barley rotation (for scale and place names see Figure 4.1)

regressions are furthermore not valid for areas receiving rainfall beyond the range represented by the trial locations. This boundary has been marked on the maps by a dashed line. Comparing Figures 4.8 and 4.9 one notes that the mean barley yields in the barley-barley rotation decrease from about 1500 kg/ha in the most favourable areas to only around 300 kg/ha in the driest parts, a decrease of 80%, whereas the yields in the fallow-barley rotation only drop from 2100 kg/ha to 900 kg/ha, or about 57%, partially

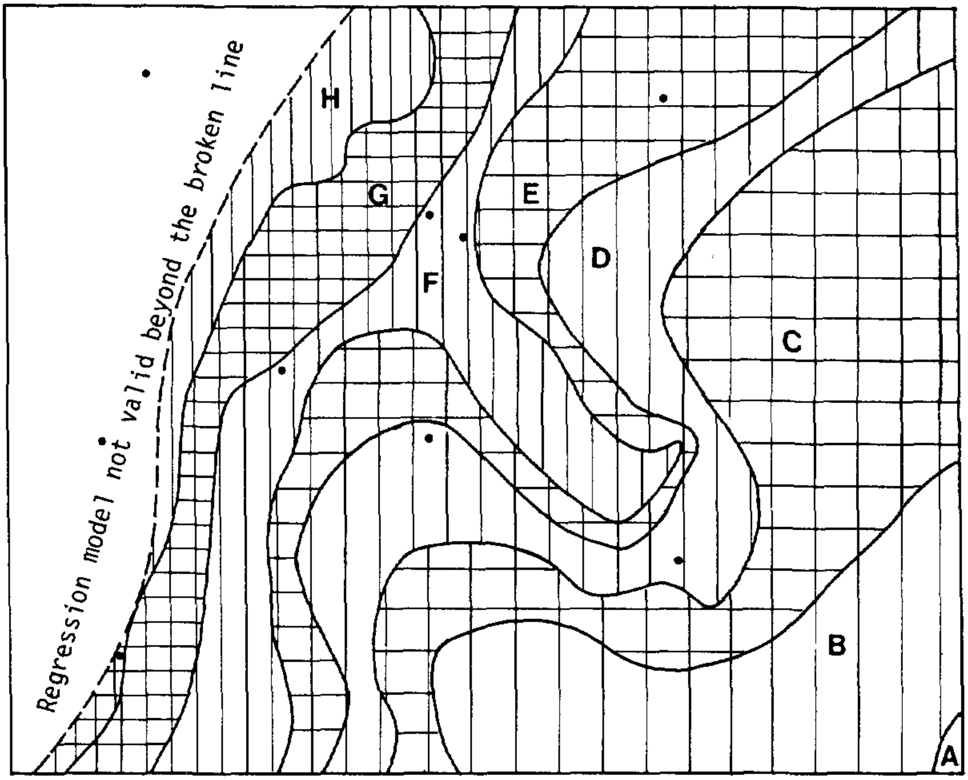


A 200- 400 kg/ha
B 400- 600 kg/ha
C 600- 800 kg/ha
D 800-1000 kg/ha
E 1000-1200 kg/ha
F 1200-1400 kg/ha
G 1400-1600 kg/ha

Figure 4.9 Mean barley yield in an unfertilized barley-barley rotation (for scale and place names see Figure 4.1)

reflecting the increased benefit of moisture conservation by fallowing in the drier areas. Other beneficial effects of fallowing such as soil fertility status, weed control and reduced incidence of pests and diseases are also known to be important.

The expected fertilizer response at the selected rate is considerably higher for barley in the barley-barley rotation compared to the fallow-barley rotation over the whole area. The



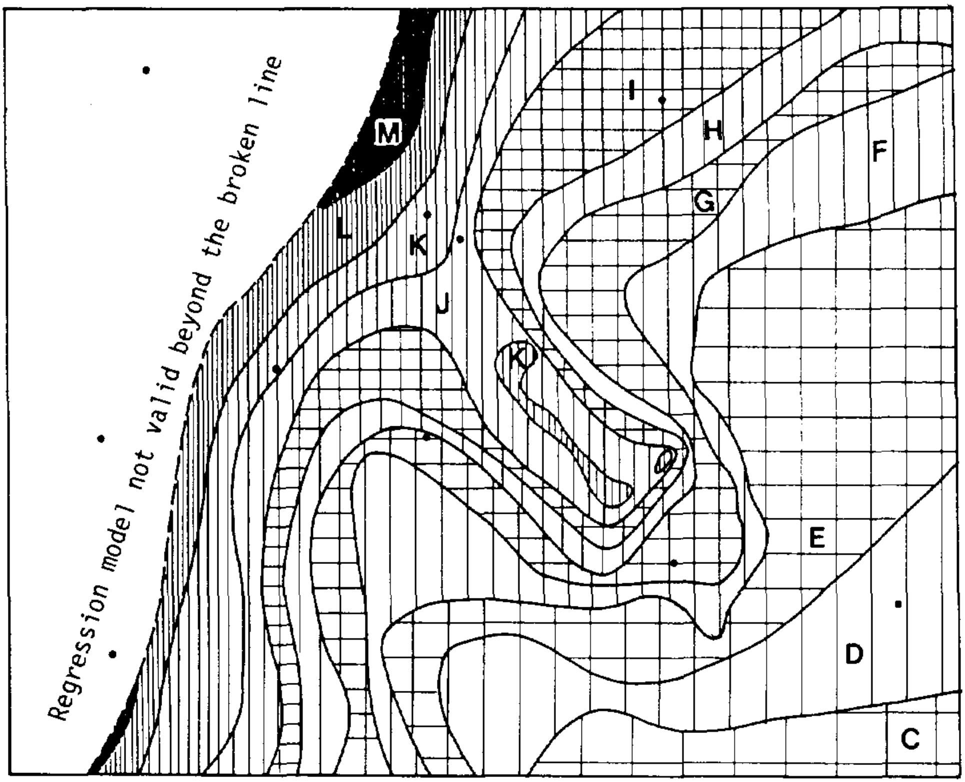
A 50-100 kg/ha
D 200-250 kg/ha
G 350-400 kg/ha

B 100-150 kg/ha
E 250-300 kg/ha
H 400-450 kg/ha

C 150-200 kg/ha
F 300-350 kg/ha

Figure 4.10 Yield increase of barley in a fallow-barley rotation from 60 kg/ha N and 30 kg/ha P_2O_5 expected in 4 years out of 5 (for scale and place names see Figure 4.1)

reasons for this behaviour are explained in section 3.1.1 of this report, and are largely associated with the greater response of barley to nitrogen when it is grown as a continuous crop. It is of interest to compare the map for the expected yield increase in barley-barley rotations (see Figure 3.1.14) with the map in Figure 4.11. Whereas the two maps agree reasonably well in general, noticeable differences exist east and southeast of Aleppo. These differences are due to a different interpretation of the rainfall



C 150-200 kg/ha D 200-250 kg/ha E 250-300 kg/ha F 300-350 kg/ha
G 350-400 kg/ha H 400-450 kg/ha I 450-500 kg/ha J 500-550 kg/ha
K 550-600 kg/ha L 600-650 kg/ha M 650-700 kg/ha

Figure 4.11 Yield increase of barley in a barley-barley rotation from 60 kg/ha N and 30 kg/ha P_2O_5 expected in 4 years out of 5 (for scale and place names see Figure 4.1)

data. In the preparation of their map, Jones and Wahbi did not make use of rainfall data from Tatt and did not assume any influence of the hills southeast of Aleppo on rainfall. Further north, differences exist in the interpretation of the somewhat contradictory and partially incomplete rainfall data of Kweiress and Jabboul, Abu Qalqal, El Khafse and Maskaneh (just beyond the eastern border of Figure 4.11), on which hinges the gradient of rainfall and, therefore, the gradient of barley yields across the plain between Aleppo and the Euphrates.

The maps in Figures 3.1.14 and 4.11 exemplify two equally valid ways to achieve regionalized predictions of variables dependent on weather or weather events themselves in probabilistic terms:

- Calculate the values of the relevant variable for a number of sites, then interpolate between sites to obtain the desired map. This process has to be repeated for each additional variable and probability level.
- Determine the values for the generator coefficients for a number of sites, map and digitize them, generate the desired results with the SWG for a grid of locations so dense that further interpolation is unnecessary.

The advantage of the second option is an operational one. Once the generator coefficient maps are digitized, all output maps can be produced so-to-speak at the push of a button, and it is guaranteed that a set of maps produced in this manner is free of mutual contradictions, something which is very difficult to achieve otherwise.

4.2.4 APPENDIX 1

Summary of Methods Employed by the SWG for Rainfall Generation

1. Modelling wet-dry sequences

1.1 Daily time-step

On a daily time-step a second order Markov chain with two states, dry (i.e. no rainfall or trace) and wet (i.e. any measured rainfall greater than trace) is used to model sequences of wet and dry.

If the following symbols are used:

W, D: wet day, dry day

WW, WD, DW, DD: two day periods of wet and/or dry days

p_w, p_d: unconditional probabilities of wet days, dry days

p_{ww}, p_{wd}, p_{dw}, p_{dd}: unconditional probabilities of two-day periods

$p_{w/ww}$, $p_{w/wd}$, $p_{w/dw}$, $p_{w/dd}$: probabilities of a wet day following a sequence of two days (transition probabilities)

$p_{d/ww}$, $p_{d/wd}$, $p_{d/dw}$, $p_{d/dd}$: probability of a dry day following a sequence of two days (transition probabilities)

n_w, n_d: numbers of wet and dry days in a month

$n_{w/ww}$, $n_{w/wd}$, $n_{w/dw}$, $n_{w/ww}$, $n_{d/ww}$, $n_{d/wd}$, $n_{d/dw}$, $n_{d/dd}$: number of occurrences of a wet or dry day after the indicated sequence of days

then, for every calendar month, the estimated transition probabilities are obtained from:

$$\hat{p}_{w/ww} = n_{w/ww} / (n_{w/ww} + n_{d/ww})$$
$$\hat{p}_{w/wd} = n_{w/wd} / (n_{w/wd} + n_{d/wd})$$
$$\hat{p}_{w/dw} = n_{w/dw} / (n_{w/dw} + n_{d/dw})$$
$$\hat{p}_{w/dd} = n_{w/dd} / (n_{w/dd} + n_{d/dd})$$
$$\hat{p}_{d/ww} = 1-\hat{p}_{w/ww} \text{ etc.}$$

The transition probabilities can be written in matrix form:

$$\begin{array}{c} \\ WW \\ WD \\ DW \\ DD \end{array} \begin{array}{c} \begin{array}{cc} W & D \end{array} \\ \begin{bmatrix} p_{w/ww} & 1-p_{w/ww} \\ p_{w/wd} & 1-p_{w/wd} \\ p_{w/dw} & 1-p_{w/dw} \\ p_{w/dd} & 1-p_{w/dd} \end{bmatrix} \end{array}$$

To find the connection between the second-order transition probabilities and the unconditional probabilities of the occurrence of a wet day, this 2 x 4 matrix of transition probabilities is transformed into a square stochastic matrix **M**.

$$
\begin{array}{c} \\ \mathrm{WW} \\ \mathrm{WD} \\ \mathrm{DW} \\ \mathrm{DD} \end{array}
\begin{array}{cccc}
\mathrm{WW} & \mathrm{WD} & \mathrm{DW} & \mathrm{DD} \\
\left[\begin{array}{l} p^2_{w/ww} \\ p_{w/wd} * p_{w/dw} \\ p_{w/ww} * p_{w/dw} \\ p_{w/dw} * p_{w/dd} \end{array}\right.
& \begin{array}{l} p_{w/ww} * (1-p_{w/ww}) \\ p_{w/wd} * (1-p_{w/dw}) \\ p_{w/dw} * (1-p_{w/ww}) \\ p_{w/dd} * (1-p_{w/dw}) \end{array}
& \begin{array}{l} p_{w/wd} * (1-p_{w/ww}) \\ p_{w/dd} * (1-p_{w/wd}) \\ p_{w/wd} * (1-p_{w/dw}) \\ p_{w/dd} * (1-p_{w/dd}) \end{array}
& \left.\begin{array}{l} (1-p_{w/ww}) * (1-p_{w/wd}) \\ (1-p_{w/wd}) * (1-p_{w/dd}) \\ (1-p_{w/wd}) * (1-p_{w/dw}) \\ (1-p_{w/dd})^2 \end{array}\right]
\end{array} = \mathbf{M}
$$

If **M** is a regular stochastic matrix, then there exists a vector **V** so that **V*M = V**:

$$[p_{ww} \quad p_{wd} \quad p_{dw} \quad 1-p_{ww}-p_{wd}-p_{dw}] * \mathbf{M} = [p_{ww} \quad p_{wd} \quad p_{dw} \quad 1-p_{ww}-p_{wd}-p_{dw}]$$

This leads to a system of four equations for the three unknowns p_{ww}, p_{wd} and p_{dw}, where $p_{wd} = p_{dw}$.

Solving the system for p_{ww} and p_{wd} or p_{dw} also gives the unconditional probability of a wet day, since the probability of occurrence of a wet day in any period of two consecutive wet days WW is 1 and in any period WD or DW it is 0.5:

$$p_w = p_{ww} + p_{wd}/2 + p_{dw}/2 = p_{ww} + p_{wd} = p_{ww} + p_{dw}$$

The resulting formula is rather lengthy and shall therefore not be reproduced here, but it is computationally very fast since no numerical method is involved.

1.2 Monthly time-step

Whether a month is without a rainy day or not is assumed to be independent of conditions during the previous months and the unconditional probabilities of wet and dry months are used to model the sequence of wet and dry months.

$$\hat{p}_w = n_w \,/\, (n_w + n_d)$$
$$\hat{p}_d = 1 - \hat{p}_w$$

2. Modelling rainfall amounts on wet days/months

Both on a daily and on a monthly time-step, the rainfall amount on a wet day/month is assumed to follow a Gamma-distribution and to be independent of rainfall amounts received during previous days or months. The probability density function of the Gamma-distribution of a variable X is given by:

$$p_X(x) = \frac{(x-c)^{a-1} * \exp(-(x-c)/b)}{b^a * \mathrm{Gamma}(a)}$$

where a is the shape parameter, b is the scale parameter, Gamma(a) is the Gamma-function value for a, and c is the distribution's bounding value.

Since rainfall cannot become negative, c is set to zero. a and b are estimated by the maximum likelihood method for every calendar month from the amounts of rainfall received on wet days/wet months, using approximate solutions given by Greenwood and Durand (1960):

$$\hat{a} = (0.5000876 + 0.1648852Y - 0.0544274Y^2)/Y \qquad \text{if } 0 < Y \leq 0.5772$$
$$\hat{a} = (8.898919 + 9.059950Y + 0.9775373Y^2)/(17.79728 + 11.968477Y + Y^2)/Y \qquad \text{if } 0.5772 < Y \leq 17$$

where: $Y = \log(\Sigma(x_w) / n_w) - \log(\sqrt[n_w]{\Pi x_w})$

i.e., the natural logarithm of the ratio of arithmetic mean to geometric mean. Values > 17 for Y do not occur in practice.

The estimator of the scale parameter is then calculated as:

$\hat{b} = \Sigma(x_w) / n_w / a$ (Johnson and Kotz 1970).

The Gamma-function value Gamma(a) is approximated by Hasting's formula for values of $a \leq 1$ (Davis 1964):

$$\text{Gamma}(a) = (1+b_1a+b_2a^2+b_3a^3+b_4a^4+b_5a^5+b_6a^6+b_7a^7+b_8a^8)/a$$

with $b_1 = -0.577191652$ $b_5 = -0.756704078$
$b_2 = 0.988205891$ $b_6 = 0.482199394$
$b_3 = -0.897056937$ $b_7 = -0.193527818$
$b_4 = 0.918206857$ $b_8 = 0.035868343$

Values for a > 1 are obtained from the recurrence formula:

$$\text{Gamma}(z + 1) = z*\text{Gamma}(z)$$

3. Correction of coefficients

3.1 Correction for periods of missing observations

Arithmetic means of rainfall received on wet days/months are corrected by the ratio method (Essenwanger 1986) for gaps in the station records. If x and y are arithmetic means of stations x and y for observation periods a and a+b as shown by indices, then:

$$\hat{x}_{a+b} = x_a * y_{a+b} / y_a$$

Usually the weighted average $\bar{y}_{a+b}/\bar{y}_a$ of several stations is used instead of a single station. The stations are selected in sequence of combined rank from geographical distance and linear correlation of the cube-root transformed monthly totals with those of the station which is to be corrected.

It has been found useful to expand the method for the correction of the probabilities of wet days/months, the transition probabilities of the daily rainfall model and of the ratio of arithmetic and geometric means of rainfall on wet days/months. If y_{a+b}/y_a are > 1, however, the equation takes the form:

$$\hat{x}_{a+b} = 1 - (1-x_a) * (1-y_{a+b}) / (1-y_a)$$

in order to avoid estimates > 1.

3.2 Correction for inhomogeneities

Inhomogeneities are detected by the double-mass method (Scultetus 1969), i.e. by plotting cumulatives of coefficients against the averaged cumulatives of a large number of surrounding stations. Inhomogeneities show up as changes of gradient. With the method of least squares, straight lines are fitted to the periods before and after the date of a inhomogeneity. If $x(t)$ is the cumulative averaged value of many stations at time t, $y'(t)$ the original value of the station to be corrected, $\hat{y}(t)$ the corrected value, a_1 and a_2 the intercepts and b_1 and b_2 the gradients of the regression lines before and after the inhomogeneity occurred, then the corrected cumulative values after the occurrence of the inhomogeneity are estimated as:

$$\hat{y}(t) = y'(t) + a_1 - a_2 + (b_1 - b_2)\ x(t)$$

If the values from the time before the inhomogeneity are to be corrected rather than those from the time after, cumulative values are calculated from the end of the record backwards.

3.3 Correction for varying reliability in recording small rainfall amounts

With the help of graphs of frequency distributions of daily rainfall values, the stations are visually sorted into a group of reference stations which is assumed to record all rainfall events reliably and another one which is assumed to miss recording part of the rain days with less than 2.1 mm of rain. For each station which is to be corrected, the ratios of the number of rain days with 0.1 to 0.7, 0.8 to 1.5, 1.5 to 2.1 mm to the total number of rain days is calculated and compared with the weighted averages of the same ratios from reference stations which are sufficiently close and well correlated. This provides an estimate of the numbers of observations missing in each of the three classes. These missing observations are redistributed between 21 classes from 0.1 to 2.1 mm in such a way that an approximately inverse J-shaped distribution results. Finally, the corresponding number of rain days are inserted into the record of the station to be corrected randomly on such days, on which rainfall was recorded at neighbouring stations, but not at the station in need of correction.

Stations from which only monthly data (totals and numbers of rain days) are available can be only very approximately corrected by adding the averaged effect of the correction on surrounding daily stations.

3.4 Correction for preference given to round or even values

Some stations report round values (half or full mm) or even values much more often than values in between. If necessary, this is simply corrected by redistributing the excess observations to the classes 0.1 to 0.2 mm above or below the preferred values.

3.5 Correction for outliers of daily and monthly rainfall totals

A method from Kimber (1979) for Gamma samples with unknown shape and scale parameters is used. Test statistic is the kurtosis of the cube root transformed rainfall values. Tables of significance levels are contained in Pearson and Hartley (1966) and Barnett and Lewis (1984). In a straightforward numerical process, upper outliers are decreased and lower outliers increased in value stepwise, until the kurtosis drops below the value tabulated for the chosen significance level.

3.6 Mutual compatibility of coefficients

After corrections have been applied to coefficients of a station, the coefficients have to be checked against each other to remove any contradictions which may have resulted from the correction procedures. Such contradictions have to be expected since the corrections made are only based on best estimates from various sources. Therefore, the coefficients are scaled up or down so that the following conditions are met for each calendar month:

- The transition probabilities of the Markov-chain model of daily rainfall must be compatible with the unconditional probability of a rainy day as described in section 1.1 above.

- The arithmetic mean of rainfall on rainy days multiplied by the unconditional probability of rainy days and the number of days in a month must yield the mean monthly rainfall total.

- The arithmetic mean of rainfall during rainy months multiplied by the probability that the calendar month has at last one rainy day must yield the mean monthly rainfall total.

4. Spatial interpolation of coefficients

In principle, spatial interpolation of the coefficients is done manually. To ensure a spatially consistent set of coefficients, the following maps are constructed for each month:

- for daily data generation: total monthly rainfall, probability of a rainy day, mean rainfall on wet days, ratio of geometric and arithmetic means of rainfall on wet days, 4 Markov transition probabilities; additionally a map of annual totals and a map of annual probability of any day being rainy,

- for monthly data generation: total monthly rainfall, probability of the month having one or more wet days, mean rainfall during months with wet days, ratio of geometric and arithmetic means of rainfall during months with wet days, additionally a map of total annual rainfall.

In some cases, regression models can be used to facilitate the construction of some of the coefficient maps. In particular, unconditional probabilities of wet days can be used to estimate the transition probabilities of the Markov model as Hershfield (1977) has demonstrated for first order chains. For a second order Markov chain, the following regressions are calculated:

$$P_{w/ww} = a_1 + b_1 P_w$$
$$P_{w/wd} = a_2 + b_2 P_w$$
$$P_{d/dw} = a_3 + b_3 P_d$$
$$P_{d/dd} = a_4 + b_4 P_d$$

$p_{w/dw}$ and $p_{w/dd}$ are obtained by subtraction of $p_{d/dw}$ and $p_{d/dd}$ from 1.

The interpolation process must not at any point cause contradictions between different coefficients as described in section 3.6 of this Appendix. Additional constraints are that the monthly maps of rainfall totals must add up to the annual total and the probabilities of a rainy day each month must not contradict the map of annual probability of a rainy day.

5. Temporal smoothing of generator coefficients

When working on a daily time-step, the generator coefficients, which are monthly averages, are smoothed over the course of the year to avoid abrupt changes. This is done with the help of polynomial splines. If n_i are the number of days in each of the twelve calendar months (i = 0 is equal to i = 12 to ensure the curve is smooth around the year), a_i, b_i and c_i are 3 sets of parameters, m_i is the mean value of the generator coefficient for month i, and t is the day of the month (t = 0 at the begin of the month and $t = n_i$ at the end of the month), then a second order polynomial is given by:

$$y_i = a_i + b_i t + c_i t^2$$

The value y_i at the begin of the month (t = 0) must be identical with the value y_{i-1} at the end of the month ($t = n_{i-1}$), leading to a first set of 12 equations:

$$-a_i + b_{i-1}\, n_{i-1} + c_{i-1}\, n^2_{i-1} = 0 \qquad (i = 1,\dots 12).$$

For smooth transitions, the first derivatives must also be equal at the transition from one month to the next. The derivatives are:

$$y'_i = b_i + 2c_i t$$

This provides a second set of 12 equations:

$$-b_i + b_{i-1} + 2c_{i-1}\, n_{i-1} = 0 \qquad (i = 1, \ldots 12)$$

The third constraint is that mean of the coefficients across the month must be maintained, i.e., the area under the fitted curve must be equal $n_i m_i$:

$$\int_0^{n_i} y_i = n_i m_i = a_i n_i + b_i n_i^2 / 2 + c_i n_i^3 / 3 \qquad (i = 1, \ldots 12)$$

The set of 36 parallel equations is solved for the 36 coefficients a_i, b_i and c_i of the 12 polynomial splines. If problems with negative values occur, these can be avoided by the use of higher order polynomials enabling the inclusion of additional constraints.

6. Generation of rainfall values

6.1 Generation of dry and wet days

A random number from a uniform distribution between zero and one is generated. If it is larger than the transition probability to a wet day from the state defined by two previously generated days, a dry day is generated, otherwise a wet day is generated.

6.2 Generation of dry and wet months

If a random number generated from a uniform(0,1)-distribution is larger than the unconditional probability of the month having at least one wet day, a dry month is generated, otherwise a wet month is generated.

6.3 Generation of rainfall values

Daily and monthly rainfall values are generated from Gamma-distributions with the same method. First shape and scale parameters are corrected for the error caused by truncation below 0.1 mm with the help of an empirically constructed table. The generation process itself is adapted from Rubinstein (1981) and largely follows procedures first described by Joehnk (1964):

1. Let a_f denote the fractional part of the shape parameter a and a_i its integer part.

2. Generate a random number from a uniform(0,1)-distribution and raise it to power $1/a_f$ to get Y_1.

3. Generate a second random number and raise it to power $1/(1-a_f)$ to get Y_2.

4. If $Y_1+Y_2 \geq 1$, repeat the procedure from step 2.

5. Generate another random number R and compute $X = (-\log R)* Y_1/(Y_1+Y_2)$.

6. Generate a_i random numbers and add their negative natural logarithms to obtain Z.

7. Compute $G = b(Z+X)$, where b is the scale parameter. G is the desired Gamma variate.

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4.3 Characterizing Dryland Farming Systems of Northern Jordan

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4.3.1 Introduction

The Jordan University of Science and Technology (JUST) and FRMP began a multidisciplinary cooperative research program in 1988 with the objective of characterizing the agricultural production systems of the so-called "marginal zone" of rainfed agriculture. Approximately 70% of the arable land in the Hashemite Kingdom of Jordan falls into this category and receives between 200 and 300 mm of average annual precipitation. Approximately 41% of the country's population lives in this marginal zone.

Characterization is an essential element in the process of agricultural technology development, testing, and eventual transfer to farmers. The most widely recognized and researched dimension of characterization is agro-ecological characterization. This is a specialized field which documents a geographical area's environmental characteristics and their variability, including rainfall, temperature, soil characteristics, growing seasons, and cropping systems. These are then translated into expressions of crop productivity and mapped onto the geographical area for the purpose of predicting how agroecological variability will interact with and modify the impact of new technology. ICARDA is presently in the process of developing and adapting a range of tools to quantify temporal and spatial variability in ecological resources so as to examine strategies for minimizing its constraints on improved productivity. Progress in this work is reported elsewhere in this year's report (see section 4.2).

Characterization also includes on-farm research into the productivity of existing farming systems and cultural practices, the economic organization and conditions of the farming population, and the longer-term agricultural strategies being followed by farmers. **Without these additional dimensions of characterization it is impossible to develop improved technology targeted to specific groups of farmers in a recommendation domain and thereby to enhance the technology's eventual impact on the agricultural population.**

The broad outlines of Jordan's dryland farming systems have been described (Jaradat 1988). Population pressure and economic growth have put unprecedented demands on the fragile resource base. Conversion of natural grazing land to regularly cropped fields has precipitated extensive soil erosion, reduction of protective ground cover, and encroachment of the desert. At the same time, cultivation has become more intensive. The practice of prolonged fallowing is giving way to annual cropping in an effort to increase on-farm production of feed for growing numbers of livestock. As a result, over-exploitation of moisture reserves and declining soil fertility appear to have led to reduced yields. Although Jordanian farmers have been ingenious in devising ways of coping with difficult environmental constraints in the context of low capital inputs, traditional production methods may no longer be the appropriate ways of managing farm resources.

But before researchers can recommend appropriate technologies to alleviate farmers' problems, it is of utmost importance to first define these problems and identify the constraints experienced by farmers at the farm level. In this way, conditions at the farm level can play a vital role in identifying and selecting the technologies and cultural practices which will have the greatest likelihood of adoption and beneficial impact.

4.3.2 The Mafraq Study Area

The JUST/FRMP team began its characterization work by selecting a small geographical area that is representative of the entire marginal zone in Jordan. Called the Mafraq area, the study area is 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. These boundaries encompass an area of approximately 1000 square kilometers. About 40% of the land is arable. The rest consists of rocky hillsides, very shallow soils, scrubby woodland, wasteland, and village sites. According to the last census in 1979 there was a population of 35,550 persons. Since then, the total rural population has expanded to about 50,000 people living in 84 villages. A reasonable estimate is that two-thirds of the people are engaged in agricultural activities, although most farm families receive a greater or lesser amount of off-farm income, as well. The sheep and goat population owned by local farmers stood at around 150,000 head in 1988 (see Figure 4.12).

Along the periphery there are three sizeable market towns: Ramtha in the northwest, Jarash in the southwest, and Mafraq in the east. Jordan's second largest town, Irbid, is some fifteen kilometers to the west, and the suburbs of Greater Amman end a few kilometers away from the southeastern corner. During the 1980s considerable road construction took place in the Mafraq area, and now every village is connected to the principal highways between Ramtha and Mafraq, Jarash and Mafraq, and Mafraq and Amman.

Rainfall characteristics are difficult to establish. A considerable amount of data going back to the 1950s has been collected at Ramtha and at Mafraq, but only recently have rainfall gauges been installed at some of the schools located within the study area. All of this information is currently been evaluated by the agro-ecological characterization project in FRMP, but no results are yet available. The provisional isohyets presented in Figure 4.12 are based upon published estimates and the advice of local experts.

These lines divide the study area into three rainfall zones. Zone 1 is the wettest and receives from 300 mm up to as high as 500 mm near Jarash. The second area, or Zone 2, lies between the 200 mm and 300 mm isohyets. It covers slightly over half the

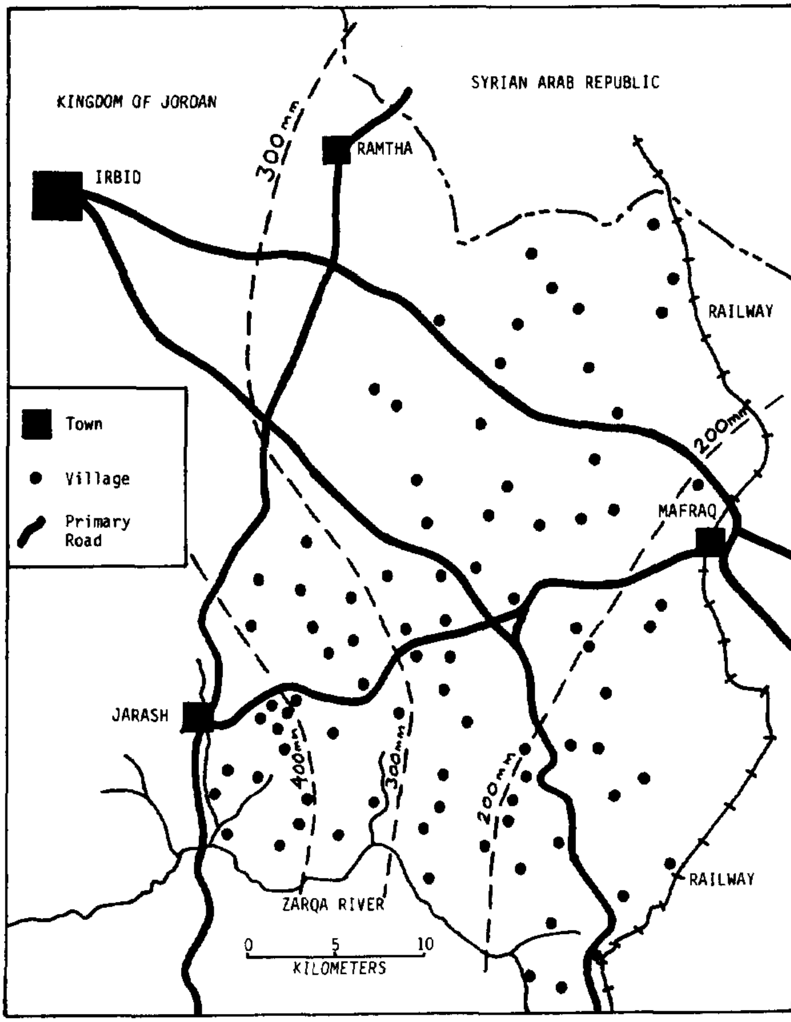

Figure 4.12 Settlements and provisional isohyets of Mafraq area

Mafraq area and includes some 60% of the farm population. Finally, the less than 200 mm area, or Zone 3, covers the southeastern corner. These zones should be considered as only broadly indicative. In fact, rainfall varies considerably from year to year and within individual years throughout the study region. For example, in the wettest year on record Ramtha received over 600 mm of precipitation. In the same year Mafraq town enjoyed just slightly under 300 mm instead of the more usual less than 200 mm.

Topography further divides the Mafraq area into distinct sub-areas. There is a line of low, barren ridges in the extreme north along the Syrian frontier. To the south of these ridges is a gently rolling plain intersected by gullies of varying width and depth. In the eastern third of the study area the plain extends southward all the way to the Zarqa valley, but in the west it abuts another line of ridges about two kilometers south of the Irbid to Mafraq road. Successive lines of ridges follow one after the other until reaching the Zarqa valley. All of these have eastern termini on a north-south line running about mid-way through the study area. The ridges turn into distinct hill country in the southwestern corner of the study area where there is heavier rainfall.

4.3.3 History of Agricultural Settlement in the Area

In classical times northern Jordan contained many agricultural villages and a few major trading towns, but existing documentation indicates that in the middle of the nineteenth century the only permanently occupied settlement east of the Ramtha to Jarash road was the police post at Mafraq (Lewis 1987). Together with Ramtha, Mafraq was an important stopping place along the old pilgrimage road running from Damascus to the holy cities of Mecca and Medina. In fact, the Hejaz railway was originally intended by the Ottoman authorities to partially supplant this ancient caravan route. There were a handful of villages in the area which had been sites of permanent settlement much earlier, but a hundred years ago they were only seasonally occupied by nomadic herders.

In the nineteenth century there was no farming system, as such, in the Mafraq area. Instead, the local economy was dominated by nomadic herding of sheep and goats and, to a much lesser extent, camels. The Mafraq area was only a small part of the geographical region utilized by the nomads. Each spring they would begin their migration out of the eastern steppe region into the Mafraq area, where they would encamp for a few months to take advantage of the natural pasture regeneration following the onset of the winter rains. Once the pasture was exhausted, the herders would move further west into the agricultural areas around Irbid to graze upon the cereal crop residues of the villagers.

The relations between eastern herders and western agriculturists were not always peaceful, and the Ottoman authorities of the time rarely had the ability to regulate relations between the villagers who produced crops and the herders who sought access to the residues. Generally speaking, if there was a dry rainfall year and the natural grazing in the Mafraq area was insufficient for spring grazing, then the herders would graze their flocks in the agricultural area by any means available to them, often including occupation of cereal fields and the ransacking of villages by force of arms. In the second half of the nineteenth century and up until the beginning of World War I, the people of Ramtha, Irbid, and their neighboring villages experienced numerous armed clashes with the pastoral tribesmen (Abujaber 1989).

The British army occupied the country of Jordan at the end of World War I, and during the next two decades they pacified the region while setting up the strong central administration which became the Hashemite Kingdom of Jordan. The present farming systems in the Mafraq area date from this period. A few scattered old villages were reoccupied and new ones sprang up in the atmosphere of peace and security. At first, the new agricultural areas were concentrated in the southwest around Jarash where conditions were most favorable, but later villages appeared throughout the area. Today's population distribution reflects these developments. Population density is two to three times as great in the wetter hill country than in the drier north and east.

The present agricultural population largely comes from the original pastoralists, who began to settle down and produce their own crops and feed supplies once access to the western grazing became more regulated by government authority. With the establishment of a strong central administration, the villagers to the west of the Mafraq area were able to more easily refuse pastoralist demands for collected crop residues and open grazing on their fields. Population growth and the intensification of agriculture to the west of the Mafraq area further forced the pastoralists back into the Mafraq area.

As early as the 1890s the leaders of the pastoral tribes utilizing the Mafraq area had encouraged their followers to take up the plow. Individual shaykhs began to lay claims to specific tracts of land in the names of their tribal sections. Tribal claims were given a great boost in the 1930s when the administration began a program of centralized land registration. To a large extent the claims of the shaykhs were affirmed and recognized by the government. Many of the villages of the area date from this period, and the families of the original owners and their followers are today the owners and cultivators of the land.

A second group of settlers were immigrants who had not previously used the resources of the area. Some of these came from the crowded agricultural areas to the west and others came from further afield in Palestine. These families settled through squatting on unclaimed land or by purchasing land from the original tribal claimants.

The founding of new villages continues today. Six new villages have been established and recognized by the government since 1979. Five of these are in the southwestern half of the study area and the remaining one is in the extreme north. New villages largely result from the younger generation leaving older villages to begin independent households, but there is still a trickle of immigration.

4.3.4 The Farming System

The characterization work of the JUST/FRMP team is planned to continue over a period of three or more years. The first year (1987-88) was spent in collecting secondary data and culminated in an exploratory farmer survey with a sample of 55 farms among 20 villages. The resulting general description of the farming system and its problems was presented at a national workshop in Amman in September, 1988 (Oglah and Jaradat 1988). The 1988-89 season continued the farm survey research. A slightly modified questionnaire was administered to 59 farmers and covered an additional 15 villages. The second sample was chosen to complement the first so that the two together are representative of the entire area.

Along with the continuing farm survey work, the 1988-89 season saw the introduction of diagnostic agronomy into the characterization process. Trials were installed in three locations across the rainfall isohyet (see Figure 4.13), and a number of simple experiments were undertaken with cooperating farmers. The trials and experiments were designed to collect productivity information for barley and feed legume varieties under various ecological and management conditions.

The remainder of this section describes the farming system in general. It is followed by a presentation of the different types of farm system in the area and the characteristics of each.

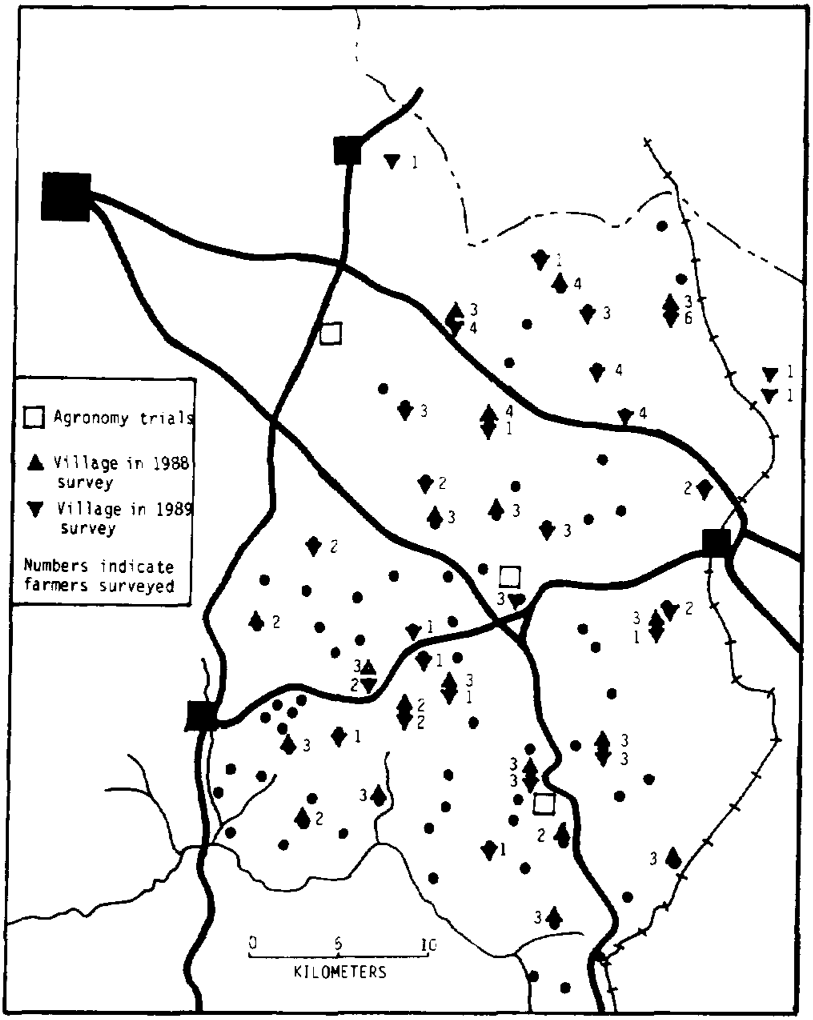

Figure 4.13 Survey samples and trials locations in Mafraq area

The first thing to keep in mind when considering the farming system of the Mafraq area is the extreme uncertainty of rainfall. Anyone who talks to farmers in the area must be impressed by their preoccupation with unpredictable weather. As a result, they devote considerable thought in selecting cultural practices which they think can ensure even a minimum productivity under these conditions.

The second important characteristic is that agriculture in the Mafraq area is extensive. Rather than concentrating their time and energy on small plots to make them more productive, farmers tend to spread their efforts over larger areas. The average labor time spent per hectare is low, and most of the work occurs at planting and harvest time. The schedule of extensive farming allows for relatively long periods when farmers can, if they wish, engage in off-farm activities. In fact, the average proportion of total income derived from off-farm activities in the Mafraq area now stands at almost 44%.

A third point is that farm holding are overwhelmingly owner operated. This no doubt stems from the recent establishment of the farming system in the area and the particular history of settlement. Only about 5% of the cultivated land is under rent or sharecrop contracts, and there are significant differences in tenure patterns among villages. However, it should be noted that although the incidence of owner-operated farms is very high, the amount of land owned jointly by more than one title holder (28%) constitutes an important proportion of the cultivated land. Usually the joint owners are close relatives, but only one of them is farming the joint property. This can have important implications for land use because although they are not engaged in production, joint owners reserve the right to have a say in how the land is used.

Finally, the agricultural households of the Mafraq area are fully integrated in the wider market economy. Even though they consume a greater or lesser proportion of what they produce, they cannot be considered subsistence farmers, nor even farmers whose first priority is to take care of their own consumption needs and then to sell any surplus left over. Hired labor and purchased inputs are pervasive. Virtually all of the farmers surveyed had at least some cash costs.

The farming system of the Mafraq area is similar to that which occurs in wide areas of the Mediterranean basin. Winter cereals, particularly wheat for human consumption and barley for animal consumption, account for most of the cultivated area. Cereals are augmented with olives, other tree crops, and to a lesser extent by legumes and vegetables. Flocks of sheep and goats often represent the most important capital assets and source of income. They are fed on barley grain, straw, and, increasingly, purchased feeds. Where available, weedy fallows and surrounding natural grazing lands are an important source of seasonally available animal feed.

Table 4.1 presents the average holding sizes and land uses in the study area according to rainfall zones. Average ewe and goat flock size per farm are included to indicate the relation between crops and animals.

Table 4.1 Mafraq Area Farm Size and Land Use

Rainfall Zone	Av. Farm Size (ha)	Barley (ha)	Wheat (ha)	Olives (ha)	Ewes (head)	Goats (head)
Zone 1 (> 300 mm)	14.1	3.0	2.6	3.0	47	19
Zone 2 (200-300 mm)	23.6	9.5	5.1	1.1	81	7
Zone 3 (< 200 mm)	26.2	13.3	4.0	1.4	59	13
Mean	22.4	9.4	4.3	1.6	69	11

Although it is reasonable to assume that there is a fair degree of stability in farm size from one year to the next, the same assumption cannot be made for land use. Land use decisions are closely related to seasonal rainfall and, to a lesser extent, to individual farmer production strategies. The proportion of the average holding planted in 1988/89 was 77%. The figures for 1987/88 and 1986/87 were 83% and 67%, respectively. These proportions parallel seasonal rainfall differences. The ratio of planted area to unplanted area tends to be greater in the drier areas than in the wetter ones. Similarly, the year-to-year fluctuations in this proportion are also greater in the drier areas where less land is under permanent treecrops and the minimum rainfall for raising cereals is less dependable.

The incidence and proportion of land intentionally fallowed from one year to the next is difficult to determine. In general, farmers laud the benefits of fallowing, and some 27% of farmers (in 1988) claim to regularly fallow their previous year's cereal fields as part of a fixed rotation. But many farmers practice what might be called circumstantial fallowing when they judge that rainfall conditions are not sufficient to permit planting or because of the desires of joint owners of land. Based on survey results, a reasonable estimate of the proportion of the total land under fallow in an average year is about 27%, with the incidence of fallow being greater in the drier areas than in the wetter ones.

Figure 4.14 shows the relative division of on-farm income among the various enterprises for the entire survey sample. Several observations need to be made. First of all, farmers were asked to estimate the relative proportion contributed by each enterprise averaged over the past five years in order to lessen the effect of dramatic price rises or declines in any single year. Second, farmers were asked to figure the relative weight of wheat and barley as a contributor to total income and not simply as income realized by sale. Thus, the contribution of barley should be seen in terms of its role in the farming system as an on-farm source of feed for livestock. Third, the average figures do not reflect the considerable variation across the study area. Livestock and crops are not evenly distributed. Tree crops and wheat are more commonly grown in the wetter

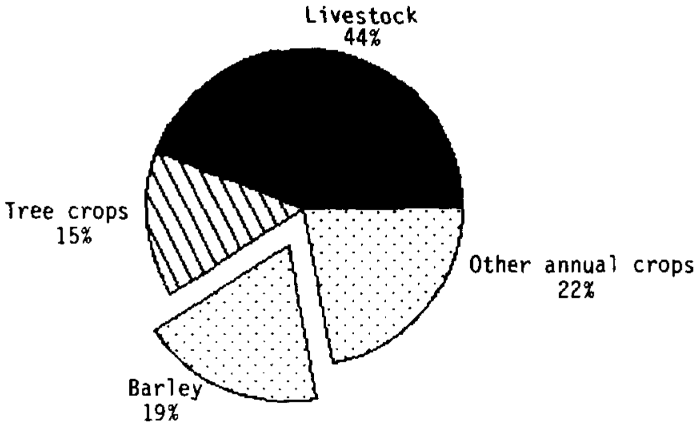

Figure 4.14 Sources of on-farm income in Mafraq area.

southwestern area whereas the north, central, and eastern areas are dominated by barley and livestock production.

Barley yields appear to be low in general and highly unstable from year to year. When asked about their experiences of the past ten seasons, farmers interviewed in 1988 gave the responses shown in Table 4.2.

Table 4.2 Barley Performances for Last Ten Seasons

Performance	Number of Years Occurring Mean	SD
No seeding	0.8	1.5
Grazed, no harvest	4.3	1.8
Low yield (av. 208 kg/ha)	1.8	1.2
Average yield (av. 626 kg/ha)	1.8	0.8
High yield (av. 1454 kg/ha)	1.3	0.7
Total years	10.0	

As with barley, olive production levels are low. In general, a mature olive tree in the Mafraq region only produces fruit every other year. The practice is to plant about 100 trees per hectare. Assuming that all the trees are mature and bearing fruit, this means that about 50 trees per ha per year should be producing. Thus a farmer with the average of 3 ha in olives in the wetter Zone 1 of the study area could expect to harvest about 150 trees per year. Because the number of new orchards is rapidly increasing from year to year, most farmers even in the wetter areas have a low percentage of mature producing trees. The present ratio is about 54 productive trees out of every 100 planted.

Farmers estimated the fruit yield per harvested tree as follows:

In a poor year	5.3 kg per tree
In an average year	12.5 kg per tree
In a good year	25.0 kg per tree

The maximum yield of a tree under irrigation is said to be 100 kg.

4.3.5 Characterizing Farmer Groups

The initial analysis of the farm survey data was done with the objective of identifying different groups of farms which display characteristics which are pertinent to the targeting of the technologies being tested in our agronomy research. Several general parameters have been recognized as potentially useful characters: rainfall zone, farm size, enterprise mix, total income, and the relative dependence on off-farm income sources.

Table 4.3 shows the distribution of the survey sample by farm size and rainfall zone.

Table 4.3 Farm Size Distribution in Rainfall Zones

Farm Size	Rainfall Zones							
	Farms (Whole sample)		Zone 1		Zone 2		Zone 3	
	No.	%	No.	%	No.	%	No.	%
Less than 5 ha	13	11	4	17	8	13	1	3
5-20 ha	62	54	16	70	30	49	16	53
20-50 ha	29	26	2	9	16	26	11	37
50-100 ha	7	6	1	4	6	10	-	
More than 100 ha	3	3	-	-	1	2	2	7
Totals	114	100	23	100	61	100	30	100

The distribution of the sampled farms is a reasonable approximation of the actual distribution of all farms in the study area, and reflects the 1979 census figures. However, the numbers of farms in the sample from Zone 1 and Zone 3 are biased slightly in favor of Zone 3 for the following reasons: (1) the proportion of full-time farmers in Zone 1 is less than Zone 3 due to the proximity of Jarash and Amman to Zone 1, and (2) the marginal zone enterprises of barley and livestock are more important to Zone 3 farmers than Zone 1 farmers. In short, Zone 3 is more characteristic of the 200-300 mm rainfall zone in Jordan as a whole than is the wetter area near Jarash.

A second generally accepted way of looking at variation within a farming system is to focus on individual farmer production strategies or mix of enterprises. This aspect is sometimes termed "farm systems," as opposed to farming systems (Fresco and Westphal 1988). All but 4 (3.5%) of the farms in the survey fell within four farm system categories. These production strategies are as follows: cereal and livestock production (CL); cereal, livestock and olive production (CLO); cereal and olive production

(CO); and cereal production only (C). Their relative frequency in the Mafraq area is given in Figure 4.15 and their land use pattern (averaged across all zones) is given in Table 4.4.

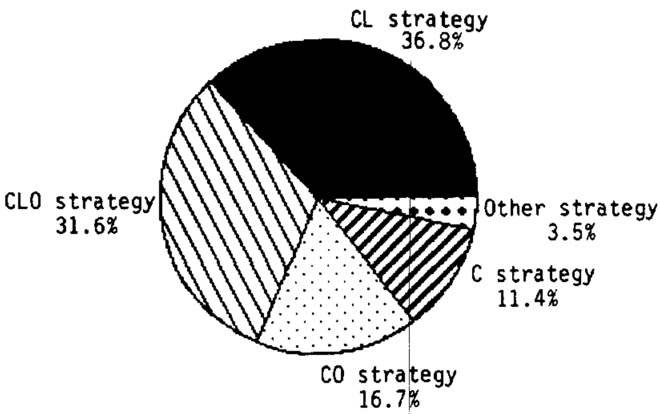

Figure 4.15 Distribution of production strategies in Mafraq area.

Table 4.4 Strategy and enterprise comparisons (average figures)

Strategy	Enterprises					
	Holding size (ha)	Olives (ha)	Wheat (ha)	Barley (ha)	Livestock Ewes	Livestock Goats
CL	22.2	0.3	4.8	11.4	107	13
CLO	29.9	3.2	4.4	8.5	89	18
CO	15.1	3.0	2.3	5.4	0	2
C	17.1	0.6	6.4	9.6	1	1
Mean	22.4	1.6	4.3	9.4	69	11

The assignment of each case to a particular production strategy was done by combining the list of enterprises on each farm with sources of on-farm income. Although virtually all farmers keep at least one ewe or goat, household flocks with fewer than ten head were not considered to constitute a farm enterprise, since the scale is not large enough to represent a major portion of household income. Similarly, most farmers have a few olive trees planted next to the house, irrigated with waste water. These were not considered to constitute a farm enterprise either. To be included on a farmer's list of enterprises, he needed to have at least 30 mature producing trees.

Table 4.5 shows the distribution of production strategies within the rainfall zones. The numbers point out the comparative advantages of olives in the wetter areas and livestock in the drier zones. When this is compared to farm size, the pattern is reinforced (see Table 4.6).

Table 4.5 Production strategy locations

Strategy	Rainfall Zones					
	Zone 1		Zone 2		Zone 3	
	No.	%	No.	%	No.	%
CL	1	4	27	44	14	47
CLO	14	61	14	23	8	27
CO	5	22	7	11	7	23
C	-	-	12	20	1	3
Other	3	13	1	2	-	-
Total	23	100	61	100	30	100

There is considerable geographical overlap between olive production, on the one hand, and livestock production, on the other hand. No ecological boundary divides the two production enterprises. There is, rather, an ecological continuum across the rainfall isohyets with a declining relative importance of olives and an increasing importance of barley and livestock as one moves from the wetter to drier areas. For example, olives are part of

Table 4.6 Farm size and production strategy

Farm size	Strategies									
	CL CL		CLO		CO		C		Other	
	No.	%	No.	%	No.	%	No.	%	No.	%
< 5 ha	3	7	2	6	3	16	5	32	-	-
5-20 ha	25	60	16	44	12	63	5	38	4	100
20-50 ha	11	26	13	36	4	21	1	9	-	-
50-110 ha	2	5	3	8	-	-	2	15	-	-
> 100 ha	1	2	2	6	-	-	-	-	-	-
Total	42	100	36	100	19	100	13	100	4	100

the production strategy of 83% of farmers in Zone 1 but only 39% of farmers in the drier areas. About 10% more farmers include livestock in their production strategy in the drier areas than in Zone 1, but more importantly in Zones 2 and 3, the average flock size is increased by about 45% and area sown to barley to feed the sheep increases four-fold.

The relative importance of on-farm versus off-farm income as contributions to total household income vary greatly. The range is from 100% derived on-farm to as little as 10%. The ratio can have important implications for farmer decision-making, especially decisions about enterprise mix, capital investments, and cash expenditures on inputs. Some 44% of income for the entire sample comes from off-farm sources. This high level is indicative of Jordan's recent economic expansion in non-agricultural sectors, the Mafraq area's location near several large towns and government centers, and the relatively meager agricultural resources of the area. The ratio of on-farm to off-farm income as affected by farmer strategy and zone is shown in Table 4.7.

Table 4.7 Distribution of household income sources by strategy and location (mean percentages)

Strategy	Zone 1		Zone 2		Zone 3	
	On-farm	Off-farm	On-farm	Off-farm	On-farm	Off-farm
CL	67.3	32.7	65.8	34.2	79.3	20.7
CLO	48.8	51.7	48.5	51.5	36.6	63.4
CO	47.4	52.6	47.0	53.0	28.3	71.7
C	-	-	39.0	61.0	86.2	13.8
Mean	55.0	45.0	55.0	45.0	61.0	39.0

What emerges very clearly is that livestock producers are different from CO and C farmers in terms of their reliance on on-farm income. When the comparison is made on the basis of location, the CL farmers are further distinguished from their CLO colleagues.

There are some plausible explanations for these differences. First and foremost, preliminary enterprise budget data and farmer comments indicate that livestock are much more remunerative than any other enterprise in the Mafraq area in terms of return to variable costs. Second, government animal feed programs and a ready market make livestock less risky than dryland cereals and olives which depend on unpredictable weather. Third, livestock raising absorbs more family labor throughout the year than cereals or olives, thus lessening time which could be spent in outside employment. In fact, the survey data indicate that livestock producers are far more likely to employ non-family labor for longer periods of time than other farmers.

Most of farm family members who are employed off-farm have not been able to secure particularly well-paid jobs. Low level civil service posts and soldiering are the most common jobs in the sample. It is difficult to achieve economic independence from farming from these occupations, and because they also require substantial amounts of time at work throughout the year it is difficult to keep an off-farm job and still maintain large numbers of sheep and goats. Nevertheless, employment, even at a low salary level, can offer the security of a regular income. Cereal and olive production on the scale most commonly practiced in the Mafraq area do not offer similar financial stability. In contrast, sheep raising if the flock is of sufficient size, can provide a certain income stability. Milk and milk products can be sold during a large part of the year, along with wool, lambs, and culled adults.

Reliable income data, expressed in money terms, is notoriously difficult to collect and interpret. Fortunately, it was possible to obtain reasonable estimates from about half the sample. Farm size, production strategy, and on-farm to off-farm income ratios for these farmers are generally much the same as for the entire sample. In terms of income level and farm size, single regression indicates that about 70% of variation in income could be related to variation in holding size. When one considers that large farms tend to produce more sheep than smaller farms, then the relation between size and income is not surprising.

There is an interesting relation between percentage of on-farm income and amount of total income. Farmers with the highest income levels also had the highest percentage of on-farm income. Farmers with a high degree of off-farm income actually appear to have lower total income. The limited data indicate that total income for livestock producers averages 64% higher than the income earned by non-livestock producers in the Mafraq area. In summary, sheep producers with more than 80 head statistically (1) tend to have the largest holdings, (2) have the highest total income, (3) are located in Zone 2, and (4) derive the least amount of their income from off-farm sources.

It is worth noting at this point that a comparison of the farmers reporting the highest barley yields against the farmers reporting the lowest barley yields on their farms showed no clear pattern of differences with regard to rainfall zone, soil type, soil depth, or holding size. In fact, the only variable which seems to correlate with yield level is degree of dependence on on-farm income. On the average, farmers reporting the highest average yields received about 25% of income from off-farm sources while the lowest yield farmers averaged 61% of income from off-farm sources.

To assess how farmers characterize their own farming system, survey participants were asked questions about what changes they have observed in their villages during the past ten years. These were followed by questions designed to elicit the farmers' investment plans for the next five years. The responses were mixed and at times contradictory. In light of the variable nature of the area and its farming system, this is understandable.

Table 4.8 gives the results of five questions about trends in the farming system. Farmers were asked to consider a list of observations about their villages during the past ten years and state whether or not they agreed with each one. The response to the observation that people are raising more livestock was about evenly divided. But there was general consensus that raising livestock is the best way to raise more income. Almost 9 out of 10 farmers agreed that people are increasing the land planted to olives, but a substantial minority disagreed with the assertion that one's best farmland should be planted in olives instead of some other crop.

Over 60% of farmers were not prepared to say whether or not the farm income levels will improve during the next five years. The most frequent response to this statement was that it is impossible to predict the future. This is certainly an understandable position given the vagaries of the weather.

Table 4.8 Farmer perceptions (1989 sample)

Observation	% Agree	% Disagree	% No answer
People are raising more livestock	50	47	3
Livestock best sources of farm income	85	14	1
People are growing more olives	89	10	1
Best farmland should be under olives	63	35	2
Farm income will improve in next 5 years	15	24	61

Farmers were less reluctant to discuss future plans for their own farms (Table 4.9). Answers were almost equally divided between increasing farm size, increasing olive area, and increasing livestock flock size. There was a large majority which stated they would not increase the area they plant to cereals.

Table 4.9 Farmer's plans (1989 sample)

Plan	% Yes	% No	% No Answer
To increase farm size	43	53	4
To increase olive area	50	45	5
To increase livestock flock	47	47	6
To increase cereal area	36	60	4

4.3.6 Conclusions

To have a reasonable chance of success, any program to improve the productivity and income from farming in the Mafraq area must avoid requiring farmers to make great changes in their production strategies, nor should it involve dramatically higher cost inputs than those already being used. The secrets to success are modest objectives and incremental benefits built upon the existing productive base and farming system. The conclusion from our characterization of farmers is that the key on-farm element to focus on is the livestock-crop interface. **When asked to identify their principal problem, almost all farmers with livestock said an adequate feed supply. Perhaps more importantly, they said they desired to increase the productivity of their land with the specific intention of lessening their dependence on external sources of livestock feed.**

Although other issues (such as the low productivity of olives, for example) are relevant to the problems of the area, the examination of farm and farmer characteristics overwhelmingly points to the focus on increasing local production of livestock feed because of the potential adoption and impact for the targeted farmer group.

Using the interrelations among the variables examined in the previous section, a preliminary target farmer population would display the following minimum characteristics: (1) mean farm size of 20 ha., (2) mean combined sheep and goat flock of 90 head, and (3) mean annual area planted to barley of 8.5 ha. Such a group would be geographically concentrated in Zone 2 (200-250mm) and would depend on on-farm sources for the bulk of its household income. It would also be a fair assumption that this group would have a reasonable level and flexibility of disposable income. Improved technologies and cultural practices targeted to this population would seek to raise the amount of livestock feed which the farmer could produce from his land.

Although agronomy research for the marginal zone is still at a very preliminary stage, the first year's results indicate that it may very well be possible to increase feed production by introducing new varieties of barley and feed legumes, better management techniques, and an alternative rotation that includes feed legumes as a substitute for fallowing and continuous barley. This is re-enforced by our greater experience in similar marginal zones of N. Syria.

4.3.7 References

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4.4 CERES-Wheat Model and Strategic Planning for Nitrogen Fertilization - A Framework

Shi Zuntong, visiting scientist, China

The CERES-wheat model was applied to the question of wheat yield responses to N fertilization under various conditions in Xian region of P.R. of China. Grain yield data obtained by applying the CERES-wheat growth model have been examined, for strategic planning of N fertilization. This study was undertaken to examine the feasibility of using tools such as this model to improve fertilizer recommendations and to develop long term policies for the maintenance of soil productivity. Due to limitations of the data resource, only nine wheat growth seasons were run by the model. The conclusions from this paper should therefore be regarded with caution until an analysis with a longer data set can be completed.

4.4.1 Wheat Grain Yield Response to Nitrogen in Relation to Different Rates of N Fertilizer under Various Soil Nitrogen Conditions

CERES-wheat was used to calculate the grain yield of crops fertilized with various rates of N through nine wheat growth seasons from 1971 to 1980 for which daily climatic data were available. Based on actual soil analysis data from Xian, four hypothetical soil groups were established with high, medium, low and zero soil nitrogen levels. The organic carbon (%), ammonium N (mg/kg), and nitrate N (mg/kg) in the 0-20 centimeter soil layer were 0.53, 5.36, 5.12 for group 1 soil, 0.26, 2.68, 2.56 for group 2, 0.13, 1.37, 1.31 for group 3, and 0 for group 4. These soil parameters, the necessary crop coefficients required by CERES and the daily climatic data were used to run the model for the nine seasons. Subsequent sections describe the model output and its implications for N fertilizer strategies of wheat in the project area.

Figure 4.16 shows that the grain yield increases due to 30 kg/ha nitrogen increments are inversely related to the soil nitrogen level. In other words, the fertilizer efficiency under lower soil nitrogen conditions is greater than that under higher ones. Figure 4.16 also shows that on average fertilizer input-

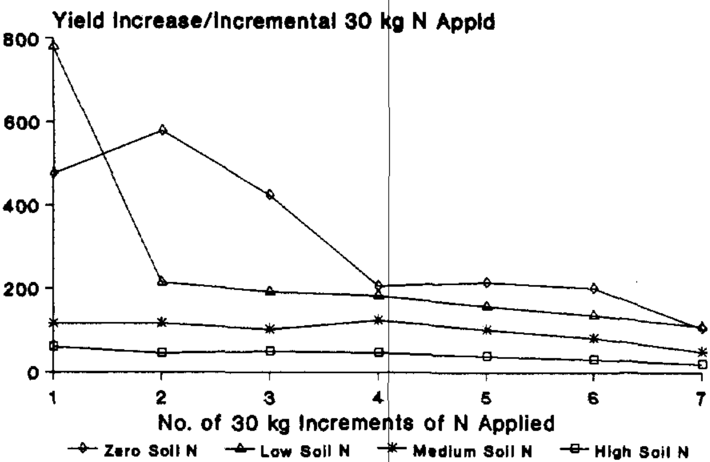

Figure 4.16 Simulated yield due to successive increments of 30 kg N/ha in four soils with hypothetical zero, low, medium and high base nitrogen levels. Each point is the mean of 9 years' simulation.

output relationships follow the law of diminishing returns. As additional units of fertilizer input are used, each extra unit results in smaller increase in yield output. Likewise, the yield response to rates of N fertilizer is obviously affected by the base soil nitrogen level. In soil groups that belong to the low soil nitrogen level, there is a sharp decrease in the grain yield increment per additional unit of fertilizer applied. A similar trend but with smaller decreases is evident in soils of a higher N-status. This implies that input-output efficiency of chemical fertilizer is low but stable at the higher soil nitrogen level, but declines sharply at the poor soil nitrogen level. The model prediction, under the given assumptions, coincides with the author's experience.

4.4.2 Effect of Water Supply Levels on Wheat Grain Yields

The total water supply is defined as soil water stored in advance of the sowing date plus rainfall during the wheat growing season. There is a positive relationship between grain yield and total water supply (Figure 4.17). On the high N-status soil, a yield of 4555 kg/ha of wheat grain was obtained from 555 mm water, while 1280 kg/ha was obtained from 243 mm. Grain yields of 3500 to 4500 kg/ha could be achieved by a water supply of 400-500 mm.

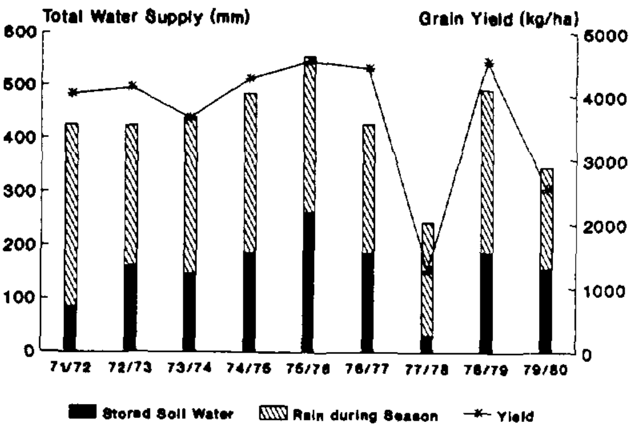

Figure 4.17 Pre-sowing soil water (mm), growing season rainfall (mm), total water supply (mm) and simulated grain yields of winter wheat (kg/ha). Simulations used 9 years of weather data from the Xian region, P.D. China.

The combination of both rainfall during growth and water stored before the season is important for wheat grain yield in the environment of Xian Province where there is substantial summer rainfall prior to planting. The grain yield is correlated neither with the rainfall nor stored water alone, but is clearly affected by total water supply (Figure 4.17). Soil surface management preceding the wheat growth season to store more of the summer rainfall in the soil is one available approach for increasing grain yield.

4.4.3 Effect of Total Water Supply on Fertilizer Efficiency

Fertilizer efficiency is described as the grain yield or benefit from a unit of fertilizer input. Table 4.10 shows that fertilizer efficiency is obviously different in different growth seasons and with different amounts of fertilizer applied on the medium nitrogen level soil. Grain yield increases produced by using 210 kg/ha nitrogen input ranged between 862 to 996 kg/ha in the seasons 1971/72, 72/73, 73/74, 74/75, 76/77 and 78/79. The increment was 506 kg/ha in season 1979/80, but almost no increase was observed in the 1975/76 and 1977/78 seasons. A series of quadratic functions were fitted to the estimated nitrogen response data for each year. According to the values of the coefficients b and c of the functions, fertilizer efficiency status can be classified into three groups. This is illustrated in Figure 4.18 where the difference in marginal yields based on the first derivative of these equations are presented. The group with high fertilizer efficiency includes six of the nine growth seasons which had similar high marginal yields. (Note: Data for 1974/75 were virtually identical to those for 1976/77 and are not shown in Figure 4.18.) The middle range of fertilizer efficiency is represented by the 1979/80 season where the marginal yield is moderate and is always lower than in the first group. The low fertilizer efficiency includes two seasons 1975/76 and 1977/78 which show negligible yield response to fertilizer input.

From Figure 4.17, it is clear that fertilizer use efficiency depends strongly on the amount of total water supply. The high fertilizer efficiency seasons had water supply between 400-500 mm. The middle fertilizer efficiency season had 300-400 mm and the low

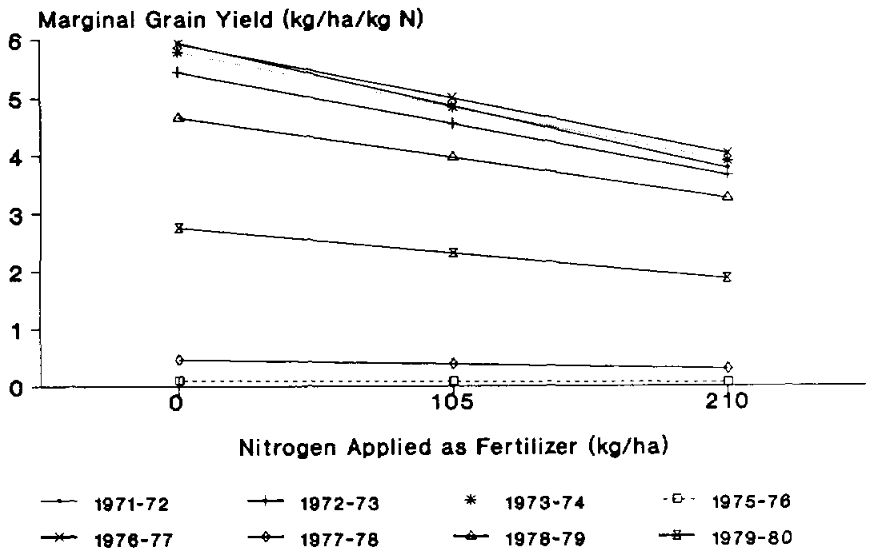

Figure 4.18 The influence of crop season on the marginal grain yield response of winter wheat to nitrogen fertilizer (kg/ha/kg N).

fertilizer efficiency seasons had either more than 500 mm or less than 300 mm. Thus the fertilizer efficiency is predicted to be highest in seasons when the water supply ranges from 400-500 mm water, but declines when the water supply becomes more or less than this quantity.

Reduced fertilizer efficiency at >500 mm of available water seems unusual. However, it appears to be explained by the fact that under these conditions more mineralization of soil N occurred prior to planting, and the plant demands were met completely from the initial soil nitrogen pool. Rainfall during the warm summer in this environment provides very favourable conditions for mineralization of N from crop residues. The average nitrate nitrogen content of the top five soil layers (45 cm) predicted by the model was 12.2 ppm in 1975/76 throughout the entire growth season and, with 555 mm, no water stress occurred. This level of available-N is about four times more than the 2.3 ppm predicted in the 1976/77 season with a more normal water supply of 425 mm. This model output needs to be confirmed against field data for high water regimes. In contrast with this, under extremely low water supply, less than 300 mm, moisture is the main constraint for crop growth. The smaller biomass and lower physiological activity caused by water stress limits nitrogen uptake by the crop. For instance, under the fertilization of 210 kg N/ha, the maximum biomass was 5190 kg/ha in the 1977/78 season with a poor water supply of 243 mm. This is only 46% of the 12,750 kg/ha in the 1976/77 season with a normal amount of water. The marginal grain yield response to fertilizer was less than 0.5 kg per kilogram of nitrogen applied.

4.4.4 Fertilizer Recommendation Based on Benefit Analysis

In terms of optimization theory, the maximum net cash benefit will be gained when marginal yield is equal to the price ratio of each unit of fertilizer to each unit of wheat grain ($dy/dx = Px/Py$, Py = the price of one kg grain, Px = the price of one kg fertilizer). In P.R. of China, the cost of nitrogen fertilizer is 1.30 yuan per kilogram of elemental N. The wheat grain price is about 0.34 yuan per kg. The ratio of fertilizer cost to grain value thus is equal to 3.82. The data listed in the marginal yield columns of Table 4.10 are the yield increase from each 30 kg/ha N increment invested. From these data and the price ratio it can be estimated that the optimum amount of fertilizer applied in every year should be that which gives a grain yield increment of approximately 115 kg/ha for each 30 kg/ha fertilizer applied. The application of fertilizer amounts above this threshold will result in higher grain yield, but lower cash benefits. Using this criterion, recommended fertilizer application rates would be slightly over 150 kg N per hectare in four of the six high fertilizer efficiency seasons identified in Figure 4.18. Slightly more would have been needed in 1974/75 and somewhat less in 1978/79. In the middle fertilizer efficiency season which had 300-400 mm total water supply, the optimum recommended fertilizer quantity would be between 30-60 kg/ha N. In the low fertilizer efficiency seasons adding any amount of fertilizer would result in negative benefits.

It is not possible to know at the beginning of a season how much total water supply will be available. Farmers, however, need to decide how much fertilizer should be prepared and applied to soil prior to the sowing date.

Table 4.11 provides reference budgeting data to help farmers make this decision. Within one fertilizer efficiency group the expected net cash returns are not significantly different among fertilizer inputs ranging from 30 to 150 kg/ha. The grain output, however, increases 449 kg/ha comparing 150 kg/ha with 30 kg/ha fertilizer input. Different preferences may exist between different farmers. The subsistence farmer is likely to be interested in harvesting as much wheat grain as possible and the higher investment option may be selected. The farmer who has a market preference may select a lower investment option and could thus place the rest of his money into a business with a potentially greater economic return. For the government, however, the increase of yield is of prime importance. It is possible to stimulate farmers to increase investment by means of adjusting the price ratio, such as increasing grain price or decreasing fertilizer price.

4.4.5 Wheat Yield Response to Different Fertilization Patterns and Time of Application

The farmers normally apply fertilizer twice. Once before sowing during soil plowing (called foundation fertilizer) and a second

Table 4.10 Simulated yield response, from 1971 to 1980, to amount of fertilizer applied to the medium N-level soil group

Amount of fertilizer applied (kg/ha)	1971/72		1972/73		1973/74		1974/75		1975/76		1976/77		1977/78		1978/79		1979/80	
	Yield kg/ha	Marginal yield kg/30	Yield	ΔY/30	Yield	ΔY/30	Yield	ΔY/30	Yield	ΔY/30	Yield	ΔY/30	Yield	ΔY/30	Yield	ΔY/30	Yield	ΔY/30
0	3090		3274		2733		3497		4547		3401		1179		3785		2044	
30	3213	123	3539	265	2893	160	3539	42	4552	5	3499	98	1226	47	3921	136	2220	176
60	3415	202	3591	52	3068	175	3674	135	4556	4	3678	179	1265	39	4069	148	2340	120
90	3598	183	3716	125	3138	70	3774	100	4560	4	3894	216	1273	8	4189	120	2440	100
120	3776	178	3890	174	3350	212	4024	250	4562	2	4052	158	1277	4	4295	106	2482	42
150	3924	148	4042	152	3507	157	4228	204	4563	1	4174	122	1274	-3	4416	121	2511	29
180	4046	122	4161	119	3637	130	4345	117	4563	0	4291	117	1268	-6	4526	110	2537	26
210	3988	-58	4260	99	3729	92	4463	118	4563	0	4390	99	1273	5	4611	85	2550	13
a*	3088.6		3303.1		2719.9		2289.7		4549.6		3371.0		1212.7		3790.2		2135.2	
b	5.95		5.44		5.79		5.94		9.55 E-2		5.93		0.46		4.66		2.75	
c	-5.174 E-3		-4.21 E-3		-4.524 E-3		-4.486 E-3		-8.699 E-5		-4.544 E-3		-3.814 E-4		-3.362 E-3		-2.129 E-3	

* Quadratic functions ($Y = a + bx + cx^2$) are estimated from above data. (x = amount of N applied, kg/ha)

All of them significantly fit with actual data by F-test.

Table 4.11 Payoff matrix for optimum decision

Type of season	Probability	Total benefits (yuan/ha)						
		30	60	90	120	150	180	210
High fertilizer efficiency season	6/9	1120.87	1140.05	1147.18	1169.27	1181.50	1183.02	1168.56
Middle fertilizer efficiency season	1/9	715.80	717.60	712.60	687.88	658.74	628.58	594.00
Low fertilizer efficiency season	2/9	943.26	911.57	874.63	836.52	797.12	737.27	719.12
Expected net cash return		1041.52	1042.34	1038.32	1041.83	1038.00	1026.80	1004.84
Expected grain output		3178	3295	3398	3523	3627	3708	3758

addition after this, called supplementary fertilizer. Using the same amount of fertilizer, but changing the pattern from foundation fertilizer to supplementary may result in an increase in grain output. How much yield could be increased depends to some extent on the date of supplementary fertilizing. In Table 4.12 simulated grain yields from different fertilization strategies with the same amount of 90 kg N/ha are shown. Splitting the fertilizer application increased yield by 6% averaged across all dates of supplemental addition. Marginally the best pattern is 30 kg N/ha applied as a foundation dressing and 60 kg as a supplementary application on Julian day 70. Over the nine seasons, this strategy showed an average yield increase of 294 kg/ha or 10% over the use of a single pre-sowing application.

There are three clear points from the Table 4.12. The first is that higher grain yield will generally result when the total amount of fertilizer (90 kg N) is applied in two doses, as basic and supplementary fertilizer application. Nitrogen requirements of plants change with time and supplementary fertilization meets the needs of plants better than a single application. Soil nitrogen concentration curves against time showing a bi-modal form were found in soil with supplementary fertilization patterns but a single peak and a declining curve were shown with basic fertilization only. It could be that the former is closer than the latter to matching the crop N requirement curve.

Secondly, the preferred time for supplementary fertilization is near the start of stem elongation, around Julian day 70. Starting from elongation, crop requirement for N increases rapidly as biomass speedily accumulates. Without doubt, fertilizer supply at this time can result in a bumper grain harvest. Application prior to or after this optimum fertilization period is somewhat less effective. Clearly if supplementary fertilization is

Table 4.12 The yield with different patterns and dates of fertilizer application*

Growth seasons	1971/72	1972/73	1973/74	1974/75	1975/76	1976/77	1977/78	1978/79	1979/80	Average
Fertilizer applied once 15 days before sowing. (Incorporated by plowing)										
90 kg/ha as basic fertilizer	2880	3273	2743	3196	4553	3243	1277	3586	2177	2992
Supplementary fertilizer applied at Julian day 35. (Soil thaw)										
30 basic + 60	2956	3503	2960	3889	4557	3794	1166	4099	1851	3197
60 basic + 30	2911	3390	2847	3423	4555	3456	1235	4863	2050	3192
Supplementary fertilizer applied Julian day 70. (Begin stem elongation)										
30 basic + 60	3109	3810	2832	4149	4558	3937	1175	4204	1800	3286
60 basic + 30	2988	3555	2891	3617	4555	3566	1235	3898	2015	3147
Supplementary fertilizer applied Julian day 105. (Pre-heading)										
30 basic + 60	3127	3395	2010	3991	4546	3481	1175	3970	1783	3053
60 basic + 30	3168	3311	2484	3758	4551	3429	1235	3984	2008	3103
Supplementary fertilizer applied Julian day 125. (Start of grain fill)										
30 basic + 60	2275	3078	1985	3255	4549	2582	1175	2844	1783	2616
60 basic + 30	2708	3125	2478	3160	4548	2811	1235	3224	2008	2810
30 basic fertilizer	2261	3076	1985	3067	4549	2563	1178	2806	1783	2585
60 basic fertilizer	2702	3125	2478	3086	4548	2801	1237	3208	2008	2799

* sowing date: 1st of October; soil nutrient basis = low level; Julian day 1 = January 1;
plant population = 250 plants per square meter.

postponed until the start of the grain filling period (at Julian day 125, Table 4.12), the grain yield is significantly lowered as it is too late then for wheat to use the additional N. This is illustrated in the last 4 rows of Table 4.12 which show that there was no response to supplementary fertilizer applied at this time.

The third point is related to the two fertilization patterns, 30 kg N/ha basic plus 60 kg N/ha supplementary and 60 kg N/ha plus 30 kg N/ha. The grain yields were approximately the same in these two cases. Therefore farmers do not need to consider carefully how much fertilizer should be added as the basic dressing or as late supplementation. This means that fertilization practice can be more flexible according to other conditions. For example, supplementary fertilization could improve the economic utilization of fertilizers in the middle and low fertilizer efficiency seasons. Winter wheat in the Xian region has a growth period of eight months, of which six have elapsed by the time a decision on supplementary fertilization needs to be made in mid-March (start of stem elongation). Most of the total water supply is known at this time and the remainder can be predicted more effectively than a full season's rainfall. In this case, the farmer can make the decision on supplementary nitrogen based on total water supply. Assuming the amount of total water is in the middle or low fertilizer efficiency seasons, farmers will adjust the amount of supplementary fertilizer. Let us say a farmer plans a total fertilizer application of 90 kg N/ha. If, after 30 kg N/ha was applied as basic fertilizer, he finds the water supply to be in the low fertilizer efficiency range he would not add supplementary fertilizer. This would save 60 kg N/ha or 78 yuan/ha of investment and, combining investment with output benefit, could prevent a loss of about 70 yuan/ha.

4.4.6 Nitrogen Cycle and Soil Nutrient Maintenance

Initial soil nitrogen is a very important factor affecting grain yield both in a single year and in a sequence of seasons as shown in the previous sections. The potential productivity of four classes with different initial soil nitrogen contents (see section 4.4.1) is illustrated in Figure 4.19. This clearly shows, as expected, that the grain yield in unfertilized soil depends on the initial soil nitrogen level. So, maintaining initial soil nutrient levels is important.

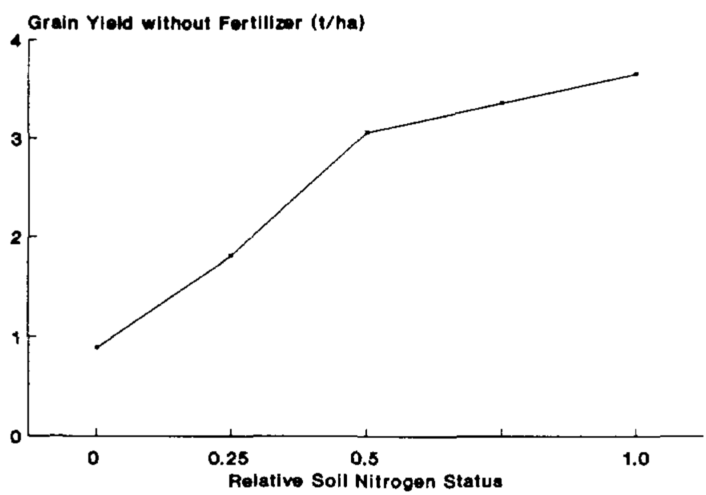

Figure 4.19 The productivity of winter wheat without addition of fertilizer on four hypothetical soils with a range in nitrogen status (0 represents severe N deficiency and 1 represents a high soil-N level).

Some grain yield will be harvested without extra fertilizer addition, but this yield output will cause a decline in the soil nutrient level and affect productivity in subsequent seasons. To prevent degradation, mineral fertilizer should be applied to complement the loss of soil mineral nitrogen through crop uptake from the soil pool. This also will help to maintain soil organic matter by the addition of fresh organic matter from greater crop residues.

To maintain soil nitrogen nutrient levels, the amount of fertilizer applied to the soil should be equal to or more than the crop uptake. Average amounts of elemental nitrogen added or taken up from the medium nitrogen level soil throughout nine years from 1971-1980 are shown in Figure 4.20. The dynamics of soil nitrogen can be assessed by calculating the amounts of soil nitrogen added or taken up. Grain yield increased as fertilizer

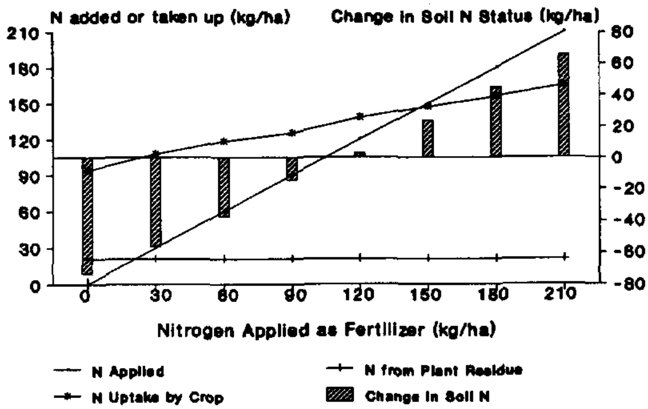

Figure 4.20 The simulated components of the nitrogen balance of winter wheat systems on a soil with an initial middle level of soil nitrogen. Each point is the mean of 9 cropping seasons from 1971 to 1980.

addition increased, and plant uptake of nitrogen increased linearly with yield. When the amount of fertilizer applied increased from 30 kg/ha to 210 kg/ha, the grain yield increased from 3178 kg/ha to 3758 kg/ha, and the nitrogen uptake increased from 110 kg/ha to 165 kg/ha. At the same time, the amount of nitrogen contributed to the soil pool increased at a higher rate than crop uptake. In addition, there is also 2150 kg/ha of root and stubble residue from the previous crop which supplies about 21 kg N/ha nitrogen to the soil every year. In reality the amount of roots and residue would be expected to increase with time at higher levels of N application. However, to avoid the accumulation of possible model errors, values are reset to the initial value each season. This estimate is therefore conservative.

After 10 years, the soil nitrogen contents differed with the amount of fertilizer applied, from -73 kg N/ha without nitrogen addition to +65 kg N/ha when 210 kg N/ha/yr of fertilizer was added. The addition of 120 kg N/ha resulted in no soil-N depletion. This indicates that in order to prevent degradation of soil nitrogen levels, at least 120 kg N/ha should be applied every season. This is in line with the economic and social benefit analysis in section 4.4.4, and suggests that a reasonable recommendation for the medium nitrogen level soil would be between 110 and 130 kg N/ha/yr.

4.4.7 Conclusion

Whilst the results in this presentation depend on model output, and only a limited number of seasons were tested, the author concludes that the estimated responses obtained in this exercise are in line with his field experience. Based on this initial analysis, a more thorough evaluation using longer climatic datasets, several contrasting locations, and validation with field trial data has been proposed.

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 develops 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.

In establishing research priorities it is important to quantify the potential impact of technologies on food production and national agricultural income. 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.

Our long term goal in this project is to assess factors related to the acceptability of new technologies, and develop methods to predict, monitor and improve the adoption and impact of technology at the national, community and farm level. We 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.

In our report this year, a variety of topics are addressed covering the adoption of winter sown chickpea in Morocco, risk associated with current strategies to meet rising sheep feed demands in Syria, a comparative analysis of changing lentil production strategies over a 10 year period in Syria, the implications of variable season rainfall on farmers' stubble management strategies and a comparative analysis of production functions as descriptors of the impact of technology on barley yields in southeast Turkey and Northern Syria.

In addition, we present summary highlights of eight case studies of agricultural labor and technological change. These studies formed part of a specially funded project and were conducted during 1987 and 1988 by national research teams in Algeria, Morocco, Tunisia, Jordan and Turkey.

5.2 Adoption Dynamics of Winter Sown Chickpea in Morocco

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M. Solh (FLIP), and R. Tutwiler (FRMP)

5.2.1 Introduction

Chickpea constitutes the second most important food legume crop in Morocco. Production is concentrated in dryland areas to the west of the Atlas mountains that receive more than 300 mm average annual precipitation. The farming systems of these areas are characteristically dominated by cereal and livestock production, but chickpeas usually fulfil an important role within the usual two-course rotations with winter cereals and, to a much lesser extent, vegetables and forage crops. Localized landrace varieties are the predominant chickpea cultivars and are traditionally sown in the spring (late February-March) for harvest in summer (June-July). Yields vary greatly from year-to-year, from region to region, and from farmer to farmer.

Figure 5.2.1 presents aggregate yield and area planted for the fifteen year period 1970-1985. When compared to rainfall data, the fluctuation in both yield and area planted corresponds

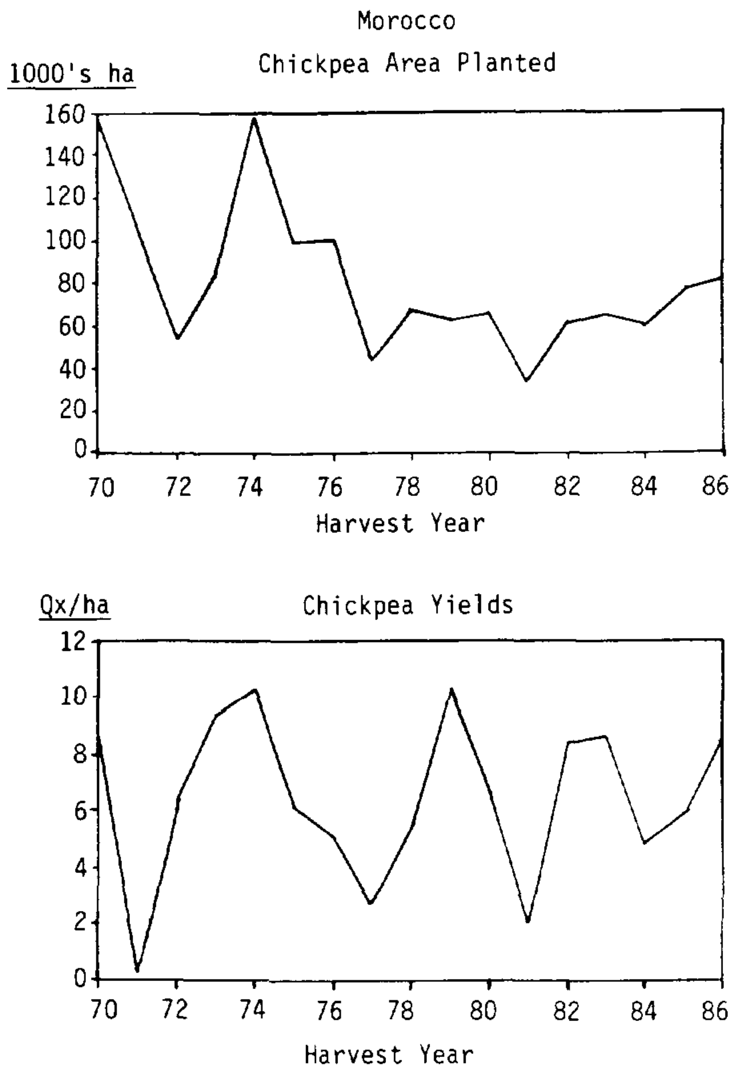


Figure 5.2.1 National trends in chickpea production in Morocco.

closely with variation in precipitation. But rainfall, although the most easily identified, is only one of a number of factors contributing to the considerable variation in productivity that are not disclosed by aggregate national statistics. There is little information available for yield variation from region to region and farmer to farmer, but there is considerable evidence that these differences are great. Wide variations in cultural practices, farm resource allocations for chickpea, incidences of diseases and pests, and other factors all serve to separate highly productive farmers from their less successful colleagues.

The last two decades witnessed a marked change in the geographical distribution of chickpea production in Morocco. Formerly highly productive regions to the south and southwest of Casablanca have considerably reduced the total area planted to chickpea, and many farmers in this region have abandoned chickpeas altogether. The retreat has been attributed to two causes: a prolonged drought and the ravages of the blight Ascochyta rabei. Another factor cited by farmers and researchers throughout Morocco is the high cost of growing and harvesting the crop using hand labor. Cereals would appear the clear victor over chickpeas in planting decisions based on considerations of risk and labor costs.

ICARDA has devoted considerable efforts towards improving chickpea yields in the West Asia and North Africa region. Scientists in the Food Legume Improvement Program have developed cultivars which are cold tolerant and therefore can be sown in November-December for harvesting in early summer. The winter sown chickpea is also bred for enhanced resistance to Ascochyta blight. On-station and on-farm trials indicate that winter sown chickpea, with its longer growing season, and therefore greater likelihood of receiving adequate rainfall in the Mediterranean climate, can produce up to twice the total biomass of spring sown varieties. Seed yields have been as high as two to three times that of spring chickpeas. Looking at the new technology from the farmers' point of view, scientists see the possible disadvantages of the winter cultivars, as opposed to spring chickpeas, as being: (1) the need for at least one additional weed control operation during the longer growing season and (2) the noticeably smaller size of the chickpea seed produced by released varieties. Smaller seed size may be translated into lower market prices. However, even accounting for increased weed control costs and possible reduced market value, the winter chickpea looks more profitable than spring because of its higher productivity and reduced risk of crop failure due to drought (see also section 3.3 of this report).

5.2.2 Development of Winter Sown Varieties in Morocco

Moroccan authorities have given considerable attention to winter sown chickpea cultivars as a possible way of stabilizing and reversing past production trends. In particular, the new technology is viewed as a means of reclaiming old production areas and expanding into new ones. If farmers adopted the new technology, then there could be a number of national benefits: (1) improved farm income, (2) increased earning of foreign income through exports, (3) increased domestic protein consumption, and (4) enhanced soil nitrogen content.

Beginning with germplasm developed at ICARDA, scientists at the Institut National de la Recherche Agronomique (INRA) started in the early nineteen-eighties with the process of adapting winter chickpea technology to the conditions of Moroccan farmers. INRA followed a dual approach: on station work concentrated on adapting germplasm and cultural practices to Moroccan conditions while on farm work aimed at verifying the new technology and identifying the constraints to achieving maximum yields. Demonstration plots were put on farmers' fields on a limited scale in the 1985/1986 season. Two varieties, ILC 482 and ILC 195, were released by INRA in 1987/1988, and a nation-wide program of demonstrations on farms was begun by the Direction du Production Vegetale (DPV) of the Ministry of Agriculture and Agrarian Reform. Demonstrations had been started earlier by INRA in the Settat and Chaouia areas, but these were on a limited scale only.

The results of these efforts were promising. The 1987/1988 demonstration plots gave excellent yields as compared to local spring cultivars, and an ambitious program of some 104 demonstration plots was planned for the 1988-89 season as work on station continued. However, there had been little in the way of farm-level analyses of farmers' reactions to the new technology nor assessment of its adoption potential. DPV, INRA, and ICARDA agreed in December, 1988 to undertake a cooperative study which would provide this much needed information to help guide further research, development, and extension efforts.

5.2.3 Objectives and Design of Winter Chickpea Adoption Study

The cooperative study began with modest objectives. The primary objectives were two-fold: (1) to describe the technical performance of winter sown varieties on farmers' fields using conventional cultivation practices and (2) to elicit farmer responses to growing winter chickpea. There were two secondary objectives: (3) to collect partial budget data enabling an economic comparison of winter and spring sown chickpea and (4) to identify the principal incentives and constraints to adopting winter sown chickpeas within the dryland farming systems of Morocco. A corollary of objectives (1) and (4) was to check the validity of a priori assumptions regarding the weeding costs and marketability constraints for adopting winter chickpea.

Data collection was done through a farmer survey. The questionnaire was divided into four groups of questions. The first group concentrated on describing the holding and the farming system. The second group related to the introduction of winter chickpea and its adoption or non-adoption by the farmer.

The third group looked at the technical and economic aspects of producing winter chickpea. Finally, the fourth group of questions sought farmer evaluations of winter chickpea and asked about future plans to grow the crop.

The survey sample was stratified along three dimensions as follows: (1) location, (2) experience with growing winter chickpea, and (3) access to resources. Geographically, four provinces were selected as target areas by Moroccan scientists. These were Safi and Settat provinces in the south and Fes and Khemisset in the north (see Figure 5.2.2). The northern provinces represent current principal producing areas of dryland spring chickpea. The two southern provinces are previously producing areas in which it is hoped the new technology will facilitate the re-introduction of chickpea.

In terms of experience, four farmer categories were delineated: Category I were farmers who had previously participated in trials and demonstrations but had decided not to grow winter chickpea in 1988/1989; Category II were farmers who were growing winter chickpea for the first time in 1988/1989 as participants in the DPV demonstration program; Category III were farmers growing winter chickpea in 1988/1989 independently of the DPV program who may or may not have had previous experience with the crop; and Category IV were farmers who had never grown winter chickpea. Category I farmers were characterized as "non-adopters" because they preferred not to continue with winter chickpea. Category II were current "trial" farmers in the process of evaluating the technology for the first time. Category III farmers represented an "adopter" group, although they had different degrees of experience. Category IV farmers were termed "neighbors" because most of them lived in close proximity to members of the other groups and had second-hand exposure to the new technology.

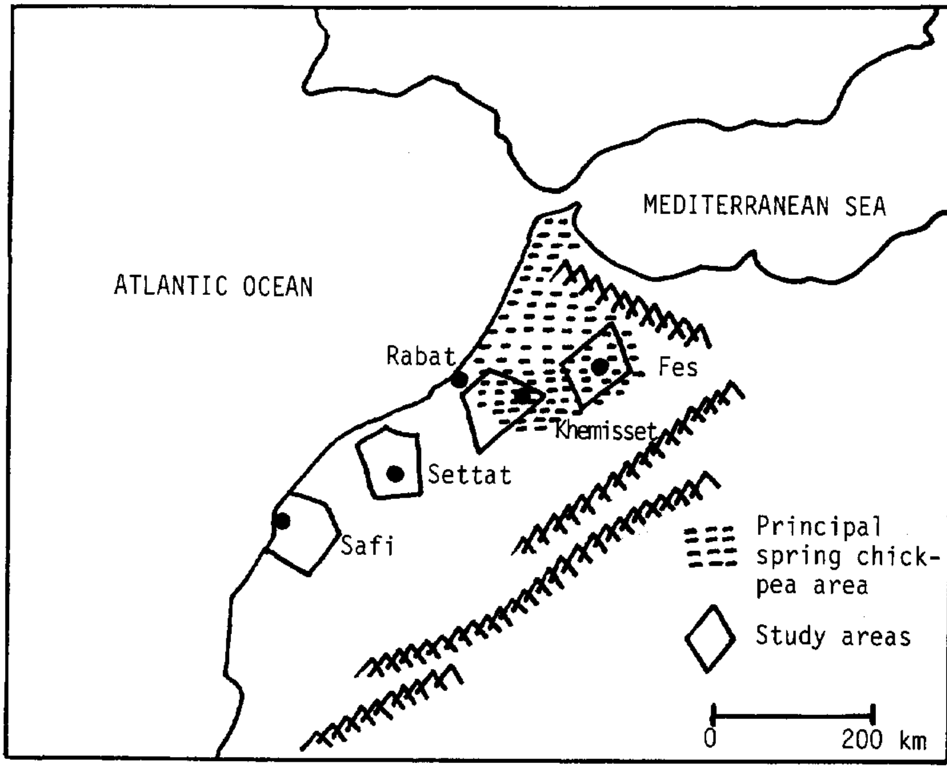


Figure 5.2.2 Winter chickpea study regions in Morocco, 1989.

Access to resources was defined broadly in terms of farm size and flexibility of land use. Three farm-size groups were decided upon. Large holdings were those with 100 hectares or more. Middle holdings contained 99 to 30 hectares, and small holdings were less than 30 hectares. In general, there was a correspondence between farm size and equipment (tractors and other implements) owned by the farmer.

Sample selection proceeded in the following way. First, the interview team visited the Direction Provinciale de l'Agriculture (DPA) in each province to be surveyed. In consultation with the director of the DPA and the directors of the Centres de Travaux

(CT) in the province, lists of farmers fitting into anyone of the four categories were compiled. Following this, farmers to be contacted and interviewed were determined by the stratification criteria and the farmers' availability.

Interviews were conducted on-farm by a team composed of two scientists from DPV and a representative of the local extension service within the jurisdiction of each CT. For all interviews in Safi province and some of those in Khemisset province, the team was accompanied by an ICARDA scientist. A pretest of the questionnaire was done in late March, and survey interviewing started in June and lasted through July. A total of 112 farmers were interviewed.

5.2.4 Winter Chickpea Performance 1988/1989

Climatic conditions during the 1988/1989 growing season were poor. The amount of rainfall was fairly good, with total accumulation near annual averages in the four provinces surveyed. Unfortunately, distribution during the season was uneven, and the heavy rains which came in April were conducive to Ascochyta blight in all areas except Safi province. High rainfall early in the season was followed by a dry period in December until February. The two northern provinces suffered both winter and spring weed infestations due to the timing of this year's rainfall (see Figure 5.2.3). Although the two southern provinces have a long term average rainfall about 150 mm less than the two northern provinces, this year they received similar amounts. So total rainfall was not as important in distinguishing north from south as was the timing of the rains.

Adverse weather and serious biotic factors are reflected in the results of on-station chickpea breeding nurseries and agronomy trials. Many tested lines outyielded the high-yielding released

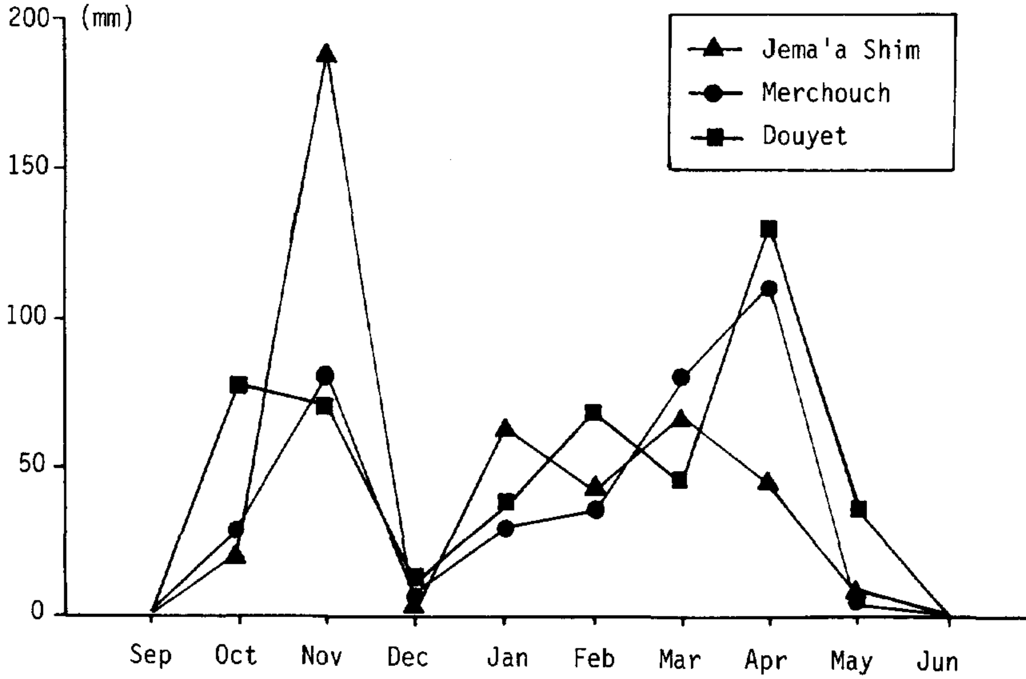


Figure 5.2.3 Precipitation at three research stations 1988/89 in Morocco

and widely adapted line ILC 482 that was seriously affected by Ascochyta Blight in almost every location. At Merchouch station in Khemisset province, for example, the highest yield for ILC 482 was only 2.3 qx/ha (i.e., 230 kg per hectare). Other stations in the surveyed provinces did better. At Jamaat Sahim in Safi province ILC 482 yielded 31.3 qx/ha, and at Douyet in Fes province ILC 482 yielded 21.7 qx/ha. Even when ILC 482 escaped the ravages of Ascochyta Blight, weeds could be a major detriment to high yields. At a herbicide agronomy trial at Douyet (Fes province), the weedy check yielded 9.7 qx/ha while completely weed-free plots gave 15.5 qx/ha.

Surveyed farmers faced similar problems with Ascochyta and weeds, and they also experienced substantial yield variations. Of the 52 farmers in Categories I and III who were growing winter chickpea in 1988/1989, 28 had serious Ascochyta attacks. Some five of these had no harvest at all because of blight, and a further eight had less than 5.0 qx/ha yield. It is little consolation to these farmers that 1988-89 was also a terrible year for spring chickpea yields because of the rainfall pattern and ensuing Ascochyta.

Chickpea yield comparisons among surveyed farmers are presented in Table 5.2.1. Despite the ravages of Ascochyta, the released winter chickpea lines ILC 482 and ILC 195 out-performed local spring cultivars by a slim margin. Interestingly, Category III farmers (adopters) had higher yields on the average than Category II farmers (demonstration plots). Location would appear to be a significant factor, with Safi average yield being more than double that of Khemisset. Winter chickpea yields show greater variation than do spring yields. The average winter yield figure in the previous year (1987/88), a year with favorable climatic conditions, was 14.3 qx/ha, a figure based upon the reported yields of the 23 farmers in the sample who grew winter chickpea last year and remembered their yields.

Table 5.2.1 Summary of winter and spring chickpea yields, 1988/89 (based on survey results)

Province	% with Blight	Yield range		Average yield	
		Winter	Spring	Winter	Spring
Safi	27%	0-22	NA	13.5	NA
Settat	90%	0-12	0-16	8.0	11.6
Khemisset	44%	0-20	5-10	6.3	8.1
Fes	70%	4.4-20	2-11	10.1	7.4
Mean for farms	54%			9.7	8.4
Weighted by area				10.3	8.6
Mean for 1987/88				15.3	NA

5.2.5 Economic Performance of Winter Chickpea Producers

Whenever possible, the survey collected from Category II and III farmers detailed accounts of all production operations for winter chickpea from first tillage to post-harvest operations. This information was then used to compile enterprise gross margins. Any cost for purchasing, renting, or sharecropping land was not included. Variable costs, such as those for tillage, labor, and inputs, were figured in two different ways. The first way was to simply record and sum all actual cash expenditures for custom hire, daily laborers, seeds, fertilizer, and so forth. This method does not include, for example, unpaid family labor as a cost. The second method sought to put an imputed cost on family labor and the use of farmer owned equipment. All labor was assumed to be hired and all tillage operations were assumed to be done with hired tractors and equipment. These items were then costed using prevailing wage and hire rates for the operation and the time of year.

By dividing each cost calculation by gross output in quintals two figures were derived: cash paid per quintal and imputed cost per quintal. To achieve a reasonable figure that would allow comparison between farms operating mostly on a cash basis and those which relied primarily on family labor and other non-cash expenditures, the cash paid and the imputed cost were averaged for each farm. It was therefore possible to rank all producers according to variable costs in Moroccan dirhams (DH) per qx. The gross margin was calculated by subtracting the average variable cost from the gross output. This was then calculated as a gross margin in DH per hectare. Table 5.2.2 presents the results of this accounting exercise.

When all 41 cases from Categories II and III which harvested winter chickpeas and could provide cost information are ranked by

Table 5.2.2 Economic performance of winter chickpea producers (ranked by Gross Margin per hectare)

Province	Farmer Category	Area planted (ha)	Yield per Qx/ha	Imputed cost/ DH/Qx	Paid cash DH/Qx	Variable Cost Ranking	Gross margin DH/ha
			Top Ten Producers by Gross Margin				
Safi	III	4.0	22.0	44	31	3	4667
Fes	II	0.8	21.0	72	0	2	4489
Safi	III	1.0	18.0	41	44	4	3738
Safi	III	1.0	16.0	68	35	5	3180
Khemisset	III	38.0	13.3	50	17	1	2881
Khemisset	II	0.5	15.6	95	50	8	2770
Khemisset	II	0.5	20.0	152	83	17	2656
Safi	III	10.0	12.0	78	41	6	2283
Safi	III	0.6	13.3	112	53	9	2226
Settat	III	0.8	12.0	157	60	13	1695
Fes	II	0.5	12.0	133	88	14	1676
Safi	II	0.1	20.0	224	120	26	1562
Khemisset	III	20.0	10.0	96	101	10	1516
Safi	II	1.0	14.5	193	101	21	1490
Fes	III	1.0	10.8	145	88	16	1441
Fes	II	1.5	10.0	136	85	15	1395
Safi	II	1.5	9.0	122	85	11	1320
Settat	II	0.8	10.7	133	127	18	1286
Fes	II	0.4	13.3	166	152	23	1211
Safi	III	6.0	6.0	120	18	7	1086
Settat	II	0.8	7.0	149	60	12	1019
Safi	III	2.5	11.5	146	179	25	1006
Fes	II	0.8	8.8	160	125	20	947
Settat	III	2.0	8.0	160	143	22	787
Fes	II	0.8	8.3	160	157	23	757
Safi	III	2.0	5.5	151	118	19	634
Khemisset	III	1.0	9.0	197	171	29	596
Fes	III	0.5	6.0	317	30	27	461
Khemisset	II	0.5	6.0	255	134	30	331
Fes	III	3.0	4.4	261	103	28	301
Khemisset	II	1.0	5.0	286	166	31	121
			Bottom Ten Producers by Gross Margin				
Fes	II	0.8	6.7	379	121	32	-2
Khemisset	II	0.8	4.7	353	193	33	-108
Khemisset	II	0.5	5.0	357	232	34	-223
Khemisset	II	0.5	2.0	669	320	36	-489
Khemisset	II	0.5	2.0	676	405	39	-581
Khemisset	II	0.5	2.2	794	285	38	-637
Khemisset	II	0.8	3.0	718	284	37	-753
Khemisset	II	0.5	1.2	1392	708	40	-960
Khemisset	II	0.8	1.0	1411	1228	41	-1070
Khemisset	II	0.5	12.0	463	239	35	-1214
All Producers:	Mean		9.7	287.5	165.4		1109.6
	Std. Dev.		5.6	312.9	209.7		1413.5
	Min.		1.0	40.8	0.0		-1213.5
	Max.		22.0	1411.0	1228.0		4667.1

gross margin per hectare, some interesting patterns emerge, particularly for the bottom ten producers who had negative gross margins. These farmers are all in Category II, and 9 out of 10 are located in Khemisset province. Not surprisingly, their yields are low and their costs are high due to weed infestations. In contrast, seven out of the top ten gross margin per hectare producers are Category III farmers, and half of the top ten are in Safi province where weeds were not a problem this year.

When asked about costs incurred in producing winter chickpea, farmers most often cited labor requirements as their biggest cost. The most labor demanding operations are reported as being crop maintenance activities to control weeds and harvesting, including post-harvest threshing and bagging. Table 5.2.3 gives the aggregate figures for labor allocation by winter chickpea producers. The left-hand column lists the farmer groups considered: all producers in the survey, four groups based on location, and two groups based on cost ranking. Production operations are divided into three categories: tillage and seeding, maintenance and weeding, and harvest and post-harvest operations. In general, about 62% of labor is devoted to weed

Table 5.2.3 Labor allocation by winter chickpea producers (person days per hectare)

Farmer groups	Average days/ha	Tillage & seeding	Mainten. & weeding	Harvest & post-har.
All producers	18	1 (5%)	11 (62%)	6 (33%)
Fes farmers	32	4 (14%)	19 (58%)	9 (28%)
Khemisset farmers	13	0 (2%)	11 (85%)	2 (13%)
Safi farmers	10	1 (10%)	7 (65%)	3 (25%)
Settat farmers	24	1 (10%)	13 (54%)	10 (42%)
Top 10 cost rank	9	0 (2%)	7 (83%)	2 (15%)
Last 10 cost rank	64	1 (4%)	34 (51%)	29 (45%)

control. This can be divided into two periods of peak demand. The first is about a month to six weeks after planting and the second is about six to eight weeks before harvest. It is interesting to note that maintenance patterns vary by location. In the northern provinces more labor is devoted to the earlier weed control operation, while in the south the later, pre-harvest operation, absorbs more labor.

In terms of absolute days per hectare devoted to weed control, location in Safi is clearly an advantage. By the same token, nine of the bottom ten group with the highest variable costs in production were located in Khemisset province. They averaged a tremendous 64 days per hectare, half of which was used in weed control. This is fully three times the average days per hectare of the total sample. The importance of weed control is also demonstrated by the relative labor expenditure devoted to it by the top ten least cost farmers. Eighty-three per cent of their labor went to the task of weed control. It should be noted, however, that their lower labor costs in harvesting was due partly to the fact that three of the ten used mechanical harvesting, accepting some yield loss in order to decrease labor costs.

The average farm-gate price for winter chickpea in June and July of 1989 was DH257 per quintal (approximately US$30.24 per 100 kg). This was slightly higher than the 1988 price of DH233 per quintal and the 1987 price of DH212 per quintal. The lowest price received in 1989 was DH185 and the highest was DH400. Just under 50% of producers selling their harvests did so in local market places. About one in eight of the sellers sold to neighbors who intended to plant winter chickpea next year. Table 5.2.4 gives the distribution of selling arrangements. The reported farm-gate price for the larger-seeded local spring chickpeas was between DH300 and DH350 per quintal, or about 25% higher than the price for winter chickpea.

Table 5.2.4 Selling arrangements for winter chickpea (producers having sold or planning to sell, July 1989)

Arrangement	Percent using arrangement
Sales in local market	48%
Sales to neighbour for seed	12%
Sales to buyers-up	7%
Sales in distant markets	5%
Sales by prior contract	5%
Still awaiting good price	23%

5.2.6 Trends in the Farming System

The adoption potential of winter sown chickpea cannot be assessed without first considering the nature of the farming system. The overwhelming majority of farmers surveyed practice a two-course rotation with winter cereals followed by both food and feed legumes or fallow. In the 1988/1989 season, cereals were sown to about 60% of the total land of the 112 farms. Food legumes covered about 20%, and the remainder was divided between fallow and forages, tree crops, and vegetables.

There are some significant differences in cropping patterns between Category I farmers, the non-adopters of winter chickpea, and Category III farmers, those who have selected the new technology. The non-adopters average 57% of their land in cereals, 20% in food legumes, and only 3% in fallow. The remainder is mostly devoted to forages and tree crops. Adopters of winter chickpea grow slightly more cereal (61%) and one-quarter less food legumes (15%), but have much more fallow land (14%). The adopters tend to have larger farms, but own less of the land they cultivate (65% as opposed to 86% ownership by non-adopters).

Almost all farmers practice mixed farming, and animals constitute an important economic resource closely linked with cereal and legume production. The overall average for the sample was 14 cattle (cows, bulls, and offspring) and 81 small ruminants (sheep and goats plus their offspring) per farm, although some farms had several hundred head and a few had none at all. Most farms also possess at least one beast of burden. Mules are particularly popular for drawing plows, but donkeys and horses are widespread. Tractors are also much in evidence, and the sample was about equally divided between those who owned one or more tractors and those who owned none.

Virtually all farmers in the sample employed seasonal labor, particularly for crop maintenance and harvest activities. A surprisingly large number also employed permanent workers. Larger flocks of sheep and goats and herds of cattle are almost always tended by a professional shepherd or cowherd who usually works for a percentage of the animal production each year. Other permanent workers tend to be specialized tractor operators or general laborers. On an average, the farms in the sample had two permanent hired workers. Also, an average of two family members, not including the farmer himself, worked on the farm without pay.

The general view that food legume production has been declining in dryland areas was borne out by the survey. Table 5.2.5 shows the changes in farm land devoted to food legumes reported by the surveyed farmers. Overall, 56% of farmers reported a decrease in land sown to food legumes on their farms in the past five years. Only 22% said they were growing more hectares in food legumes than in the past, for a net figure of 34% of farmers growing less land in food legumes.

The decline varies from province to province, farm size to farm size, and category of farmer to category of farmer in the

Table 5.2.5 Reported changes in food legume area planted (over past five years)

Farmer group	Percentages of farmers reporting: Increase in area	Decrease in area	No change in area	Net farmers changing
All farms	22%	56%	22%	-34%
Safi province	38%	38%	24%	0%
Settat province	13%	69%	18%	-56%
Khemisset province	14%	62%	24%	-48%
Fes province	30%	50%	20%	-20%
Size more than 99 ha	28%	60%	12%	-32%
Size between 99-30 ha	21%	64%	15%	-43%
Size less than 30 ha	21%	48%	31%	-27%
Category I	6%	63%	31%	-57%
Category II	20%	60%	20%	-40%
Category III	32%	52%	16%	-20%
Category IV	26%	52%	22%	-26%

survey. Safi province has a net balance between farmers decreasing their area of food legumes and farmers increasing the area they plant. In Fes province, half the farmers said they decreased, but 30% are increasing, so the net number of decreasers is only one farmer in five. Settat and Khemisset provinces, where Ascochyta is particularly prevalent, show that about two-thirds of farmers have decreased food legume production, and only slightly over 13% are increasing. With regards to farm size, the smallest farms (under 30 ha) show the most stability. Large farms (100 ha and over) show the highest degree of change. Large farms decreasing area are more offset by farms increasing than is the case for medium-sized farms, where food legumes have declined the most.

Comparison based on the survey farmer categories does most to indicate the potential impact of winter sown chickpea. Non-adopters, by and large, are phasing down their food legume production. One suspects that they are not pre-disposed to consider adopting any new food legume technology. But when Category III adopters are considered, they have the smallest net decline and the highest increase percentage of all four farmer categories. This shows the effect of adopting winter sown chickpea. Taken as a whole, the numbers in Table 5.2.5 would seem to indicate that the most likely area of expansion of food legume production in the next five years might be among winter chickpea adopters in Safi province, and probably this will be most evident among farmers with holdings of 100 ha and above.

When asked the principal reason for decreasing or keeping stable food legume area planted, 44% of farmers cited diseases and pests, particularly Orobanche for faba bean, rust for lentil, and Ascochyta for chickpea. A further 30% stated that high labor costs made food legumes less profitable than cereals. The remainder gave other reasons, or no reason at all, but only 4% asserted that food legumes received poor prices in the market (see Table 5.2.6).

Table 5.2.6 Reasons for increase, decrease and stagnation of food legume area (over past five years)

Reasons for increase and % farmers reporting		Reasons for decrease or stagnation and % farmers reporting	
Good prices	40%	Diseases and pests	44%
New rotation	24%	High labor costs	30%
Acquired land	16%	Conflict with cereals	5%
Mechanical harvest	8%	No land available	5%
Good yields	8%	Poor prices	4%
Early harvest	4%	Risky yield, weeds, other	3%
		No reason given	9%
	100%		100%

Most farmers agree that food legumes fetch good prices in the market. In fact, 40% of the farmers reporting that they have increased the area they plant to food legumes claimed that they did so to take advantage of high prices. Another 16% said they devoted any new land they acquired to food legume production. About a quarter of those who increased production did so as a way of diversifying their farming system. In addition to taking advantage of good prices and reducing the risk of loss due to the failure of any single crop, these farmers claimed that food legumes gave the advantage of feed for livestock and enhanced yields for cereals on the same land in the following year. Increasing food legume area usually was done by decreasing fallow and not cereal area.

Since 1987, about 92% of the winter chickpeas produced in Morocco have been sold. The remainder has stayed on-farm, either destined for household consumption (1%) or used as seeds the following year (7%). Large farms tend to sell a greater proportion of their production, whereas small farms tend towards household consumption. In 1989, the proportion of the total harvest sold, kept for consumption, and intended for seed was the same as in previous years. However, if the figures are broken down and looked at from the point of view of farmer categories, a slightly different pattern emerges. On an average, Category III adopters sold 87%, but Category II demonstration farmers withheld from the market 62% of their production, perhaps an indication of intention to plant winter chickpea again next year.

It is worth noting that all winter chickpea producers mentioned the value of the straw and crop residues for feeding household livestock.

5.2.7 Perceived Advantages of Winter Chickpeas

Curiosity about a new agricultural technology motivated most of the farmers to plant winter chickpea for the first time. This was especially the case for the non-adopters and demonstration farmers in the sample, about 85% of these farmers cited curiosity rather than another reason for first producing winter chickpeas. Curiosity alone was less important for the adopters. Half of them had seen winter chickpeas growing on someone else's farm before they themselves cultivated the crop, and it was the easily observable higher yields which motivated them to accept the new technology. In addition to higher yields, a number of adopters cited secondary advantages as motivations. The two most important of these were the potential for mechanical harvesting due to greater plant height and the early harvest date for winter chickpea as opposed to spring chickpea.

When asked specifically about earlier harvesting, the sixty-five farmers in Categories II and III gave a variety of reasons as to why this was advantageous. About a third said that casual labor was cheaper and more readily available at winter chickpea harvest time, which is about four to six weeks before the cereal harvest peak demand period. About a quarter said they took advantage of the earlier harvest to prepare the field sooner for the next crop, noting that this conserved more moisture in the soil. A fifth of the farmers said that early harvest and early sale of their winter chickpeas gave them the needed cash flow to either repay outstanding debts or finance the upcoming cereal harvest. Twelve per cent simply said that having chickpeas harvested and ready for sale a month before anyone else meant that they could take advantage of the best possible prices. A month later, when spring chickpeas hit the market, prices fall dramatically. Only nine per cent of the farmers said that an early harvest was of no benefit to them.

All farmers were asked to compare winter with spring chickpea along a number of dimensions. Seven farmers in Category IV felt that they did not know enough about one or the other crop to do this, but the remaining 105 farmers gave their opinions (see Table 5.2.7). The poll showed winter chickpea a clear winner with regard to better plant stand, more straw produced, higher yield, less risk of low yield, and better resistance to diseases. Winter chickpea received lower scores for seed size, market prices, and seed quality (all of which are closely related in farmers' minds).

Table 5.2.7 Comparison of winter and spring chickpea

Characteristics	Number of farmers Winter better	Spring better	Do not know
Plant stand and growth	91	12	2
Amount of straw	90	12	3
Yield	65	29	11
Less risk of crop failure	59	25	21
Resistance to diseases	52	35	18
Seed quality	26	52	27
Market prices	6	72	27
Seed size	5	91	9

A few farmers said that they preferred spring chickpea because it allowed them greater flexibility in response to the unpredictable rainfall. Planting decisions for winter chickpea have to be made in November or early December at the latest, whereas the farmer can wait until February to decide whether or not to plant spring chickpea. Delaying the planting decision allows the farmer to leave land fallow if the first half of the rainy season brings a disappointing amount of precipitation. In contrast, the winter chickpea farmer must commit land to the crop before knowing how much rain will fall. Those who prefer spring chickpea often do so because they feel it gives them more flexibility within the cereal - fallow/legume rotation. For others, however, this is not a dis-incentive for winter chickpea because they feel the less risk of crop failure and greater potential yield outweighs the need to see how much rain falls in December and January before planting.

Finally, there is considerable disagreement and debate about the effect of winter and spring chickpea on the following year's cereal crop. Some say chickpea depresses yields, others say it either has no effect or the effect is beneficial (see also section 3.5 of this report). Interestingly, of the ten Category IV farmers who offered an opinion as to which crop winter chickpea would replace on their farms, five said another food legume, four said fallow, and one said maize (which is grown in the spring as a fodder crop in Safi province).

5.2.8 Perceived Problems and Constraints

Farmers were asked a series of questions designed to elicit their critical evaluations of winter chickpea. The first question had to do with the problems they had encountered in producing winter chickpea. It was asked of all farmers except those in Category IV. Table 5.2.8 presents their responses. The left-hand column lists all the problems mentioned by farmers. The remaining columns list the number of times a problem was mentioned. Farmers were asked to mention a maximum of three problems and to rank these according to degree of severity. If a problem was mentioned as being most serious, then it was given a weighted value of three points; somewhat serious received two points, and least serious got one point. Thus weighted values for each problem mentioned is the sum of points received for being mentioned according to severity. Table 5.2.8 ranks the problems according to weighted values.

Table 5.2.8 Problems encountered in producing winter chickpea (responses by farmers in categories I, II and III)

Problem	Most serious	Somewhat serious	Least serious	Frequency mentioned	Weighted value
Small seed size	27	17	2	46	117
Diseases & pests	22	7	1	30	81
Weeds	11	1	8	20	43
Market & prices	2	14	6	22	40
Labor costs	4	1	1	6	15
Uncertain yield	3	3	0	6	15
Conflict w/cereals	1	2	1	4	8
Need information	1	2	1	4	8
Seed availability	1	1	0	2	5
Need new equipment	0	0	1	1	1
No problem given	9	32	59		

Small seed size leads the list, being closely followed by susceptibility to diseases and pests. The disease in question is primarily Ascochyta Blight, although there were incidences of fusarium wilt in Safi province. The "problems encountered in production" question is designed for an immediate referent, that is, the farmer's direct experience with the crop. Therefore, it is hardly surprising that in this year of an Ascochyta epidemic that diseases and pests rank so high. Small seed size is considered a problem primarily because of the perception that small size is translated in the market into lower prices. Many farmers emphasized this point by listing "market and prices" as a secondary or tertiary problem after having already mentioned small seed size. It should also be noted that "weeds" received a fairly high ranking.

The second question asked farmers to think about possibly expanding the area they might sow to winter chickpea next year and in the following years, and what would be the constraints they would face in increasing the area they devote to winter chickpea. Table 5.2.9 gives their responses. There are subtle differences in farmers' thinking from the previous question about problems already experienced. Small seed size again tops the list, but not by the same margin. And diseases and pests drops significantly down to the sixth position. The need for more information about cultivation practices and questions about seed availability for planting fill the number two and three slots. Weeds are barely mentioned at all. When asked about why they did not rank diseases and pests or weeds any higher as constraints to expanding production, farmers tended to respond that these are problems they expect with any crop and that this year was a particularly bad one for chickpeas. They did not expect that these problems would re-occur in every year. The small seed size of winter chickpea, however, they saw as a recurrent economic problem rooted in the nature of consumer demand.

Table 5.2.9 Constraints to expanding area planted to winter chickpea (responses to farmers in categories I, II and III)

Problem	Most serious	Somewhat serious	Least serious	Frequency mentioned	Weighted value
Small seed size	18	7	2	27	70
Need information	16	8	0	24	64
Seed availability	12	4	0	16	44
Market & prices	6	9	3	18	39
Labor costs	7	3	0	10	27
Diseases & pests	4	4	1	9	21
Conflict w/cereals	5	1	0	6	17
Land availability	3	2	0	5	13
Uncertain yield	1	1	1	3	6
Weeds	0	1	1	2	3
No problem given	9	41	73		

The third question asked farmers to speculate about the adoption potential of winter chickpea. This was addressed to all farmer categories. They were asked to name factors which they felt would limit the ability of other farmers to accept the new technology. Table 5.2.10 shows their responses. The majority of farmers either thought that knowledge was the most limiting factor or could not comment on what their colleagues might experience as a most limiting factor. The impression is given that the farmers in the survey were optimistic about the adoptability of winter chickpea. They thought it was a good idea, although they acknowledged that there were some problems, as there are with any crop. But they generally advised the extension services, DPV, and INRA to expend more resources on educating farmers in the new technology.

Table 5.2.10 Factors limiting adoption of winter chickpea (responses by farmers in all categories)

Limiting factors	Most limiting	Somewhat limiting	Least limiting	Frequency mentioned	Weighted value
More information	43	9	0	52	147
Small seed size	14	11	1	26	65
Seed availability	7	12	1	20	46
Market & prices	6	6	1	13	31
Diseases & pests	4	2	2	8	18
Land availability	2	3	0	5	12
Labor costs	3	1	0	4	11
Uncertain yield	1	1	1	3	6
Conflict w/cereals	2	0	0	2	6
Weeds	0	1	3	4	5
No factors given	27	66	103		

Table 5.2.11 represents a combination of the answers given by Category III farmers to the previous questions. The overall picture is that small seed size and need for more information about winter chickpea are the biggest constraints to its adoption and increased cultivation. These are followed by the lack of seed available to potential adopters and those who wish to expand the

land they sow to winter chickpea. Marketing problems and low prices follows, and in turn are followed by diseases and pests. After this, with values less than half those of the two leaders, are a number of problems which would tend to be specific to certain farmers and their particular farming systems, such as potential conflict with cereal production and the availability of suitable land.

Table 5.2.11 Perceptions of winter chickpea adopters (weighted response values)

Problem/Constraint	Regarding production	Regarding expansion	Regarding adoption	Total value
Small seed size	33	18	6	57
Need more information	0	23	32	55
Seed availability	5	13	21	39
Marketing & low prices	18	12	6	36
Diseases & pests	18	6	0	24
Conflict w/cereals	4	9	6	19
Weeds	15	0	0	17
Land availability	0	10	6	16
Labor cost	3	5	2	10
Uncertain yield	3	0	0	3

As a way of gauging adoption potential, is there a noticeable difference between the responses of Category I non-adopters and Category II 1988/1989 demonstration farmers? Table 5.2.12 presents the responses of the non-adopters and gives clues as to why they decided to suspend production of winter chickpea. If marketing and low prices are taken as closely related to small seed size, then it can be seen that these two account for most of the decision not to adopt. However, a number of farmers in the non-adopter category are still interested in the new technology to the extent that they would like to know more about it. In particular, they are interested in learning ways to reduce costs and raise yields, willing to take lower prices as compared to spring chickpea if they can achieve higher yields at lower cost.

Table 5.2.12 Perceptions of winter chickpea non-adopters (weighted response values)

Problem/Constraint	Regarding production	Regarding expansion	Regarding adoption	Total value
Small seed size	29	16	16	61
Marketing & low prices	11	10	8	29
Need more information	2	14	13	29
Labor cost	3	11	3	17
Seed availability	0	8	8	16
Diseases & pests	9	3	0	12
Weeds	10	0	0	10
Conflict w/cereals	2	3	0	5
Land availability	0	0	0	0
Uncertain yield	0	0	0	0

Table 5.2.13 relates to the demonstration farmers in Category II. Having had the experience of growing winter chickpea in a season with unfavorable weather conditions and severe blight problems, they see small seed size and the need for more information as being equally constraining. Diseases and pests take third place and is followed by the rest in expected order.

Table 5.2.13 Perceptions of winter chickpea trials farmers (weighted response values)

Problem/Constraint	Regarding production	Regarding expansion	Regarding adoption	Total value
Small seed size	55	36	21	112
Need more information	6	27	74	107
Diseases & pests	54	12	12	78
Marketing & low prices	11	17	10	38
Seed availability	0	23	15	38
Uncertain yield	12	6	6	24
Labor cost	9	11	3	23
Weeds	18	3	0	21
Conflict w/cereals	2	5	0	7
Land availability	0	3	0	3

5.2.9 Encouraging Adoption: Putting Survey Results to Work

Winter chickpea adopters appear to be mostly self-selected. Most of them first cultivated winter chickpea because of a healthy curiosity to try new technologies. This quality was coupled by a perception that the new varieties would lead to higher chickpea yields and larger profits. At least half the adopters had no direct contact with INRA, DPV, or extension agents before they decided to plant the new varieties. They had, however, seen winter chickpeas growing either on neighbors' fields or on research stations located in the countryside.

Both those with more than one year's experience with winter chickpea and those who are growing the crop as part of the demonstration plot program are doing so with a minimum of outside supervision and expertise. The limited people working in CT's have only the barest of logistical support, and they rarely are able to visit farms more than once or twice in a growing season. To its credit, DPV has designed its demonstration plot program to encourage a "minimum input" package. This is wholly in keeping with farmer practice with regards to spring chickpea, and it would not serve the objective of facilitating adoption among a wide spectrum of farmers to demand costly inputs in addition to the new varieties. Surprisingly, the survey found that many adopters and demonstration farmers are indeed committing additional resources to winter chickpea which they would not usually devote to spring chickpea or to other food legumes. In particular, many farmers applied fertilizers, and others applied herbicides or fungicides (to combat blight). From the point of view of whether or not farmers are inclined to accept new ideas and new technology, these actions are very encouraging.

Another finding of the survey is the high degree to which individual farmers rely upon their neighbors as a source of new information, expertise, and even technology itself. The resulting "spread effect" from simple observation of what is happening on neighboring farms has been mentioned, but through informal interviews in Safi province, it was revealed that successful demonstration plot farmers quickly become an important, if localized, source of seeds for neighboring communities. One farmer who got 30 qx/ha from an INRA verification trial in 1985/86 has continued to plant each year and sell the bulk of his harvest as seeds in his own and four surrounding villages. He alone can account for about a dozen adopters, albeit all of them are on a modest scale. He reported that by selling winter chickpeas as seed to his neighbors, he can get much higher prices than are offered by buyers-up or merchants in the local market.

This happens elsewhere, as well. The largest producer of winter chickpea this year, a large-scale agribusiness, sold about 40% of its harvest to an export firm and kept about 6% as seed for next year. But 54% was sold ad hoc to farmers who, having seen the crop before harvest, came and requested to buy seeds for planting. The producer was happy to do this because the per kg price farmers were willing to pay was substantially higher than the bulk price offered by the export firm.

Casual observation, however, can sometimes lead to serious disappointment. One farmer related a story about his own attempt to adopt "winter chickpea." Apparently, he saw chickpea growing on a research station near his village in February of 1988. Thinking that the secret to getting a crop as impressive as the one he saw lay in an early planting date, he planted his local spring chickpea cultivar in December of 1988. Things were going fine until February and March when his field was struck by Ascochyta and his crop suffered from a cold spell. The crop was ruined. It was only later that he learned that winter chickpea is a new variety specially developed for early planting.

Without denying that farmers face problems and constraints in adopting winter chickpea, it must be stressed that Category III farmers in the survey were enthusiastic about the new technology. They are certainly the best "salesmen" for promoting its adoption in the future. When confronted with problems of disease, weeds, labor costs, or market prices, they respond in two ways. First, they list benefits like higher yield and less risk of crop failure as outweighing the problems. Second, they suggest ways to get around the constraints. Herbicides and mechanical harvesting are popular ideas for reducing labor costs. Farmers want to know if there is a fungicide which is effective against Ascochyta. These are people who are willing to adapt their farming practices to the new technology if they believe there is good reason to do so.

Any effort to encourage the accelerated adoption of winter chickpea must listen to and work closely with the Category III farmers and those in Category II who decide to continue with winter chickpea production. These are the best "experts" with the most experience in producing winter chickpea under farmers' conditions. They also know their fellow farmers and the incentives and constraints facing these potential adopters.

From a farming systems perspective, the most promising population for future adoption targeting would appear to be farmers who have not already decided to decrease or abandon their production of food legumes. Moreover, within this category attention should be paid to those who either cultivate a higher than average percentage of their holding in food legumes or who tend to fallow more of their land than others. This inference is based upon the farm use characteristics of Category III versus Category I farmers, the responses presented in Tables 5.2.5 and 5.2.6, and the answers given by Category IV farmers to the question regarding allocation of land to winter chickpea.

The 1988/89 survey indicates a number of areas for further action and research. First and foremost, the results show that the DPV demonstration plot program, with certain modifications, should continue. It is true that the yield and economic results this year were disappointing for many farmers in Fes, Khemisset, and Settat provinces. Blight and weeds were devastating, but this will not necessarily be the case every year. The variety ILC 482 was not as blight resistant as expected, but ILC 195 did considerably better and some lines being tested on-station did very well indeed. Of course, it should not be forgotten that the local spring chickpea was equally hard hit. More to the point, the importance of having winter chickpea being grown by farmers where it can be seen by other farmers cannot be over-stressed. The responses of the Category III farmers in the survey show the efficacy of the DPV approach.

Adding herbicide treatments to the demonstration plot program, while increasing the costs of the winter chickpea package offered to farmers, is necessary to test an alternative to hand weeding. The survey shows that weed control by some means other than hand labor is the obvious way to increase farmer gross margins for winter chickpea. Farmers are well aware of this. When asked how many hectares of winter chickpea they would plant if an effective herbicide was available, 17 out of 81 (or one in five) said that they would increase their area. Over half of these 17 do not presently grow winter chickpea. More surprising, perhaps, is that if these farmers were to actually plant the additional area, then the total winter chickpea area planted by all the farmers surveyed would jump an astounding 108%.

In terms of on-station work, increased seed size should be the number one priority in breeding and selection. However, this should not be pursued at the expense of losing resistance to Ascochyta. Already, a few new lines which combine large seed size with high resistance to Ascochyta Blight are being evaluated. It should be noted also that fusarium wilt is also a potential problem area. Table 5.2.14 indicates farmer response to the idea of new, larger seeded varieties of winter chickpea. Not only do the vast majority (80-96%) of Category II and III farmers say they would grow more winter chickpeas, but 80% of the non-adopters in Category I claim that larger seeded varieties would make the difference between adopting and not adopting the new technology.

Table 5.2.14 also indicates the considerable interest farmers have in mechanical harvesting technology for winter chickpea. At present, a number of the adopters are using combines to harvest, and they claim that it cuts labor costs and harvest time considerably. The economic and technical evaluation of mechanical harvesting options should be studied carefully. This is an avenue through which the recognized benefit of taller plants could be enhanced.

Table 5.2.14 Positive replies to the question: Would you grow any or would you grow more winter chickpeas if the following was available?

	Percent of farmers in category			
	I	II	III	IV
Mechanical harvesting	44%	63%	80%	6%
Larger seeded variety	80%	80%	96%	23%

Regarding the information constraint, DPV, INRA, and ICARDA are already taking concrete steps. In cooperation with the Moroccan national program ICARDA will hold an in-country training course for extension agents on winter chickpea agronomy and production methods during the 1989/90 season. Also, Moroccan scientists are organizing the production of a short (20-25 minutes) video tape about winter chickpea, its advantages, and how to grow it for viewing by groups of farmers.

The problem of seed availability is more complex. First, there is the issue of having enough seeds to meet demand. Then there is the question of quality control and certification. Third, there are questions about which lines to multiply for release to farmers and when and where they should be released. This is a matter needing careful consideration. Perhaps the involvement of the more successful adopters in certified seed production schemes could be helpful in future years.

In addition to the demonstration plots, on-farm work should continue to monitor the process of adoption. This involves return visits to the Category II and III farmers covered in the 1988/89 survey and inclusion of next year's demonstration farmers in the general data base. Adoption is a long-term process, and this year's survey provides only a snapshot of the situation at one point in time. Longitudinal data are required if development research and adoption efforts are to be informative and effective.

Monitoring includes the continuing analysis of data already collected. This report has presented an exploratory analysis that provides a simple description of the present situation. It has sought to identify important areas for further research and development. The next step is to test hypothetical relationships between farm characteristics and cultural practices, on the one hand, and adoption and successful economic performance, on the other hand. The statistical analysis of the survey data is the place to start, but to increase its utility the data need to be expanded in terms of numbers of farmers and yearly production and adoption variations. In addition to continuing the structured survey method, tracer studies of winter chickpea production and farmer decision-making studies could contribute substantially to our understanding of the adoption dynamics of winter chickpea in Morocco.

Finally, more attention needs to be paid to the dynamics of the dryland farming system as a whole, for it is only if winter chickpea can be integrated into the larger system practiced by farmers that it will, in fact, be widely adopted.

5.3 An Assessment of Risk Associated with Increasing Sheep and Feed Supplies in Syria. Current and Alternative Strategies

P. Cooper and E. Bailey

5.3.1 Introduction

Mediterranean farming systems have evolved in an environment characterized by highly variable and often chronically deficient rainfall. Many of the strategies developed as "buffers" against this uncertainty of rainfall are still common features of current farming systems, but are becoming increasingly threatened as radical changes in food and feed demand place greater pressure on the region's land resources.

Whilst the climate, soils, crops and livestock which form the essential edaphic and biological components of the farming systems have probably changed little over time, both the social and economic environment in which farmers operate are today radically different. Throughout the region the relative importance of agriculture has declined in recent decades, and in most countries food production per capita has also declined, yet the population is increasing. It has been estimated that by 1990 the countries within the Mediterranean basin will face an annual 30-34 million ton food deficit.

Table 5.2.2 Economic performance of winter chickpea producers (ranked by Gross Margin per hectare)

Province	Farmer Category	Area planted (ha)	Yield per Qx/ha	Imputed cost/ DH/Qx	Paid cash DH/Qx	Variable Cost Ranking	Gross margin DH/ha
Top Ten Producers by Gross Margin							
Safi	III	4.0	22.0	44	31	3	4667
Fes	II	0.8	21.0	72	0	2	4489
Safi	III	1.0	18.0	41	44	4	3738
Safi	III	1.0	16.0	68	35	5	3180
Khemisset	III	38.0	13.3	50	17	1	2881
Khemisset	II	0.5	15.6	95	50	8	2770
Khemisset	II	0.5	20.0	152	83	17	2656
Safi	III	10.0	12.0	78	41	6	2283
Safi	III	0.6	13.3	112	53	9	2226
Settat	III	0.8	12.0	157	60	13	1695
Fes	II	0.5	12.0	133	88	14	1676
Safi	II	0.1	20.0	224	120	26	1562
Khemisset	III	20.0	10.0	96	101	10	1516
Safi	II	1.0	14.5	193	101	21	1490
Fes	III	1.0	10.8	145	88	16	1441
Fes	II	1.5	10.0	136	85	15	1395
Safi	II	1.5	9.0	122	85	11	1320
Settat	II	0.8	10.7	133	127	18	1286
Fes	II	0.4	13.3	166	152	23	1211
Safi	III	6.0	6.0	120	18	7	1086
Settat	II	0.8	7.0	149	60	12	1019
Safi	III	2.5	11.5	146	179	25	1006
Fes	II	0.8	8.8	160	125	20	947
Settat	III	2.0	8.0	160	143	22	787
Fes	II	0.8	8.3	160	157	23	757
Safi	III	2.0	5.5	151	118	19	634
Khemisset	III	1.0	9.0	197	171	29	596
Fes	III	0.5	6.0	317	30	27	461
Khemisset	II	0.5	6.0	255	134	30	331
Fes	III	3.0	4.4	261	103	28	301
Khemisset	II	1.0	5.0	286	166	31	121
Bottom Ten Producers by Gross Margin							
Fes	II	0.8	6.7	379	121	32	-2
Khemisset	II	0.8	4.7	353	193	33	-108
Khemisset	II	0.5	5.0	357	232	34	-223
Khemisset	II	0.5	2.0	669	320	36	-489
Khemisset	II	0.5	2.0	676	405	39	-581
Khemisset	II	0.5	2.2	794	285	38	-637
Khemisset	II	0.8	3.0	718	284	37	-753
Khemisset	II	0.5	1.2	1392	708	40	-960
Khemisset	II	0.8	1.0	1411	1228	41	-1070
Khemisset	II	0.5	12.0	463	239	35	-1214
All Producers: Mean			9.7	287.5	165.4		1109.6
Std. Dev.			5.6	312.9	209.7		1413.5
Min.			1.0	40.8	0.0		-1213.5
Max.			22.0	1411.0	1228.0		4667.1

Such predictions highlight recent trends of increased demand for livestock products, both meat and milk, and the associated derived demand for increased supplies of coarse grain feed, principally barley. Substantial regional deficits in barley production already exist, and are predicted to rise sharply by the year 2000.

In the context of increasing sheep feed supply to meet the demands of expanding national flocks, the nations of the region will *continue* to rely heavily on barley production as a major source of feed through the consumption of grain, straw and often through green grazing of immature crops. In addition, they will also continue to depend on the natural pastures which are seasonally available on marginal lands. Such lands are unsuitable for cultivation, either due to topographical features or because they occur in areas too dry for sustainable agriculture. Since barley is also largely produced in the drier and lower potential agricultural systems of the region, it is clear that much of the projected increase in sheep feed supply must come from the region's most fragile and vulnerable environments. Both the challenges involved and the potential threat to the agricultural resource base are very real.

5.3.2 Recent Trends in Sheep Numbers and Barley Production

Within the Mediterranean region of WANA, Syria demonstrates some of the most dramatic trends in livestock and livestock feed production (Figure 5.3.1).

Since 1951, the national flock size has increased steadily from 3.1 million to a level of 13.3 million in 1988, reflecting similar human population changes. Within this general upward trend, two periods of decline in numbers occurred, 1958-1961 and

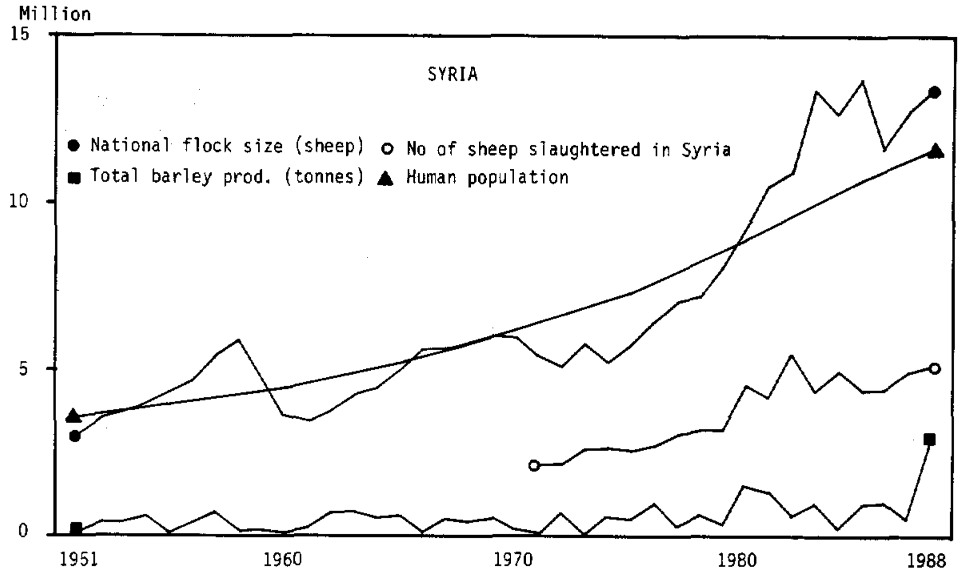


Figure 5.3.1 National trends in sheep number, human population and barley grain production: Syria 1951-1988.

later from 1970 to 1973. These downward trends correspond to periods of successive drought years when national barley production levels were very low indeed, and other sources of feed must also have been similarly affected. Under such circumstances, farmers are forced to sell a part of their flocks in order to raise capital to purchase feed to sustain the remainder.

The numbers of sheep slaughtered for consumption within Syria rose in proportion to population until 1982, but since then has levelled off suggesting that rising prices of meat may be reducing per capita consumption. However, we must caution that the figures represent those animals registered in Syria's official slaughter-houses, and do not include animals slaughtered privately (Bahhady, 1989). The increasing difference in the national flock size and the number of sheep slaughtered probably also reflects increased export of live animals to some of the Gulf States.

In contrast to the dramatic changes observed in livestock numbers, barley production has largely stagnated, with only a slow upward trend starting in the early 1970s. However, a more detailed examination (Figure 5.3.2) indicates that this increase in total production results entirely from an expanded area under production, rising from a relatively constant 750 thousand ha between 1960 and 1970 to over 1.4 million ha from 1983 onwards. **In the 1988/89 season, 2.9 million ha of barley was grown in Syria, and government plans are for 2.5 million ha in the current 1989/90 season.** A part of this increased area has occurred at the expense of wheat in the higher potential wheat based systems, but the vast majority has been achieved through the expansion of barley cultivation into drier and more marginal environments, and the gradual abandonment of fallow by farmers in traditional barley growing areas. The implications of these changes are examined in more detail in section 2.3.4.

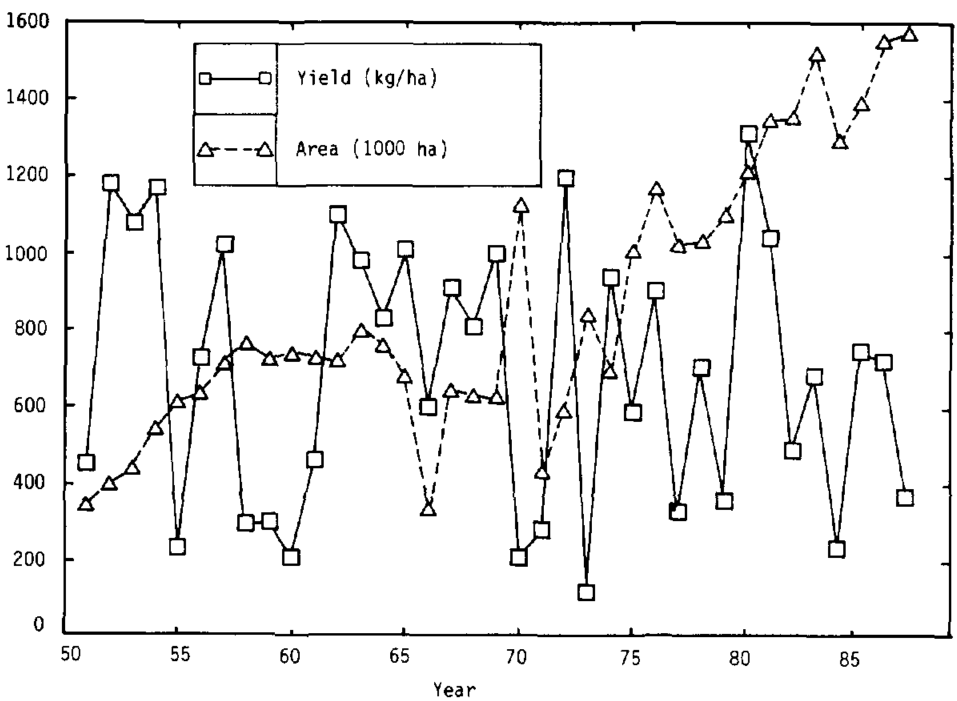


Figure 5.3.2 Barley production in Syria 1951-1987.

National average yields of barley have however remained highly variable and show no upward trend over time. Such variability is typical within the region and is largely attributable to variations in seasonal rainfall. To illustrate this association, we took the seasonal rainfall totals from over 25 meteorological stations within the barley growing areas of Syria and from these records, obtained a mean "national average" rainfall for each of the years from 1961 to 1986. These "national average" rainfall estimates were closely related to national average barley yields according to the equation:

$$\text{Nat. Av. Yield} = -\,283 + 3.50\ \text{Nat. Av. Rain} \quad (R^2 = 0.684) \quad .... \quad (1)$$

Research at ICARDA and elsewhere (see Cooper et al. 1987, 1989) has shown that improved crop and soil management offers considerable scope for greater crop water use efficiency, growth and yield of barley in these dryland areas, and yet in contrast to similar studies on Syria's wheat production, a simple comparison of "national water use efficiency" indicates no such improvement between the period 1960-1970 and 1975-1985 (Table 5.3.1).

Table 5.3.1 National average barley grain yields, rainfall and water use efficiency

Period	Nat. Av. Yield (kg/ha)	Nat. Av. Rain (mm)	Nat. Av. Water Use Efficiency (kg/ha/mm)
1960-1970	780 (37) [1]	308 (29)	2.53
1975-1985	681 (50)	273 (18)	2.49

[1] Figures in parentheses are CVs (%)

Our survey results and research trials would suggest that this apparent lack of change probably conceals some improvement in production practices in the wetter areas which are offset by the minimum input practices followed by farmers as continuous barley becomes more widespread and production expands into more marginal and risky environments.

5.3.3 Barley: Its Potential to Meet the Energy Requirements of the Syrian National Flock. 1960 and 25 Years On

In the previous section we have shown that the national average barley yields show a natural variability, closely associated with seasonal rainfall, and that there are no apparent trends in yields or water use efficiency. We do note however (and will discuss in more detail later) that the coefficient of variation (CV) of national average yields in the period 1975-1985 is considerably higher than that of 1960-1970, and yet the CV of national average rainfall was substantially lower (Table 5.3.1).

For the purpose of our analysis, however, we have utilized the entire 27 years yield dataset (1960-1986) to calculate the cumulative frequency distribution of national average yields, and have assumed that this distribution was equally valid for the two five year periods, 1960-65 and 1982-87. Based on this assumption, we have made a series of calculations which illustrate some dramatic changes in the ability of the barley crop (grain and straw) to meet the energy requirements of the national flock, and the extent to which additional sources of feed must be sought. Such sources include importation of barley grain, purchased agro-industrial by-products and the use of marginal grazing areas. These results are presented as cumulative frequency distributions in Table 5.3.2.

Section A of the table presents the cumulative frequency distribution of national average grain yields, and in section B, these are converted into cumulative frequency of grain production for the periods 1960-65 and 1982-87 using the average areas under production during those periods. A further transformation of the

Table 5.3.2 Cumulative Frequency Distribution of National Average Barley Grain Yields, total grain production, sheep feed equivalents and sheep feed equivalent deficits. Based on Syrian National Statistics (1960-1986)

	A	B		C		D		E	
Decile	Grain Yield kg/ha	Total Production (million tons)		Sheep Feed Equivalents (millions)		Sheep Feed Equivalent Deficit (millions)		Percent Energy Requirements of National Flock met by barley	
		1960-65	1982-87	1960-65	1982-87	1960-65	1982-87	1960-65	1982-87
0.1	230	0.172	0.345	0.81	1.61	3.19	10.39	20.3	13.4
0.2	318	0.238	0.477	1.12	2.23	2.88	9.77	28.0	18.6
0.3	424	0.318	0.636	1.49	2.98	2.51	9.02	37.2	24.8
0.4	609	0.457	0.914	2.14	4.29	1.86	7.71	53.5	35.8
0.5	723	0.542	1.084	2.54	5.08	1.46	6.92	63.5	42.3
0.6	826	0.619	1.239	2.90	5.81	1.10	6.19	72.5	48.4
0.7	929	0.697	1.394	3.27	6.53	0.73	5.47	81.8	54.4
0.8	1004	0.753	1.506	3.53	7.06	0.47	4.94	88.3	58.8
0.9	1119	0.839	1.678	3.93	7.87	0.07	4.13	98.3	65.6
		Note 1		Note 2		Note 3			

Note 1 Uses average area under production of 0.75 million ha in 1960-65 period, and 1.50 million ha in 1982-87 period.

Note 2 Conversion of production to SFE assumes (1) Harvest Index of 0.40, (2) Barley Grain = 11.5 MJ/kg, (3) Barley Straw = 5.5 MJ/kg, (4) Annual Energy Requirement = 4200 MJ/ewe.

Note 3 Uses average National Flock of 4.0 million in 1960-65 period and 12.0 million in 1982-87 period. Deficit figures represent additional feed required over and above that provided by barley.

data into sheep feed equivalents is presented in section C, based on the energy content of barley grain and straw, an assumed harvest index, and the annual energy requirements of a sheep.

Section D of Table 5.3.2 presents the cumulative frequency distribution of sheep feed equivalent deficits, based on the average National Flock size in the two periods. These figures represent the additional feed required over and above that provided by barley and illustrate the dramatic changes which have occurred. Many observations are possible, some important ones are:

- In the period 1960-65, the "sheep feed equivalent deficit" would only have been expected to exceed 3.2 million one year in ten, whereas now it can be expected to <u>exceed</u> this figure by 1 million sheep feed equivalents nine years in ten.

- Traditionally, barley grain and straw were, on average, expected to meet about 60% of the sheep's energy requirements in Syria (Thomson, 1987). Our calculations (section E) confirm that this would have indeed been achieved or exceeded in 50% of the years in the period 1960-65, but now is only likely to be possible in the 20% most productive years.

5.3.4 The Impact of Recent Trends on the Uncertainty of Barley Production and Syria's National Resource Base

In order to meet the expanding feed requirements of its national flock, Syria has moved from being a frequent net exporter of barley to a frequent net importer (Figure 5.3.3).

As illustrated in Figure 5.3.2, Syria has responded to this increasing dependence on barley imports by the abandonment of fallow (see also Table 5.3.3) and the expansion of barley cultivation into drier and more marginal areas. We believe that

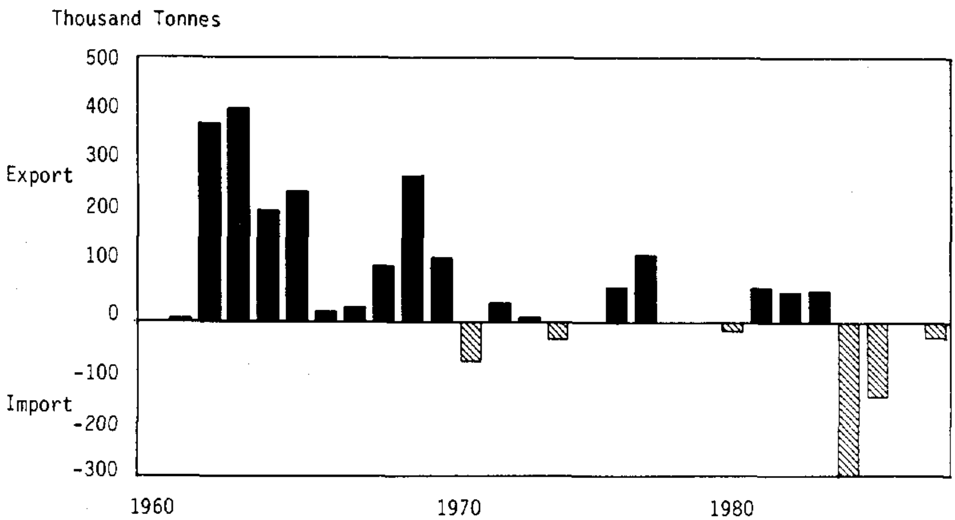
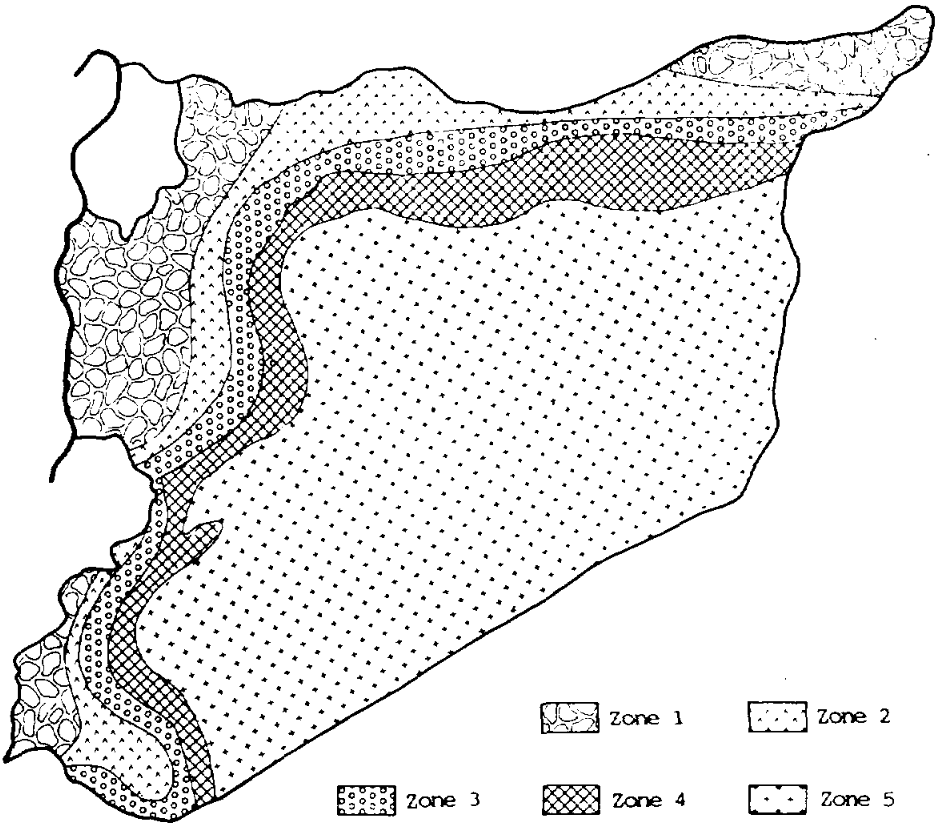


Figure 5.3.3 Syria: net trade in barley.

this trend has alarming implications for the future uncertainty of national barley production and for the conservation of the fragile resource base which is currently being exploited.

In 1975, Syria defined Agricultural Stability Zones based on expected seasonal rainfall, and to some extent on the probability of receiving those amounts. Recommendations of the agronomic suitability of crops and cropping sequences were based on years of previous experience, years when the absence of more recent pressures had allowed the development of farming systems well buffered against climatic uncertainty (Figure 5.3.4).

Barley was recommended to be grown in Zones 2, 3 and to some extent in Zone 4. In Zone 2 it was largely restricted to the shallow soils of low water holding capacity, such land usually being under a two year barley/fallow rotation. In Zone 3, barley was identified as the principal crop, again largely being grown in



Zone 1a Average rainfall over 600 mm. A wide range of crops may be grown here. Fallowing is not necessary.

Zone 1b Average rainfall between 350 and 600 mm and not less than 300 mm in two thirds of the years surveyed. At least two crops can be grown every three years. The main crops are wheat, pulses and summer crops.

Zone 2 Average rainfall between 250 and 350 mm and not less than 250 mm in two thirds of the years surveyed. Two crops are normally planted every three years. Barley, wheat, pulses and summer crops are grown.

Zone 3 Average rainfall over 250 mm and not less than this in half the years surveyed. One or two crops will yield in every three years. Barley is the principal crop but some pulses can be grown.

Zone 4 Average rainfall between 200 and 250 mm and not less than 200 mm during half the years surveyed. Barley is grown. The area is also used as grazing land.

Zone 5 Covers the rest of the country. This desert and steppe land is not suitable for unirrigated agriculture but parts of it offer some winter pasturage.

Figure 5.3.4 Agricultural stability zones of Syria.(from Watson 1979).

a barley/fallow, or barley/barley/fallow rotation, but sometimes in rotation with lentils. In Zone 4, some barley was also recommended, but it was also recognized that much of Zone 4 was too dry for cultivation and should only be used as grazing land.

Zone 5 was clearly identified as an area unsuitable for the cultivation of rainfed crops, reserved only for the provision of winter grazing or for irrigated agriculture.

Since the establishment of these zones in 1975, the area under barley has expanded from 1.01 to 1.84 million ha in 1988, and to a staggering 2.89 in 1989. 2.54 million ha are planned for the 1989/90 season. The details of this expansion in area for each zone are given in Table 5.3.3, and the associated barley yields in Table 5.3.4. The percent contribution of each zone to the national production are given in Table 5.3.5.

Table 5.3.3 Total land area, arable area and area under barley production in the different Agricultural Stability Zones of Syria (1000 ha)

Zone	1	2	3	4	5	Total
Total land area	2710	2470	1300	1800	10200	
Total arable land	1710	1878	859	998	563	
Land under barley						
1979	110	270	285	323	100	1088
1980	101	308	280	328	177	1193
1981	130	335	279	414	170	1328
1982	118	331	303	505	317	1574
1983	106	357	341	519	181	1505
1984	69	361	291	363	189	1274
1985	58	358	299	435	217	1367
1986	79	463	302	464	221	1529
1987	71	486	330	455	221	1563
1988	88	562	402	463	308	1822
1989	87	807	634	806	541	2876
Planned 1990	43	646	580	867	400	2536

Table 5.3.4 Average yields of barley grain obtained in the different Agricultural Stability Zones of Syria (kg/ha)

Zone	1	2	3	4	5
1979	840	620	300*	80*	20*
1980	2360	1660	1220	970	780
1981	1760	1080	920	910	810
1982	1330	700	380	200*	10*
1983	1340	860	680	490	440
1984	1110	460	50*	10*	90*
1985	1220	830	440	400	200*
1986	1470	980	610	510	360*
1987	1240	740	200*	80*	30*
1988	1890	1644	1482	1577	1202
1989	475	160*	55*	51*	12*
Mean	1367	885	576	480	359
CV (%)	37	51	81	103	114
% Years no harvest	0	9	36	45	64

* Occasions on which the bulk of the crop would have either been grazed during the vegetative stage or as as mature standing crop (Thomson et al., 1983).

Table 5.3.5 Percent contribution of different Agricultural Stability Zones to Syria's total barley production

Zone	1	2	3	4	5
1979	24	45	23	7	1
1980	15	33	22	21	9
1981	17	27	19	27	10
1982	25	40	18	16	1
1983	14	30	23	25	8
1984	27	60	5	2	6
1985	10	42	18	24	6
1986	11	42	17	22	8
1987	16	64	12	7	1
1988	6	33	21	26	13
1989	16	51	14	16	3
Mean	16	42	17	18	6

The area under barley has gradually expanded in all zones except in Zone 1 (Table 5.3.3). In Zone 2, our survey results indicate that this is largely due to displacement of wheat by barley on the better soils (Tully and Rassam, 1985), but in zones 3 and 4 the increased area largely results from the abandonment of fallow. In a national survey of 153 barley producers conducted in 1982, Somel et al. (1984) showed that many farmers were already growing continuous barley or were reducing the frequency of fallowing as shown below.

	% Farmers			
Rotation	B/F	B/B	B/B/F	Other
Zone 2	53	20	20	7
Zone 3	33	36	25	6
Zone 4	25	65	10	0

The dramatic increase in area under barley in Zone 5 results from land traditionally reserved for grazing being put under the plough. Inevitably, it is the higher potential steppeland bordering on Zone 4 which is cultivated first. As can be seen in the area planned for the current season, this policy of ploughing steppeland has received the official sanction of the Government of Syria, together with the abandonment of fallow.

Average yields obtained in each zone are given in Table 5.3.4. As would be expected, yields decline steadily from Zone 1 to Zone 5, and the coefficient of variation rises dramatically. Accompanying this rise in the variability of yield is an increase in the frequency of occasions on which no grain would be harvested. This does not, of course, constitute crop failure in the accepted sense, since both green grazing and the grazing of mature crops, uneconomic to harvest, do provide valuable sources of feed. Such practices may make barley cultivation in Zone 5 economic for individual farmers, but we certainly question its wisdom at the national planning level. Not only are the severely threatened natural pastures of the steppeland, already overgrazed, being gradually destroyed through cultivation, but soil, wind and water erosion in these areas has accelerated rapidly during recent years (Fryrear, 1989). If we examine the percent contribution of each zone to Syria's national barley production (Table 5.3.5), this point is further re-enforced. Even in extremely wet seasons, such as 1989, the contribution of Zone 5 is marginal at 13%. Given that such seasons are only likely to occur once every thirty years, and the highly variable yields obtained (CV of 114%), we believe that cultivation of barley in Zone 5 is neither sustainable in economic terms, nor, and more importantly, in terms of the conservation of the natural resource base.

Furthermore, the trend towards barley monoculture, although attractive at first sight, and now apparently officially recommended by government policy, is also unlikely to provide sustained increases in production. Long term trials at ICARDA have demonstrated that yields decline unless fertilizer is applied regularly, and even when it is, the variability of yields over time remains greater than in the traditional barley/fallow rotation.

5.3.5 Recent Research on Improved Barley Production Systems in Syria: Their Potential to Meet National Flock Feed Requirements

Potential Barley Production from Improved Practices

In 1984 the Syrian Soils Directorate and ICARDA initiated a collaborative research project to assess the biological and economic effects of the use of nitrogen and phosphorus fertilizer on barley, through multiple-season multiple-location trials on farmers' fields in the agricultural stability zones 2 and 3 of N. Syria.

The trials have been conducted over four years (1984/85-1987/88) on a total of 75 sites. Sites were deliberately selected to represent a range of soil type and depth, rainfall and rotation, including land in both barley/barley (B/B) and barley/fallow (B/F) rotations. Although the trials were restricted to zones 2 and 3, it should be noted that during the four years, two extremely dry years occurred representing conditions normally prevailing in Zone 4.

The trials are described in detail in section 3.1 of this report and elsewhere (SMAAR/ICARDA 1985 to 1988). In this paper, results from these on-farm trials (OFT) are used, in conjunction with data on national average rainfall and barley areas, to assess the potential of improved barley production to meet feed requirements.

To do this we have restricted our analysis to yield data from four treatments representing the two rotations without fertilizer (Bo/Bo and Bo/F) and with 20 kg N/ha and 60 kg P_2O_5/ha applied in the barley phase (Bnp/Bnp and Bnp/F). The treatments without fertilizer still represent improved practices of seed dressing and drill planting. The fertilizer treatment of 20 kg N/ha and 60 kg P_2O_5/ha was selected because it is close to the rate recommended from results from the trials and currently being demonstrated to farmers.

Yields (grain and straw) per hectare were converted to Sheep Feed Equivalents (SFE), as discussed earlier, and the relationships between SFE/ha and the rainfall recorded at each OFT site were estimated, with the following results:

Bo/F: SFE/ha = -11.05+0.1008 Rain-0.0001 $Rain^2$ (Adj R^2=0.552)
Bnp/F: SFE/ha = -11.09+0.1136 Rain-0.0001 $Rain^2$ (Adj R^2=0.632)
Bo/Bo: SFE/ha = -7.68+0.0664 Rain-0.0001 $Rain^2$ (Adj R^2=0.507)
Bnp/Bnp: SFE/ha = -12.47+0.1073 Rain-0.0001 $Rain^2$ (Adj R^2=0.649)

The estimated response relationships and our "national average" rainfall estimates were used to predict the potential "national average" SFE/ha obtainable from each of the four selected treatments for the 27 year period.

To estimate the potential production from these treatments requires some assumptions to be made regarding the area planted to barley. The total arable area in agricultural stability zones 2 to 5, and the Syrian Government's planned area for barley in 1989/90 were given in Table 5.3.3 and are reproduced below:

Million ha	Zone 2	Zone 3	Zone 4	Zone 5	Total
Total arable area	1.878	0.859	0.998	0.563	3.725
Planned barley area	0.646	0.580	0.867	0.400	2.493
% of arable area	34.4	67.5	86.9	71.0	66.9

The planned barley area represents some two thirds of the total arable area in Zones 2 to 5. The planned area for Zone 4 implies that barley is to be grown in continuous rotation, reflecting a deliberate policy to abandon fallow rotations.

In estimating the production potential of the four selected treatments we hypothesized two scenarios. Scenario I retains the planned barley area for 1989/90, excluding that planned for Zone 5. Zone 5 is excluded firstly because it was not included in the OFT and, secondly, because the principal concern which prompted this research was to investigate means of reducing feed deficits while at the same time halting the expansion of cultivation into the fragile environments of the dry zones.

The second scenario, Scenario II, reduces the barley area in the drier marginal zones even further. Here, we referred to the original definition of agricultural stability zones. The planned area for Zone 2 was retained. The original description of Zone 3 states that barley is the principal crop, though some pulses can be grown. We therefore allocated 75% of the total arable area in Zone 3 to barley. This represents an increase of 65,000 ha on the planned area in Zone 3 for 1989/90. Finally we allocated half the arable area of Zone 4 to barley, the remainder being conserved for natural grazing.

The two scenarios are summarised below:

Million ha	Zone 2	Zone 3	Zone 4	Zone 5	Total
Scenario I	0.646	0.580	0.867	0	2.093
Scenario II	0.646	0.645	0.499	0	1.790

The estimated "national average" SFE/ha from the four OFT treatments were multiplied by these areas to obtain the distribution of potential production over the 27 year period 1960-1986. In the case of the two barley/fallow rotation treatments, the area in each zone was halved to estimate barley production in each year. Estimated cumulative frequency distributions of potential production for each of the two scenarios are presented in Table 5.3.6.

The distribution from the two scenarios differ only in their scale; the degree of variation (% CV) is the same, therefore general comments on the relative effects of rotation and fertilizer use apply to both scenarios.

Fallow is found to be valuable in maintaining output in only the very driest years, reflecting the soil moisture conserving advantage of a fallow rotation. In these driest years the B/F rotation would produce more than continuous barley despite the fact that only half the area is yielding a crop. However, as rainfall increases, the area advantage of continuous barley outweighs the moisture conserving advantage of the barley/fallow rotation.

Table 5.3.6 Cumulative frequency distributions of potential production (million SFE) from improved practices for two hypothetical scenarios

Deciles	Seasonal rain (mm)	Predicted SFE (million)			
		Bo/F	Bnp/F	Bo/Bo	Bnp/Bnp
Scenario I					
0.1	168	2.8	4.5	2.9	4.5
0.2	197	4.6	6.6	5.3	8.4
0.3	268	8.1	10.5	9.9	15.9
0.4	278	8.5	11.0	10.5	16.7
0.5	286	8.8	11.3	10.9	17.4
0.6	294	9.1	11.6	11.3	18.0
0.7	326	10.1	12.7	12.6	20.2
0.8	355	10.8	13.5	13.5	21.7
0.9	392	11.4	14.2	14.4	23.0
Mean	283	8.0	10.4	9.8	15.7
% CV	27.2	39.3	33.9	42.2	42.4
Scenario II					
0.1	168	2.4	3.9	2.4	3.8
0.2	197	3.9	5.6	4.5	7.1
0.3	268	6.9	9.0	8.5	13.6
0.4	278	7.3	9.4	8.9	14.3
0.5	286	7.5	9.7	9.3	14.9
0.6	294	7.8	10.0	9.6	15.4
0.7	326	8.6	10.9	10.8	17.3
0.8	355	9.2	11.6	11.6	18.6
0.9	392	9.7	12.1	12.3	19.7
Mean	283	6.8	8.9	8.4	13.5
% CV	27.2	39.3	33.9	42.2	42.4

Notes:

a) Scenario I:Planned barley area (1989/90) excluding Zone 5
Scenario II:Planned area in Zone 2; 75% of arable area in Zone 3; and 50% of arable area in Zone 4.

b) Bo/F: Barley/fallow rotation, no fertilizer
Bnp/F: Barley/fallow, 20 kg N/ha, 60 kg P_2O_5/ha
Bo/Bo: Continuous barley, no fertilizer
Bnp/Bnp: Continuous barley, 20 kg N/ha and 60 kg P_2O_5/ha

c) For Bo/F and Bnp/F areas were halved (only half the area utilized for barley in any given year).

When fertilizer is applied to a barley/fallow rotation, production would exceed that from unfertilized continuous barley (from double the area) in all but the wettest 20% of years. However, continuous barley with added fertilizer clearly dominates Bnp/F in all but the driest years.

Production Potential and National Feed Requirements: Alternative Strategies

In selecting the OFT treatments and defining the two scenarios analyzed here, we were concerned with assessing to what extent improved production practices on a reduced area could fulfill national feed requirements compared with the current production strategy.

We will take as our reference point Scenario I (planned barley area excluding Zone 5) under continuous barley (Bo/Bo), reflecting current policy to abandon fallow. This represents a reduction in the cultivated area in only the very driest areas (steppe), and the minimum improvements in production practices (seed dressing, drill planting). This will be referred to as Strategy A. Improved strategies are represented by:

Strategy B: reintroducing fallow into the rotation and adding fertilizer to the barley phase (Bnp/F), and reducing the cultivated area in Zone 4 (Scenario II); and

Strategy C: adding fertilizer to continuous barley (Bnp/Bnp) on the same reduced area (Scenario II).

The cumulative frequency distributions for these three contrasting strategies are shown in Figure 5.3.5.

By adding the improved practices of seed dressing and drill planting to continuous barley production on the current planned

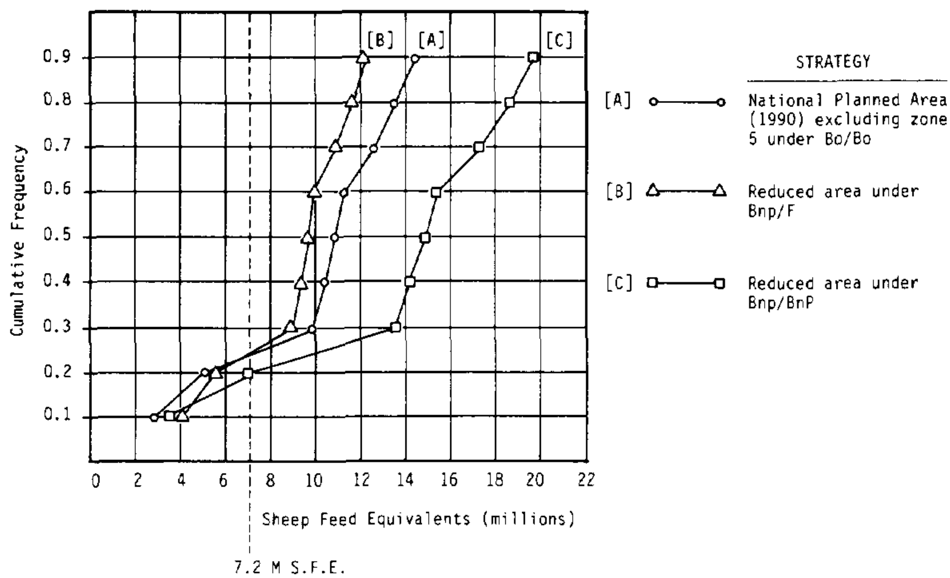


Figure 5.3.5 Comparison of production strategies. Cumulative frequency distributions.

area in zones 2 to 4 (Strategy A), Syria would achieve or exceed 60% of its feed requirements (7.2 million SFE) in approximately 75% of years. However, the same result would be achieved by applying fertilizer in a barley/fallow rotation on a reduced area (Strategy B). In Figure 5.3.5, the crossover point between the distributions from Strategies A and B occurs at approximately 6.5 million SFE. Below this crossover point, in drier years, potential production is higher under Strategy B. Strategy C, applying fertilizer to continuous barley on a reduced area, shifts the distribution to the right and potential production is higher in all but the very driest years. Sixty percent of national feed requirements would be achieved or exceeded in approximately 80% of years.

Any distinction made between the three strategies depends on the criteria used. If the objective is to maximize the probability of meeting national flock feed requirements, then Strategy C is preferred. If, on the other hand, the objective is to maximize the SFE obtained in the poorest of years, then Strategy B is preferred (but only marginally). Equating risk with variability, then Bnp/F (Strategy B) would be preferred (compare % CVs in Table 5.3.6). In Strategy A, areas in Zone 5 were excluded. In a wet year, yields from the planned barley area in Zone 5 may indeed boost production above that shown in Figure 5.3.5. However, the negligible yields achieved in Zone 5 in dry years (see Table 5.3.4) would merely serve to increase the variability in production. Even in the infrequently occurring very wet seasons (eg. 1987/88), the contribution of Zone 5 to Syria's total production is minimal (see Table 5.3.5).

In any event, the analysis demonstrates that there <u>are</u> alternatives to the current strategy of expanding cultivation into more and more marginal areas. Reducing the area under barley in the marginal areas of zones 4 and 5 and improving production practices on the remaining area (by encouraging fertilizer use and maintaining a barley/fallow rotation) would reduce the probability of drastically low production in dry years from land under continuous barley, and increase the stability of production over time.

<u>The Introduction of Forage Legumes into Barley Rotations</u>

In assessing the potential contribution to the nation's sheep feed supply through the introduction of forage legumes in barley based rotations, we have used a dataset from a single long term rotation trial established in 1980/81 at Breda (long term average rainfall 270 mm) in N. Syria. Unlike our analysis from the multi-season, multi-location on-farm fertilizer trials, we recognize the dangers of extrapolating the results of this single location trial across space. Instead we have used long-term climatic data (1960-1987) from Breda for extrapolation over time only. Details of this trial have been reported elsewhere (Jones 1989).

We have selected the yield data from six treatments representing a combination of three rotations (barley/fallow, barley/barley, barley/vetch hay) and two fertilizer treatments (0, and 20 kg N, 60 kg P_2O_5/ha applied to the barley phase). The barley and vetch yield data were converted into sheep feed equivalents (Table 5.3.7), and the relationships between sheep feed equivalents/ha and seasonal rainfall were established for each rotation/fertilizer combination. These are presented in Table 5.3.8.

Table 5.3.7 Basic Dataset converted into Sheep Feed Equivalents (SFE)/ha [1]

Season	Rainfall (mm)	Rotations					
		Bo/F	Bnp/F	Bo/Bo	Bnp/Bnp	Bo/Vo	Bnp/Vo
1982/83	265	1.93	4.80	2.51	6.56	3.25	6.61
83/84	204	1.68	3.18	1.53	3.93	1.94	3.11
84/85	277	1.47	5.17	2.57	8.90	3.72	7.92
85/86	218	2.28	5.31	2.67	4.51	3.96	6.46
86/87	245	2.01	3.45	2.34	4.56	3.59	5.46
87/88	400	5.26	8.26	4.39	8.63	8.56	11.73
88/89	194	1.01	1.92	0.84	1.92	2.23	3.11

1 a) Conversions made assuming following metabolizable energy values:
Barley grain = 11.5 MJ/kg; Barley straw = 5.5 MJ/kg;
Vetch hay = 9.0 MJ/kg; and 1 sheep requires 4200 MJ metabolizable energy per year.
b) Values for Bo/F and Bnp/F were divided by 2 (only 1/2 ha utilized)
c) Values for Bo/Vo and Bnp/Vo assume 1/2 ha barley, 1/2 ha vetch.

Using the relationships in Table 5.3.8, and seasonal rainfall records from Breda village for the period 1960-1987, production in terms of sheep feed equivalents were predicted for the 27 year period. These are presented as cumulative frequency distributions in Table 5.3.9.

Table 5.3.8 Relationships between SFE's of contrasting rotations and seasonal precipitation (P) at Breda (N. Syria)

Rotation [1]	Equation	R^2
Bo/F	SFE = -2.34 + 0.018 P	0.795
Bnp/F	SFE = -2.14 + 0.026 P	0.808
Bo/Bo	SFE = -1.31 + 0.014 P	0.840
Bnp/Bnp	SFE = -2.17 + 0.030 P	0.670
Bo/Vo	SFE = -3.72 + 0.030 P	0.888
Bnp/Vo	SFE = -4.06 + 0.040 P	0.898

1 B = Barley, F = Fallow, V = Vetch Hay
0 = no fertilizer, np = 20 kg N + 60 kg P_2O_5

Table 5.3.9 Cumulative frequency distributions of sheep feed equivalents/ha from contrasting rotations at Breda, N. Syria

Decile	Seasonal Rain (mm)	Rotation					
		Bo/F	Bnp/F	Bo/Bo	Bnp/Bnp	Bo/V	Bnp/V
0.1	136	0.11	1.49	0.59	1.91	0.36	1.38
0.2	203	1.31	3.14	1.53	3.92	2.37	4.06
0.3	238	1.94	4.05	2.02	4.97	3.42	5.46
0.4	260	2.34	4.62	2.33	5.63	4.08	6.34
0.5	269	2.50	4.85	2.46	5.90	4.35	6.70
0.6	284	2.77	5.24	2.67	6.35	4.80	7.30
0.7	298	3.02	5.61	2.86	6.77	5.22	7.86
0.8	333	3.65	6.52	3.35	7.82	6.27	9.26
0.9	419	5.20	8.75	4.56	10.40	8.85	12.7

The effects of rotation (barley/fallow v. barley/barley), and the implications of adding fertilizer are similar to those predicted from our on-farm trial results, and needn't be further discussed. The introduction of vetch, either to replace fallow or continuous barley, appears to be beneficial. Compared with a barley/fallow rotation, a barley/vetch rotation is clearly superior in terms of sheep feed equivalents, except in the driest years (compare Bo/F v. Bo/Vo; Bnp/F v. Bnp/Vo at decile 0.1 in Table 5.3.9). In spite of twice the area being under production in the barley/vetch rotation, it has little or no advantage in such dry years. However, seasons with as little as 136 mm rainfall have not been experienced in the life of the trial, and hence we must view this conclusion with come caution.

Considering the situation of replacing continuous barley with a barley/vetch rotation, we again observe the benefit of including vetch except in the drier years (compare Bo/Bo v. Bo/Vo; Bnp/Bnp v. Bnp/Vo at decile 0.1 in Table 5.3.9).

Our analysis suggests that the introduction of vetch as a hay crop would produce greater sheep feed equivalents in about 90% of the years compared with either a barley/fallow or barley/barley rotation both in the presence and absence of fertilizer. However, we must emphasize two important points:

- Concurrent on-farm surveys and trials in Syria, focusing on the introduction of forages, have clearly indicated that whereas farmers appear ready to accept this technology, they prefer to utilize the forage as a source of green grazing rather than a hay crop. This is associated with the cost of hand harvesting (Tully, 1984) and dry matter losses incurred during the hay making process (Osman and Thomson, 1985). More recent on-farm trials have shown that either green grazing or harvesting the forage as a mature crop are both economic and acceptable to the farmers (Thomson et al., 1989).

- Our analysis indicates that forages may be considered risky by some farmers due to their poor performance in the drier years.

This assessment is based only on output data and does not consider the costs involved in the production of the various rotations. Thomson et al. (1989) have shown substantially increased production costs when replacing fallow with forages, and this would undoubtedly contribute further to some farmers reluctance to adopt this technology.

5.3.6 Conclusions

Syria's rapidly increasing population and rising standard of living, accompanied by a gradual process of urbanization has led to a dramatic increase in the demand for livestock products over the last quarter of a century. This has been reflected in a threefold increase in its national sheep flock and an equivalent increase in demand for livestock feed.

Resulting from this increased feed demand, several clear trends are evident.

- Syria has moved from being a frequent net exporter of barley to a frequent net importer.

- Due to greater livestock numbers and greater frequencies of feed shortages, the natural pastures are rapidly being destroyed through overgrazing.

- In order to increase its principal feed supply, Syria has officially sanctioned the cultivation of the steppeland and the abandonment of the traditional barley/fallow rotation and the adoption of barley monoculture.

- As a result of this policy, barley production is becoming more variable, but has only shown slight increases on a national basis in recent years.

We do not believe these marginal increases are sustainable, and already an accelerated degradation of the natural resource base is evident in the marginal environments where barley is being grown.

However, alternative strategies are possible. Reducing the area under barley in the marginal areas of zones 4 and 5 and improving production on the remaining area through the introduction of simple improved practices such as seed dressing, drill sowing, the use of nitrogen and phosphorus fertilizer and the maintenance of the barley/fallow rotation, has the potential to meet national flock feed requirements in 75% of years and, at the same time, will increase the stability of production over time. In addition, the introduction of forage legumes would further enhance the national feed supply in all but the driest years.

For such strategies to succeed, Syria would need to develop positive support policies which not only make the essential inputs available, but also encourages an active demonstration of their effective use to farmers.

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5.4 Changes in Lentil Production Technology in Syria: A Comparative Study Over Ten Years

A. Mazid

5.4.1 Introduction

Lentil is an important crop in the drier areas of West Asia and North Africa in the cereal based rotation. Not only does the grain provide a valuable source of protein in human diets, but the straw is widely used as feed for livestock and, as with other legumes, nitrogen fixation by the lentil crop helps to improve the soil nitrogen dynamics in cropping systems (see also section 3.5 of this report).

Ten years ago, in 1978/79, ICARDA recognized the lack of information available on lentil farming in general and on production practices in particular. Thus, a diagnostic survey was conducted in the major producing provinces of Aleppo, Idleb, Hama and Hassakeh during the growing seasons of 1978/79 and 1979/80 to gather more information. One hundred and fifteen lentil producers in Syria were interviewed (Survey I).

In 1989, the Farm Resource Management Program (FRMP) at ICARDA held its annual residential training course in Aleppo. The course focused on the design, conduct and analysis of farm surveys, particularly diagnostic surveys. The course had a strong practical bias.

For this purpose, following the design of a questionnaire, a sample of 55 lentil producers in Aleppo and Idleb provinces was chosen. Within the lentil growing areas of these two provinces, villages, and lentil growing farmers within villages, were selected at random. This sample was interviewed by the trainees in March 1989 (Survey II).

Many of the variables recorded in the two surveys are directly comparable. Thus, it is possible to compare lentil production practices in the current season (1988/89) with those of ten years ago and determine whether lentil production technology has undergone any changes during the last ten years.

Difficulties do exist in comparing results from the two surveys due to some difference in geographical area and the unavailability of the raw data from Survey I. In addition, both surveys largely focused on the production strategies of farmers in the actual season of interview, and thus we must emphasize that some season specific responses may contribute to apparent long term changes in production strategies. However, the findings presented below serve to give some important indication of developments in lentil production over the last ten years.

5.4.2 Area and Production in Syria

Figure 5.4.1 presents national area and production data for Syria for the ten year period under review. Between 1979 and 1985, there was a decline in the area planted to lentil almost entirely due to the relative prices of production and harvest value. However, recent increases in the price of lentil (1986 onwards) has resulted in a substantial increase in the area planted. Overall, lentil prices have increased from 0.8 SYL/kg to 9.0 SYL/kg during the ten year period. In general, production trends mirror those of area, but yearly variations in national average yields, largely due to rainfall differences, are apparent. High yields were obtained in the very wet season of 1987/88, when national average yields exceeded 1 ton/ha for the only time in the ten year period.

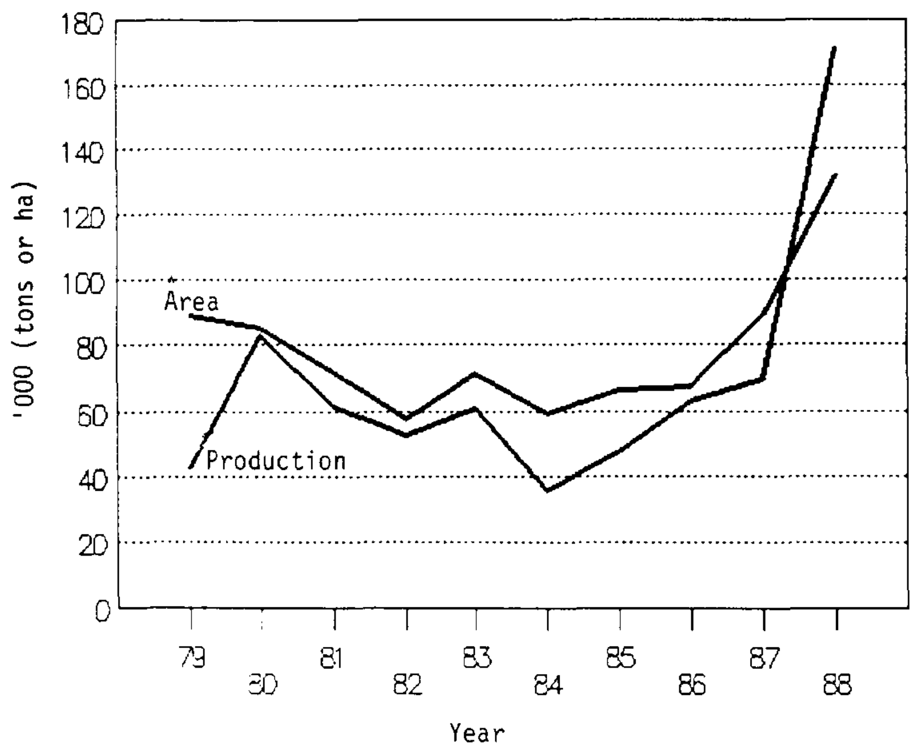

Figure 5.4.1 Total area and production of lentils in Syria.

5.4.3 Expected Lentil Yields

In Survey I and II, farmers were asked to state the lentil yields that they would expect in good, poor and normal years. The data obtained from farmers indicate that farmers believe that yields have increased during the study period. It was found that average expected yield in poor years has increased by 21 percent compared to about 6 percent in good and normal years (Table 5.4.1). However, only the increase in normal years was statistically significant at the 5% level.

Table 5.4.1 Changes in farmers expected lentil grain yields (kg/ha) over 10 years

	1978/79	1988/89	Increase (%)
Average yield in good years	1683	1775	5.5
S.D.	(605)	(480)	
Average yield in poor years	386	468	21.2
S.D.	(190)	(272)	
Average yield in normal years	973	1028	5.7*
S.D.	(308)	(289)	
Average yield during the long term	NA	1113	
		(330)	

To describe the changes in technology in lentil farming and their impact on yields, the data from the two surveys were grouped into (a) farmers' practices (b) fertilizer application by farmers (c) production costs of lentil. Comparative analyses were made between important variables in each group. These are presented in the subsequent sections.

5.4.4 Farmers' Practices

Farmers' practices compared are: seed rates, number of cultivations, seeding methods, varieties, planting date, harvesting method and crop rotations. A comparison of these practices are given in Table 5.4.2.

It was found that the average seed rate in 1988/89 is over 28 percent higher than ten years ago. Farmers attributed this to two main reasons. Firstly, they use a higher seed rate to increase plant population in an effort to control weeds; secondly they increase seed rates when they use fertilizer, and, as will be shown, fertilizer use has increased since 1978/79.

Table 5.4.2 Changes in lentil production practices over 10 years

	1978/79		1988/89	
Seed rate (kg/ha)	144		185	
S.D.	(28)		(47)	
Land preparation (%)				
No tillage	6.5		0	
One tillage	45.7		20.0	
Two tillage	44.9		65.5	
Three tillage	2.9		12.7	
Four tillage	0.0		1.8	
Seeding method				
Manual	66		69	
Mechanical	34		31	
Seed variety				
Red small seed (local)	83		82	
White large seed (local)	17		18	
Seeding date (%)				
1st week of Nov.	8.4		-	
2nd week of Nov.	6.5		1.8	
3rd week of Nov	5.6		1.8	
4th week of Nov.	15.9	36.4	3.6	7.3
1st week of Dec.	25.2		14.5	
2nd week of Dec.	17.8		12.7	
3rd week of Dec.	4.7		23.6	
4th week of Dec.	6.5	54.2	18.2	69.1
1st week of Jan.	3.8		7.3	
2nd week of Jan.	2.8		12.7	
3rd week of Jan.	1.9		3.6	
4th week of Jan.	0.9	9.4	-	23.6
		100.0		100.0
Manual harvesting	100.0		100.0	
Rotation				
No specific rotation	18.7		23.6	
Cereals-lentil-summer crop	66.3		54.5	
Cereals-lentil	15.0		21.8	

There was also a difference in the numbers of cultivations recorded in the two surveys. This may be explained by the fact that the number of farmers owning tractors has increased by 31%, and the relative "lentil grain equivalent" cultivation cost per/ha/pass has decreased from 52 kg of lentil in 1978/79 to 20 kg of lentil in 1988/89.

Most farmers still sow by hand broadcasting; only one-third of farmers in the samples in the two surveys used either a fertilizer spinner or a cereals drill for sowing.

There has been no change in the lentil varieties grown by farmers; most farmers used the red small seeded variety, and all farmers used local varieties because no new varieties were available to them.

The results also indicate a tendency among farmers to plant lentil later, although some "season specificity" may be responsible for this observation. Ten years ago, most of the farmers planted lentil in the first week of November and finished planting in the second week of December, while in the 1988/89 season it was found that most of the farmers planted their lentil during the first week of December through to the second week of January. This shift in date of planting is due to the farmers' belief that Orobanche and weeds can be controlled by delaying cultivation until after the onset of rain. Farmers' believe that their weed problems are increasing and associate this with greater fertilizer use on both lentil and the preceding wheat crop.

Most farmers still practice a three course rotation (cereals-lentil-summer crops, particularly melon and water melon); this rotation is most common in wheat based systems where the lentil is grown.

All farmers are still harvesting by hand which requires a lot of labor during a short period. Manual harvesting costs are still high. Farmers indicated that the introduction of a new technology for mechanical harvesting would reduce one of the major problems associated with lentil production.

5.4.5 Fertilizer Application

Results from the two surveys indicate an increase in fertilizer application by lentil farmers in northern Syria during the period 1979-1989. In 1979, about 47 percent of sample farmers did not apply any fertilizer on lentil compared to only 13 percent in 1989 (Table 5.4.3). Increases in the application of phosphate fertilizer are particularly significant. Around 35.5 percent of the sample farmers applied phosphate in 1978/79 compared to 63.3 percent in 1988/89 while the percentage of farmers applying both phosphate and nitrogen increased from 11.2 percent to 23.6 percent. It was also found that the average rate of fertilizer applied had increased by more than 127 percent for Triple Super Phosphate, and 41 percent for Urea. The increased use of urea is interesting. Previous research at ICARDA (see FRMP Annual Report 1988, section 3.7) also tested the potential of nitrogen fertilizer on lentil crops in farmers' fields. This was studied because we had shown that many farmers' crops were severely attacked by sitona weevil larvae which destroy the nitrogen fixing nodules. Sitona control gave substantial increases in lentil yield, but the chemical (carbofuran) is toxic and would require stringent safety precautions. The possibility of compensating for poor biological nitrogen fixation through the application of N-fertilizer was clearly attractive, but our results showed no significant responses.

In general, the increased use of fertilizer on lentil almost certainly results from large changes in the relative cost of fertilizer to lentil prices. In 1989, the farm gate price of 1 kg of TSP was equivalent to 0.35 kg of lentil grain, compared to 1 kg in 1979, while the price of 1 kg of Urea in 1989 was equivalent to 0.33 kg of lentil grain compared to 0.8 kg in 1979.

Table 5.4.3 Fertilizer use (% of farmers)

	1978/79	1988/89
No fertilizer	46.7	12.7
Only P_2O_5	35.5	63.6
Only nitrogen	6.6	0
Both N and P_2O_5	11.2	23.6
Distribution of phosphate use kg/ha of TSP		
0	50.0	12.7
50-75	3.0	7.3
90-120	21.0	18.2
130-170	14.0	18.2
200	8.0	38.2
250	4.0	1.8
<250	0.0	3.6
	100.0	100.0
Average TSP rate (kg/ha)	64	145
S.D.	(77)	(24)
Distribution of Nitrogen use kg/ha of Urea		
0	77	76.4
50	7	10.9
70	0	1.8
100-120	10	1.8
130-160	6	5.5
200	0	3.6
350	1	0.0
	100	100.0
Average Urea rate (kg/ha)	17	24
S.D.	(43)	(52)

5.4.6 Production Costs

In monetary terms, lentil production costs show a sharp increase. In the 1978/79 season, the estimated cost of production was 974 SYL/ha compared to 6003 SYL/ha in the 1988/89 season. Figure 5.4.2 presents the estimated production costs by main items.

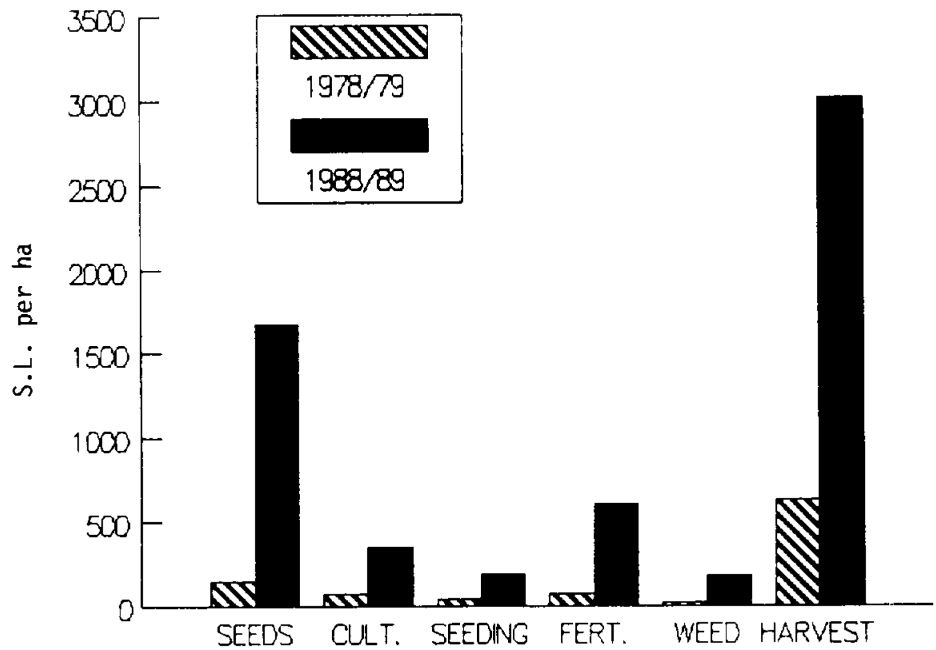

Figure 5.4.2 Production costs of lentils, 1978/79 vs 1988/89.

However, the relative production costs of lentil grain per hectare have declined from 1218 kg of lentil grain in 1978/79 to 667 kg in 1988/89.

Figures 5.4.3 and 5.4.4 compare the percentage costs by item. It is noted that seed costs represent 28 percent of total costs in 1988/89 compared to 15 percent in 1978/79. This is due to the increase in seed rates discussed earlier, while fertilizer costs were higher in 1988/89, compared with 1978/79, due to the

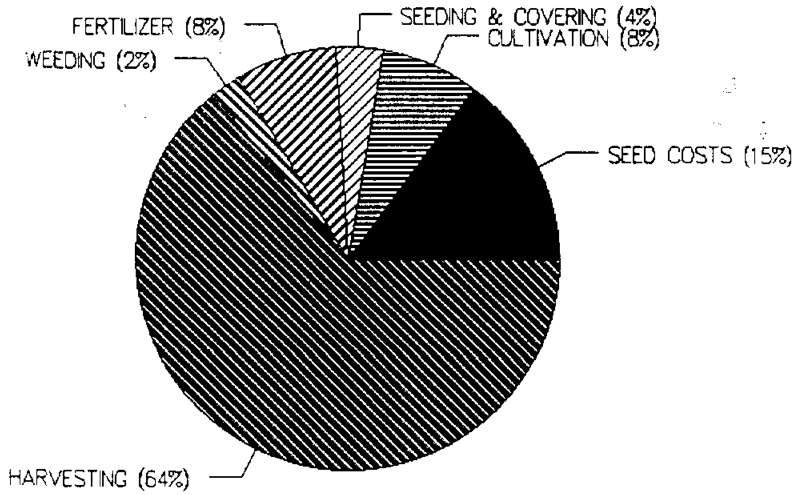

Figure 5.4.3 Production costs of lentils, 1978/79.

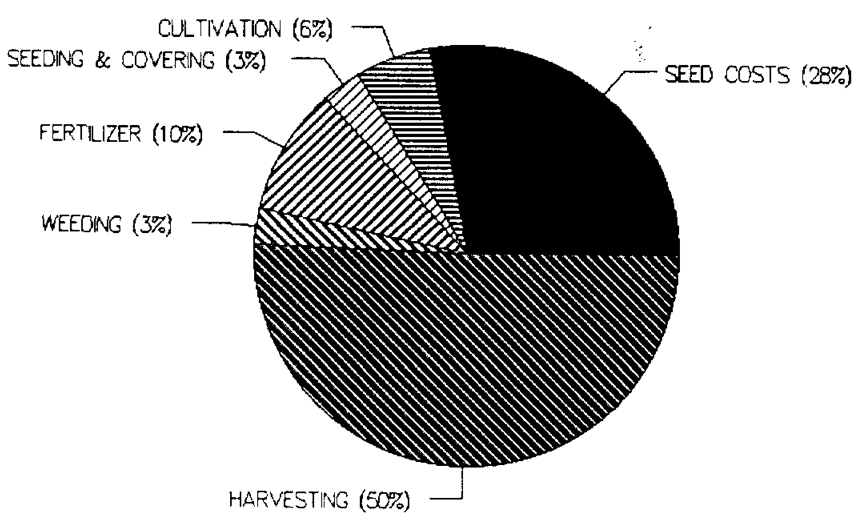

Figure 5.4.4 Production costs of lentils, 1988/89.

increase in the rate of fertilizer application. On the other hand, there has been a decline in harvesting costs, from 64 to 50 percent, due to decreases in the relative price of labor.

5.4.7 Conclusions

By conducting two comparable surveys over a 10 year interval, it has not only been possible to describe current lentil production practices in Syria, but the results also give some indication of developments in lentil production since 1978/79.

There has been an overall positive trend in production and area at the national level. It was found that the average seed rate has increased, that there are differences in the number of pre-seeding cultivations. There is also a tendency among farmers to plant lentil later. The costs of manual harvesting are still very high; new technology for mechanical harvesting would solve many of the problems associated with lentil production.

The average application rate of fertilizer has increased by more than 127 percent for phosphate and 41 percent for nitrogen. This is due mainly to the decline in the relative price of fertilizer to lentil grain and to the rapid rate of adoption of fertilizer in general.

There has been a sharp increase in production costs in monetary terms, but it was found that the relative production costs of lentil per hectare declined from 1218 kg of lentil grain in 1978/79 to 667 kg of lentil grain in 1988/89.

Acknowledgements: The staff of FRMP are grateful for the enthusiasm and hard work of the trainees who attended our 1989 Residential Training Course. Without them this study would not have taken place.

5.5 Stubble Burning in North-West Syria, 1988. An Interim Report

R. Tutwiler (FRMP),
A. Termanini (PFLP), and F. Bahhady (PFLP)

5.5.1 Initial Analysis

Following the unusually plentiful rains of the 1987/88 growing season, there appeared to be a marked increase in the number of stubble fields being put to the torch by farmers as compared to previous years. Since it is well known that cereal crop residues constitute an important grazing resource for sheep and goats, it would at first glance appear surprising that farmers were destroying the stubbles. FRMP and PFLP organized a quick survey among 31 villages of cereal farmers in order to ascertain the frequency of burning and the reasons why farmers chose to burn their crop residues in 1988. Villages were stratified within broad rainfall isohyets to represent both the wheat based and barley based farming systems, and then selected at random.

Of fields covered in the survey, 38% had been burned for the first time in 1988. This suggests that 1988 burning represented a substantial increase over previous years. Fifty-three percent of the sample increase occurred in areas receiving less than 350 mm of annual precipitation. Farmers in higher rainfall areas tend to burn stubbles, and in particular wheat stubbles, more often than do farmers in the low rainfall zone where sheep and goats often represent more important economic assets than in the higher rainfall areas. In terms of reasons given by sampled farmers for burning stubbles in 1988, easier cultivation (tillage) and improved seeding for the next crop, together with pest (e.g., insects, weeds, and rodents) control, accounted for 63% of the fields burned. Need to remove residues by the fastest method possible before planting a summer crop accounted for a further 23% of the burning.

Despite the rise in burning frequency, cereal residues continued to be viewed as an important resource for livestock. Only one out of 43 burned fields surveyed was burned immediately after harvest without first being either grazed or having straw collected or both. Barley straw was considered relatively more valuable by farmers than wheat straw. For barley, straw was collected on 78% on the fields before burning and grazing took place on 100%. For wheat, straw collection took place on only 37% of the fields before burning.

Why did farmers decide to burn stubbles more often in 1988 than in previous years? Initial analysis of the survey results indicates that the constraints to burning, especially the need to preserve crop residues for livestock feed, were greatly lessened by the relative abundance of residues and natural pasture produced by the unusually plentiful 1987/88 rains. The reduced need to preserve residues allowed farmers to take advantage of what they see as the benefit provided by burning, especially easier cultivation and pest control for the next crop. In short, farmers felt that in the summer of 1988 they had more stubbles than were needed or desired.

Farmers' responses to the much higher than usual rainfall across the entire gradient in northwest Syria may be useful to the on-going research into crop residue management. In ordinary years of low or medium rainfall, residues in the 200-300 mm areas are managed simply by having sheep and goats graze the stubbles down to ground level, leaving only the root system in the soil to possibly make tilling more difficult. Grazing is done by either the farmer's own flock, the communal village flock, or by migrants from the eastern steppe who rent stubble fields to graze their own flocks. In the 1987/88 season, however, there were considerably more residues than livestock could eat, and consequently residue management became a real question farmers had to face. At this point, the issues of easier cultivation and pest control came to the fore. And farmers very definitely have opinions as to how stubbles left in the field hinder the productivity of next year's crop by increasing tillage costs and encouraging the propagation of insects and rodents. Whether or not the farmers' opinions are justified by the facts must await another study. In particular, it is debatable whether or not stubble burning is an effective way of discouraging insect pests common to the area. Agronomy trials conducted by FRMP scientists at Tel Hadya are designed to provide some on-station answers, but farmers' attitudes will of course be very important in the process of adopting recommended methods of residue management in those times and places where livestock do not completely remove the residues by grazing.

5.5.2 Future Analysis

The survey year of 1988 was exceptionally wet. Such years have a one in thirty probability of occurrence. The following year, 1989, was, in complete contrast, an unusually dry year, again with a one in thirty probability of occurrence. Cereal straw production was, as a result, substantially less, and stubble burning greatly reduced. A second identical survey was undertaken in the summer of 1989, and in next years report we will present a detailed comparative analysis of these two contrasting and extreme seasons.

5.6 Barley Production Functions as Descriptors of the Impact of Technology on Yield in Southeast Turkey and Northern Syria

O. Erkan (Cukurova University, Turkey)
and A. Mazid (FRMP)

5.6.1 Introduction

Barley is grown in almost all geographical regions of Turkey and

Syria. It is used mainly for livestock feed and is the second most important crop after wheat in terms of area and production, in both Turkey and Syria.

The agricultural production process is complex and continually changing as new technologies are introduced and input-output relationships are continuously changing. However, the economic issues in relation to barley have not been examined adequately in either country. In order to gain a better understanding of the barley production environment in Northern Syria, a survey was conducted by scientists from FRMP in ICARDA in the 1981/82 season. Later, in the 1984/85 season, a similar survey was conducted, with the support of ICARDA, by scientists from Cukurova University in Southeast Turkey. Data were collected to initiate a comparative analysis of barley production in SE Turkey and N. Syria.

The purpose of this study is (a) to show that diagnostic farm surveys may be organized to obtain data for the estimation of production functions which are necessary for the formulation of appropriate research topics in the region, and (b) to determine which environmental factors and inputs have an impact on yield variation in the combined region of SE Turkey and N. Syria.

5.6.2 Data Collection*

Surveys were conducted in the contrasting environments of N. Syria and SE Turkey. Data in N. Syria were collected through questionnaires from 153 farmers in areas receiving 200-350 mm average rainfall. The survey covered the provinces of Aleppo, Idlib, Hama, Homs, Al Hassakeh, Al Raqqa and Deir Ezzor.

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* More information about survey area selection, sampling of villages and farmers, method of data collection can be found in "Barley Production Economics in SE Turkey and N. Syria: A Comparative Study", ICARDA, Aleppo, Syria. (Forthcoming).

In SE Turkey the survey was conducted in areas receiving 350-550 mm average rainfall and 181 farmers were interviewed. The survey area covered the provinces of Gaziantep, Sanliurfa and Mardin.

5.6.3 Analysis

In agricultural production, for each level of inputs, there will be a unique output. The production function describes this input-output relationship. It explains the rate at which resources are transformed into products. Mathematically, a production function can be written as:

$$Y = f\ (X_1,\ X_2,\ X_3\ \ldots .\ X_n)$$

where Y is output and X_1 .. X_n are different inputs used in the production of Y.

In the analysis of production functions in this research, data relating to the largest barley plot on each farm surveyed were used. Most farmers had more than one plot of barley, and on some farms soil quality differed significantly between barley plots, so that production practices differed also. Including all the different soil characteristics and management practices into a single production function would greatly complicate the analysis.

In most economic production function studies, output is measured in terms of monetary value, but in this study the output is measured by grain yields. The reason for this is that the study was conducted in two different countries and in different years and the barley price policies followed by the governments are very different. Barley straw is used by some farmers but straw production was not taken into consideration in the functional analysis.

The variables having most influence on barley yields were selected using technical methods of correlation and factor analyses. These included amount of rainfall, amount of fertilizer used, seed rate, seed variety, and soil quality.

5.6.4 Results and Discussions

In order to assess the impact of different variables on yields, we pooled the Turkish and Syrian data and analyzed the data set as a whole.

Different specifications of production functions (linear, quadratic, square root and Cobb-Douglas) were examined and it was found that the linear model was the best fit.

The equation of linear form is given below:

$$Y = -679 + 2.93X_1 + 3.13X_2 - 127.39X_3 + 4.73X_4 + 3.93X_5 + 132.65X_6$$
$$(0.001)\quad (0.001)\quad (0.001)\quad (0.05)\quad (0.03)\quad (0.04)\quad (0.03)$$

Adjusted R^2 = 0.621
F(4.281) = 79.51**

where, Y = Yield of barley (kg/ha)
X_1 = Average rainfall (by zone)
X_2 = Seed rate (kg/ha)
X_3 = Variety (black = 1, white = 0)
X_4 = Amount of P_2O_5 (kg/ha
X_5 = Amount of nitrogen (kg/ha)
X_6 = Soil depth (deep=1, others=0)

All coefficients were significant at the 0.05 level or less (the figures in parentheses give the level of significance of the coefficients). The interaction between the above variables was tested and adjusted R^2 did not improve much. Also the t-test for the coefficient of this interaction was not significant. Therefore it was not included in the above formula.

The effect of changes in average rainfall on barley yields is large and highly significant. Each additional mm of rainfall is estimated to increase yields by 2.93 kg/ha.

Seed rate also has a positive influence on yields. As seed rate is increased by 1 kg/ha, yield is estimated to increase by 3.13 kg/ha. However, this result must be treated with caution. It does not imply that if seed rate is increased, production will rise accordingly in all areas. It may also be related to rainfall and other factors. In addition, in the case of both seed rate and rainfall, increasing values will only contribute to greater yields up to a certain optimum value beyond which no further contribution to yield will occur. In spite of this fact, the introduction of the quadratic form of both these variables was not significant.

An interesting finding of the study relates to variety. In the survey area of Turkey and Syria the majority of farmers use a black two-row local variety. This factor was introduced into the equation as a dummy variable and the lower yield of the black variety is reflected in the equation by the negative coefficient on variable X_3.

The variables X_4 (P_2O_5) and X_5 (N) have positive effects on yield, significant at 0.03 and 0.04 levels respectively. Although P_2O_5 and N have yield increasing effects, these effects will vary by rainfall zone and soil type (see also section 3.1 of this report).

Soil depth (X_6) has been introduced into the equation as a dummy variable with deep soils having a positive effect on yields, as would be expected.

The overall conclusion from the estimation of production functions from the pooled data for the region as a whole, is that the linear function performed better than the other models in explaining the relationship between yield per hectare and the selected variables. To demonstrate the efficiency of the linear model, average actual and estimated yields are given in Table 5.6.1.

Table 5.6.1 Average actual and estimated barley yields (kg/ha)

Country or Zone	Average Yields		
	Actual	Estimated	Difference
Turkey	1,530 (749)	1516 (389)	14
Syria	464 (403)	420 (275)	44
Zone 4	341 (229)	206 (87)	135
Zone 3	387 (356)	374 (117)	13
Zone 2	652 (498)	659 (313)	-7
Zone A	827 (536)	980 (283)	-153
Zone B	1640 (638)	1578 (244)	62
Zone C	1933 (837)	1931 (233)	2

Note: Zones A, B, C are in Turkey and 2, 3, 4 are in Syria. Figures in parenthesis show standard deviation values.

The coefficient of correlation between actual yields and estimated yields is 0.792.

The biggest difference between actual and the estimated yield is in Zone 4 in Syria and Zone A in Turkey, but the difference was not statistically significant. However, the general results are considered quite satisfactory for a study of this type.

Production functions in agriculture are highly specialized. A particular production function is meaningful only for a certain soil type, soil fertility, variety, growing season, or level of fixed inputs. A change in any of these "givens" may cause a change in the production function. Therefore, to be useful, a production function must be appropriate for the production process and the environmental conditions being studied.

5.7 Agricultural Labor and Technological Change

D. Tully

In last year's FRMP Annual Report (see section 6.2.3) we reported progress on our regional overview and case studies conducted within our agricultural labor project. The contents of the two-volume publication resulting from this project were finalized in 1989, the last year of project funding and will be published in 1990. The first volume contains regional overviews on Labor Markets in Non-Agricultural Sectors; Off-farm Employment in Agriculture; and Changing Availability and Allocation of Household Labor; as well as review papers for Cyprus, Iraq, Jordan, Morocco, Syria, Tunisia, Turkey, and the Yemen Arab Republic.

The second volume includes eight case studies by national scientists which were financed by the project and presented at the concluding workshop in Aleppo, July 1988. The following are summaries of the principal findings of each case study:

5.7.1 Agricultural Changes on Private Farms of the Sersou, Algeria

Ahmed Bouaita and Claudine Chaulet

In the Tiaret area of Algeria, as the availability of off-farm employment has declined, are farmers attempting to make more use of family labor on their farms through intensification? A survey found that intensification of the predominant cereal cultivation is occurring but to a limited extent. Rotations with other crops are scarcely seen. Improved cultivation and input use are found but primarily on large farms. Irrigation is adopted whenever it is feasible, and opportunities are expected to increase in the future. However due to the market situation and poor technical practices, irrigated market gardening is often a parallel commercial activity rather than a part of an integrated family farm. The most popular approach to increasing on-farm employment is through livestock. Of the surveyed farms 69% had substantial numbers of sheep, cattle or poultry. On large farms sheep can be fed from ample crop residues and barley, but on small and medium farms raising sheep involves both growing and buying feed. While providing some employment, livestock enterprises are not enough to solve the problems of unemployment. Nevertheless the changes which farmers have initiated demonstrate their active involvement and interest in intensification, and the challenge for research is to present technical solutions which improve employment and are more accessible to small and medium sized farms.

5.7.2 Implications of Technological Change for Labor and Farming in the Karia Ba Mohamed District, Morocco

Driss Khrouz and Moha Marghi

A study of a highly productive rainfed area of Morocco documents the effect of eight years of focused effort by the government, with World Bank support, to improve agricultural productivity and rural living conditions. Based on a sample survey researchers found that 10% of the farms have become "modern", market-oriented farms using high levels of mechanization and inputs to maximize productivity. Further, 50% of farms have adopted such practices to a significant degree. Labor makes up a smaller proportion of total costs on these farms compared to traditional farms. However, because mechanization was introduced in combination with diversification and intensification, overall demand for labor has actually increased and many semi-skilled, relatively steady jobs have been created.

5.7.3 Mechanization and Agricultural Employment in Arid and Semi-Arid Zones of Morocco: The Case of Upper Chaouia

Larbi Zagdouni and Driss Benatya

In a study of a dry-farming area southeast of Casablanca, mechanization exists side-by-side with animal traction and manual techniques as an option for farmers. This study demonstrates that the choice of mechanization is part of a range of choices including several options for crops, leasing of land, and off-farm employment as well. Choices depend upon the land and labor available to the households and the consumption requirements of the farm families. Farm strategies can be understood in terms of a limited number of basic farm types, ranging from the microfarm of less than 5 hectares, dependent upon outside income, through the small, medium and large sized farms in which the availability of labor or finances are differentiating variables, to agribusinesses at the other extreme. Leasing of land is shown to be an important factor allowing farmers with surplus labor or machinery to more effectively use it. Labor-intensive practices and crops continue to be economically attractive for farmers with adequate land and sufficient family labor. Mechanical techniques are chosen to maximize profitability on larger farms, to free up labor for employment on smaller farms, and often to complement labor or free labor for other agricultural activities on medium farms; it is also important in special circumstances such as the recent drought which reduced the stock of draft animals.

5.7.4 The Acceptance and Rejection of Agricultural Innovations by Small Farm Operators: A Case Study of a Tunisian Rural Community

Arbi Ben Achour

In a community study of Lorbous, northwestern Tunisia, it was found that small farm size and low incomes were the major factors affecting technology adoption by farmers. In addition, a series of agricultural projects which have failed to benefit small farmers have generated a negative and passive attitude towards innovation. Low availability of farm labor results from emigration of rural populations as a result of the poor situation of rural areas and agriculture generally and thus is not a primary cause of low adoption of technology. On small farms labor requirements are low and non-farm sources of income are of much greater importance in maintaining the household. Many family members work off-farm and young people in general are uninterested in agriculture.

5.7.5 Farm Mechanization and Socio-economic Changes in Agriculture in a Semi-Arid Region of Tunisia

Alia Gana and Rawda Khaldi

In a rainfed area of northern Tunisia, mechanization has proceeded under the influence of government policy for some decades, and since 1969 mechanization by private farmers has been encouraged. Ownership of machinery is mostly found on the medium and large farms. Large farms have benefitted most from mechanization in terms of improved farm economics. On medium sized farms the owners do not have sufficient land to fully utilize the machinery, and must rent it out in order to maximize their profits. On smaller farms, hiring of equipment has become a major cash cost in farming while reducing the demand for labor. Smaller farms use more labor per hectare, by diversifying into legumes, tree crops, and livestock, but labor remains in surplus. Household cash needs lead to part-time farming by men with increased labor on the farm by women. In spite of higher labor use small farms have lower crop yields because of inability to afford optimal amounts of cultivation, fertilizer, herbicide, improved seed, and fallowing. The small holding cannot be used as a significant source of income and so the small farm production strategy is limited to subsistence.

5.7.6 The Impact of Technology on Employment in the Rainfed Farming Areas of Irbid District, Jordan

Imad Karablieh and Mahmoud Ali Salem

Rainfed areas of Jordan have seen a low level of technology adoption and productivity growth. However, due to emigration of farm labor to urban areas and abroad, labor-saving technologies, primarily mechanization, have been widely adopted. Hired labor, both skilled and manual, is predominant, contributing 81% of farm labor hours, including 33% by migrant workers. In a sample survey, total labor input increased with area farmed and number of males in the family, but was less in families with absentees and students, so the effects of emigration are not eliminated by hired labor. Women contribute less than 20% of total labor and are primarily involved in weeding, harvesting, winnowing and cleaning; women of the farm family participate at very low levels. Skilled labor is mostly hired locally and is commonly associated with farm machinery. Migrants were most active as unskilled workers. Legumes require more labor, mostly unskilled, than cereals and this labor is mostly provided by migrants.

5.7.7 Labor Use on Farms in Dry-Farming Areas of Konya Province, Turkey

Ahmed Erkus, Taner Kiral,
Hassan Tatlidil, and F. Fusun Tatlidil

An analysis of current farm practices in Konya Province, Turkey, documented high rates of idle labor on rainfed farms, particularly severe on the small and medium sized farms. Small farms are more diversified, growing greater amounts of legumes, vegetables, and industrial crops, and depending more on livestock. Although they support smaller families and earn more than larger farms from off-farm income,small farms have the highest levels of idle labor. Under existing technology, changes in crop choice and livestock numbers can increase incomes and labor use particularly on small and medium sized farms. With more intensive use of improved farm technology, unemployment could be further reduced and income increased. Thus the extension services have important roles to play in advising farmers of these possibilities.

5.7.8 Social and Economic Aspects of Decision Making Related to Labor Utilization and Choice of Technology: A Case Study of a Turkish Village

Haluk Kasnakoglu, Halis Akder, A. Arslan Gurkan,
Nukhet Sirman, Nazim Ekinji, and Mehmet Ecevit

An interdisciplinary study of a village in rainfed central Turkey documents the interaction of the economics and social organization of farming. With adequate land and capital, farming can be expected to provide a reasonable livelihood in years of average or better rainfall. However, for many farmers repairs or payments on capital equipment, high interest on loans of operating capital, and debts incurred in poor seasons make farm income much more precarious. Further, land is not sufficient, and sharecropping, rental or purchase may be employed to increase the holding size. From the farmers' point of view, what is needed are ways to increase the productivity of land to enable independent farm households to continue to exist. Due to land shortages, males are often educated so that they can find off-farm employment, so women are taking on a greater share of farm activities. Labor exchange within the village makes up for some seasonal shortages and hired labor is also employed. Equipment is purchased by farmers to replace family labor, and as tractors can do much more than people they replace, there is an excess of machinery.

6. TRAINING AND AGROTECHNOLOGY TRANSFER

M. B. Said

During 1988/89 season a number of training activities were carried out by FRMP staff. These activities are detailed in the following sections.

6.1 Residential Training Course

The fourth annual residential training course in Farming Systems Research and Resource Management at Tel Hadya research station was conducted during the period 26 February-30 March 1989. The first week of the course provided a general overview of the work of the Program including some information on survey work, on-station research and on-farm trials conducted on lentil. The remainder of the course focused on the design, conduct and analysis of farm surveys. In particular, diagnostic surveys were stressed and practical survey exercises were carried out to expose the trainees to the many types of problems involved in such work and how solutions can be found. The complementary nature of farm survey work and on-farm trials was dealt with in some detail. The course was attended by 11 participants coming from Syria, Turkey, Morocco, Algeria, Sudan, Ethiopia, North Yemen and Pakistan. Section 5.4 of this report presents a summary of the results of the survey work undertaken by the trainees.

6.2 Short Courses

During the 1988/89 season, three short training courses were organized by the Program. The first one focussed on Soil and Plant Analyses, and was held at Tel Hadya during the period 5-16 February 1989. The course described methods of soil and plant analysis, and provided the participants with a sound technical understanding of these methods. Commonly used methods were compared and results of soil analysis and plant responses to fertilizer were correlated. Emphasis was given to soil nitrogen and phosphorus, being the two most important soil nutrients which limit food production in countries of ICARDA region. The course was attended by eight participants representing Syria, Algeria, Tunisia, North Yemen and Ethiopia.

The second course was a sub-regional training course in Farm Survey Methods. It was conducted in cooperation with ITGC at Sidi Bel Abbes, Algeria, during the period 17-26 June 1989. As in the previous season (when the course was conducted in Tunisia), the training focused on methods of farm survey work. Specifically the course covered planning of diagnostic farm surveys, the use of relevant field techniques for data collection, and evaluation of collected data to identify and prioritize researchable problems. Training activities included lectures and practical field/laboratory work. The course was attended by 15 official participants representing Algeria, Tunisia, Morocco and Libya plus 7 unofficial participants from ITGC, Algeria.

The third short training course was on Scheduling of Supplemental Irrigation. It was presented by FRMP's water management group to ten members of the Extension Service of Aleppo Province during the period 7-9 November 1989. This course was aimed at the specific extension personnel who will be managing the ten cooperative (ICARDA/DAAR) supplemental irrigation demonstration sites within Aleppo Province during the 1989/90 crop season.

6.3 Individual Training

FRMP scientists, in collaboration with university staff from countries within or outside the region, continued to identify and provide supervision for postgraduate students. During 1988/89 season 10 postgraduate students (4 MSc and 6 PhD) were receiving this type of training, 2 of whom have now completed their studies. Plans have already been made to increase this number in 1989/90 season. Detailed information on these studies are given in Table 6.1.

In the individual non-degree training, opportunities for training in various research topics were available for both junior and senior scientists. Names, countries, subjects and duration of these training programs are given in Table 6.2.

Table 6.1 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 (Ms)	Syria	MSc	Aleppo	Soil Test Calibration for Phosphorus
T. Razzouk	Syria	PhD	Aleppo/ Nottingham	Wheat Extension in Syria
M.S. Issa	Syria	MSc	Aleppo	Variation in Wheat Production in Syria
M. Saade	Syria	PhD	Michigan	Fertilizer Allocation in Syria
E. Afif	Syria	PhD	Cordoba	Phosphorus Behaviour in Calcareous Soils
M. Khazma	Syria	MSc	Damascus	Adoption of Medic Pasture Systems
M. Whitaker	USA	PhD	Stanford	Risk Analysis of N-Fertilizer Use on Wheat

Table 6.2 Individual Training, Non-degree related

Name	Country	Subject	Duration
Z. Masri	Syria	Soil Fertility Research	1 year
I. Hassan	Syria	On-farm Fertility Trials	1 year
S.E.K. Ahmed	Sudan	Plant-soil Water Relations	3 weeks
H. Ghodbane	Tunisia	Neutron Probe Usage	3 weeks
T. Soltani	Tunisia	Neutron Probe Usage	3 weeks
L. Medaa (Ms)	Syria	Fertilizer Allocation	6 months
M.H. Nagi	Syria	Tillage/Moisture Conservation	9 months
Z. Zahir	Syria	On-farm Fertility Trials	1 year

6.4 Workshops

Four workshops were conducted by the program during 1988/89 season. The first one was an International Seminar on Farming Systems Research sponsored by Cukurova University and FRMP and was held between the 31st October-2nd November 1988 at Cukurova University in Adana, Turkey. The first two days of the seminar were devoted to the explanation of Farming Systems Research and for paper presentations; the third day was reserved for a field trip. There were approximately 60 Turkish scientists from 6 universities and 5 research institutions. ICARDA scientists presented 3 papers and the Turkish scientists 9.

The second workshop held during the period 11-18 March, 1989 was a Travelling Workshop on Soil Test Calibration in Tunisia and Morocco. The purpose of the workshop was to visit and evaluate the joint field experiments on soil test calibration conducted in the two countries. It was attended by 10 participants representing Turkey, Cyprus, Jordan, N. Yemen, Syria, Morocco and ICARDA. The workshop activities included presentation of a seminar on soil fertility in Tunisia.

The third workshop was the joint ICARDA/WHO symposium on the Agrometeorology of Barley - Based Farming Systems which was held in Tunisia during the period 6-10 March, 1989. The symposium was attended by social scientists, agronomists and meteorology specialists. There was a total of 64 participants coming from Tunisia, other countries of the region and elsewhere. 23 papers were presented (as well as 6 poster presentations) in 5 sessions and each session was followed by a lively period of discussion. Following the symposium a week-long training workshop was given, focusing on crop and climate analyses and the use of climate and crop growth models in characterizing barley growing environments.

The fourth workshop was held in Turkey. The Turkish Ministry of Agriculture, Forestry and Rural Affairs, ICARDA and CIMMYT organized an international workshop entitled "Soil and Crop Management for Improved Water Use Efficiency in Rainfed Areas" held in Ankara 15-19 May, 1989. The workshop was attended by 32 national scientists from WANA region, 10 invited speakers and 28 scientists from ICARDA, CIMMYT and Turkey. Six technical sessions were held, covering tillage and stubble management, crop establishment, fertilizer management, weed control, crop rotations and transfer of information. A total of 34 scientific papers were presented at the workshop. In addition, participants met in small working groups over two evening sessions to discuss broader issues relating to sustainable food and feed production increases in WANA region. A summary of the synthesis of working group discussions and recommendations is presented in Appendix A of this report.

The fifth meeting, jointly organized with the Syrian Soils Directorate was held on June 11 and 12th at Tel Hadya and was attended by senior representatives of the Extension services from the major barley producing provinces of Syria. An overview of our collaborative fertilizer research on barley was presented, and plans were formulated for extension and demonstration of fertilizer in 1990. These will be conducted in 5 provinces (Dara'a, Hama, Aleppo, Raqqa and Hassakeh).

6.5 Miscellaneous Activities

FRMP continued to attract visiting scientists and postdoctoral fellows from the region to work in collaboration with the program's scientists on research topics of mutual interest. During 1988/89 season, four visiting scientists and two postdoctoral fellows visited the program and worked with ICARDA scientists in various areas of study including barley production functions, application of climate and crop models, fertilizer allocation, land tenure and management of marginal land and finalization of research reports and training manuals. The duration of these assignments ranged from 1-12 months.

As in the past, the program staff contributed to other programs' training courses through lectures and practicals on approaches to resource management research. They also visited many countries of the region for meetings and discussions with their colleagues in the national programs.

7. PUBLICATIONS

7.1 International Journals 1982-1989

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.

Brown, S., Gregory, P.J., Cooper, P.J.M. and Keatinge, J.D.H. 1989. Root and shoot growth and water use efficiency of chickpeas (Cicer arietinum) grown in dryland conditions: effects of sowing date and genotype. **Journal of Agricultural Science (Cambridge).** 113, 41-49.

Cooper, P.J.M., Ketinge, J.D.H. and Hughes, G. 1983. Crop evapotranspiration -- a technique for calculation of its components by field measurements. **Field Crops Research.** 7:299-312.

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Cooper, P.J.M., Gregory, P.J., Tully, D. and Harric, H.C. 1987. Improving wter use efficiency of annual crops in the rainfed farming systems of West Asia and North Africa. **Experimental Agriculture.** 23, 113-158.

Cooper, P.J.M., Gregory, P.J., Keatinge, J.D.H. and Brown, S. 1987. Effects of fertilizer, variety and location on barley production under rainfed conditions in northern Syria. II. Soil water dynamics and crop water use. **Field Crops Research.** 16, 67-84.

Dennett, M.D., Rodgers, J.A. and Keatinge, J.D.H. 1983. Simulation of a rainfall record for the site of a new agricultural development: an example from northern Syria. **Agricultural Meteorology.** 29:247-258.

Dennett, M.D., Keatinge, J.D.H. and Rodgers, J.A. 1984. A comparison of the rainfall egimes of six sites in northern Syria. **Agricultural and Forest Meteorology.** 31:319-328.

Gregory, P.J., Shepherd, K.D. and Cooper, P.J.M. 1984. Effects of fertilizer on root growth and water use of barley in northern Syria. **Journal of Agricultural Science (Cambridge).** 103:429-438.

Harris, H.C., Koudsieh, S. and Bin Shuaib, O.S. 1987. Competition between wheat and weeds for fertilizer under rainfed conditions. **Research Journal of Aleppo University.** 9, 35-64 (Arabic summary).

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Hughes, G., Keatinge, J.D.H. and Cooper, P.J.M. 1987. Solar radiation interception and utilization by chickpea crops in northern Syria. **Journal of Agricutlural Science (Cambridge).** 108, 419-424.

Jones, M.J. 1987. Plant population and sorghum production in Botswana. I. Results of experiment station trials. **Experimental Agricutlure.** 23:335-347.

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.

Jones, M.J. and Sinclair, J. 1989. Effects of bare fallowing, previous crop and time of ploughing on soil moisture conservation in Botswana. **Tropical Agriculture (Trinidad)**, 66: 54-60.

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 Agricutlural Science (Cambridge).** 100:667-680.

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Keatinge, J.D.H., Dennet, M.D. and Rodgers, J.A. 1985. The influence of precipitation regime on the management of three-course crop rotations in northern Syria. **Journal of Agricultural Science (Cambridge).** 104:281-287.

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Keatinge, J.D.H., Chapanian, N. and Saxena, M.C. 1986. The effect of improved management of legumes in a legume-cereal rotation on field estimates of crop nitrogen uptake and symbiotic nitrogen fixation in northern Syria. **Journal of Agricultural Science (Cambridge).** 110:651-659.

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Matar, A.E. and Brown, S.C. 1989. Effect of rate and method of phosphate placement on productivity of durum wheat in Mediterranean environments. I. Crop yield and P uptake. **Fertilizer Research** 20: 75-82.

Matar, A.E. and Brown, S.C. 1989. Effect of rate and method of phosphate placement on productivity of durum wheat in a Mediterranean climate. II. Root distribution and P dynamics. **Fertilizer Research** 20: 83-88.

Mazid, A. 1982. The transfer of technology and its effects on agricultural development in Syria. **Research Journal of Aleppo University.** 4:255-266.

Nordblom, T.L., Ahmed, A.H., Miller, S.F. and Glenn, D.M. 1985. Long-run evaluation of fertilization strategies for dryland wheat in northern Oregon: simulation analysis. **Agricultural Systems**. 18:133-153.

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Acevedo, E. and Wahbi, A. Root growth, water uptake and dry matter partitioning in a group of barley genotypes. Montpellier, France, July 3-6, 1989. (Proceedings in preparation)

Cooper, P.J.M., Jones, M.J., Harris, H.C. and Matar, A.E. Agro-ecological constraints to crop production in West Asia and North Africa, and their impact on fertilizer use. ICARDA/IFDC publication. IFPC Paper Series no. IFDC-P-9.

Cooper, P.J.M. Fertilizer use, crop growth, water use and water use efficiency in Mediterranean rainfed farming systems. Presented at the International Workshop on Soil and Crop Management for Improved Water Use Efficiency in Rainfed Areas. Ankara, Turkey, May 15-19, 1989. (Proceedings in preparation)

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Matar, A.E. Agronomic aspects of plant nutrition management in rain dependent food crop production systems in West Asia and North Africa. Presented at the FAO/FIAC Fertilizer Industry Advisory Committee - Technical Sub-committee Annual Meeting, 10-14 April 1989. Rome.

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8. FARM RESOURCE MANAGEMENT PROGRAM

STAFF LIST IN 1989

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 [1]	Agricultural Economist
Mustafa Pala	Wheat Based Systems Agronomist
Eugene Perrier	Water Management Agronomist
Mohamed Bakheit Said	Training Scientist
Thomas Stilwell [2]	Agronomist/Tunisia
Mahmoud Al-Ashram [2]	Visiting Scientist/Economist
Onur Erkan [2]	Visiting Scientist/Economist
Elizabeth Bailey	Visiting Scientist/Agri. Economist
Shi Zuntong	Visiting Scientist/China
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 Naggar [2]	Post-Doc. Fellow/Agronomist
Ciro D'Acunzo	Associate Expert/FAO
Maurice Saade	Postgraduate Research Student/Economist
Meri Whitaker [2]	Postgraduate Research Student/Economist
Sobhi Dozom	Research Associate I
Mahmoud Oglah	Research Associate I
Afif Dakermanji	Training Assistant
Sonia Garabet	Research Assistant II
Layth El-Mahdy	Research Assistant II
Mireille Abdul Nour [2]	Reserach Assistant II
Zuhair Arous	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 Salem	Research Assistant II
Mohamed Tahhan	Research Assistant I
Pierre Hayek	Senior Research Technician I
Abdul Kader Summakieh [2]	Senior Research Technician I
Sabih Dehni	Senior Research Technician I
Samir Barbar	Research Technician II
Ahmed Nael Hamwieh	Research Technician II
Mohamed Aziz Kassem	Research Technician II

Mohamed Lababidi	Research Technician II
Suleiman Kharboutly	Research Technician II
Issam Halimeh	Research Technician II
Dolly Mousalli	Research Technician II
Samir Baccari [2]	Research Technician/Tunisia
Mohamed Zeki	Research Technician I
Nabil Musattat	Research Technician I
Shereen Baddour	Research Technician I
Ghassan Kanjo	Research Technician I
Ra'la El-Naeb	Research Technician I
Ghazi Yassin	Technician I
Karim Hamou	Technician I
Hayel El-Shaker	Technician I
Marica Boyagi	Senior Secretary III
Katia Artinian	Secretary II
Bana Rifaii [3]	Secretary I
Zuka Istanbouli	Secretary I
Samir Baradai	Driver II
Mohamed Elewi Karram	Farm Laborer

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1 On Sabbatical Leave
2 Left in 1989
3 Transferred to Visitors Section

APPENDIX A

INTERNATIONAL WORKSHOP
SOIL AND CROP MANAGEMENT FOR IMPROVED WATER USE EFFICIENCY IN RAINFED AREAS

15-19 May 1989, Ankara, Turkey

SYNTHESIS OF WORKING GROUP DISCUSSIONS AND RECOMMENDATIONS

GENERAL ISSUES OF CONCERN EXPRESSED BY ALL WORKING GROUPS

To help meet the very large projected food and feed deficits within West Asia and North Africa, and to ensure that production increases are sustained over the long term, national and international agencies must give greater priority to improved crop and soil management and the conservation of natural resources.

Three major issues need to be addressed:

1) Linkages
2) Priority of resource allocation
3) Training

Linkages

- Multi-disciplinary linkages are essential. At the moment these are constrained by existing research infrastructures which are often departmentalized on a commodity or discipline basis.

  N.B. It is also important to try to avoid overlapping or conflicting research programs and advice to extension agents and farmers.

- Good linkages between policy makers-researchers-extension agents-farmers will greatly help in the development of relevant research programs and the transfer of information to farmers. Current infrastructures and lack of awareness make it very difficult to establish such a chain of linkages.

- Also if linkages have been established, they are often broken by enforced staff movement.

- Multi-national and regional linkages are not well established within crop and soil management research. Such networks and information transfer systems would greatly enhance the efficiency and status of agronomic research and extension.

Priority of Resource Allocation

- National agencies must give greater priority to agricultural research and extension, and create conditions which encourage men and women in the region to commit themselves to a career in agriculture.

- Within the agricultural research and extension sector, national agencies should give greater priority to crop and soil management research and the conservation of the natural resource base upon which future agriculture will depend.

- Much of this research is long term in nature. National and international agencies and research workers themselves must give such research higher priority and recognize that "quick" solutions are not always possible, and may be misleading.

- On-farm research has a vital role to play in:

  1) Developing relevant research programs through better scientist-extension-farmer links.

  2) Development of more precisely targeted recommendations in variable environments.

  3) More realistic economic evaluations.

  Greater priority and resource allocation should be given to such research.

Training

Achieving sustainable production increases in the harsh and variable environments of West Asia and North Africa is going to pose a continuing challenge. To meet this challenge, governments must continue and expand their investment in training.

In general, the region has a deficit of skilled manpower in:

- Agronomy (and a range of related disciplines)
- Livestock science
- Rural sociology and economics

In particular, the region would benefit enormously from the creation of a permanent and specialized regional training center for Extension Agents.

TILLAGE AND STUBBLE MANAGEMENT

Main Issue

Development of appropriate tillage and stubble management systems for soil and water conservation, plant growth, and sustainable production.

Major Under-Researched Issues

1. Tillage-stubble-animal interactions (The use of stubble for water and soil conservation compared with the current practice of stubble for livestock feed)

2. Effectiveness of stubble retention for water infiltration and reduced evaporation.

3. Effectiveness of primary tillage on water infiltration and retention.

4. Efficient use of additional soil water through good management (nutrients, weed control, rotations), and the role of chemical weed control in reduced tillage.

5. Research and development on appropriate tillage equipment and planters.

6. Availability of spare parts and technical know-how about setting and maintaining machinery.

Research Strategy

1. There should be long term, multi-disciplinary, multi-factor trials on the major soil types of a country. These could be on research stations or on-farm, but must be well-controlled.

2. Such research should be integrated into national programs to ensure long term commitment and continuity.

3. Site characterization is essential for comparisons and extrapolation of findings.

4. Tillage equipment must be realistic for adoption by farmers.

5. Training in usage and maintenance of equipment is essential.

6. Local practice should be included as control.

7. All research must include monitoring of economics and social factors.

Constraints to Research

1. Interactions of tillage-residue-livestock are complex and control is difficult.

2. Tillage equipment is often site (soil type) specific, and expensive.

3. Multi-disciplinary approach to research is lacking within the region.

4. There are not enough experienced research scientists.

5. Training is inadequate.

6. Continuity of research funds and personnel (scientists and support staff) is needed.

Possible Solutions

1. Long-term government commitment at planning stage required.

2. Special project research funding is needed from national government or external sources.

3. Young research graduates should be involved.

4. Support staff must be trained.

CROP ESTABLISHMENT

Major Under-Researched Issues

1. Appropriate methods of seedbed preparation.

2. Determination of interaction of seed rate/plant density with environmental factors.

3. Matching of varietal characteristics to environments.

4. Prediction (modelling) of appropriate time of sowing for continuous cropping.

Lower Priority Issues

1. Plant arrangement and row spacing
2. Crusting of soils
3. Seed dressings
4. Seed size and depth of planting

Research Strategies

1. Environmental characterization is important for extension of results beyond site of experiment.

2. Multi-disciplinary research linked to multi-factorial experiments.

3. A regional agronomic network to enhance information exchange.

Constraints to Research

1. Lack of facilities for training

2. Poor status of agricultural research — reflected in poor logistic support and operational funds.

3. Poor communication amongst regional and national scientists.

Possible Solutions

A regional information transfer mechanism in order to:

1. Facilitate research
2. Give individual researchers a wider sense of support
3. Offer training opportunities

FERTILIZER MANAGEMENT

Major Under-Researched Issues and appropriate research strategies

1. Phosphate dynamics: depletion/build up of soil-P availability over time, its relation to fertilizer regime, cropping pattern and soil type, and its basic soil chemistry.

   Strategies for Research: Long-term Trials; Site Characterization

2. Efficient nitrogen fertilization: rate, method and time of application: development of recommendations flexible enough to take account of locality, season, previous crop and rainfall situation.

   Strategies for Research: On-farm Research; Site Characterization

3. Diagnostic techniques: for assessing N and P availability and fertilizer need, in particular standardization of analytical methods and determination of critical levels -- in soil, but also perhaps, for N in plant -- in relation to soil type, recent fertilizer use and crop sequence.

   Strategies for Research: Site Characterization
   Regional Information Network

4. Fertilizer interactions: with other management practices (e.g. tillage, weed control) and soil moisture conditions, leading to targeted recommendations for specific rotations, management levels, etc.

   Strategies for Research: Multi-disciplinary Research
   Multi-factor Research
   Long-term Trials
   Site Characterization

5. Micro-nutrient deficiencies: simple methods are needed to identify and anticipate micro-nutrient problems according to soil type/crop/intensity of production. [Regional information system.]

   Strategies for Research: Site Characterization
   Regional Information Network

6. Economic dimension: analyze fertilizer trials economically; recommendations to farmers based on results of on-farm trials and studies of related socio-economic factors and risk.

   Strategies for Research: Multi-factor Research
   Multi-disciplinary Research
   On-farm Research
   Site Characterization

Lower Priority Issues

- Phosphate placement: banding v. broadcasting
- Comparison of fertilizer forms (high v. low analysis; compounds)
- Microbiological aspects -- rhizobia and mycorrhiza
- Modelling fertilizer response
- Use of N^{15} and P^{32} to study fertilizer efficiency.

Wider Issues i.e. Fertility Not Just Fertilizer Management

- Soil physical properties (evolution in relation to rotation, soil organic matter content)
- Legume effects on soil N dynamics
- Organic manures
- Long-term monitoring of fertility; nutrient balances.

Constraints to Research

Financial		Strategies most affected
Manpower	- numbers - training - salaries/incentives/inequalities	All
Operations	- equipment - vehicles, operating costs	On-farm Research Long-term Research Site Characterization
Travel	- conferences, etc.	Information Network

Organizational	Strategies most affected
Institutional barriers (Research v. Extension; but also within Research)	Multi-disciplinary Research
Bureaucratic procedures	On-farm Research Multi-disciplinary Research Information Network
Staff changes	Long-term Trials

WEED CONTROL

Major Under-Researched Issues

1. Change in population and species of weeds due to shift in farming system from fallow to continuous cropping, taking livestock interaction with the systems into consideration

2. Knowledge of weed flora and emergence patterns in winter sown crops

3. Economic and agronomic analysis of the systems

4. Integrated weed control in food legumes, particularly broadleaved and parasitic weeds (chemical use and cultural practices such as sowing date, interrow cultivation, solarization, etc.)

5. Integrated weed control in cereals, particularly grassy weeds (use of chemicals and cultural practices such as tillage, sowing date, planting pattern, etc.)

6. Selection of crop varieties with higher competitive ability

7. Control of late germinating weeds.

Research Strategies

- farmer monitoring
- long-term trials
- multi-disciplinary research
- multi-factor trials
- site characterization
- regional agronomic network

Constraints to Research

- Insufficient infrastructure
- Integration of different disciplines
- Involvement of researchers, extension and farmers from planning onwards

CROP ROTATIONS

Major Under-Researched Issues

1. Fallow replacement by annual legumes

   - Identification of suitable legume species
   - Studies of water and N balance
   - Economic analysis

2. Ley farming system

   - Social, cultural aspects need to be defined
   - Is a new technology feasible for introduction
   - Need to find more adaptable varieties or species
   - Need to study the effect of ley farming on the chemical and physical characteristics of soil and water use efficiency

3. Integration of livestock into cropping systems

   - Effects on soil properties and soil compaction
   - Determine stocking capacity
   - Economics of cereal-legume-livestock systems

4. Cropping sequences

   - Alternatives for various climatic situations
   - Need to fit the system into local situation

5. Need to have methods for economic evaluations

Research Strategies

1. Multi-disciplinary approach

2. Long-term, well-designed experiments

3. Group experiments with similar objectives in the region but slightly different species and approach according to local conditions

4. Initial trials-experiment station

5. Introduce new technology (new varieties, new planting techniques, seeding date...) to farmers already using some type of rotation

6. Crop sequence effects can be determined on shorter term basis and on farmers' fields

7. Design and method of analysis of rotation experiments must be carefully considered before initiation of actual field trials

Constraints to Research

- Commitment to long-term trials

- Expensive in terms of land, time, personnel and finance

- Quick results are expected but may be misleading

- Procedures for conduct of rotation experiments not well understood. Not many good past examples are available

- Long time-lag between initiation of trials and usable (and publishable) results

- Demonstration of results in farmers' fields difficult because of time and land required from farmer

TRANSFER OF INFORMATION

Major Issues Concerning Extension

1. Inclusion of extension officers and farmers in project teams from the outset

2. Establishment of extension/rural sociology training center in region (a possible role for ICARDA was suggested by participants)

Major Constraints to Extension Services

1. Attitudes of governments/policy makers to rural development
2. Government infrastructures, financial support, etc.
3. Low credibility of extension workers: skills, roles, career development
4. Poor knowledge of extension skills/methods/technologies
5. Lack of economic information

Possible Solutions

1. Upgrading of extension services/manpower, funds and support
2. Specialized training:
   - Inter-regional travel
   - Travelling workshops
   - Establishment of extension/rural sociology/research training center
3. Greater use of electronic media
4. Planned projects

Constraints to Farmer Adoption

1. Poor linkages, poor coordination between research extension and farmers
2. Unavailability of inputs (seed etc.) and lack of technical support services for farmers
3. Advice to farmers often conflicting, instead of clear and targeted
4. Level of education of farmers

Possible Solutions

1. Improvement of relationships between each group in the research- extension-adoption continuum through:

   - Better organizational structures
   - Multi-disciplinary project teams involving researchers
   - Regular training and/or workshops
   - Technological transfer coordination committees for regions

APPENDIX B

EXPERIMENT NUMBER AND TITLE OF FRMP CORE RESEARCH PROGRAM

1988/1989

PROJECT 1. MANAGEMENT OF SOIL AND WATER NUTRIENTS

Improved Efficiency of Fertilizer Use

SWAN-1	Nitrogen and phosphate soil test calibration for wheat in farmer's fields (cooperative with Syrian Soils Directorate)
SWAN-2A	The effect of fertilizers on different durum wheat cultivars (cooperative with CP)
SWAN-3	Contribution of mineralization potential in soils to nitrogen nutrition of wheat (cooperative with FLIP)
SWAN-4	On-farm barley fertilizer trials (cooperative with Syrian Soils Directorate)
SWAN-5A	The effect of soil depth on the efficiency of fertilizer use by barley
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-adsorption 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 rotations
SWAN-13	The effect of stubble burning and seedbed preparation systems on a wheat/lentil rotation
SWAN-14	The productivity of farming systems (cooperative with PFLP and FLIP)

Improved Production Practices for Food Legumes

SWAN-16A The effect of soil tillage, row spacing and weed control on yields of winter sown chickpea (cooperative with FLIP)

SWAN-19A Sitona and weed control for lentil in farmers' fields (cooperative with FLIP)

SWAN-20 Improved production practices for chickpea (cooperative with FLIP)

Forage Agronomy Trials

SWAN-21 Forage legume potential in dry areas (cooperative with FLIP)

SWAN-22 Vetch utilization trials

Water Management Studies

SWAN-23 Supplemental irrigation of wheat: nitrogen and variety effects (cooperative with Irrigation Department)

SWAN-24 Research managed supplemental irrigation of wheat (cooperative with Irrigation Department)

SWAN-25 Research managed supplemental irrigation of barley (cooperative with CP)

SWAN-26 Research managed supplemental irrigation of chickpeas (cooperative with FLIP)

Fallow Replacement

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

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

SWAN-29 Continuous barley trials (3rd year)

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

SWAN-31 PFLP/FRMP medic barley rotation trial (2nd year, cooperative with PFLP)

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 Spatial climate model

ACRM-3 SIMTAG Wheat Growth Model. Determination of genotypic coefficients

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

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

ACRM-6 Prediction of crop-environment interactions

ACRM-7A CERES barley model validation and calibration

ACRM-8 Whole-farm risk analysis based on experimental flocks and crop rotations at Tel Hadya, NW Syria

ACRM-10 Intensification of small ruminant production in rainfed crop and pasture systems of NW Syria

ACRM-11 Characterization of dryland farming systems in the arid zones of Jordan

PROJECT 3. ADOPTION AND IMPACT OF TECHNOLOGIES

Estimation of Adoption and Production Impact

ADIM-1 Analysis of crop-livestock production in the Breda-Bueda area

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

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

ADIM-4	Household practices in sheep management
ADIM-5A	Stubble burning in Northwest Syria
ADIM-7	Economical fertilizer allocation in Syria (cooperative with Aleppo University and Syrian Soils Directorate)
ADIM-8	Barley production function in Syria and Turkey (cooperative with Cukurova University)
ADIM-9	Overall evaluation of socio-economic implications of lentil harvesting mechanization research (cooperative with FLIP)
ADIM-10	Socio-economic survey of winter sown chickpea in Syria and Morocco (cooperative with FLIP, INRA - DPV Morocco)

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