FARM RESOURCE MANAGEMENT PROGRAM

Annual Report for 1990

ICARDA

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International Center for Agricultural Research in the Dry Areas
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TABLE OF CONTENTS

APPENDICES

1. INTRODUCTION

1.1 Content of this Report

This report covers the work of FRMP during the calendar year 1990. Following the pattern set over a number of years, not all activities are described every year. Some of sections that follow here report a single year's findings, but others are summaries of several years' results or updated accounts of material partially reported before. This style matches the relatively long-term nature of many of the ongoing studies and the importance that attaches to the seasonal weather interaction with many of the applied experimental treatments.

As before, the main scientific reporting is organized according to the four major projects within the program: The Management of Soil, Water and Nutrients (Chapter 3); Agroecological Characterization for Resource Management (Chapter 4); The Adoption and Impact of New Technology (Chapter 5); and Training and Agrotechnology Transfer (Chapter 6). However, it should be said that there are no real boundaries between these projects, and many activities straddle two project areas or evolve from one to the other. For instance, results from diagnostic agronomy trials in northern Jordan, though strictly concerned with soil, water and nutrients, are part of a wider and otherwise largely socio-economic characterization of the area and so are reported within the Agroecological Characterization project. Likewise, the work on the supplemental irrigation of wheat, which has evolved over five years from technical on-station research, through on-farm trials to an extension and demonstration phase, is now concerned largely with the transfer and adoption of technology and so is reported as part of the Adoption and Impact project. These examples serve to illustrate how the widely ranging disciplines found within FRMP are in many respects strongly interlinked through adherence to broad farming systems and resource management philosophies.

For those with limited time and interest, Chapter 2 provides in an Executive Summary a brief overview of each activity reported in Chapters 3-6; and three appendices list FRMP staff during 1990, publications during the year and all field trials and experimental activities.

1.2 Staff Changes

1990 has been a year of considerable change for FRMP; several scientists have left us, and program strength has temporarily been at a low level. Peter Cooper left in July after many distinguished years in ICARDA to take up the post of Director of Research at ICRAF, Nairobi; Eugene Perrier, who had established a firm basis for supplemental irrigation research and transfer to farmers during his five year stay, retired in June; and there was a further loss in this field of work later in the year when Ciro D'Acunzo, FAO associate expert in supplemental irrigation, completed his three-year term with us. Other departures have been those of Ammar Wahbi, on the completion of his three years post-doctoral fellowship in soil fertility and on-farm fertilizer trials, and Maurice Saade, to finish his doctoral studies on fertilizer allocation at Michigan State University. Both of these scientists will be remembered for their major contributions to cooperative work between FRMP and the Syrian national program. Of two visiting scientists, one, Shi Zuntong, who had been assessing the potential of our agroecological characterization package for use in wheat-growing areas of China, has returned home; the other, Noureddine Mona, reviewing information on the ownership and management of marginal lands, has followed Tom Nordblom to PFLP.

To rebuild the program scientific strength, advertisements have been placed for the positions of Program Leader; Senior Economist (already vacant over 2 years); Water Management Specialist (to cover both supplemental irrigation and water harvesting) and Agroclimatologist (new position). At the time of writing, suitable appointees have been identified from long lists of applicants for the two latter positions; and it is expected that all four positions will be filled by mid-1991. Meanwhile, we have been very happy to welcome Benny Timmerman from the Netherlands to a postdoctoral position to initiate studies on wind erosion. This appointment demonstrates the increasing commitment within FRMP towards resource management in drier areas.

The balance of changes among regional staff has been more favorable. Unrecorded in our 1989 report, Karim Hamou left us at the end of that year; and he was followed during 1990 by Samir Baradai, program driver for many years; by Suleiman Kharbotly, of the wheat-based systems agronomy team;' and by Bernadette Jallouf of the Soils Laboratory. However, on the positive side, we have been happy to welcome Malika Abdul-Ali (from CODIS) to the socio-economic group where her trilingualism is a great asset; Ghalia Martini to the agroclimatological group; and, not least, three former daily-paid staff, George Estephan (Soils laboratory), Ali Haj Dibo (Soil Water studies) and Jihad Abdullah (Barley-based systems agronomy team), deservedly to the ranks of contract staff.

1.3 The Weather in Syria During the 1989/90 Season

The season of 1989/90 in northern Syria was in many ways similar to the 1988/89 season. Total rainfall was almost exactly the same, reaching about two thirds of the long-term average. The total number of frost days was also similar and, with around 50, markedly above the average. Even the intraseasonal distribution of rainfall and frost was reminiscent of the previous year. In both years, most of the rain fell early on in the season, and January was by far the coldest month with most frost days, followed by February. Yet there were significant differences: rainfall in 1989/90 did not stop quite as abruptly as the year before; there was significant precipitation during February, and there was a very severe frost period in March.

The season started with ample rain falling in distinct spells from 12 November to 11 December. This made timely planting easy and ensured a good early crop development. However, the rest of December and January were rather dry except for one wet spell around the turn of the year, and January temperatures were noticeably cooler than average (there was frequent frost down to -8°C), so that by end of January crop stands were visibly poorer than the year before at the same time. The

February rainfall total was average, nearly all of it falling before 18 February. No significant rainfall was recorded after that except for one shower at the start of April. With the dry weather in the second half of February and in March, night temperatures dropped again and stayed well below average until well into April. Late frosts in March (-8.9°C in Tel Hadya on 17 March) inflicted severe damage, especially in the drier part of the area, although they were less severe in the wetter part. Soil moisture reserves for the later growth stages of the crops were better than in the season before, due to the later cessation of rainfall and smaller losses to evaporation. Those crops which had not been too damaged by frost in the wetter parts of the area were therefore still able to produce fair yields, whereas many crops in the drier parts, with meagre soil water reserves available to them, yielded little or nothing. Grazing of crops was again widespread in these drier areas and, on the whole, the 1989/90 season was as unfavorable as that of 1988/89.

Table 1.3.1 Monthly precipitation (mm) for the 1989/90 season

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	TOTAL
Jindiress													
1989/90 season	0.0	54.0	71.2	57.8	41.8	90.4	6.6	1.0	9.6	1.2	0.0	0.0	333.6
Long term average (30s.)	1.4	30.5	55.7	94.0	84.6	74.7	65.8	42.4	19.0	2.4	0.4	0.9	471.8
% of long term average	0	177	128	61	49	121	10	2	51	50	0	0	71
Tel Hadya													
1989/90 season	0.0	10.2	78.5	34.9	30.4	50.5	8.6	13.9	6.3	0.1	0.0	0.0	233.4
Long term average (12s.)	0.4	25.9	51.0	56.5	60.1	51.5	41.4	27.6	13.7	3.3	0.0	0.1	331.5
% of long term average	0	39	154	62	51	98	21	50	46	3	n/a	0	70
Breda													
1989/90 season	0.0	24.6	27.8	34.2	37.0	42.6	8.4	3.0	5.6	0.0	0.0	0.0	183.2
Long term average (32s.)	1.3	17.3	31.0	54.6	48.7	38.9	33.6	31.3	15.7	1.6	0.2	0.0	274.2
% of long term average	0	142	90	63	76	110	25	10	36	0	0	n/a	67
Boueidar													
1989/90 season	0.0	34.7	12.0	31.4	24.4	33.8	8.0	4.8	1.4	0.0	0.0	0.0	150.5
Long term average (17s.)	0.1	15.4	23.5	35.9	36.8	34.8	27.8	17.2	9.0	0.8	0.1	0.0	201.4
% of long term average	0	225	51	87	66	97	29	28	16	0	0	n/a	75
Ghrerife													
1989/90 season	0.0	26.0	26.0	34.0	28.8	35.2	10.4	3.0	6.2	0.0	0.0	0.0	169.6
Long term average (5s.)	0.0	45.5	24.1	42.5	41.3	39.3	32.0	11.4	10.5	0.8	0.0	0.0	247.4
% of long term average	n/a	57	108	80	70	90	33	26	59	0	n/a	n/a	69
Terbol													
1989/90 season	0.0	9.4	56.8	43.8	54.6	91.5	40.2	13.2	8.4	0.0	0.0	0.0	317.1
Long term average (9s.)	0.0	25.7	64.1	81.9	87.1	99.4	92.7	24.2	8.5	0.7	0.4	0.0	484.7
% of long term average	n/a	37	89	53	63	92	43	55	99	0	0	n/a	65

Table 1.3.2 Monthly air temperature (°C) for the 1989/90 season

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
Jindiress												
Mean max.	32.4	25.0	18.5	11.3	10.9	13.5	20.0	24.2	30.0	33.2	33.9	34.3
Mean min.	18.3	11.6	7.5	4.1	-0.9	2.7	4.6	9.4	13.0	17.4	22.4	21.1
Average	25.3	18.3	13.0	7.7	5.0	8.1	12.3	16.8	21.5	25.3	28.1	27.7
Abs. max.	37.4	30.9	26.9	16.0	16.3	18.2	24.0	34.9	42.6	41.2	36.1	39.6
Abs. min.	13.4	5.8	-0.8	-4.0	-7.0	-1.1	-3.7	-0.9	6.4	11.8	19.7	17.8
Tel Hadya												
Mean max.	34.0	26.5	18.8	12.0	10.9	13.7	20.0	24.4	30.3	34.8	37.2	37.1
Mean min.	17.3	11.3	6.9	3.3	-2.1	0.7	2.3	6.7	11.2	16.6	22.0	20.8
Average	25.6	18.9	12.8	7.6	4.4	7.2	11.1	15.5	20.7	25.7	29.6	28.9
Abs. max.	39.2	31.4	27.0	16.6	16.6	19.1	26.2	35.2	42.8	42.0	40.6	41.1
Abs. min.	9.7	5.4	-0.8	-5.8	-8.7	-6.3	-8.9	-0.2	3.8	9.3	19.0	18.1
Breda												
Mean max.	33.9	25.8	18.4	11.1	10.3	12.9	19.6	24.9	31.1	34.9	37.6	38.3
Mean min.	16.5	11.3	6.7	3.7	-1.3	1.9	2.9	7.9	13.1	17.1	21.2	19.5
Average	25.2	18.5	12.5	7.4	4.5	7.4	11.2	16.4	22.1	26.0	29.4	28.9
Abs. max.	38.3	33.0	25.8	16.0	14.9	18.5	25.3	36.2	43.1	41.6	40.8	40.5
Abs. min.	12.6	6.8	-2.0	-4.4	-7.2	-4.6	-7.2	-1.1	4.2	11.0	16.5	16.0
Boueidar												
Mean max.	33.6	26.0	18.7	10.8	9.1	13.5	20.0	24.9	31.0	35.1	37.3	36.4
Mean min.	13.1	10.3	5.4	2.5	-2.1	1.2	1.6	7.2	11.2	15.6	17.6	15.4
Average	23.3	18.1	12.0	6.6	3.5	7.3	10.8	16.0	21.1	25.3	27.4	25.9
Abs. max.	38.3	33.3	25.1	16.0	14.0	18.6	26.3	35.4	40.9	41.0	40.9	38.6
Abs. min.	8.6	3.0	-6.2	-9.5	-7.7	-5.5	-7.4	-0.7	3.6	8.2	14.5	13.0
Ghrerife												
Mean max.	33.8	26.1	18.1	10.8	9.0	12.9	19.5	24.8	31.5	34.8	37.1	37.1
Mean min.	17.5	13.2	8.0	4.0	-0.9	2.7	3.8	9.9	15.1	18.1	21.0	20.0
Average	25.6	39.3	13.0	7.4	4.1	7.8	11.6	17.3	23.3	26.4	29.0	28.5
Abs. max.	38.8	33.0	26.2	16.8	16.1	18.5	25.7	36.3	42.9	41.0	40.7	40.6
Abs. min.	13.2	8.0	-0.5	-5.5	-7.1	-5.3	-5.0	-1.0	8.1	12.0	18.4	18.2
Terbol												
Mean max.	30.8	24.2	18.8	14.1	9.9	10.1	16.8	21.6	27.0	30.9	33.3	32.3
Mean min.	9.6	6.1	3.6	-0.8	-2.2	-1.2	-0.9	3.7	5.7	8.3	9.5	11.3
Average	40.4	15.1	11.2	6.6	3.8	4.4	7.9	12.6	16.3	19.6	21.4	21.8
Abs. max.	35.0	31.5	25.0	21.0	16.0	15.0	23.5	32.0	38.0	37.0	37.0	35.0
Abs. min.	4.5	0.0	-2.5	-7.5	-8.0	-6.0	-5.0	-5.0	-2.5	3.0	6.5	7.0

Table 1.3.3 Frost events during the 1989/90 season

	NOV	DEC	JAN	FEB	MAR	APR	MAY	SEASON
Jindiress								
No. of frost days	2	5	21	9	2	1	-	40
Abs. min. (°C)	-0.8	-4.0	-7.0	-3.3	-3.7	-0.9	-	-7.0
Tel Hadya								
No. of frost days	3	7	20	15	8	1	-	54
Abs. min. (°C)	-0.8	-5.8	-8.7	-6.3	-8.9	0.2	-	-8.9
Breda								
No. of frost days	2	6	20	12	7	2	-	49
Abs. min. (°C)	-2.0	-4.4	-7.2	-4.6	-7.2	-1.1	-	-7.2
Boueidar								
No. of frost days	5	7	22	15	11	1	-	61
Abs. min. (°C)	-6.2	-9.5	-7.7	-5.5	-7.4	-0.7	-	-9.5
Ghrerife								
No. of frost days	2	7	21	11	4	1	-	46
Abs. min. (°C)	-0.5	-5.5	-7.1	-5.3	-5.0	-1.0	-	-7.1
Terbol								
No. of frost days	6	21	20	18	19	8	3	95
Abs. min. (°C)	-2.5	-7.5	-8.0	-6.0	-5.0	-5.0	-2.5	-8.0

Table 1.3.4 Frost events at 5 cm above the ground during the 1989/90 season

	NOV	DEC	JAN	FEB	MAR	APR	MAY	SEASON
Tel Hadya								
Frost days	4	9	22	16	9	1	-	61
Abs. min.	-1.6	-7.2	-10.7	-7.2	-7.5	-1.2	-	-10.7

2. EXECUTIVE SUMMARY

In this section, we present summaries and highlights of the research results reported in the rest of the report. Readers are referred to specific sections in which the full and detailed reports are presented. In addition, we give in Appendix A a full list of experiments and research activities ongoing during the 1989/90 season.

2.1 Project 1. Management of Soil, Water and Nutrients

Soil Cultivations (section 3.1)

Mechanized tillage is a relatively recent innovation in most rainfed arable areas of the WANA region, and there are good reasons to suppose that in some cases farmers utilize particular tools for particular operations more as a result of their commercial availability than proven technical need. It is therefore necessary to ask whether certain applications of mechanization are appropriate, from the point of view both of economics and of safe soil husbandry. Equally, it is useful to consider whether certain tasks not currently mechanized could be done more effectively and/or economically by machine. Both of these points are currently being followed up in FRMP trials.

With regard to the first, specifically we question whether swelling clay soils, important for wheat and grain legume production in many parts of the region, really need the deep tillage they are often given. It is costly in terms of time, fuel use and -- in the longer term -- on the maintenance of soil structure. A trial was started at Tel Hadya in 1985/86 to test the hypothesis that tillage can be reduced without loss of crop yield. It compares deep discing (20 cm), chisel ploughing (20 cm), ducksfoot sweeping (8-10 cm) and zero tillage, applied to two three-course rotations: bread wheat-chickpea-water melon and durum wheat-lentil-water melon.

Results to date show no significant effect of tillage type on legume yield. Significant differences in wheat yields have no consistent pattern except that zero tillage tends to yield least, and this may be attributed to the technical limitation of the zero-till planter which plants at 30 cm row-spacing instead of the 17.5 cm spacing used in other treatments. One rationalization of deep tillage is that it promotes water infiltration and storage, but the monitoring of profile moisture in this trial has failed to show any increased storage of water in deep-tilled plots -- if anything, rather the reverse; and no consistent differences have been found in soil-water availability at planting time. Thus, so far, under the conditions of this trial, there is no evidence of a deep-till advantage in either crop yield or soil water relations.

Preparatory tillage provides nearly weed-free conditions for chickpeas sown in the spring, but a winter-sown crop often faces a serious weed problem. Rising costs impose limitations on traditional hand-weeding. Chemical control is possible, but most effective herbicides are for pre-emergence application, and farmers are reluctant to invest in herbicide until they see how the season and crop progress. Mechanical weed control needs special equipment but should still be tried. To this end, after a preliminary trial at Tel Hadya in 1988/89, trials at three sites in 1989/90 examined the effects of tillage depth, crop geometry and weed-control methods (by hand, herbicide and inter-row cultivation) on crop and weed performance.

Deep tillage did not affect grain yield but decreased weed population, significantly at one site, non-significantly at another. Narrow row spacing tended to reduce weed density; but grain yields were not reduced by the wide spacing necessary for inter-row cultivation, which was no less effective than herbicide in reducing weed mass and promoting grain production. However, 1989/90 was a very dry season. It will be necessary to continue this investigation for two or three more seasons to confirm that these results remain valid under wetter conditions.

<u>Supplemental Irrigation (section 3.2)</u>

Full irrigation provides the total crop water requirement in situations where rainfall is insufficient for growth. Supplemental irrigation is distinct, being used -- as seasonally required -- in situations where rainfed crops can be grown but are subject to high risk of yield loss from drought. Supplemental irrigation can alleviate that risk, stabilize yields and justify the use of high-cost inputs (high-yielding cultivars, fertilizers, herbicides, etc.). However, since supplies of water are often limited, it is important to try to maximize response-- biological and economic -- per unit of water use. Appropriate management is important here, as is the adoption of the right variety. Trials concerned with these factors were conducted on three different groups of crops in 1989/90, barley, wheat (bread and durum), oil-seed crops (rapeseed and sunflower).

At Breda, 37 barley genotypes (classified according to their adaptation to high, medium and low rainfall regimes) were supplemented, using a linesource system, with 0 to 232 mm of irrigation. Rates of application were greater than usual due to very low rainfall, 185 mm, and crop response was dramatic. Mean grain yields increased from 0.40 t/ha under rainfed control to 3.37 t/ha at the highest irrigation rate. Rihane-03 (a high-rainfall genotype) confirmed its previous high-yielding performance by significantly outyielding all other genotypes at the highest rate of irrigation; but SLB 39/60 (a low-rainfall genotype) outyielded all others, including Rihane-03, at zero and low irrigation rates. It seems that, in general, genotypes adapted to higher rainfall regimes are needed where supplemental irrigation is being introduced, because local varieties are unable to make best use of the extra water. Nevertheless, where water availability is limited, SLB 39/60 should be considered, because it seems able to utilize a limited water supply more efficiently than other genotypes.

At Tel Hadya, 20 genotypes each of bread wheat and durum wheat were grown under a linesource irrigation system. Water receipt ranged from 233 mm in the rainfed control up to a maximum of 486 mm. For both types of wheat, differences between genotypes were significant and all genotypes responded significantly to increasing water. Although interactions between genotypes and water rates proved to be statistically non-significant, differences between lowest- and highest-yielding genotypes tended to increase with increasing water supply, e.g. a 500 kg difference at 300 mm might become a 1400 kg difference at 500 mm. Among the bread wheats, steepest yield response to increasing water was shown by Cham 4.

The introduction of such crops as sunflower, rapeseed, safflower and sesame has potential to alleviate the current deficits of vegetable oil found in many countries of the region. Two experiments were started at Tel Hadya in 1989/90 to compare three rapeseed cultivars and two sunflower cultivars at different plant densities, and to ascertain the lower limit of water supply required to obtain economic yields.

Rapeseed yields were low, probably due to cold weather during early growth and some frost damage. Highest yields were obtained from an Australian cultivar of Brassica napus, although a Canadian cultivar of the same species performed badly, indicating perhaps poor adaptation to Mediterranean conditions. All three cultivars responded strongly to supplemental irrigation, and these (as yet) single-year data suggest that the seasonal water supply should be above 400 mm to optimize rapeseed yields.

Over three seasons at Jindiress, spring-sown trials, utilizing stored soil moisture, had indicated that no yield increase is obtained by increasing plant populations of sunflower above 20,000/ha. However, it is difficult to protect trials against bird damage at this site. Investigations of cultivar response to different plant densities and water regimes were therefore undertaken in 1989/90 at Tel Hadya, using a drip irrigation system. Yields increased up to the highest rate of water applied, but effects of plant density and cultivar were not significant. However, the oil-content of the local large-seeded cultivar was significantly lower than that of the small-seeded Turkish cultivar. This confirms that if sunflowers are to be grown for oil rather than confectionery purposes, as is now often the case, attention must be given to choice of cultivar.

Four Years On-farm Fertilizer Trials on Wheat (section 3.3)

In last year's report (section 3.1), we summarized results from a four-year program of fertilizer trials on barley in farmers' fields. This year we report on a parallel program of trials on wheat.

Over the four seasons, 1986-1990, 70 researcher-managed wheat fertilizer trials were successfully conducted on farmers' fields above the 300 mm isohyet in Aleppo, Idleb and Hama provinces. Sites were selected to represent the range of soil types and fertility status used by farmers for wheat and the three main crop rotations, wheat following lentil, chickpea and water melon. Each trial comprised two replicates of four rates each of nitrogen and phosphate factorially combined; and each trial site was characterized with respect to the range of environmental variables thought to influence fertilizer response.

About half the sites had soil mineral-N contents < 10 ppm and available-P < 5 ppm, values taken to represent critical levels in respect to fertilizer response. Mineral-N status tended to be lower at sites previously planted to lentils, but available-P status was apparently unrelated to previous crop. Of the four experimental seasons, two were dry, one wet, and one close to the average. Altogether seasonal rainfall ranged from 153 to 907 mm (mean 363 mm). The yield-rainfall relationship appears to be best described by a quadratic equation, with a maximum between 500 and 600 mm rainfall. Highest wheat yields tended to be after water melons, especially under low rainfall. This agrees with other studies that show that summer crops like melons do not utilize all the soil-stored water from the previous winter.

Crop response to nitrogen fertilizer increased with increasing rainfall and was greater where soil mineral-N content was relatively low; but effects of rotation were only minor. Crop response to phosphate fertilizer appeared little related to site factors. In fact, significant positive responses to phosphate were not very numerous, 15 for grain and 10 for straw, compared with 38 and 61 significant responses, respectively, to nitrogen. The failure of wheat to respond to phosphate is often attributed to residual effects from heavy previous application of phosphate fertilizer. That may be so, but a comparison with barley results given last year (FRMP 1990) is interesting. Of fifty barley trials that had less than 5 ppm soil available-P, 34 showed a significant grain response and 44 a significant straw response to phosphate fertilizer; whereas, of 32 wheat trials with less than 5 ppm available-P, only seven showed significant grain or straw responses. This may point to a difference in critical value for available-P between wheat and barley or to a difference between the wheat soils of the relatively wet arable zone and the barley soils of drier areas in the ability of the Olsen-P extraction method to indicate true availability. Phosphate sorption studies (section 3.4.1) should, in time, help to clarify this situation.

Regression equations have been developed to describe wheat yields in terms of fertilizer rate and rainfall, for the three different rotations and for four different initial soil values of mineral-N and available-P. Such was the lack of response to applied phosphate, that the most appropriate form of the regression, accounting for 58-83% of the variance, was found to be quadratic with respect to N-fertilizer rate and rainfall (including their interaction term) but to involve no P-fertilizer rate term at all.

A partial budget analysis showed that all the fertilizer treatments tested were profitable, but the optimum rate was 120 kg N/ha, without any phosphate where the wheat followed lentil or chickpea and with 40 kg P_2O_5/ha where the wheat followed water melons. An extension of the calculations to cover a range of relative fertilizer prices indicated that fertilizer use would still be beneficial and the benefit:cost ratio still exceed 40% for fertilizer N prices (per kg) up to 3, 4, and 6 times higher than that of grain for rainfall values of 250, 350 and 450 mm, respectively.

<u>Phosphate Studies (section 3.4)</u>

In a region in which most arable soils are naturally suboptimal in available phosphate, it is important to develop strategies for the management of soil phosphate that are effective and economic. The complexity of the task lies, on the one hand, in the chemical processes of phosphate in the soil (numerous transformations between dissolved, adsorbed and solid states), and, on the other, in the effects and interactions of crop growth and variable soil moisture conditions on the uptake of the dissolved form. We report here progress in three ongoing studies bearing on these problems.

The phosphate sorption characteristics of a soil control what happens to fertilizer phosphate added to that soil and, hence, control the size and frequency of fertilizer applications required to maintain phosphate availability at a concentration optimal for crop growth. Direct characterization of phosphate sorption for each and every soil is very laborious. We are therefore examining the possibility of characterizing WANA soils in respect of P-sorption indirectly from properties that are, or could be, easily measured in the laboratory on a routine basis.

Phosphate sorption data, obtained by standard techniques, for a heterogeneous group of 21 soils (from Syria, Jordan, Tunisia and Pakistan) have been related to analytical data from the same soils. Iron oxide content seems to be important. Citrate-bicarbonate-dithionite soluble Fe apparently accounted for 74% of the variance in phosphate sorbed from a solution at an equilibrium concentration of 0.2 mg P/litre (considered to be the soil-solution concentration required for optimum crop growth). Correlations with soil clay content were much poorer, although in a more homogeneous group of soils -- for which a high degree of covariance between clay and iron oxide might be expected -- clay content might provide an index. More work is needed to clarify the relationships between P sorption and iron oxides (and other soil properties) in different groups of soils.

Frequent heavy applications of fertilizer phosphate are wasteful and cause an unnecessary build-up of available phosphate in the soil. Trials started at Breda, Tel Hadya and Jindiress in 1986/87 aim to identify the rate of phosphate addition that maintains an availability of phosphate in the soil just adequate for optimal crop growth (assumed to be 7 ppm Olsen available-P). A range of soil available-P status was created initially by broadcasting and incorporating five fertilizer rates supplying between 0 and 200 kg P_2O_5/ha. Since then each one of those five treatments has been cropped annually under five different rates of annual P addition, 0-60 kg P_2O_5/ha. Yields and soil available-P status have been monitored annually.

High initial rates of phosphate do not seem to reduce the subsequent annual maintenance requirement very much. And site differences have been unexpectedly high. The maintenance rate is high at Jindiress (45 to 60+ kg P_2O_5/ha, depending on the size of the initial application), quite low at Breda (15-27 kg/ha) and least at Tel Hadya (0-25 kg/ha).

The third study is examining the interactive effect of phosphate fertilization and crop water use on yield and nutrient uptake by lentils, again at Breda, Tel Hadya and Jindiress. Somewhat surprisingly, data from two seasons (one wet, one dry) show that the effects of phosphate added in the previous season (to a wheat crop or fallow) may be equal or superior to those of a similarly-sized application drilled with the lentil seed. At both Tel Hadya and Jindiress, positive effects from newly added phosphate tended to be evident during early growth but had disappeared by harvest, at which time responses to phosphate residual from the previous season were more important. Only at Breda, the driest site and seriously P-deficient, did the newly added phosphate significantly increase yields of lentil grain and total dry matter.

<u>Soil and Cereal Crop Nitrogen Dynamics (section 3.5)</u>

There has been increasing interest recently both in the year-to-year dynamics of nitrogen in the soil, particularly the effects of rotation and of legumes in rotations, and in the quality of cereal straw for animal feed; and quality of cereal grain, especially its protein content, is always a concern of germplasm improvement. Several sets of results obtained this year, analyses of soil and plant materials taken from FRMP agronomic trials, demonstrate an urgent need to coordinate our thinking on these topics. There is abundant evidence of gross differences in grain and straw protein contents, resulting from differences in water supply (from rainfall, soil storage and supplemental irrigation), rotation and fertilizer use, that far exceed any likely genotypic difference.

The inter-relationships we have to consider are fairly complex. Thus, the availability of water and nitrogen this year affect not only this year's crop but will also usually have a knock-on effect on the growth conditions for next year's crop; and the quantity and quality of that crop will be the net product of both current and residual conditions. Last year we reported on crop productivity in a two-course rotation trial at Tel Hadya, growing wheat in rotation with fallow, summer crop (melon), vetch, lentil, chickpea, medic and wheat, with plots in the main wheat phase subdivided for both N-fertilizer rates and stubble-grazing management. Prior to planting the 1989/90 season crops, soils in this trial were sampled and analysed for mineral-N content. Rotation effects were highly significant. In plots that had carried wheat in 1988/89, there was a high content of soil mineral-N in the wheat-medic rotation but a low content in the wheat-fallow rotation. This was very likely due to differences in productivity in the preceding wheat crop. Wheat in rotation with fallow had removed about three times as much nitrogen as wheat in rotation with medic; and this, in turn, was due to 140 mm of soil-stored water available in the previously fallowed soil, following the very wet 1987/88 season.

The effect of a greater water supply, whether from rainfall, soil storage or supplemental irrigation, is to increase crop mass and total nitrogen uptake; but the two rarely increase proportionately. All else equal, dry matter production usually increases more strongly than does nitrogen uptake. The result is a lowered concentration of nitrogen in both grain and straw, sometimes referred to as the "dilution effect", i.e. a dilution of a relatively restricted amount of nitrogen within a larger mass of plant material. This was demonstrated this year in the analyses of grain from a trial in which wheat had been grown under four different rates of nitrogen fertilizer factorially combined with six rates of supplemental irrigation. Where no nitrogen was applied, with increasing irrigation rate, grain nitrogen decreased from 2.86 to 1.92% in Cham 1 and from 2.22 to 1.62% in Cham 4. This decrease was alleviated where nitrogen fertilizer was applied, and except at the highest irrigation rate the nitrogen rate that optimized grain production also maintained grain N percentage. Nevertheless, it is important to be aware that the use of supplemental irrigation to increase and stabilize yields can have implications for the nutritional quality of the product.

For barley, nitrogen concentration is an important quality index of both grain and straw. Samples from four treatments in each of the 75 trials in a four-year series of on-farm barley fertilizer trials, 1984-1988, for which the agronomic yield results were published previously, have been analysed for nitrogen content. Results show highly significant, negative linear regressions between the percentage nitrogen concentration of grain and straw and rainfall, in both fertilized and unfertilized treatments. Values calculated from these regressions show the magnitude of the 'quality' difference that may be imposed by rainfall:

	Fertilizer, kg/ha	N concentration, %	
	$N:P_2O_5$	150 mm	400 mm
Grain	0:0	2.16	1.34
	60:90	2.60	1.53
Straw	0:0	0.79	0.28
	60:90	1.00	0.33

The difference here from the case of supplementally irrigated wheat is that rainfall is largely unpredictable, and its effects on grain and straw nitrogen content are correspondingly difficult to allow for. One consolation is that where yields are restricted by low rainfall, the product -- grain and straw -- is, weight for weight, substantially more nutritious.

However desirable it may be to grow cereals in rotation with legumes, most barley is still grown either in rotation with fallow or, increasingly, with more barley. These two rotations, fallow-barley and barley-barley, are compared in long-term trials initiated in 1986 at Tel Hadya and Breda. Analyses of grain and straw samples from the third and fourth seasonal crops in these trials show that percentage nitrogen concentrations were greatly affected by rotation, fertilizer rate and season: grain values varied from 1.22 to 3.09%, and straw values from 0.40 to 1.94%. At each site, total rainfall was almost the same in the two seasons. The considerable seasonal differences in barley nitrogen concentration must therefore be attributed to other factors -- residual effects in the soil, perhaps, and rainfall distribution through the season. It is interesting that in this case higher nitrogen concentrations coincided with somewhat higher dry matter yields, showing that a 'dilution' effect cannot be automatically assumed.

Together, these various results prompt a number of thoughts:

- Emphasis on increasing output, at farm and national level, may well lead to a poorer quality product, to the detriment of the consumer.

- Breeding for higher quality, though desirable, may have almost negligible influence, given the major effects of management and environment. Do we know how genetic improvements in quality interact with these other, more powerful factors?

- Nitrogen concentration, though an important parameter of quality, is not the only one. Can we specify others? Do they also vary widely with growth conditions?

- One of our general aims is to seek ways to stabilize yield quantity. A second aim should be to stabilize yield quality. In fact, the two are quite closely linked, but no measure for improved stability can be very effective in a rainfed environment.

Supplemental irrigation, where available, offers a major management tool for stability, if fertilization is managed wisely for yield quantity and quality; and some control of nitrogen in rainfed crops should be possible through rotation and through a matching of nitrogen topdressings to the seasonal conditions.

Fallow Replacement Studies (section 3.6)

A trial established at Breda in 1987 compares four rotations, barley following medic pasture, lathyrus, fallow and barley. Barley yield data for the two dry seasons, 1988/89 and 1989/90, allow some early comparisons to be made of the effects of these different rotations on barley performance. In neither year were yields of barley following medic significantly different from those following lathyrus; and barley after either legume was significantly outyielded by barley after fallow (one season only) but did itself significantly outyield barley after barley (in both seasons). A topdressing of 20 kg N/ha tended to depress barley grain yields but to increase straw yields (in one season, significantly).

2.2 Project 2. Agroecological Characterization for Resource Management

Spatial Weather Generation: More Examples from a Case Study in the Aleppo Area, NW Syria (section 4.1)

A major thrust of the Agroecological Characterization project is the development and application of a spatial weather generator. Last year we reported its output with respect to rainfall and demonstrated the application of such output to the generation of maps of the probabilities of barley yield responses to fertilizer. This year we present techniques for generating temperatures, solar radiation and rainfall data simultaneously and give examples of output and its application to wheat and barley production.

Maps are used to depict, for the study area of northwest Syria, first parameters describing thermal and moisture conditions during early crop development; and, secondly, risks of night frosts and damagingly high daytime temperatures around the time of anthesis. Then from the application of generated temperature, radiation and rainfall data to the SIMTAG wheat growth model, using the genetic coefficients for Cham 1, it is shown how the development rate of the crop varies with environmental conditions across the area of study. Crop adaptation to environment appears to be good. Development is regulated to ensure the optimum evasion of both types of temperature stress, with anthesis late enough to reduce frost risk but also early enough to avoid heat damage.

Comparisons are made over 99 years between wheat yields simulated by the SIMTAG model, using generated weather data, and yields predicted from a multiple regression model based on data from 70 on-farm trials (see section 3.3) using only the generated rainfall data. Both models give maps of mean total dry matter and grain yield that are similar to the annual rainfall isohyets, and this may be taken to indicate the overriding importance of moisture as the growth-limiting factor in the area of the study.

Nevertheless, certain differences arose between the predictions of the two models. In particular, the SIMTAG model indicates higher yields than the regression model in wetter areas. Such differences are at least partly explicable in terms of the different assumptions of the models themselves. The simulation model is more sensitive to variations in the growing conditions than is the regression model, but grain and dry matter predictions from the regression model agree more closely than those of the simulation model with yield data from two relatively high-rainfall research stations. It is suspected that, under more humid conditions, SIMTAG overestimates the green area of Cham 1 and hence its eventual grain yield, but it appears to perform as well or better than the regression model in drier areas.

Finally, a comparison is made of the fertilizer efficiencies of barley and wheat, using similar regression models for each crop and one thousand years of generated rainfall data. Grain yield values obtained suggest that, under the production conditions chosen, barley uses fertilizer more efficiently than wheat everywhere except in the wetter part of zone 1. However, a price differential in favour of wheat, say 1 to 1.5, can push the line of relative advantage, wheat/barley, towards the drier end of zone 2, that is to the approximate point of transition between wheat and barley predominance.

Two Years Results from Diagnostic Agronomy Trials in the Mafraq Area, Northern Jordan (section 4.2)

The farm survey work in the Mafraq area (reported last year) was complemented by a series of diagnostic agronomy trials, conducted to explore possible options for the improved production of feed from arable land. They examined the potential under farmers' field conditions of nine fodder legume cultivars, an improved barley cultivar and various improved practices for barley production.

Results from two very dry seasons demonstrate that forage legumes can be productive in this environment. The mean dry matter yield at the grazing stage from the six driest sites (mean rainfall, 153 mm), 1.63 $\pm$ 0.19 t/ha, was, for the conditions, both remarkably high and stable across sites. Vicia narbonensis and Vicia ervillia were the most promising materials tested, particularly for grain production.

Fertilizer was the most important factor in the barley trials: 100 kg/ha of diammonium phosphate increased grain yields by more than 20% at six sites out of eight. Differences between the improved cultivar (WI 2269) and the local barley, Arabi Abiad, were negligible. There was a slight tendency for Arabi Abiad to produce more dry matter under low-yielding conditions, while IW 2269 produced 10% more at one relatively wet site but the eight-site means were virtually identical at 3.6 t/ha. Other factors tested were: herbicide, which gave no yield increase (but under conditions in which weeds were not a serious problem); and sowing method — drilling gave no advantage over broadcast sowing. Almost certainly, all such results are to a considerable degree season-dependent, and it is intended to continue this work for at least one more year.

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

Changes in agricultural production practices arising from economic pressures and rapidly expanding populations are threatening the fragile and limited natural resource base of the drier areas of WANA. Traditional systems of land use, well adapted to the environment, are becoming more intensified; cultivation is expanding into more and more marginal areas; and natural rangelands are being overgrazed. Understanding land users' perspectives and their rationale for actions that degrade resource is essential to the development of workable strategies for achieving conservation.

The Dryland Resource Management Project, initiated in 1990, with support from Ford Foundation, aims to produce a series of national case studies, each assessing an existing dry-area system of agricultural production and its impact on the natural resource base, with a view to formulating recommendations for improvement. Each case study will be conducted by a multidisciplinary team of national scientists, and their work will be viewed as the first phase of a process of developing sustainable production systems in dry areas. A preliminary meeting of case-study teams is planned for 1991, with a final workshop to present results about a year and a half later. Details of studies to be conducted in southern Jordan and southern Tunisia have already been finalized.

Jordan. Scientists from the University of Jordan and the National Center for Agricultural Research and Technology Transfer, building on existing research in this area, will study the resource situation, its use and productivity, and resource-users' perceptions in a tract of land at Lajoun in southern Jordan which includes a spectrum of land-use management systems: open rangeland (uncontrolled and subject to opportunistic incursions of barley planting), government range reserve, cooperative range reserve and arable (barley) farming.

Tunisia. A team from the Institut des Regions Arides, Medenine, will study resource management problems in a transect running from the Matmata mountains to the Jeffara plain in southern Tunisia. In the mountains, agriculture is supported by traditional water-harvesting techniques involving small dams and terraces. On the plain, recent increases in the area cultivated for barley production have reduced the available grazing area, encouraging overgrazing, the blowing of sand and the formation of dunes.

2.3 Project 3. Adoption and Impact of Technology

Adoption of Winter Sown Chickpeas in Syria: 1989/90 Season (section 5.1)

In over ten years of trials, winter chickpeas have consistently outyielded local Syrian spring-sown cultivars; and economic evaluations of on-farm trials and contract seed producers have shown winter chickpeas to be more profitable. The years immediately following the release of new varieties, Ghab 1 in 1982 and Ghab 2 in 1986, were devoted to seed multiplication, but by the start of the 1989/90 growing season stocks were sufficient to allow sale to the general public. At this time, the Socio-Economic Studies and Training Section of the Syrian ARC and ICARDA together organized a survey in Aleppo, Hama and Hassakeh provinces to assess the performance of winter-sown chickpeas under farmer conditions and to hear the farmers' view of their potential for adoption and positive impact.

Crop growth conditions in 1989/90 varied greatly between provinces. Hassakeh experienced relatively wet and mild weather, whereas in both Aleppo and Hama it was dry with frequent frosts until as late as March. This combination of low rainfall and late frosts, though curtailing disease and pest incidence, nonetheless made 1989/90 a very bad year for rainfed chickpeas in Hama and much of Aleppo. Differences in weather were reflected in yields. For winter-sown and spring-sown cultivars, mean yields (kg/ha) were respectively 1474 and 922 in Hassakeh, 847 and 578 in Aleppo but only 355 (both types) in Hama.

Farmers' intentions whether or not to continue growing winter chickpeas would appear to mirror the yields, and therefore the profits, they obtained. Those with higher yields were more likely to continue. Further, the survey showed that among farmers for whom this was at least their second year growing winter chickpeas, 47% intended to continue doing so; with those for whom this was their first season, the adoption rate was 42%. There were differences between provinces in these figures, at least largely reflecting the weather. Fully 78% of first year producers in Hama decided to abandon winter chickpea, but only 31% decided this way in Hassakeh.

Unquestionably, Syrian farmers are receptive to winter-sown chickpeas. Neither qualities such as seed size and marketability nor problems of resistance to disease and weed control are recognized as serious constraints to adoption (as they are in some other Mediterranean countries). However, annual weather variations, particularly drought and late frosts, could limit adoption in some areas, as the 1989/90 survey results clearly show.

Monitoring Winter Chickpea Adoption in Morocco (section 5.2)

Winter-sown chickpeas were introduced to Moroccan farmers through a program of farmer-managed trials initiated jointly by Moroccan institutions (DPV, INRA and DVRA) and ICARDA. In the first season, 1987/88, winter chickpeas significantly outyielded the local spring-sown varieties in most of the 33 trials covering 9 regions. However, in 1988/89, ascochyta blight ravaged a majority of the 104 trials planted across 19 regions; yields were much lower than in the previous year, and the winter varieties only marginally out-performed the local spring-planted check.

A survey was run concurrently with the trials program in four representative regions to gauge farmers' reactions to winter chickpeas and identify the principal constraints to adoption. The 1989 results (reported last year) showed that farmers appreciated the advantages of winter sowing but were worried about the possibly adverse market effect of small seed size and about greater weed-control costs. One purpose of the 1989 survey was to create a baseline against which to measure the adoption process. Now, from the continuation of the survey in 1990, some very preliminary calculations can be made of adoption rates.

Among 98 farmers in the baseline sample the adoption rate in 1990 was 43%. An indication of the effect of the 1988/89 blight is given by a comparison of adoption rates, including dis-adoption, in areas of low and high incidence. In Fes-Taounate and Safi (areas of low incidence) 62% of farmers with at last one year's experience had adopted, but in the highly afflicted areas of Khemisset and Settat the figure was 22%. One interesting result was that, even under harsh disease conditions, winter chickpea adopters obtained higher yields than those farmers participating in trials. Perhaps through better management derived from experience, some adopters were able to achieve a substantial yield advantage over spring chickpea even in Khemisset and Settat.

The high costs of hand-weeding were another problem, causing 9 out of 15 trials participants in Khemisset to suffer economic loss in 1989. It is hardly surprising that only 8% of these participants decided to adopt winter chickpeas in 1990. Fortunately, the situation in Safi and Fes-Taounate was much brighter.

Trials participants, adopters, and non-adopters in both survey years consistently stated the importance of providing new winter chickpea varieties with larger seeds. The reason is consumer preference in Morocco and the consequent effect on market prices. Efforts have accordingly been focussed on developing and releasing new, larger-seeded winter varieties. Whether the new varieties and better climatic conditions than those of 1989 will raise adoption rates will be discovered over the next few years, as the monitoring program for winter chickpea adoption in Morocco continues.

Supplemental Irrigation Project: from Research to Extension (section 5.3)

The research program of the supplemental irrigation of wheat, initiated by ICARDA and the Syrian Ministry of Agriculture and Agrarian Reform in

1985/86 included diagnostic surveys, basic research on crop-environment relationships, and on-farm research and demonstrations. Findings from all this work are summarized in the present report.

Farm surveys and various field trials, on-station and on-farm, over four seasons indicated that in zone 1 wheat requires between one and three irrigations, according to seasonal rainfall, and in zone 2, between 2 and 4 irrigations; but timing, frequency and volume of supplemental irrigation depend also on the distribution of the rainfall. Supplemental irrigation was required in all four seasons, even in the wettest season, 1987/87 (504 mm rainfall at Tel Hadya). Data from all sources suggest that wheat yields in zones 1 and 2 can be increased from an average of 1.5 t/ha to about 5 t/ha by supplementing rainfall with 600-1800 m^3/ha of irrigation water. Such irrigation also reduced yield fluctuation: CV's of the four-yield means were 21% and 23%, respectively, for the grain and straw of the supplemented crop compared with 70% and 56% for the rainfed crop.

Further, experimental results showed that a system of 'deficit irrigation' -- replenishing only part, not all, of the water-balance requirement and so subjecting the crop to some stress -- can be adopted without serious yield loss, at least in normal or wet seasons. In three out of four seasons at Tel Hadya, there were no significant yield differences between wheat crops receiving 33-40% of the water-balance requirement and those receiving 100%. The differences were significant only in the dry season of 1988/89.

The low supplemental irrigation requirement of wheat and its high water-use efficiency were reflected in high economic returns. One cubic meter of rain water produced, on average, 0.69 kg grain and 1.42 kg straw (equivalent, in 1988 prices, to a gross revenue of 3.78 SYP), whereas one cubic meter of supplemental irrigation yielded, on average, 2.97 kg grain and 2.30 kg straw (13.35 SYP); and profitability has increased considerably in the last two years, as the 1990 prices of wheat grain and straw are about double those of 1988 (giving a net revenue of 26.90 SYP per cubic meter of supplemental irrigation).

In fact, farmers' net revenue is often much less than the theoretical, due to lower yield levels and much higher irrigation rates. It has been found that farmers, on average, obtain yields of supplementally irrigated wheat 22% lower than those of research while they apply more than three times the optimum amount of water. So, although the supplemental irrigation of wheat has already become more attractive to farmers, there is potential for much greater profits: from water saving and better scheduling, from savings in other inputs and from higher yields.

After four years of on-station and on-farm research, it became necessary to verify, test and demonstrate supplemental irrigation techniques to different farming communities. To do this the Directorate of Agricultural Extension was included in the project, and nine field demonstration tests were implemented in 1989/90. They aimed to familiarize farmers with new and improved techniques; to test the practicability of scheduling irrigation according to water-balance methods; and to verify research findings on deficit irrigation in different agroclimatic and socioeconomic environments, comparing 50% with 100% of water-balance requirement. To achieve this, sites were equipped with evaporation pans and raingauges, and local extension agents were appropriately trained.

As 1989/90 was a dry season, yield differences between treatments were highly significant. Mean yields obtained by participating farmers were 553 kg/ha in rainfed plots, 4216 kg/ha in deficit irrigation treatments (50% water balance) and 5003 kg/ha in non-deficit irrigation treatments. These results supported research findings that 100% of water balance should be provided in dry seasons, because deficit irrigation may reduce profitability under such conditions. Even so, deficit irrigation increased yields over those of rainfed wheat by 680%; an extra investment of about 3000 SYP/ha in deficit irrigation produced an extra gross revenue of about 31,000 SYP/ha.

2.4 Training and Agrotechnology Transfer

See Chapter 6 of this Report.

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

Introduction

Our long-term goal in this project is to contribute to 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 seek to attain this goal through the following medium term objectives:

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

2. To develop strategies for the efficient management of soil, water and nutrients in agricultural 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 socioeconomic evaluation of problems of farming systems and of the adaptability of research results to strategies for resource management at the farm level. [Linked to Project 3]

3.1 Soil Cultivations

3.1.1 Tillage Trials at Tel Hadya

H. Harris

3.1.1.1 Introduction

Widespread introduction of mechanization in rainfed farming systems of West Asia and North Africa in the last forty years has resulted in quite dramatic changes in tillage practices. Whereas minimal tillage was practiced when only draught animals and simple implements were available, now, in many places, it has become standard practice to carry out primary tillage to depths of 20 to 30 cm with a disc or mouldboard plough. This operation usually takes place in the autumn before the onset of rain, and is followed by the use of offset discs (North Africa) or tyned cultivators (West Asia) to prepare a seedbed.

Three reasons often advanced for the deep ploughing are that it:

i) promotes more rapid infiltration of water to increase the quantity stored in the soil profile and reduce runoff.

ii) assists in weed control by burying weed seeds

iii) breaks up a compacted layer of soil and promotes root extension.

In North Africa weed control is the main reason given for the practice being widespread. In Syria and Jordan it is widely held that it is essential to plough deep before planting some crops, including legumes, to maximize their yield. For example, in northwest Syria, where three-course rotations of cereal-legume-summer crop are common in areas with mean rainfall of about 350 mm or more, deep ploughing is carried out prior to planting both the legume and summer-crop phases of the rotation. In these systems the legume is either chickpea or lentil, and the summer crop is often melon. Melon is sown in the spring (April) and grows on water stored in the profile during the winter rainy season. Traditionally, chickpea has also been sown in spring, and deep tillage repeated just before planting. However, that is now changing to late autumn or winter planting with the advent of cold- and disease-tolerant cultivars.

Swelling clay soils predominate in substantial production areas of the region. These soils crack extensively when dry. The cracks, which at the surface may be several centimeters wide, extend to depths of over one meter and form pathways for the rapid intake of water from early rains. As the soil swells with wetting, the cracks close at the surface and infiltration rates are slowed, although the cracks may remain at depth. Thorough wetting of the soil profile can cause as much as 10 cm vertical displacement of the soil surface.

We question the need for deep tillage on these soils. The practice is costly itself in both time and fuel use, and it creates the need for further tillage to prepare a seedbed. Since it is increasingly recognised that tillage destroys soil structure, it is also undoubtedly 'costly' in terms of the long-term maintenance of the soil resource. If tillage can be reduced economic and environmental benefits should result.

A trial was begun on Tel Hadya in the 1985/86 cropping season to test the general hypothesis that, on swelling clay soils, tillage, and production costs, can be reduced without causing a reduction in crop yields. We report here on the yields achieved in the five years of the trial, on the effect of tillage practices on the storage of water in the soil profile, and on crop water use.

3.1.1.2 Trial Details

The trial was established in long-running three-course crop rotations of cereal-legume-summer crop -- specifically, bread wheat-chickpea-water melon and durum wheat-lentil-water melon. The trial is laid out in two blocks with four replications, two of which are completely randomized within each block on a slightly sloping site. All three phases of the rotations are included. Plot size is 300 x 50 m, and the tillage treatments are superimposed in a split plot design, each tillage sub-plot being 300 x 12.5 m. The tillage treatments, based around farmers' practice, are: deep discing (20 cm); chisel ploughing (20 cm); sweep (ducksfoot) cultivation (8-10 cm); and zero tillage. The sequence of operations is shown in Table 3.1.1.

Table 3.1.1 The sequence of operations for each phase of three course rotations, Tel Hadya

Phase	Deep tillage	Sweep
Legume	Ploughed in autumn, before rain. Seedbed prepared with spike-toothed harrow and/or offset disc. Planted in late November-early December.	Cultivated in autumn after rain. Seedbed prepared with spike-toothed harrow. Planted in late November-early December.
Melon	Ploughed in autumn, before rain. Sweep cultivation in spring for planting, and in summer. Hand planted in mid-April.	Cultivated in autumn, after rain. Repeated in spring for planting, and in summer. Hand planted in mid-April.
Wheat	Seedbed prepared with spike-toothed harrow. Planted in mid- to late November.	As for deep tillage.

Zero-till plots are direct drilled.

In line with farmers' practice, water melon is planted only when the soil profile is wet to a depth of about 1 meter (approximately 100 mm of plant extractable water) or more in April. Unless at least this amount of water is present the crop is uneconomic and the land is fallowed.

3.1.1.3 Soil Water Measurements

Soil water has been monitored since 1986/87 by neutron scattering techniques. Two neutron probe access tubes per plot are permanently installed where the soil is uniformly deep in two of the four replicates. Neutron probe readings are taken at 15 cm intervals in the profile from 15 to 180 cm. The surface 15 cm is sampled gravimetrically by the taking of soil cores. Data are reported as 'stored soil water' which is calculated as the difference in the water content between the first measurement of the season and subsequent measured points during the crop cycle. We aim to begin measurements in September, before the opening rain, but this has not always been possible. In the data presented, negative values of 'stored soil water' arise when there was rain before the first measurement.

3.1.1.4 Seasonal Conditions

Conditions during the crop season have varied considerably (Figure 3.1.1). There have been two seasons with near average rainfall (1985/86; 1986/87), one wet one (1987/88), and two dry ones (1988/89; 1989/90). Winter temperatures in the first three seasons were not extreme, but in both 1988/89 and 1989/90 minimum temperatures in January and February were quite severe (Figure 3.1.2). A low of -8.9°C on March 17th 1990 was particularly damaging. Summer temperatures were extreme in the 1986/87 season.

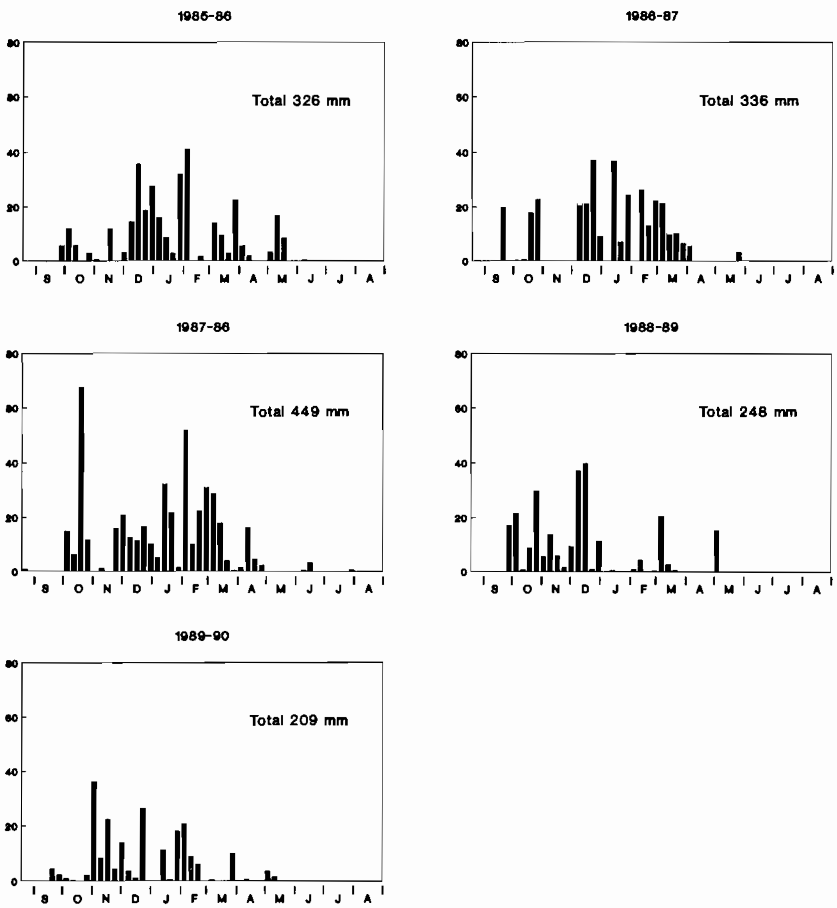


Figure 3.1.1 Weekly rainfall on Block B of the Tel Hadya Research Station in five crop seasons, 1985/86 to 1989/90

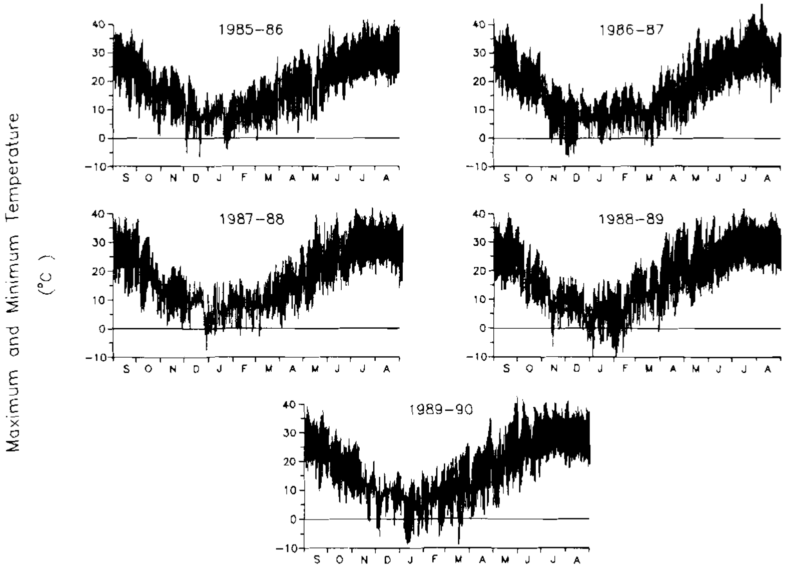


Figure 3.1.2 Daily maximum and minimum temperatures recorded at the Tel Hadya Meteorological Station in five crop seasons, 1985/86 to 1989/90

3.1.1.5 Crop Yields

There has been no significant effect of tillage type on the yield of legumes (Table 3.1.2). In watermelon, reduced yield from zero-till plots was due in large part to difficulties of plant establishment. Satisfactory techniques for planting into reserve moisture without tillage have yet to be devised. Significant differences in wheat amongst the tillage treatments show no real consistency although there is a trend for yield to be least from zero-till plots. This is undoubtedly due, in part, to the configuration of the zero-till planter which has 30 cm row spacing, whereas the other plots are sown with a local seed drill at 17.5 cm spacing.

Very poor performance by the legumes in 1988/89 and 1989/90 was only partly due to the dry conditions. The planting of legumes was delayed by rain during December in both years, and the cold during January and February delayed germination and emergence and resulted in

Table 3.1.2 Crop yields (kg/ha) in four tillage treatments within three-course rotations, Tel Hadya, 1985/86 to 1989/90

Crop	Season	Tillage Treatment 1 DD	CP	Df	ZT	Sign.	LSD
Chickpea	85/86	765	860	845	875	ns	
	86/87	860	880	935	915	ns	
	87/88	1230	1205	1220	1150	ns	
	88/89	220	225	245	285	ns	
	89/90	195	165	215	215	ns	
Lentil	85/86	745	795	760	790	ns	
	86/87	1265	1245	1235	1365	ns	
	87/88	660	705	635	595	ns	
	88/89	280	355	345	375	ns	
	89/90	60	105	70	60	ns	
Water melon [2&3]	85/86	1395	1810	1565	940	ns	
	86/87	2490	3070	3060	810	***	684
	87/88	7825	7280	7915	5095	***	1527
Bread wheat	85/86	2305	2245	2360	2195	ns	
	86/87	2275	2335	2440	2400	ns	
	87/88	4480	4420	4560	4255	ns	
	88/89	1725	1630	1815	1390	*	275
	89/90	1015	1340	1175	1395	***	104
Durum wheat	85/86	2720	2615	2620	2535	**	82
	86/87	2175	2390	2680	2235	*	306
	87/88	4255	4325	4090	3880	ns	
	88/89	1235	1250	1305	975	***	95
	89/90	1630	1775	1910	1600	ns	

1. DD = Deep Disc; CP = Chisel Plough; Df = Ducksfoot; ZT = Zero Till.
2. Yield of fresh fruit.
3. Water melon was not planted in 1988/89 or 1989/90.

poor crop stands; and in 1989/90 the late frost further severely reduced yields. Planting of lentil was also delayed in the wet year of 1987/88, so that in three of five years there has been some difficulty in implementing winter planting of legumes. This factor needs to be taken into account in assessing the potential impact of changed practices.

3.1.1.6 Tillage and Soil Water Storage

Measured soil water profiles (expressed as 'stored soil water') at the point of maximum recharge for each tillage treatment and season are shown in Figures 3.1.3a,b,c,d. These data are for the legume plots, but those for water melon plots, fallowed during the rainy season, are very similar. In both 1986/87 and 1988/89 the total quantity stored is greater than that shown as there was rain before the first sampling (61 mm and 45 mm in the two years respectively) and water stored from these events is not included in the amounts illustrated (Figure 3.1.3a and c).

The depth of wetting in the four years varied from >180 cm in 1987/88 to only 60 cm in 1989/90. The pattern amongst the tillage treatments is not wholly consistent. It does appear clear, however, that there is no increased storage of water due to deep tillage. If anything the trend is in the opposite direction, and, in the wet year especially, reduced or zero tillage lead to more water being stored at depth in the profile (Figure 3.1.3b).

Lack of difference between the tillage treatments in the top 15 cm of the profiles is probably due largely to the sampling method and regime. Because of the variability of the water content of gravimetric samples it is difficult to detect differences. Also, because the soil is very sticky when wet, sampling is deferred until the surface is dry enough not to adhere to the feet. This prevents damage to the soil surface and the crop around access tubes during sampling, but reduces our capability to monitor closely the pattern of water loss from the surface layer.

As with the maximum profiles, there is no consistency among the tillage treatments in the extent to which the soil is dried by the time of harvest. Negative values at the top of the profile in 1986/87 and 1988/89 represent water stored at the time of the first sampling. There is nothing in the data to suggest that root development differed with the tillage treatment.

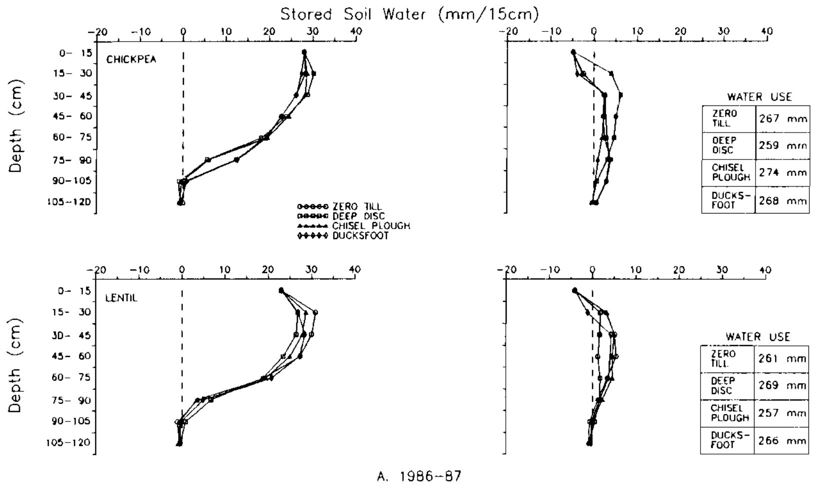


Figure 3.1.3a Stored water in the soil profile at maximum recharge (left) and harvest (right) in four tillage treatments. Data are for legume crops in four seasons: a) 1986/87; b) 1987/88; c) 1988/89; d) 1989/90. Total water use for the crop season is also shown

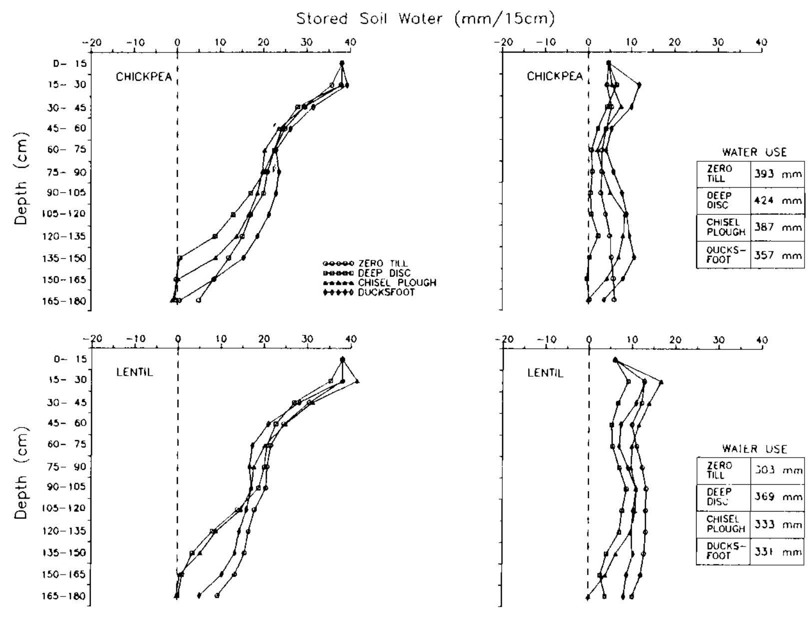
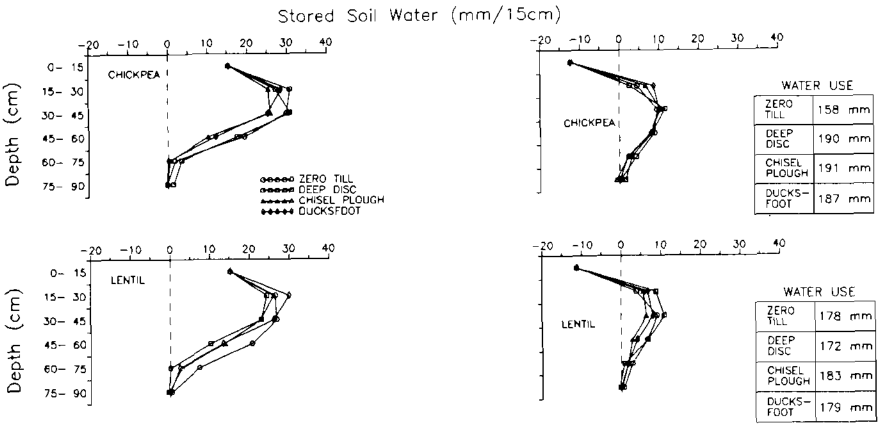
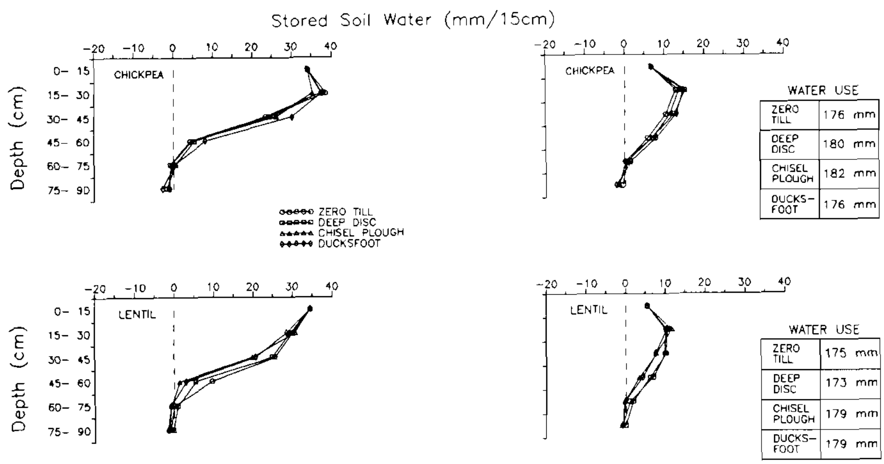


Figure 3.1.3b Stored water in the soil profile at maximum recharge (left) and harvest (right) in four tillage treatments. Data are for legume crops in four seasons: a) 1986/87; b) 1987/88; c) 1988/89; d) 1989/90. Total water use for the crop season is also shown



C. 1988-89

Figure 3.1.3c Stored water in the soil profile at maximum recharge (left) and harvest (right) in four tillage treatments. Data are for legume crops in four seasons: a) 1986/87; b) 1987/88; c) 1988/89; d) 1989/90. Total water use for the crop season is also shown



D. 1989-90

Figure 3.1.3d Stored water in the soil profile at maximum recharge (left) and harvest (right) in four tillage treatments. Data are for legume crops in four seasons: a) 1986/87; b) 1987/88; c) 1988/89; d) 1989/90. Total water use for the crop season is also shown

Some water apparently remained at harvest in all treatments. This is a recurring pattern in lentil, but differs from observations elsewhere for chickpea (FRMP 1990). The poor chickpea crops in the two drought seasons were unable to fully use water which could have been expected to be available to them. Both crops were affected by nematodes (Pratylenchus thornei and Meloidogyne artiellia), which increasingly are seen as a problem of winter sowing of chickpea and may affect the uptake of water.

3.1.1.7 Cumulative Water Use

Patterns of water use by the legumes during crop growth are shown in Figure 3.1.4a,b. As would be expected from the above, there is little consistency in the data. Apparent greater use with deep discing in the wet year is the inverse of the water storage pattern. Rates of use during the spring period of most rapid crop growth are very similar in all tillage treatments within each season.

3.1.1.8 Conclusion

The data available so far on both crop yields and water relations give no indication that there is any advantage to be gained from deep tillage in the conditions of this trial.

Obviously, as with all field trials, the results are both site and season specific. Almost certainly they cannot be expected to be relevant to other soil types. There may also be situations where results would differ on similar soils. For example, on sites with greater slopes, increased surface roughness of deep tillage due to deep discing (or mouldboard ploughing) may help to retain water on the surface for longer following high intensity rainfall and thereby increase infiltration and reduce runoff. However, we do feel that the use of deep tillage should be critically reappraised where it is practiced on flat or gently sloping land where swelling clay soils predominate.

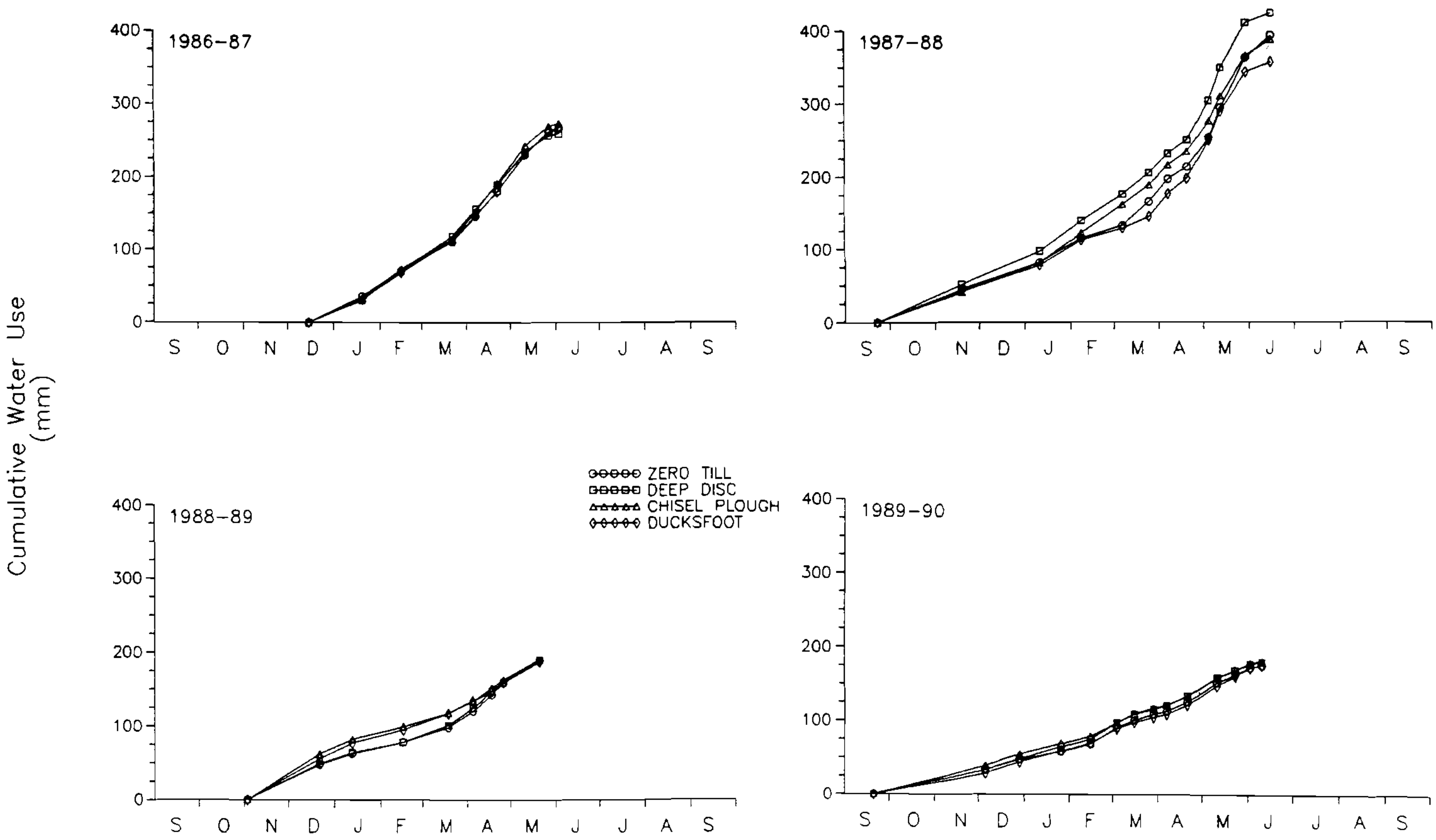


Figure 3.1.4a Cumulative water use by legume crops in four tillage treatments and four crop seasons at Tel Hadya. a) Chickpea, and b) Lentil

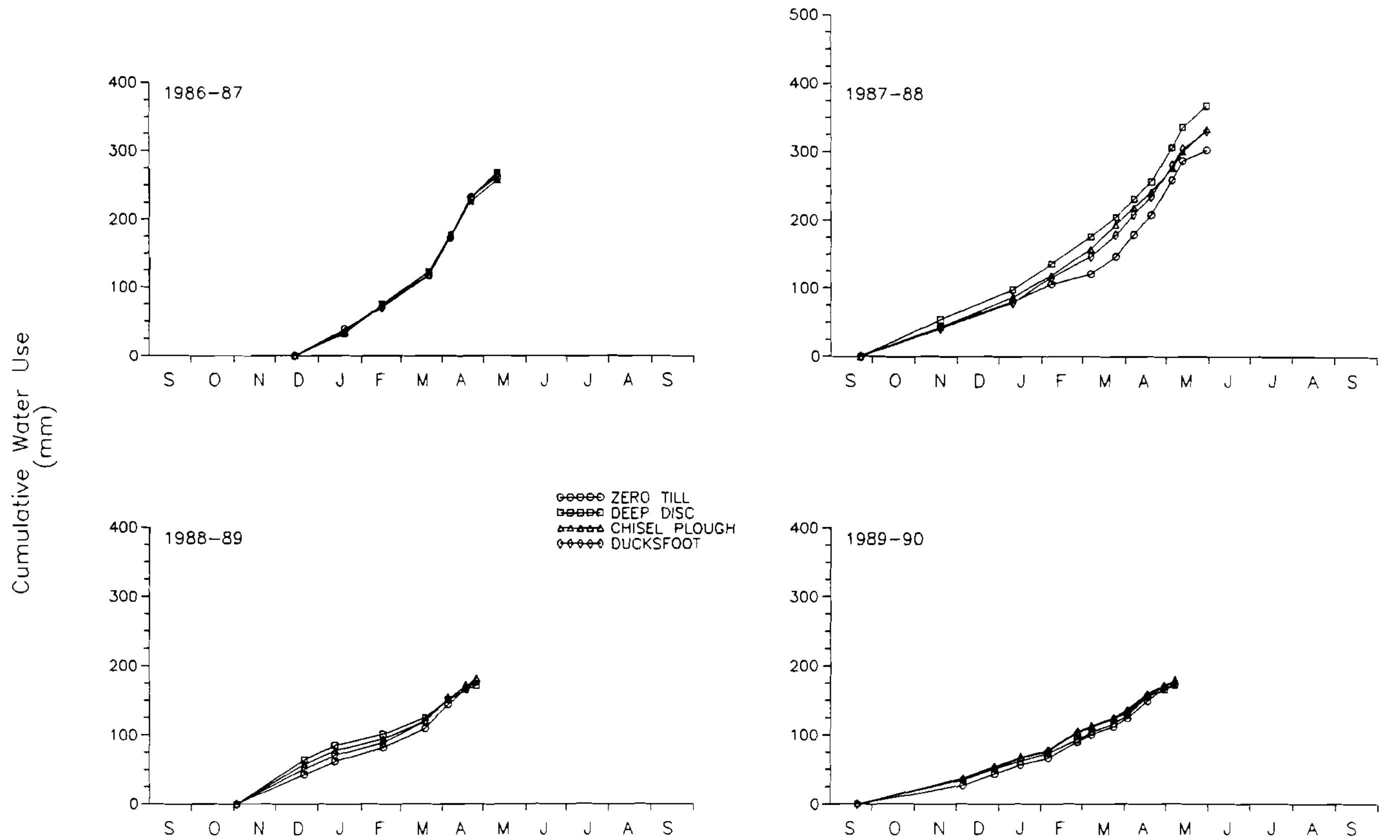


Figure 3.1.4b Cumulative water use by legume crops in four tillage treatments and four crop seasons at Tel Hadya. a) Chickpea, and b) Lentil

3.1.2 A Study on the Possibility of Mechanical Weed Control in Winter Sown Chickpea

M. Pala

3.1.2.1 Introduction

Food legumes are important for a nutritionally well-balanced diet, especially for lower-income people who cannot afford much meat. About 8.7 million ha are sown to chickpea worldwide and 24% of the total chickpea area is found in ICARDA's region (FAO 1988). The crop is grown in the more favorable environments where annual rainfall exceeds 400 mm. However, local varieties are susceptible to cold and ascochyta blight, a disease favored by cold and moist weather conditions. Chickpeas in WANA, are, therefore, traditionally planted in the spring (late February-May depending on the locality), and they grow on soil moisture stored during the winter months. Most of the plant development takes place under conditions of increasing temperature, day length and aridity, with a diminishing soil moisture supply and a decreasing probability of any significant precipitation.

A potential increase in chickpea production in WANA is possible through a shift in the date of sowing from spring to early winter through the use of an ascochyta blight tolerant cultivar such as ILC 482, which was released as Ghab 1 in Syria in 1986, and with other names in some of the other countries of the region. This ensures a better use of the available soil moisture. Winter planting and increased water-use efficiency result in a larger vegetative frame capable of supporting a bigger reproductive structure, earlier harvest and increased productivity (Hawtin 1975; Saxena 1980, 1984; Keatinge and Cooper 1983, 1984).

However, a winter-sown crop is likely to face a more serious weed problem than a spring crop, as the preparatory tillage for spring sowing results in nearly weed-free conditions. An earlier study (Pala and Mazid, not published yet) showed that weed infestation was five times greater in a winter than in a spring crop (1174 vs 274 kg/ha of weed dry matter across 8 trial sites). Other studies also reported high losses in grain yield due to weeds in several chickpea producing countries (Ahlawat et al. 1981; ICARDA 1981; Yadav et al. 1983; Katare et al. 1983; Shaktawat and Sharma 1986; Bhan and Kukula 1987; Solh and Pala 1988), and losses have been estimated to range from 23 to 54% in West Asia (ICARDA 1981).

Traditionally, weeds are controlled by hand hoeing during early growth, hand pulling for fodder, or a combination of both. All weeding systems have been shown to improve yields but, since rising costs impose increasing limitations on hand-weeding, chemical control merits consideration. Several herbicides have been tested in different countries, as well as at ICARDA stations, for control effectiveness and crop tolerance. A pre-emergence application of terbutryne with pronamide appears promising for broad-spectrum control.

However, the most effective herbicides are for pre-emergence application; and farmers, in general, tend not to adopt any methodology which would show its effect only later in the season, because of unpredictable weather conditions for crop growth. Local availability of the chemicals is also another source of uncertainty.

Mechanical weed control is a feasible alternative, but it requires special and carefully set equipment as well as improved crop sowing geometry. However, it is not impossible. Research was therefore initiated in 1988/89 to compare the feasibility of mechanical weed control to that of other methods. Then it was extended in the 1989/90 season to different ecological conditions. The objectives were to assess the effectiveness of different weed control methods in winter-sown chickpeas and to assess the main effects and interactions of preparatory tillage, crop sowing geometry and weed control measures on crop yield and weed competition.

3.1.2.2 Materials and Methods

A preliminary trial was conducted at Tel Hadya in 1988/89 under 219 mm of total seasonal (Oct-May) rainfall. Then, in 1989/90, there were trials at three sites, which received 153, 233 and 337 mm rainfall, to examine the main effects and interactions of depth of tillage (deep discing + cultivation vs cultivation), crop sowing geometry (35 cm row spacing vs 17.5-52.5 cm paired rows) and weed control methods (weedy check, hand-weeding, herbicide use and inter-row cultivation).

Experimental design was split plot with sub-plots factorially arranged, with 3 replicates. Plot sizes were 5 x 12.5 m. Ghab 1, improved at ICARDA as a cold- and ascochyta-tolerant cultivar was sown at the rate of 50 seeds per m^2 (app. 140 kg seed per ha) with a local drill adjusted for chickpea. The herbicide used was a tank-mix of terbutryne (2.0 kg/ha) and pronamide (0.5 kg/ha), applied pre-emergence. Hand-weeding was done twice, starting 40 days after planting. A mechanical brush (not available locally) was used for inter-row cultivation at the very early growth stage (at the first hand-weeding time) in the 35 cm row spacing treatment, and a local ducksfoot cultivator was used in the 17.5-52.5 cm pair-row planting treatment.

3.1.2.3 Results and Discussions

The preliminary trial (1988/89) was conducted under extremely dry conditions, with only 219 mm rainfall, compared with a long-term seasonal average of about 335 mm. Although there was no weed infestation to affect crop performance, it was important to examine whether the mechanical weed control method caused any crop damage. There were no significant yield differences between treatments. Herbicide application caused some slight crop damage, but this was not significantly reflected in the grain yield (Table 3.1.3).

In the second season, three sites with different rainfall amounts provided a better picture for the future of the work (Tables 3.1.4 and 3.1.5). There were no significant interactions between treatments.

Deep tillage decreased weed population, compared to shallow tillage, significantly at Afrin, nonsignificantly at Tel Hadya and

Table 3.1.3 The effects of tillage, row spacing and weed control methods on chickpea total dry matter and grain yield (kg/ha) at Tel Hadya, 1988/89

	TDM	Grain
Tillage		
Deep	1267	532
Shallow	1254	499
LSD (.05)	NS	NS
SE (±)	110	40
Row spacing		
35 cm	1289	527
17.5-52.5 cm	1232	504
LSD (.05)	NS	NS
SE (±)	52	25
Weed control	**	
Check	1358	533
Weeding	1351	553
Herbicide	1103	477
Mechanical	1229	498
LSD (.05)	150	NS
SE (±)	73	35
General mean	1260	516

* p<0.05 ** p<0.01

showed no difference at Hamdaniyeh; but grain yield was not affected by tillage at any of the sites.

Narrow row spacing (35 cm) tended to decrease weed density at each site, with a significant reduction in weed dry matter at Hamdaniyeh. However, grain yield was not affected by sowing geometry, indicating a potential for weed control by inter-row cultivation; and comparing weed control methods it seems that herbicide application was no more effective than mechanical control in promoting grain production or reducing weed dry matter. However, the comparison needs to continue several more years to include some more favorable seasons.

Table 3.1.4 The effects of tillage, row spacing and weed control methods on chickpea grain yield at three sites, 1989/90

	Chickpea grain yield (kg/ha)			
	Afrin	Tel Hadya	Hamdaniyeh	Mean
Tillage				
Deep	1905	425	200	843
Shallow	1903	538	265	902
LSD (.05)	NS	NS	NS	
SE (±)	61	60	47	
Row spacing				
		*		
35 cm	1872	511	220	868
17.5-52.5 cm	1936	452	245	878
LSD (.05)	NS	47	NS	
SE (±)	69	23	37	
Weed control				
		**	*	
Check	1936	414	128	826
Weeding	1953	565	247	921
Herbicide	1749	378	308	811
Mechanical	1979	569	248	932
LSD (.05)	NS	67	106	
SE (±)	97	33	60	
General Mean	1904	481	232	872

* p<0.05 **p>0.01

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Table 3.1.5 The effects of tillage, row spacing and weed control methods on total dry matter of weeds at three sites, 1989/90

	Total dry matter of weeds (kg/ha)			
	Afrin	Tel Hadya	Hamdaniyeh	Mean
Tillage	*			
Deep	123	123	226	157
Shallow	260	192	222	213
LSD (.05)	NS	NS	NS	
SE (±)	55	42	49	
Row spacing			*	
35 cm	181	148	197	175
17.5-52.5 cm	168	167	251	195
LSD (.05)	NS	NS	41	
SE (±)	49	34	20	
Weed control		*	**	
Check	256	232	351	280
Weeding	95	94	155	115
Herbicide	175	200	196	190
Mechanical	193	103	196	157
LSD (.05)	NS	97	57	
SE (±)	70	48	34	
General Mean	174	157	235	185

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

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3.2 Supplemental Irrigation

3.2.1 Screening Barley Genotypes for Response to Supplemental Irrigation

Ciro D'Acunzo, FAO Associate Expert, and
Eugene Perrier

3.2.1.1 Introduction

Irrigation is termed "supplemental" when it is used in situations where the crop in question can be grown by natural rainfall alone but where additional water stabilizes and improves yields. In addition, supplemental irrigation ensures conditions suitable for using high inputs, such as high yielding varieties, fertilizers, herbicides, etc., irrespective of seasonal rainfall.

Trials have been implemented in Aleppo province over three seasons to compare different barley genotypes under supplemental irrigation and to select those showing, along with a good environmental adaptation, a favorable grain and straw yield response to additional water.

The first two seasons results have been reported previously (D'Acunzo and Perrier 1990). Here, we report the third season with references, as necessary, to the previous findings.

3.2.1.2 Trial Management

An experimental field was chosen adjacent to Breda station. The soil is a typical Calciorthid. Profile data are summarized in Table 3.2.1. The average bulk density of the profile was 1.13. Total available water-holding capacity was 238 mm/m, and the pF desorption curve is shown in Figure 3.2.1.

Table 3.2.1 Average pH, $CaCO_3$ and organic matter contents, and granulometry of the Breda soil

	Depth (cm)				
	0-20	20-40	40-60	60-90	90-120
pH	8.3	8.2	8.3	8.4	8.5
$CaCO_3$, %	30.0	31.0	37.1	56.5	50
Organic matter, %	1.17	0.74	0.58	0.35	0.25
Clay, %	30	40	44	44	39
Silt, %	45	40.5	41	41	42
Sand, %	25	19.5	15	15	19

Because the agronomic history of the field was unknown, a heavy, uniform fertilizer application was used to eliminate possible fertility variations due to previous management: 250 kg P_2O_5/ha and 100 kg N/ha.

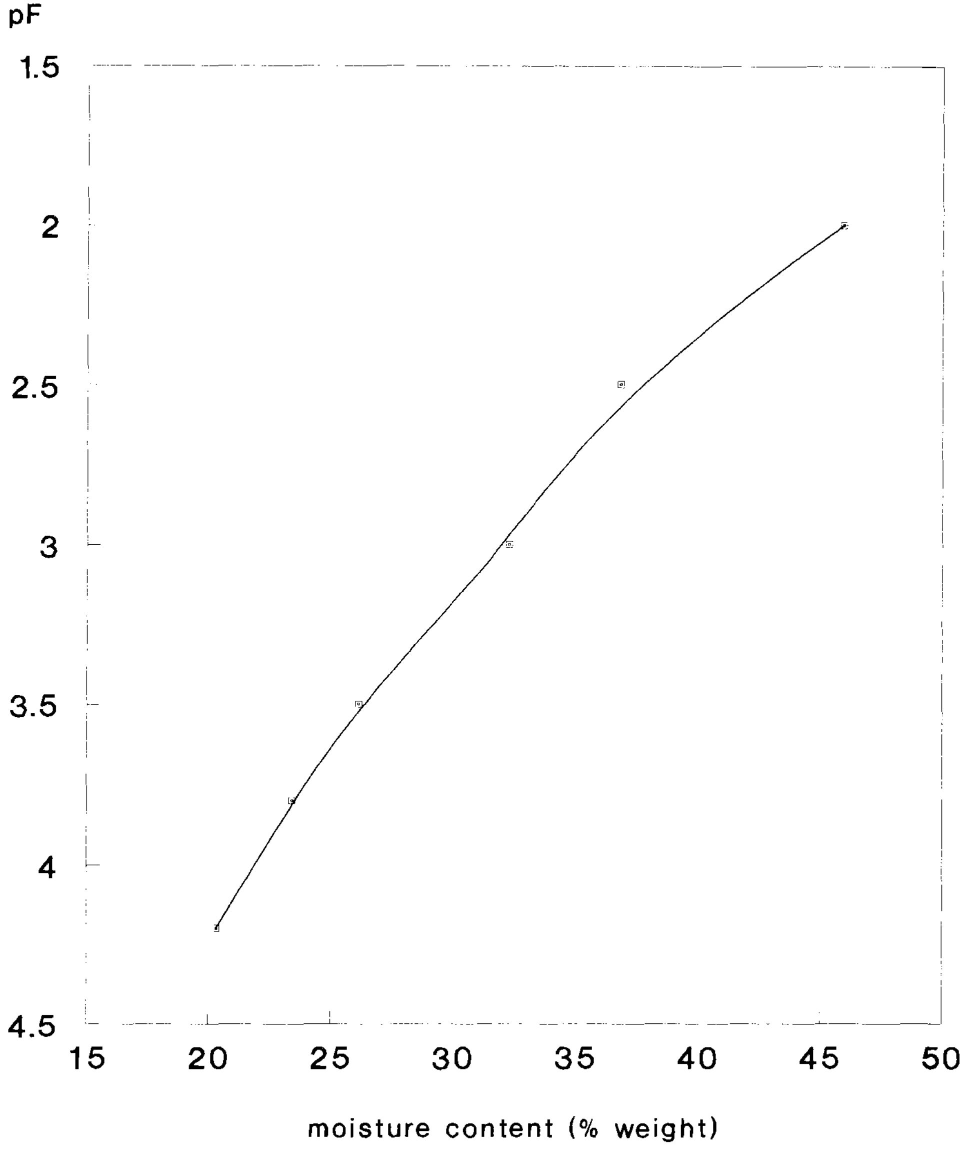


Figure 3.2.1 pF desorption curve for Breda soil

The latter N application was split: half at planting and half at the start of stem elongation. Carbofuran (10%) was applied before planting. Seeding was done on November 21 and 22, 1989 using an Øyjord seed drill on a seed bed previously prepared by plowing and harrowing. Three replicates were planted, each in two parts, one each side of the linesource. The barley entries were planted in strips 24.4 m long and 2.4 m wide, with a 20 cm row-spacing, arranged perpendicularly to the linesource. Each strip was subdivided into six sub-plots to carry six irrigation rates; the sub-plot for treatment I-0 (rainfed) was 9.15 m long, the other five were each 3.05 m long. A large border was planted around the field.

Herbicides were used to control weeds. Brominal plus was applied at a rate of 1.5 l/ha on February 18 and Illoxan at 2.5 l/ha on March 6. There were also three hand-weedings.

A linesource sprinkler system was used to obtain a continuously varying irrigation (Hanks et al. 1976). This comprised sprinklers (Rain Bird model 30 H) on stands 1 m tall and 6 m apart.

Monitoring the amount of water applied on each side of the linesource is important in this kind of system, because distribution can be affected by wind and by the pressure in the water main. For this purpose, catchment cans were placed at 1.5 m intervals in rows replicated three times on each side of the linesource. These cans were held by rings on metal stands so that it was possible to adjust them to plant height to avoid crop interference. Volumes of water were measured after every application and the amounts of irrigation received were calculated.

3.2.1.3 Experimental Design

The experiment used an adapted split-block design with 3 replicates. Thirty-seven barley genotypes of different origin were entered (Table 3.2.2). They included 15 genotypes already tested at Boueidar in the 1988/89 season (D'Acunzo and Perrier 1990). Field positions of the genotypes were randomized, but those of the irrigation treatments were not because of the constraints of the system.

Table 3.2.2 Names and/or pedigrees of the barley genotypes composing the pool under test at the Breda station during the 1989/90 season

Ref. no.	Name or pedigree	Group
1	Arizona 5908/Aths/Lignee 640 (ICB81-0210-1AP-9AP-0AP)	HR
2	Ctn/RM1508/10876-2/3/70-22423/BI	HR
3	Sawsan/Lignee 527//Arar	HR
4	Arizona 5908/Athns//Asse/3/F208-74	HR
5	Lignee 527/Sawsan//Bc	HR
6	Mari/Aths*2/3/Apm/IB65//B6	HR
7	Cr. 115/Por/Bc/3/Api/CM67/4/Man//Api/CM67	HR
8	Aths/Lignee 686	HR
9	SP(Gh)/Apro//Cal.mr/3/Apm/IB65/4/DL71/Strain 205	HR
10	Aths/Bc	HR
11	BKF Maguelone 1604/Badia//Arar	HR
12	Mari/Aths*2//Ky63-1294	MR
13	WI 2291	LR
14	Rihane-03	HR
15	Arabi Abiad	LR
16	SLB 39/10	LR
17	SLB 39/60	LR
18	Arta	LR
19	Faiz	HR
20	Esp/1808-4L//WI 2291	MR
21	MPYT169-1Y	HR
22	WI 2269	LR
23	Iris/Mopal's	HR
24	Matnan	HR
25	Assala-04	HR
26	AS46/Ath*2	HR
27	CI08887/CI05761	HR
28	Roho/Mazurka	HR
29	Roho/Delisa	HR
30	Arr/Esp	HR
31	Emir/Apm	HR
32	Wi 2198/Emir	HR
33	Soufara-02	HR
34	Salmas	HR
35	Alger/Ceres	HR
36	Mr 25-84/Attiki	MR
37	WI 2291/WI 2269	LR

HR = adapted to high rainfall regimes
MR = adapted to medium rainfall regimes
LR = adapted to low rainfall regimes

The supplemental irrigation treatments, defined when the water deficit in the active root zone of the wet treatment was 50% of the available water (Doneen and Westcost 1984), were:

1) I-0: rainfed (no irrigation)
2) I-1: irrigated to replace 11% of the deficit;
3) I-2: irrigated to replace 33% of the deficit;
4) I-3: irrigated to replace 57% of the deficit;
5) I-4: irrigated to replace 81% of the deficit; and
6) I-5: irrigated to replace 100% of the deficit.

Soil moisture at sowing was adequate for germination. Subsequent scheduling of irrigation was by water balance methods (Perrier and Salkini 1989), employing Class A pan evaporation measurements and verified using gravimetric soil samples and neutron probe measurements.

3.2.1.4 Weather Conditions 1989/90

Figure 3.2.2 shows mean minimum and maximum temperatures on a 10-day basis from the beginning of November to the end of May. There were 47 frost events, of which 4 occurred during the period of March 10 to 20. On March 17 and 18, minimum temperatures recorded were -7°C and -7.2°C respectively. These two frosts caused severe damage to the crop that was then at the rapid growth stage.

Monthly accumulated rainfall is shown in Figure 3.2.3. The seasonal total was 184.6 mm (compared with an average seasonal rainfall for this site of about 280 mm). Distribution was good until March 1. After that, there was no significant rainfall, and the water balance started to show a rapid depletion of the already small reserves of water in the soil. During that period three irrigations were applied, although the third irrigation was not completed as per the proposed schedule due to problems of water availability. The level of the water table from which supplies were being drawn fell by 10.2 m during April and by a further 7.2 m during May. Table 3.2.3 details the total quantities of water applied in each irrigation treatment and values of total water use.

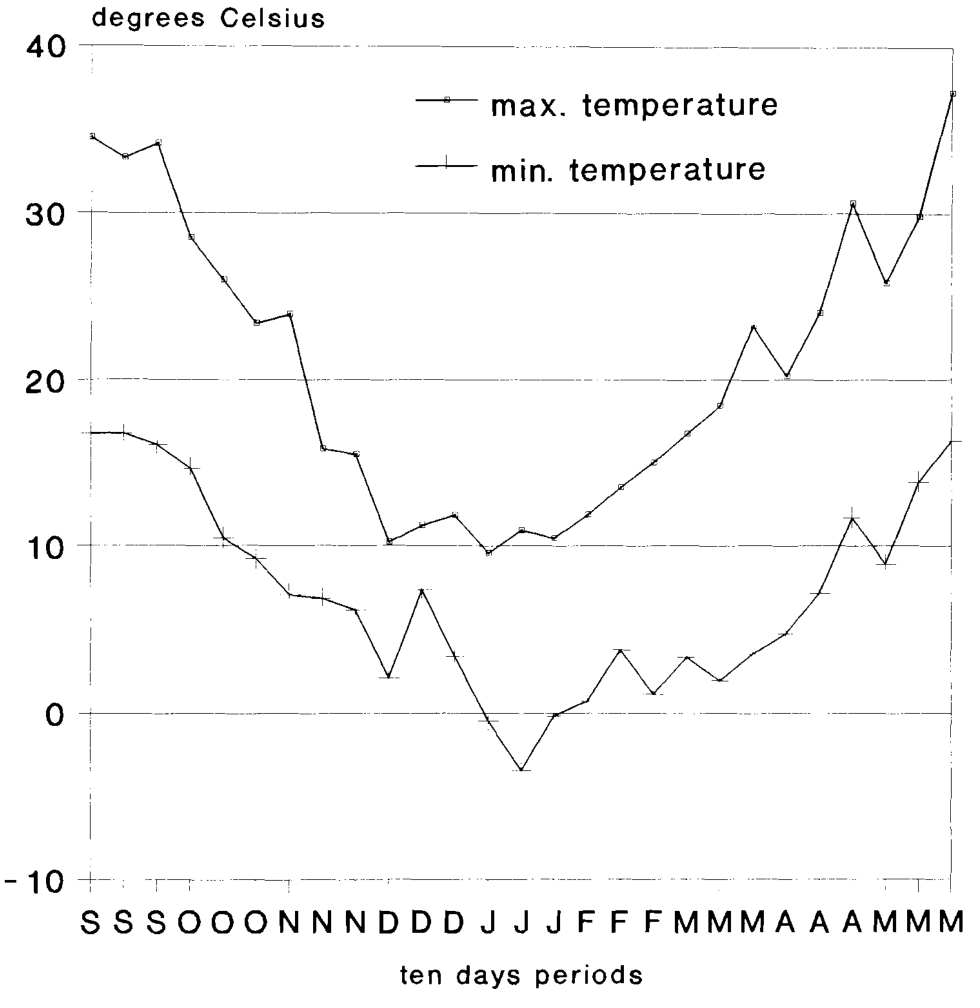


Figure 3.2.2 Minimum and maximum temperatures on a ten-days basis at Breda, September 1989 to May 1990

Figure 3.2.4 shows the active root:shoot pattern of growth of the reference genotype, Rihane-03. This pattern differs from the one found the previous season at Boueidar (D'Acunzo and Perrier 1990), but resembles that described for wheat at Tel Hadya by Perrier and Salkini (1989). Root growth was shallower than in 1988/89. Chemico-physical properties of the soil were involved. Electrical conductivity values increased steeply with increasing depth (Figure 3.2.5), and mechanical resistance to penetration was experienced during coring.

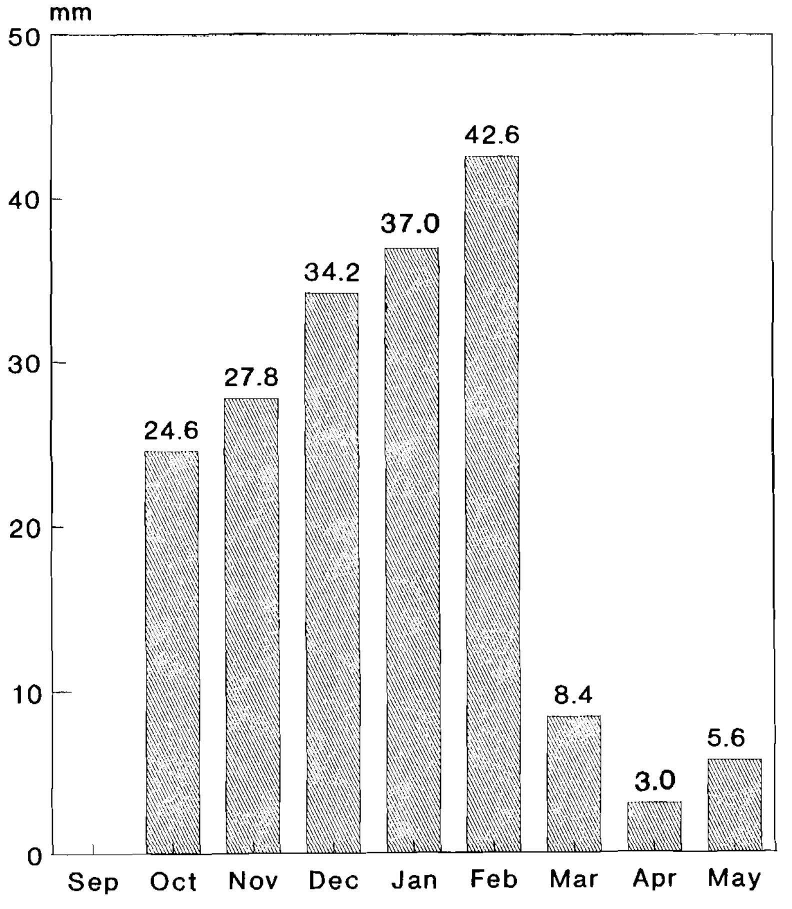


Figure 3.2.3 Monthly accumulated rainfall at Breda, 1989/90

Table 3.2.3 Soil water balance, seasonal rainfall, total supplemental irrigation receipt and total water use at each supplemental irrigation level (mm)

Irrigation levels	Soil water balance *	Rainfall	Supplemental irrigation	Total use
I-0	-17.14	184.6	0.0	201.7
I-1	-16.69	184.6	25.0	226.3
I-2	-16.45	184.6	76.1	277.2
I-3	-1.72	184.6	131.8	318.2
I-4	5.86	184.6	186.4	365.1
I-5	35.33	184.6	232.4	381.7

* (Soil water content at planting - soil water content at harvest)

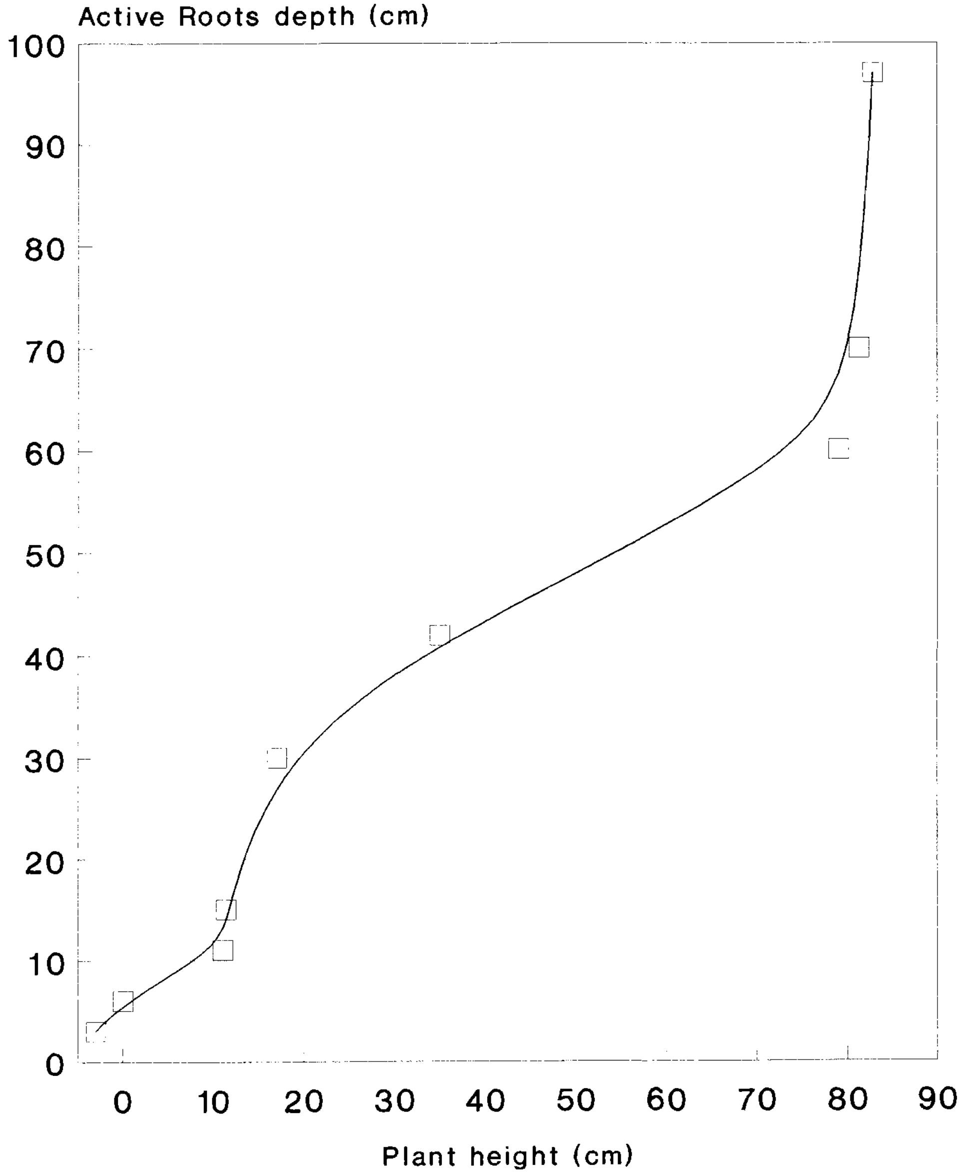


Figure 3.2.4 Relationship between active root depth and plant height of Rihane-03, Breda, 1989/90

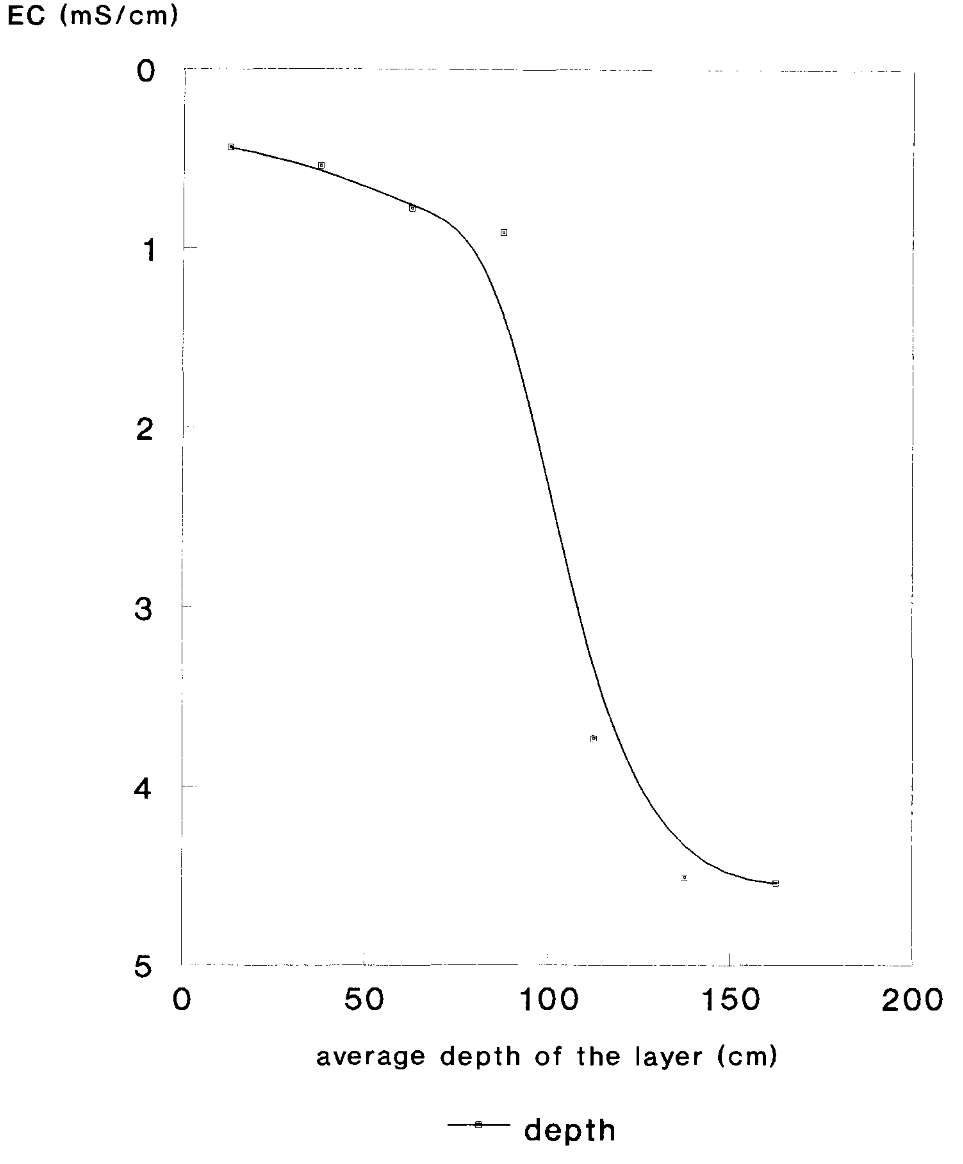


Figure 3.2.5 Average EC (mS/cm) for the different layers of profile (interval 25 cm) at the experimental field at Breda

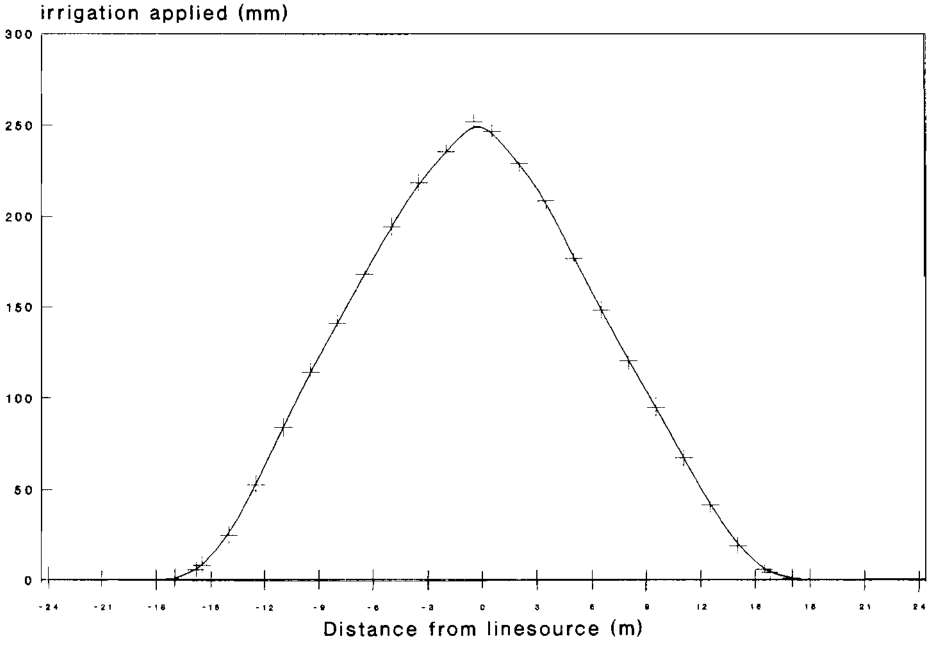


Figure 3.2.6 Pattern of water distribution of the line source used at Breda (average of three replications).

The pattern of water application is shown in Figure 3.2.6. The amount of water applied was very highly correlated with the distance from the linesource and, thus, to the planned irrigation levels. An average coefficient of determination (R^2) of 0.986 was found for the two sides of the linesource. This means that the linesource sprinkler system, when used under optimal wind conditions, is the easiest method for obtaining continuous variation of irrigation.

The pattern of water demand of the reference genotype, based on Class A pan evaporation, is shown in Figure 3.2.7, which plots the crop coefficient (kc) against days from January 1, 1990. This illustrates the increase in water demand that follows stem elongation.

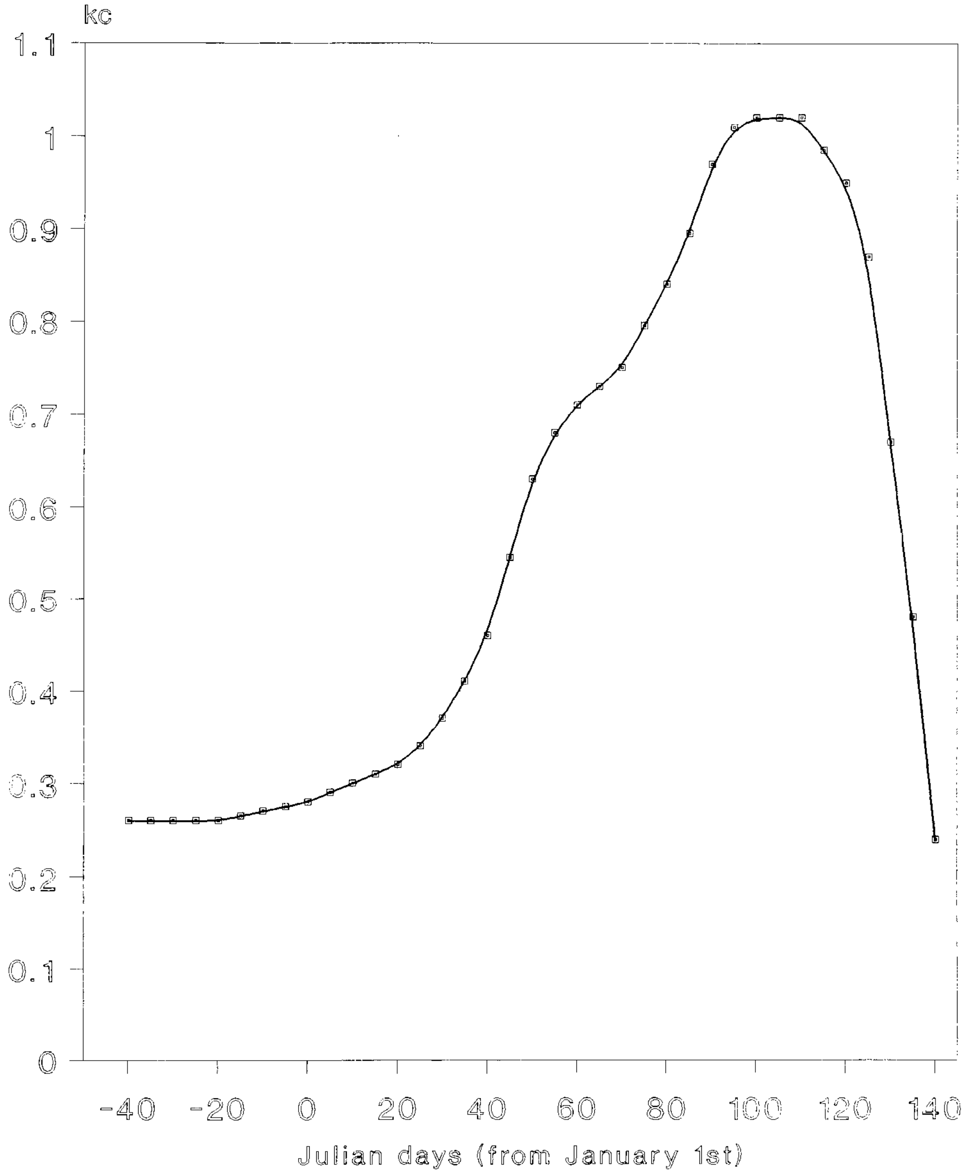


Figure 3.2.7 Barley crop coefficient relative to Breda and to 1989/90 season

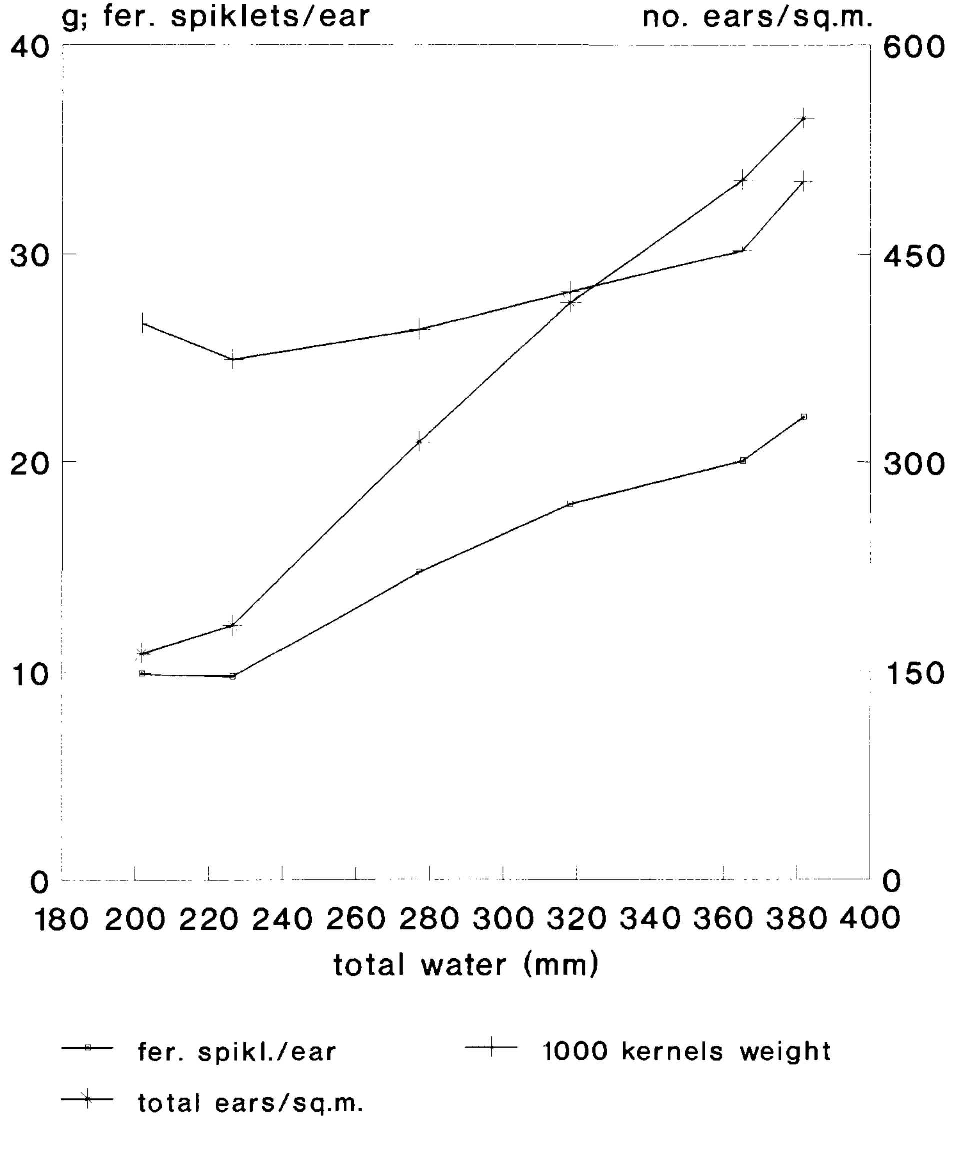
3.2.1.5 Results

All the data needed to estimate the effects of the different supplemental irrigation treatments were measured (lodging, biomass, no. of ears/m^2, grain yield, 1000 kernels weight, no. of fertile spiklets/ear) or calculated (water-use efficiency indexes).

The systematic arrangement of supplemental irrigation levels has the disadvantage for statistical analysis that it provides no valid estimates of error for the irrigation main effect or for comparisons involving the irrigation effect (Cochran and Cox 1957; Federer 1955). However, the ANOVA provides valid error terms for testing barley genotypes and their interactions with supplemental irrigation levels (Hanks et al. 1980); and since the distribution of water on both sides of the linesource did not differ significantively, the ANOVA table is simpler than that proposed by Hanks et al. (1980).

The factors of yield, numbers of ears/m^2 and of fertile spiklets/ear and 1000-grain weights, seemed to be related to irrigation level (Figure 3.2.8); and these contributed to increased grain yields. However, an inflection can be noticed in different variables between the I-0 level to I-1 levels. This may be due to the late frosts.

Grain yields showed a dramatic increase from I-0 to I-5 irrigation levels, because of the drought during the year and the consequent necessity to apply more water than might normally be required for supplemental irrigation at this location (Table 3.2.4). Interaction between barley genotypes and supplemental irrigation was significant.



<u>Figure 3.2.8</u> Yield determinants. Average of the barley genotypes, Breda 1988/90 season

Table 3.2.4 Mean grain yields (t/ha at field moisture content*)

Ref. No.	Supplemental irrigation treatments						Means
	I-0	I-1	I-2	I-3	I-4	I-5	
1	0.66	0.72	1.23	2.02	2.80	4.35	1.96
2	0.51	0.67	1.21	1.78	2.29	2.67	1.52
3	0.24	0.41	0.91	1.60	2.60	3.85	1.60
4	0.44	0.69	0.99	1.77	2.55	3.21	1.61
5	0.33	0.24	0.95	1.80	2.39	3.51	1.54
6	0.34	0.38	0.94	1.70	2.10	3.07	1.42
7	0.73	0.71	1.23	1.98	2.39	2.69	1.62
8	0.22	0.28	1.12	1.85	2.81	3.44	1.62
9	0.13	0.31	0.76	1.58	2.21	3.48	1.41
10	0.59	0.53	1.10	1.73	2.54	3.50	1.66
11	0.13	0.18	0.71	1.47	2.55	3.31	1.39
12	0.65	0.47	1.26	1.84	2.60	3.23	1.68
13	0.43	0.32	0.75	1.51	2.36	3.05	1.40
14	0.72	0.95	1.20	2.76	3.96	6.17	2.63
15	0.29	0.42	0.68	0.99	1.32	1.86	0.92
16	0.65	0.74	1.32	1.33	1.86	2.02	1.32
17	1.02	1.04	1.76	2.58	2.94	3.54	2.15
18	0.37	0.26	0.98	1.76	2.27	2.68	1.39
19	0.40	0.49	1.13	1.71	2.70	3.54	1.66
20	0.22	0.10	0.60	1.39	2.39	3.50	1.37
21	0.38	0.27	0.69	1.60	2.60	3.58	1.52
22	0.61	0.51	1.09	1.71	2.56	3.46	1.66
23	0.30	0.33	0.82	1.60	2.56	3.30	1.49
24	0.42	0.42	0.88	2.06	2.89	4.02	1.78
25	0.41	0.57	1.23	2.07	3.32	4.67	2.05
26	0.07	0.10	0.56	1.41	1.92	3.14	1.20
27	0.37	0.67	1.02	1.64	3.26	3.52	1.75
28	0.65	0.78	1.58	2.45	2.36	2.54	1.73
29	0.43	0.37	0.96	1.64	2.15	2.74	1.38
30	0.35	0.15	0.86	1.57	2.69	3.71	1.56
31	0.35	0.22	0.62	1.34	2.19	3.27	1.33
32	0.15	0.23	0.76	1.26	1.94	2.84	1.20
33	0.21	0.09	0.59	1.63	2.09	3.37	1.33
34	0.16	0.20	0.86	1.44	2.37	2.34	1.23
35	0.13	0.27	0.52	1.74	2.92	4.49	1.68
36	0.30	0.28	0.49	0.87	1.89	3.03	1.14
37	0.66	0.74	1.21	1.93	2.08	3.39	1.67
Means	0.40	0.43	0.96	1.70	2.48	3.37	

LSD 0.05 = 0.14 between two genotypes means

LSD 0.05 = 1.03 between two genotypes means at the same level of supplemental irrigation

* approximately 5%

Rihane-03 was the highest-yielding genotype, with 0.72 t/ha under rainfed conditions increasing to 6.17 t/ha in I-5. Its linear regression coefficient for yield on water use, b = 27 kg grain/mm, was significantly greater than those of 29 of the other 36 genotypes (Table 3.2.5). Lowest-yielding genotypes were Arabi Abiad and SLB 39/10, with regression coefficients (7.8 and 7.6 kg grain/mm) significantly lower than those of almost all the other genotypes.

Figure 3.2.9 shows the regression curves of the genotypes grouped according to rainfall-regime adaptation (Table 3.2.2). The HR group differs significantly from the LR group, with the MR group not significantly different from either of them.

Table 3.2.6 reports total biomass production for each genotype and irrigation level. Major factors underlying the increases in biomass production with increasing levels of irrigation were increases in plant height, from less than 30 cm in I-0 to over 70 cm in I-5, and in the number of tillers per square meter.

Values of water-use efficiency, WUE, (Bolton 1981; Cooper 1983) were computed from:

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

where biomass is the total weight of the harvested plants (not including roots and crowns). The highest WUE's were achieved by Rihane-03 and Alger/Ceres in I-5 (Table 3.2.7). WUE values for grain only show that Rihane-03 produced 16.2 kg/ha of grain at I-5 level per millimeter of total water use. Other efficient genotypes were Matnan, Assala-04, CI08887/CI05761 and Alger/Ceres.

Table 3.2.5 Regression coefficient, intercepts, and coefficients of determination for grain yield vs total water

Genotype	b slope	a intercept	R^2	n
1	0.01825	-3.42098	0.6468	18
2	0.01189	-1.98732	0.6733	18
3	0.01821	-3.77319	0.7222	18
4	0.01469	-2.72553	0.7335	18
5	0.01681	-3.42457	0.8384	18
6	0.01414	-2.75050	0.5916	18
7	0.01151	-1.77536	0.5731	18
8	0.01786	-3.65097	0.6898	18
9	0.01669	-3.51412	0.6386	18
10	0.01536	-2.86746	0.6096	18
11	0.01730	-3.71480	0.7885	18
12	0.01457	-2.62244	0.4640	18
13	0.01458	-2.90039	0.7877	18
14	0.02701	-5.34263	0.7916	18
15	0.00780	-1.37473	0.6341	18
16	0.00759	-0.91794	0.7416	18
17	0.01404	-1.99786	0.7285	18
18	0.01357	-2.61386	0.6972	18
19	0.01663	-3.24361	0.5373	18
20	0.01743	-3.77424	0.7497	18
21	0.01735	-3.59766	0.8064	18
22	0.01528	-2.85085	0.7849	18
23	0.01637	-3.34584	0.8511	18
24	0.01925	-3.89803	0.7638	18
25	0.02193	-4.42296	0.7839	18
26	0.01556	-3.38818	0.7779	18
27	0.01770	-3.47569	0.7153	18
28	0.01123	-1.58569	0.4184	18
29	0.01284	-2.40762	0.7152	18
30	0.01825	-3.82756	0.7028	18
31	0.01530	-3.18388	0.6962	18
32	0.01376	-2.86274	0.7473	18
33	0.01647	-3.52975	0.8151	18
34	0.01344	-2.73895	0.7791	18
35	0.02226	-4.89025	0.8009	18
36	0.01345	-2.82510	0.7065	18
37	0.01312	-2.20125	0.7254	18

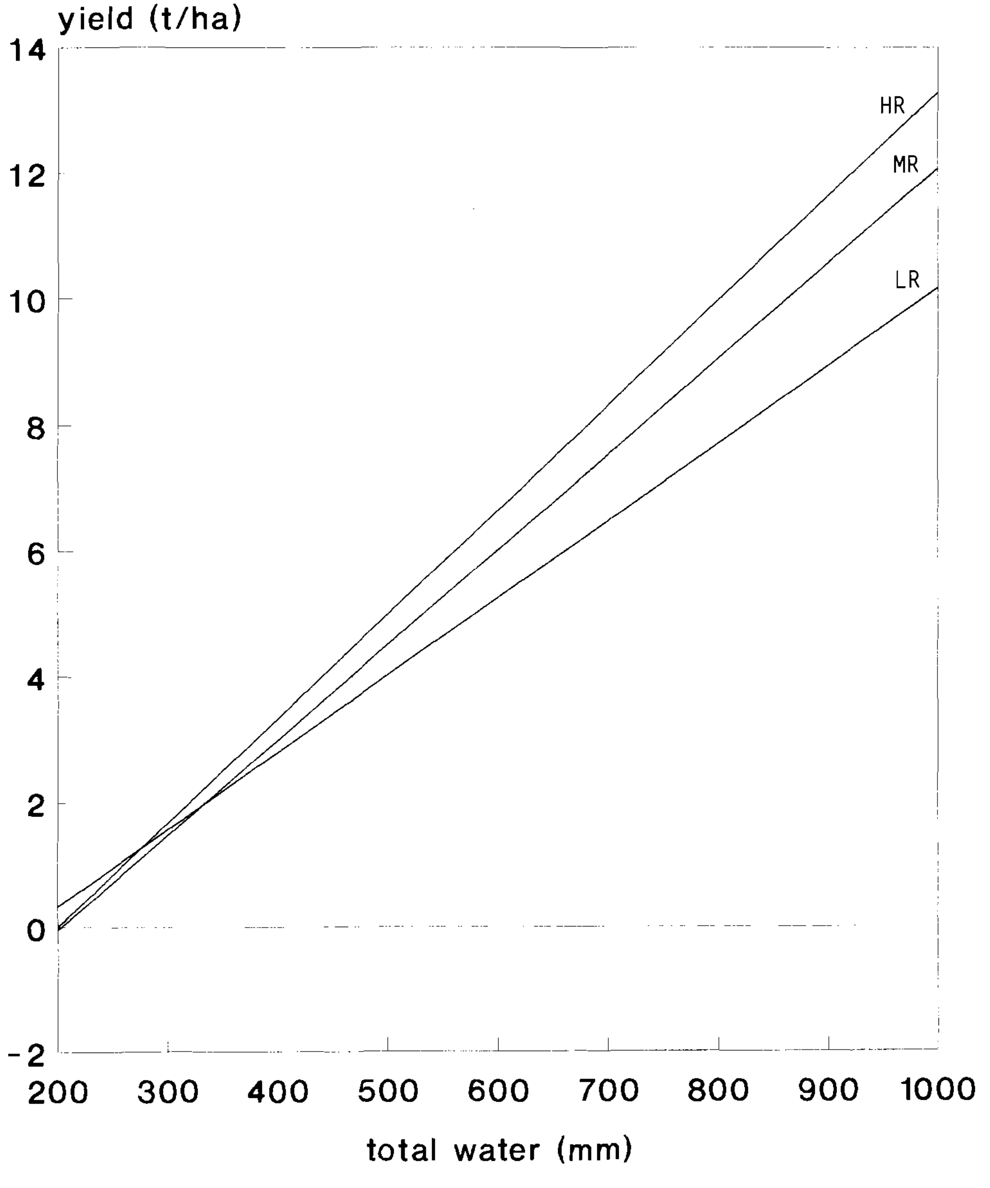


Figure 3.2.9 Linear regression for barley groups vs. total water, Breda, 1989/90 season

Table 3.2.6 Mean biomass harvested (t/ha at field moisture content).

Ref. No.	Supplemental irrigation treatments						Means
	I-0	I-1	I-2	I-3	I-4	I-5	
1	2.25	2.17	3.08	4.89	6.34	8.67	4.57
2	1.94	2.10	3.03	4.44	5.59	5.83	3.82
3	1.86	2.41	3.32	4.56	6.42	8.17	4.46
4	1.70	1.97	2.86	4.64	5.52	6.96	3.94
5	1.83	1.73	2.88	4.40	5.98	7.71	4.09
6	2.22	2.26	3.54	4.95	5.67	6.95	4.26
7	2.53	2.41	3.39	4.85	5.63	5.79	4.10
8	2.04	2.22	4.18	5.28	6.61	7.84	4.69
9	1.73	1.84	3.24	5.15	6.14	8.12	4.37
10	2.48	2.44	3.67	4.88	6.32	8.22	4.67
11	1.32	1.54	2.74	4.42	6.26	7.57	3.98
12	2.57	2.20	3.57	4.80	6.25	7.18	4.43
13	2.55	2.18	2.86	4.45	6.38	7.75	4.36
14	2.27	2.59	4.01	5.90	8.53	12.28	5.93
15	1.89	1.87	2.60	3.59	4.85	6.29	3.52
16	2.45	2.47	3.34	3.55	4.40	5.27	3.58
17	3.38	3.02	4.39	5.74	6.65	8.17	5.23
18	2.08	1.96	3.12	4.36	5.45	5.87	3.81
19	1.82	1.98	3.26	4.52	6.21	7.18	4.16
20	1.58	1.36	2.68	4.50	6.26	8.13	4.09
21	1.95	1.78	2.65	4.43	6.37	8.08	4.21
22	2.42	2.19	3.07	4.16	5.83	7.36	4.17
23	2.18	2.41	3.52	5.37	6.77	8.01	4.71
24	2.09	2.16	2.91	4.93	6.48	8.51	4.51
25	2.11	2.45	4.04	5.73	7.47	9.50	5.22
26	1.47	1.72	2.73	4.50	5.33	7.58	3.89
27	1.43	1.93	3.03	3.80	5.84	7.11	3.86
28	2.25	2.41	4.05	5.49	5.51	6.53	4.37
29	2.14	1.97	3.20	4.43	5.98	6.52	4.04
30	2.09	2.02	3.43	5.23	6.66	8.48	4.65
31	1.81	1.79	2.55	4.11	6.18	7.85	4.05
32	1.55	1.54	2.60	3.85	5.16	6.53	3.54
33	1.83	1.27	2.73	4.72	5.96	7.28	3.96
34	1.82	1.73	3.03	4.40	6.38	6.40	3.96
35	2.02	2.27	3.07	5.18	7.61	10.56	5.12
36	1.86	1.96	2.54	3.61	4.96	6.08	3.50
37	2.33	2.40	3.39	4.70	5.49	7.40	4.29
Means	2.05	2.06	3.18	4.64	6.10	7.57	

LSD 0.05 = 0.25 between two genotypes means
LSD 0.05 = 1.83 between two genotypes means at the same level of supplemental irrigation

Table 3.2.7 Water-use efficiency indexes (kg biomass/ha/mm) for the different genotypes and supplemental irrigation treatments

Ref. No.	Supplemental irrigation treatments						Means
	I-0	I-1	I-2	I-3	I-4	I-5	
1	11.16	9.58	11.10	15.38	17.37	22.71	14.55
2	9.66	9.30	10.92	13.96	15.31	15.28	12.40
3	9.21	10.64	11.99	14.35	17.59	21.42	14.20
4	8.40	8.71	10.31	14.59	15.10	18.24	12.56
5	9.07	7.59	10.41	13.84	16.39	20.20	12.91
6	10.98	9.98	12.76	15.56	15.53	18.21	13.84
7	12.53	10.63	12.25	15.25	15.41	15.16	13.54
8	10.09	9.81	15.07	16.59	18.11	20.53	15.03
9	8.59	8.12	11.70	16.18	16.82	21.27	13.78
10	12.30	10.77	13.26	15.33	17.32	21.54	15.09
11	6.54	6.80	9.88	13.89	17.15	19.84	12.35
12	12.73	9.73	12.87	15.09	17.13	18.81	14.39
13	12.66	9.62	10.33	13.97	17.48	20.31	14.06
14	11.24	11.43	14.45	18.55	23.35	32.17	18.53
15	9.35	8.28	9.39	11.28	13.30	16.47	11.35
16	12.15	10.91	12.05	11.16	12.04	13.81	12.02
17	16.75	13.36	15.84	18.06	18.22	21.42	17.27
18	10.33	8.66	11.25	13.71	14.93	15.38	12.37
19	9.02	8.76	11.77	14.23	17.01	18.80	13.27
20	7.84	6.01	9.68	14.14	17.16	21.31	12.69
21	9.67	7.87	9.55	13.93	17.44	21.16	13.27
22	12.01	9.69	11.07	13.06	15.97	19.28	13.51
23	10.82	10.63	12.69	16.88	18.54	20.98	15.09
24	10.33	9.53	10.51	15.48	17.74	22.31	14.32
25	10.44	10.80	14.57	18.01	20.46	24.89	16.53
26	7.30	7.59	9.84	14.14	14.60	19.87	12.22
27	7.11	8.54	10.95	11.94	15.99	18.64	12.19
28	11.17	10.66	14.62	17.27	15.08	17.10	14.32
29	10.62	8.68	11.55	13.91	16.39	17.07	13.04
30	10.36	8.92	12.36	16.45	18.24	22.22	14.76
31	8.98	7.90	9.20	12.90	16.91	20.56	12.74
32	7.68	6.80	9.38	12.10	14.14	17.11	11.20
33	9.06	5.60	9.83	14.83	16.32	19.07	12.45
34	9.02	7.66	10.93	13.82	17.46	16.77	12.61
35	10.03	10.02	11.07	16.28	20.85	27.66	15.98
36	9.20	8.64	9.16	11.34	13.60	15.92	11.31
37	11.54	10.61	12.24	14.78	15.04	19.38	13.93
Means	10.16	9.16	11.54	14.66	16.69	19.81	

LSD 0.05 = 0.66 between two genotypes means
LSD 0.05 = 5.32 between two genotypes means at the same level of supplemental irrigation

3.2.1.6 Conclusions

Rihane-03 confirmed its previous high-yielding performance at higher levels of supplemental irrigation. In this season, it significantly outyielded all the other genotypes tested at the I-5 level. At lower irrigation levels, however, this superiority was less marked, and yields of Assala-04 (HR), SLB 39/60 (LR), CI08887/CI05761 (HR), Matnan (HR), Alger/Ceres (HR), WI2291/1I2269 (LR), genotypes 2, 4, 5, 7, 8 (all HR), and 12 (MR) approached or equalled those of Rihane-03.

Within this group, SLB 39/60 is particularly interesting. At I-0, I-1, and I-2 levels, it appreciably (though not significantly) outyielded all other genotypes including Rihane-03.

It is concluded that genotypes adapted to high rainfall regimes should be introduced in those situations where supplemental irrigation of barley is feasible, because the local varieties are unable to make efficient use of the extra water. Where water availability is restricted, SLB 39/60 should be considered, because it seems to be able to utilize limited amounts of water to produce grain more efficiently than other genotypes.

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3.2.2 The Performance of Durum and Bread Wheat Genotypes under Different Moisture Regimes

M. Pala

3.2.2.1 Introduction

Winter cereals contribute a large proportion to the total food production of West Asia and North Africa (WANA). Bread wheat ranks first in production among cereal crops; approximately 82% of total wheat production is bread wheat (CP 1987, p. 64). However, durum wheat is, after barley, the most important crop in lower rainfall areas. Given the importance of the wheat crop generally and an increasing interest to use limited water supplies efficiently as supplemental irrigation to increase and stabilize yields, it was decided to test selected wheat genotypes under different moisture regimes. This was done using the linesource sprinkler system in cooperation with Cereal Program scientists, Drs Nachit (durum wheat breeder) and Ortiz Ferrara (bread wheat breeder).

Durum and bread wheat genotypes (20 each) were sown with a plot drill at 125 kg seed/ha in 17.5 cm rows perpendicular to the linesource system. There were six rates of water application, a rainfed (W0) control treatment and five irrigation levels: approximately 20 (W1), 40 (W2), 60 (W3), 80 (W4) and 100% (W5) of water balance requirement.

Total seasonal water receipts were 233, 258, 309, 362, 424 and 486 mm, respectively. Experimental design was split plot with 3 replicates. Sub-plot size was 2.1 m x 3.0 m for W1 to W5 and 2.1 m x 9 m for W0.

3.2.2.2 Results and Discussion

The season 1989/90 was very dry with total of 233 mm rainfall, received mainly between November and February (83% of total season). Therefore, early crop development was very good and produced much straw, but this was not reflected in grain development in W0 and W1 treatments, which suffered from drought. Severe frost in mid-March was also a factor.

Data for yield and quality parameters and water-use efficiency (WUE) indexes of durum and bread wheat genotypes are given in Tables 3.2.8 and 3.2.9. There were no significant interactions between genotypes and water regimes in relation to any yield or other associated parameters. Individual genotypes are therefore compared for their mean performances across the six rates of water application.

Durum Wheat Performance. Mean grain yield, straw yield, 1000 kernel weight, grain protein %, TDM, and grain WUE's were significantly different between genotypes (Table 3.2.8). Minimum grain yield was 1571 kg/ha (DRM2), 639 kg/ha less than the maximum of 2210 kg/ha (Om Rabi 3). Minimum and maximum values were 4105-5232 kg/ha for straw, 31.6-38.8 g for 1000 kernel weight, 10.0-13.1% for grain protein, 16.8-19.42 kg/ha/mm for TDM water use and 3.81-5.54 kg/ha/mm for grain water-use efficiency. Genotypes 3, 9, 11, 13, 15 (Om Rabi 5), 19 (Om Rabi 3) and 20 (Belikh 2) gave the highest mean grain yields (more than 2.0 t/ha). Cham 1 and Belikh 2 gave the highest straw yields, and so also the highest WUE for total dry matter production.

All genotypes responded significantly to increasing water regimes and, because interactions between genotypes and water rates were non-significant, crop responses to water are presented just as means (Table 3.2.10). Grain, straw and 1000 kernel weight all increased linearly with increasing rate of water application. However, grain protein

Table 3.2.8 Yield and quality parameters and WUE indexes of durum wheat genotypes, Tel Hadya, 1989/90 (means across six rates of water application)

Genotype	Grain kg/ha	Straw kg/ha	1000 k. weight g	Grain protein %	TDM-WUE kg/ha/mm	Grain-WUE kg/ha/mm
	**	*	**	*	*	**
1. Stork (chk)	1994	4676	34.3	11.5	18.02	4.94
2. DRM 2	1571	4768	31.9	10.0	17.00	3.82
3. DRM 3	2156	4542	34.1	12.6	18.02	5.34
4. DRM 4	1961	4336	34.9	12.4	16.81	4.80
5. DRM 5	1978	4540	33.8	12.3	17.45	4.79
6. DRM 6	1730	4787	36.5	13.2	17.43	4.20
7. DRM 7	1758	4568	38.8	11.9	17.26	4.31
8. Awalbit-2	1723	5021	36.2	11.5	17.80	4.24
9. DRM 9	2211	4369	34.8	11.7	17.69	5.45
10. DRM 10	1960	4741	32.7	12.2	18.31	4.87
11. DRM 11	2131	4105	35.6	12.2	16.80	5.15
12. Cham 1	1720	5232	31.6	13.0	18.80	4.24
13. DRM 13	2181	4729	35.5	12.9	18.60	5.48
14. Sabil 1	1954	4605	38.4	13.1	17.96	4.94
15. Om Rabi 5	2199	4518	36.1	12.6	18.30	5.54
16. Loukos 3	1964	4731	36.8	12.5	18.24	4.82
17. Hourani	1947	4844	32.7	13.1	18.34	4.90
18. Gallareta	1974	4834	37.8	13.1	18.27	4.96
19. Om Rabi 3	2210	4321	34.7	12.5	17.73	5.53
20. Belikh 2	2005	5187	33.7	12.0	19.42	4.93
LSD (.05)	378	890	3.0	2.0	2.25	0.90
SE (±)	193	454	1.5	1.0	1.15	0.46

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

content was negatively correlated with water because of the "dilution" effect. For higher rates of water application or in the higher rainfall areas, it may be necessary to put on larger amounts of N fertilizer. Parallel to grain and straw yields, WUE indexes for TDM and grain production also increased with increasing amount of water.

Regressions of genotype grain yield on the environmental mean or water rate showed all genotypes to be behaving in the same way. The difference between the highest- and the lowest-yielding genotypes (nos 9 and 2) increases with increasing water (Figure 3.2.10a). For

Table 3.2.9 Yield and quality parameters and WUE indexes of bread wheat genotypes, Tel Hadya, 1989/90 (means across six rates of water application)

Genotype	Grain kg/ha	Straw kg/ha	1000 k. weight g	Grain protein %	TDM-WUE kg/ha/mm	Grain-WUE kg/ha/mm
	**	**	**	**	**	**
1. TSI/VEE	1421	5901	29.0	12.8	19.45	3.43
2. TSI/VEE'S' (1)	1367	5499	26.7	13.1	18.12	3.30
3. VEE'S'/TSI	1425	6042	26.9	12.5	19.91	3.49
4. Nesser	1620	5400	26.8	12.8	18.72	3.86
5. Zidane 89	1276	6910	30.1	13.1	21.35	3.11
6. Cham 4	1748	6425	28.8	12.1	21.87	4.28
7. Saker	1189	5611	26.4	13.5	17.73	2.81
8. Hagel	1435	6551	28.9	14.1	20.60	3.38
9. Maya 74'S'/ON..(1)	1274	5888	28.1	13.6	18.89	3.08
10. CC//CAL/..	1438	6229	27.7	13.4	20.35	3.46
11. Baz	1471	5724	29.9	14.2	19.04	3.51
12. Chilero	1481	6379	30.1	13.7	20.65	3.51
13. Sanono	1434	6859	29.7	13.8	21.44	3.45
14. Ghurab	1352	5808	28.3	13.7	19.04	3.30
15. ANI'S'/PVN'S'	1457	5200	27.3	13.6	17.86	3.49
16. CC//CAL/..	1287	4669	27.3	13.6	16.26	3.08
17. TSI/VEE'S' (2)	1255	6380	29.2	13.5	20.11	3.05
18. PVN'S'/CLI	1563	6982	28.1	13.2	22.58	3.77
19. Maya 74'S'/ON/..(2)	1225	5254	27.9	13.6	17.35	2.94
20. DOVE'S'/BUC'S'	1492	7326	28.5	13.3	22.98	3.55
LSD (.05)	229	1279	1.7	0.6	3.21	0.56
SE (±)	117	653	0.9	0.3	1.64	0.28

* p<0.5   ** p<0.01

example, 500 kg difference at 300 mm becomes 1400 kg at 500 mm. This shows the wide adaptability of a given genotype in a given homogeneous region across different seasons or conditions.

Bread Wheat Performance. Mean grain yield, straw yield, 1000 kernel weight, grain protein %, TDM and grain WUE's differed significantly between genotypes (Table 3.2.9). Minimum mean grain yield was 1189 kg/ha (Saker), 559 kg/ha less than the maximum mean yield of 1748 kg/ha (Cham 4). Minimum and maximum values were 4669-7326 kg/ha for straw, 26.4-30.1 g for 1000 kernel weight, 12.1-13.8% for grain protein,

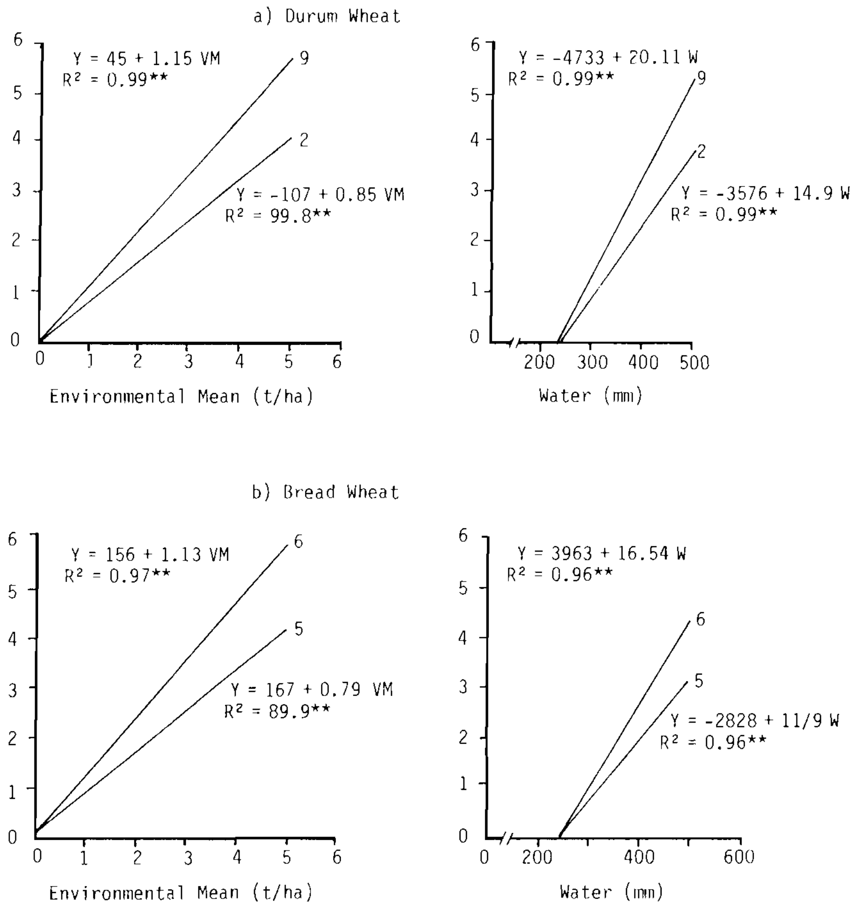
Table 3.2.10 Mean yield and quality parameters and WUE indexes of durum and bread wheat under different water regimes, Tel Hadya, 1989/90

Water levels, mm	Grain kg/ha	Straw kg/ha	1000 k. weight g	Grain protein %	TDM kg/ha/mm	Grain kg/ha/mm
			Durum wheat, n = 20			
	**	**	**	*	**	**
233 (W0) (rainfed)	59	2211	26.3	16.3	9.74	0.25
258 (W1)	200	2547	29.2	15.9	10.65	0.77
309 (W2)	1398	4221	31.2	14.2	18.18	4.52
362 (W3)	2467	5916	35.9	11.7	23.16	6.82
424 (W4)	3404	6291	42.6	10.2	22.86	8.03
486 (W5)	4271	6851	45.0	9.9	22.88	8.79
LSD (.05)	368	891	3.3	3.3	2.36	0.87
SE (±)	165	400	1.5	1.5	1.06	0.39
			Bread wheat, n = 20			
	**	**	**	**	**	**
233	43	2409	24.1	16.3	10.53	0.19
258	137	2110	24.1	15.7	8.71	0.53
309	720	5796	26.8	14.3	21.09	2.33
362	1513	7007	29.7	12.4	23.54	4.18
424	2262	7403	31.5	11.1	22.79	5.34
486	3788	11585	33.6	10.4	31.63	7.79
LSD (.05)	111	1663	0.5	0.5	3.58	0.26
SE (±)	50	747	0.2	0.2	1.61	0.12

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

16.26-22.98 kg/ha/mm for TDM water-use efficiency and 2.81-4.28 kg/ha/mm for grain water-use efficiency. Cham 4 and Nesser gave the highest mean grain yield (more than 1.5 t/ha), and Cham 4 also gave one of the highest straw yields. WUE values for grain naturally followed the yield levels. TDM-WUE was derived from the total of grain and straw yields. Cham 4 again was among the genotypes giving the highest WUE's.

As with durum wheat, bread-wheat genotypes all responded significantly to applied water, but interactions between genotypes and



<u>Figure 3.2.10</u> Linear regressions of the grain yield of the highest and lowest yielding genotypes on environmental mean and on water levels. (0) show actual mean of all genotypes on respective water levels

water rates were again non-significant. Mean crop responses to water are shown in Table 3.2.10. Response trends were again similar to those of durum wheat.

Regressions of genotype grain yield on the environmental mean or water rate gave similar trends. The steepest slope was that of Cham 4, the least steep slope that of Zidane 89. All other genotypes were distributed between these cultivars (Figure 3.2.10b). Differences between the highest- and the lowest-yielding genotypes started to be significant above about 300-350 mm total water receipt.

Conclusions from data obtained in 1989/90 should be drawn with caution, as results were affected by the characteristics of the season, which was particularly dry during the later stages of growth. Moreover, the supplemental irrigation supplied by the linesource sprinkler system was not sufficient to fulfill the designated percentages of the water balance, because the continuously windy conditions greatly reduced the efficiency of the system.

However, we can say that durum and bread wheat genotypes responded similarly to supplemental irrigation treatments. Durum wheat, in general, gave higher grain but lower straw yields than did bread wheat, at any given rate of water application.

3.2.3 The Performance of Oil-Seed Crops Under Different Moisture Regimes

M. Pala

3.2.3.1 Introduction

Most of the countries in the ICARDA region have a deficit of egetable oil. Currently the main source is olives, but to overcome the shortage of supply there is a need to introduce oil-seed crops into the farming systems. The only economic way to do this in rainfed areas is to utilize fallow areas wherever possible to maximize land-use efficiency.

Oil-seeds and their products are some of the most valuable agricultural commodities in world trade:

- they are high value crops and readily marketed
- they extend the range of products for export
- they displace imports and satisfy domestic needs for edible vegetable oil and high protein meal
- they disperse the risk of grain production and marketing, and increase options for crop rotation.

Sunflower (Helianthus annuus), rapeseed (Brassica napus and B.

campestris), safflower (Carthamus tinctorius) and sesame (Sesamum indicum) are the main oil-seed crops that can be introduced into the more favorable rainfed areas of the region. Two experiments were conducted: (i) to test the three available rapeseed cultivars under different moisture regimes using a linesource sprinkler systems and (ii) to study two sunflower cultivars at different plant densities in response to supplemental irrigation using a drip system. An additional objective was to find out the lower limit of water supply required to obtain an economic yield from oil-seed crops.

3.2.3.2 Materials and Methods

Rapeseed. Three rapeseed cultivars, Westar (B. napus) and Tobin (B. campestris) (from Canada) and Maluka (B. napus) (from Australia) were tested under 6 water regimes. These were rainfed (W0) and with supplemental irrigation to replenish 20, 40, 60, 80 and 100% of water balance requirements (W1, W2, W3, W4, W5, respectively). At the end of the irrigation period cumulative totals of water receipt were 233, 258, 309, 362, 424 and 486 mm, respectively. Experimental design was split plot with 3 replicates. Plot size was 2.1 m x 3.0 m for sub-plots of W1 to W5 and 2.1 m x 9 m for W0. Planting was done by a plot-drill with 17.5 cm row spacing using 8 kg seed/ha. 50 kg P_2O_5/ha and 80 kg N/ha were applied. Weeds were controlled by hand.

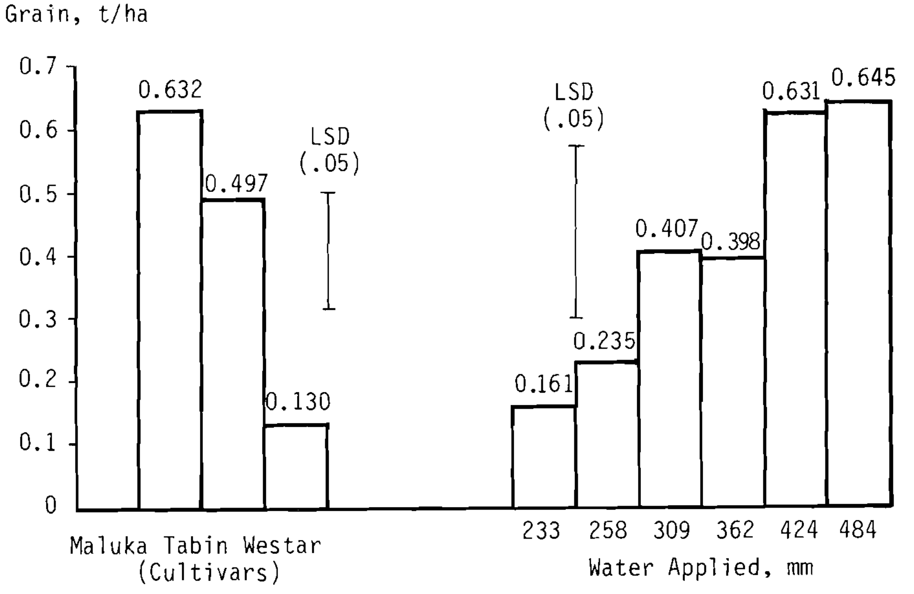
Sunflower. Two sunflower (Helianthus annuus) cultivars, local large and Viniminк (from Turkey), were tested at 4 plant densities (10000, 20000, 30000 and 40000 plant/ha) under 4 water regimes (W0, W1, W2 and W3). W0 was rainfed apart from 30 mm applied to initiate emergence (total, 263 mm). W1, W2 and W3 received 190, 350 and 370 mm of additional water in the root zone, respectively. They were irrigated to 100% available water when the water content in the root zone fell to 50%, 65% and 85%, respectively. Experimental design was split plot for water regimes with sub-plots factorially arranged in 2 replicates. Plot size was 4.8 m x 8 m for sub-plots. The trial was planted by hand at 60 cm row spacing, with varying in-row plant densities, using fertilizer rates, 50 kg P_2O_5/ha and 80 kg N/ha. Weeds were controlled by hand.

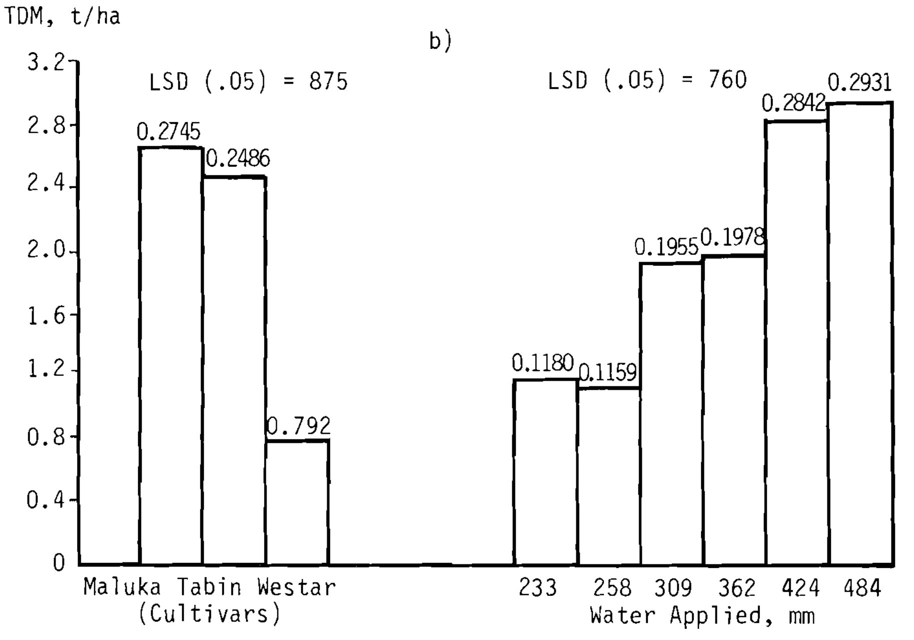
3.2.3.3 Results and Discussion

Rapeseed. It is unfortunate that there were only three rapeseed cultivars available for the 1989/90 season, which was quite cold as well as dry. The opportunity was lost to test other cultivars in an extreme season. However, having three cultivars from two different agroecological environments was not without interest. Westar (B. napus) requires a long frost-free season to produce an economic yield (Thomas 1984), so it could hardly survive under the weather conditions of Tel Hadya, 1989/90. Tobin (B. campestris) requires fewer degree-days (860-920) for growth than does Westar (B. napus) (1040-1100). The yield difference of these two rapeseed species from Canada may be attributed to their difference in required degree-days (Figure 3.2.11). That the highest yield was given by Maluka (B. napus, from Australia) seems reasonable, because it comes from similar Mediterranean conditions (Figure 3.2.11). However, yields obtained were well below the potential for rapeseed cultivars elsewhere, which range from 1.5 to 2.0 t/ha (Thomas 1984). This was mainly due to the long period of cold weather experienced during early growth and to some frost damage.

All cultivars responded similarly to irrigation, so that yield results are presented in the form of mean responses (Figure 3.2.11). We can conclude that the seasonal rainfall should be above 400 mm to obtain optimum yield from rapeseed crops, although one-year data should be evaluated cautiously. Yield parameters and WUE of the cultivars parallel the yield data (Table 3.2.11). Increasing water quantity significantly increased plant height, pod/plant, pod size and seed/pod and these were reflected in the yield.

Sunflower. Sunflower has previously been grown in higher rainfall areas of Northwest Syria (> 400 mm) on a small scale, on stored soil moisture, after spring sowing. Some preliminary work conducted by ICARDA at Jindiress station showed that an increase in plant density from 10000 to 20000 plants/ha increased grain yield, but there was no further yield increase from 30000 or 40000 plants/ha; and this result was obtained in each of three different seasons (Table 3.2.12).





<u>Figure 3.2.11</u> Mean grain and total dry matter yields of three rapeseed cultivars and mean response to applied water

Table 3.2.11 The effect of cultivar and water regime on the yield parameters and WUE of rapeseeds, Tel Hadya, 1989/90

	HI	Plant height, cm	Pod/ plant	Pod size (cm)	Seed/ pod	WUE, kg/ha/mm TDM	WUE, kg/ha/mm Grain
Cultivar	**	**	**	**	**	**	**
Maluka	0.22	89.1	84	4.3	19	7.7	1.7
Tobin	0.18	88.7	111	3.5	17	7.2	1.3
Westar	0.06	30.7	30	1.3	6	2.2	0.4
LSD (.05)	0.07	23.7	22	0.9	5	2.3	0.6
SE (±)	0.03	11.5	11	0.4	2	1.1	0.3
Water, mm		**	**	**	**		
233 (rainfed)	0.11	55.0	50	2.0	11.3	5.1	0.7
258	0.15	60.0	68	2.7	12.6	4.5	0.9
309	0.17	66.8	73	3.1	13.5	6.3	1.3
362	0.15	73.0	85	3.3	14.9	5.5	1.1
424	0.17	78.4	87	3.4	16.3	6.7	1.5
486	0.18	83.8	84	3.7	15.9	6.0	1.4
LSD (.05)	NS	7.1	8	0.3	1.5	NS	NS
SE (±)	0.04	3.2	4	0.1	0.7	0.9	0.4

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

Table 3.2.12 Mean grain response of sunflower at different planting densities, Jindiress, 1986-1989

Plants/ha	Grain, kg/ha 1986/87	1987/88	1988/89
10000	828	933	728
20000	1201	1141	881
30000	1141	1119	788
40000	1165	1075	765
Seasonal rainfall, mm	601	686	347

Because of the difficulty in protecting trials at Jindiress against bird damage, it was decided for 1989/90 to examine cultivar response at different plant densities to different water regimes at Tel Hadya.

The results show no significant differences between cultivars and plant densities, but crop response to water was positive and significant (Figure 3.2.12). These results are in agreement with data obtained in earlier seasons under different rainfall regimes (Table 3.2.12).

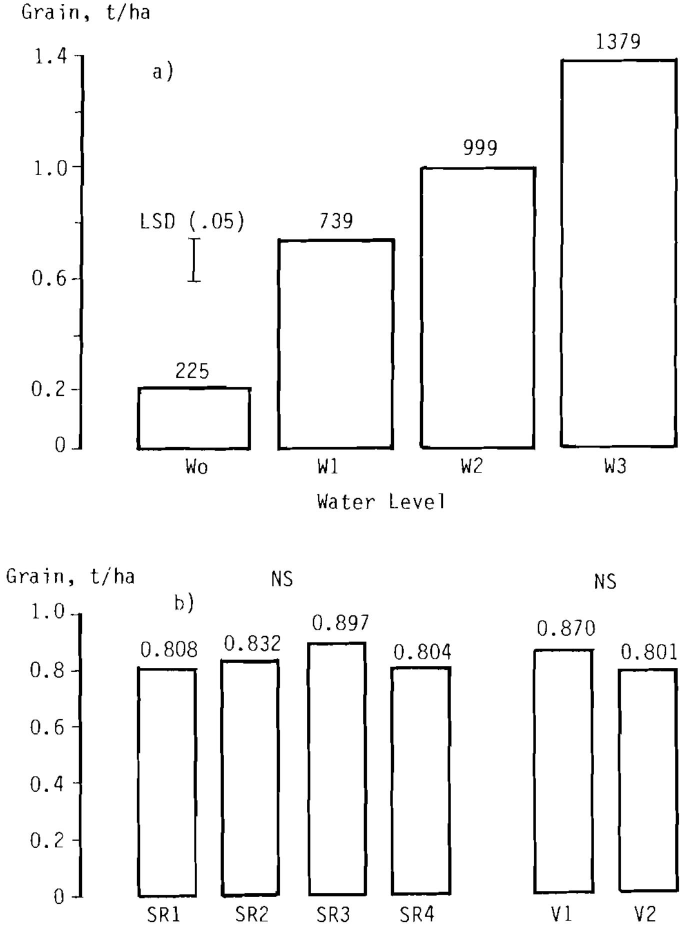


Figure 3.2.12 Mean grain yield response of sunflower to different irrigation levels (a); mean grain yields of cultivar and response to different plant density (b)

Plant head diameter and height show a similar pattern to that of grain yield in relation to cultivar and water supply. Increasing the amount of water significantly increased the value of each of these parameters. But they were negatively correlated with plant density. Increases in density significantly decreased plant head diameter and plant height. Low plant density was thus compensated by taller plants and larger heads to produce a similar grain yield to that of the others. WUE was not affected by any treatment at all, in parallel with grain yield (Table 3.2.13).

Table 3.2.13 The effect of cultivar, water regime and plant density on head diameter, plant height, WUE and oil content of sunflower seed, Tel Hadya, 1989/90

	Head diameter (cm)	Plant height (cm)	WUE (kg/ha/mm)	Oil content %
Cultivar				
				**
Local large	15.3	122.5	2.3	25.9
Viniminik	14.3	121.1	2.1	35.8
LSD (.05)	NS	NS	NS	5.2
SE (±)	0.6	4.1	0.1	1.2
Plants/m^2				
	**	+		
10000	18.5	128.8	2.0	29.9
20000	15.0	126.6	2.2	-
30000	13.1	116.3	2.3	-
40000	12.5	115.6	2.2	31.8
LSD (.05)	1.8	11.7	NS	NS
SE (±)	0.9	5.7	0.2	1.2
Water regime				
	**	**		
W0	9.6	83.4	-	32.5
W1	14.5	127.8	3.0	30.2
W2	15.3	133.8	2.5	31.7
W3	19.7	142.2	3.3	29.1
LSD (.05)	1.7	20.5	NS	NS
SE (±)	0.5	6.5	0.1	1.6

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

Oil content of sunflower was not affected by either water supply or plant density, but it was significantly different between the cultivars. The local large-seed cultivar had an oil content 10% lower than that of the small-seed cultivar, Vinimink (Table 3.2.13). This shows how important it is to introduce a new cultivar with higher oil content even with the same yield level to a region where there is a deficit of edible oil in general.

Reference

Thomas, P. 1984. Canola Growers Manual. Canola Council of Canada, Winnipeg, Manitoba.

3.3 Four Years On-Farm Fertilizer Trials on Wheat in NW Syria*

M. Pala, A. Matar, A. Mazid

3.3.1 Introduction

Wheat is the most important staple food crop grown in West Asia and North Africa. In Syria, wheat is grown from the wettest to the driest areas. In dry areas, where barley predominates, wheat is grown for subsistence, even at the edge of the steppe (Thomson et al. 1985). In wetter areas (over 325 mm mean annual rainfall), wheat is the dominant crop and is grown in rotation with food legumes and summer crops.

National programs in the ICARDA region, have focused their research on the higher potential wheat-based farming systems. Potential crop production is greater in these areas, and farmers are financially more secure. Nevertheless, production of wheat can and must be increased further and sustained, because of its major importance as a source of calories and protein in the diet.

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* This study is conducted jointly with the Soils Directorate/Ministry of Agriculture in Damascus, Syria.

According to the results of a survey held in 1984/85 to determine wheat production practices in northwestern Syria, wheat growers know about fertilizers, have access to them and have been using them for some time. Fertilizer use is variable, but this is a response to local factors, particularly soil type, previous crop and rainfall (Rassam and Tully 1985).

In general, less fertilizer is used on poorer soils. Nitrogen use is also significantly related to the previous crop, for example more nitrogen is applied to wheat following summer crops regardless of soil type. Bailey (1982) reported that farmers in two Hama villages believed that irrigated summer crops deplete the soil of nutrients, so that a subsequent wheat crop required more fertilizer. However, contradictory results were obtained from on-farm trials in the same area. The effects of both phosphate and nitrogen use on wheat grain yield following summer crops were found to be non-significant, whereas the effect of nitrogen on grain yield was significant where the previous crop had been chickpea, which is the opposite of farmers' opinions (Pala et al. 1987).

Since fertilizer use is not a new input in wetter areas, research on this subject should be oriented towards technology optimization rather than generation. Nutrient levels in soils at sowing are also very important criteria for optimum and economic fertilizer use.

The oldest method of estimating fertilizer requirements is by means of field trials, and even today field trials are considered to have the last word in establishing fertilizer requirements, although soil testing and plant testing would be cheaper and less time-consuming. To save time and hasten the economic use of fertilizer, soil and plant testing should therefore be calibrated against field trials.

Since 1986, ICARDA has maintained a soil test calibration network for scientists in the WANA region, to help them coordinate their findings regarding relationships between crop response to fertilization and the initial soil content of available P and N. A large number of field fertilizer experiments have been conducted, and these have indicated that values of $NaHCO_3$-extractable P and NO_3-N in the soil at sowing time can be used as reliable tests.

Under dryland conditions on farmers' fields in Turkey, approximately 55 kg available P_2O_5/ha was found to be the critical level in the top soil beyond which no economic response to P fertilization could be expected from wheat (Yurtsever 1986). For rainfed wheat in northwest Syria, Matar et al. (1986) reported that a critical level of available P of about 33 kg P_2O_5/ha gave around 90% of the maximum total dry matter production.

The objectives of the present work are:

- To assess the biological and economic responses of wheat to N and P fertilizer through multiple season-multiple location trials on farmers' fields, in wetter areas (over 325 mm mean annual rainfall) of northwest Syria.

- To study the relationship between the available N and P in soils at the time of sowing and crop response; and to determine the critical values of the soil N and P tests, beyond which no response to N and P fertilization is expected.

- To establish guidelines for establishing fertilizer recommendations for wheat based on soil N and P tests and rainfall values.

3.3.2 Materials and Methods

A series of researcher-managed wheat fertilizer trials were conducted on farmers' fields across northwest Syria in the four seasons, 1986-1990, with a total of 70 successfully harvested trials. Trial sites were distributed in Aleppo, Idleb and Hama provinces above the 300 mm isohyet.

Sites were selected each year to represent the main soil types used by farmers for wheat, the range of natural fertility found in those soils, and the three predominant crop rotations, wheat following lentil (W-L), chickpea (W-Ch) and summer crop mostly water melon (W-SC). Each trial comprised two replicates of a randomized complete block with four rates of phosphorus (0, 20, 40 and 80 kg P_2O_5/ha), supplied as triple superphosphate, and four rates of nitrogen (0, 40, 80 and 120 kg N/ha), supplied as ammonium nitrate, 32 plots in all (each 10 m x 5 m).

Wheat (Cham 1, durum cultivar) seed was treated with fungicide (Vitavax) and sown at a rate of 150 kg/ha, following the farmers' practice of hand-broadcasting seed and fertilizer over ridged land, with subsequent covering by splitting the ridges with a one-set ducksfoot-tyned cultivator (row spacing 45 cm). Mean sowing date was 17 November $\pm$ 6.1 days. The phosphorus fertilizer and half of the nitrogen were applied at sowing, the remaining nitrogen being topdressed at the tillering stage. Weeds were controlled with a tank-mix application of brominal (0.5 kg bromoxynil/ha) and illoxan (1 kg diclofop-methyl/ha), applied once when the crop was at the 3-4 leaf stage, usually during February. Harvest was during the last week of May and the first week of June, depending on the rainfall conditions.

Soils were sampled in 20 cm increments down to 100 cm depth at planting time for the determination of mineral-N. Available-P (Olsen) was measured only at the depths, 0-20 and 20-40 cm. Soil profile descriptions were undertaken at each location.

The main soil sub-groups were either "Typic chromoxerert": deep, moderately well-drained, fine-textured (clayey) Vertisol, or "Typic xerochrept": deep, more or less freely drained, brownish Inceptisol of mediterranean climate. They both have deep wide cracks in summer if no irrigation is applied.

Rainfall was recorded on a daily basis at each site, starting a month before planting and continuing until harvest. Grain yields were determined by using a Hege plot harvester to cut the central three rows in each plot at maturity. At the same time two 1-meter lengths of row were cut at ground level, for the determination of harvest index. Finally, total dry matter and straw yields were calculated from the Hege grain yields using the harvest index. These samples were subsequently analysed for N and P contents.

3.3.3 Results and Discussions

The present report summarizes only the main agronomic findings and economic analyses. Other results will be reported later.

3.3.3.1 Crop Response to Site Conditions

Crop response to fertilizer is closely related to environmental conditions like soils and weather. So it is appropriate to describe briefly the conditions at the experimental sites and their effect on crop growth.

Soils were not greatly different from each other being mostly Typic Chromoxererts in Aleppo and Idleb or Typic Xerochrepts in Hama province. Out of 70 sites, 68 had soils between 105 and 170 cm depth, 2 only 0.5-1.0 m deep. These two sites were chosen because of their low available-P.

Soil available-P and mineral-N contents at planting time were well distributed between low and high values: about 50% of the sites had available-P less than 5 ppm and mineral-N less than 10 ppm, values taken to be critical nutrient levels (Table 3.3.1). Available-P values did not differ according to previous crop; but mineral-N values tended to be higher at W-SC sites, probably due to a greater mineralization of soil-N promoted by inter-row cultivation during the summer (Table 3.3.2).

Seasonal (October-May) rainfall totals varied widely between sites over the four years, with a mean of 363.4 (± 151.5) mm and an extreme

Table 3.3.1 Distribution of (a) soil Olsen available-P contents (0-20 cm depth) and b) soil mineral-N contents (0-60 cm depth) at planting time among the 70 experimental sites as distributed according to previous crop

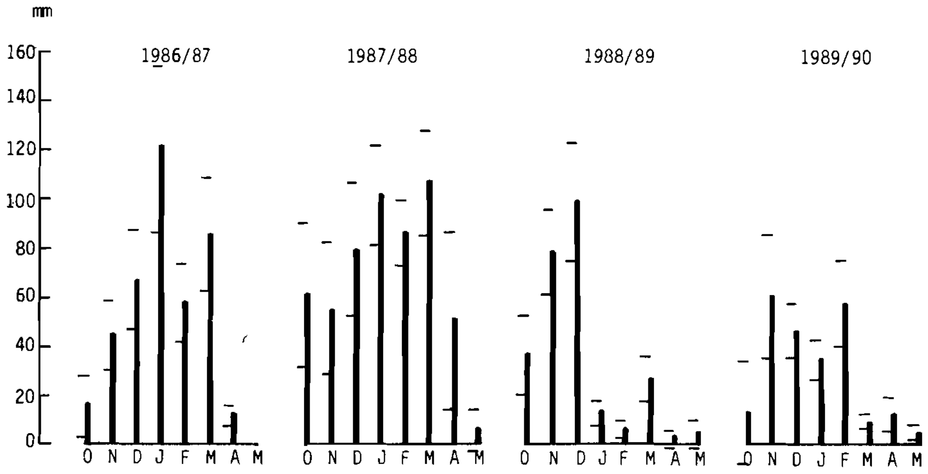
a) Available-P, ppm	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	≥10
Lentil	0	3	5	1	4	3	4	0	0	1
Chickpea	0	1	4	3	2	4	1	3	1	2
Summer Crop	2	1	9	4	4	4	2	1	0	1
Total No. of sites	2	5	18	8	10	11	7	4	1	4

b) Mineral-N, ppm	<5	5-10	10-15	15-20
Lentil	2	16	2	1
Chickpea	1	12	4	4
Summer Crop	0	8	15	5
Total No. of sites	3	36	21	10

Table 3.3.2 Mean site conditions and mean yields of wheat (16 treatments)

Previous Crop	Rain, mm	Mineral-N ppm	Available-P ppm	Yield, kg/ha Grain	Straw	Total
Lentil	367.1	8.1	5.4	2072	4301	6373
Chickpea	363.2	11.1	6.1	2133	4563	6676
S. Crops	363.4	12.4	5.0	2600	5062	7662
All Sites	364.4	10.7	5.4	2296	4661	6977

range, 153.0-907.4 mm. Half of the sites received less than 325 mm, mostly in the last two seasons and the other half got more than 325 mm, mostly in the first two seasons. 1986/87 was a typical season for the wheat-based farming system, followed by a relatively wet season, 1987/88, then the two very dry seasons of 1988/89 and 1989/90. Irrespective of certain common features each year, sites differed widely in both seasonal and monthly rainfall totals (Figure 3.3.1).



Total rain, mm:

	1986/87	1987/88	1988/89	1989/90
Mean	404.6	543.2	261.8	235.7
Range	284.7-571.1	396.5-907.4	203.8-347.1	153.0-336.6
No of sites	14	20	19	17

Figure 3.3.1 Pattern of rainfall in each experimental year: monthly means (+ S.D.) and seasonal totals, means and ranges

Wheat yield was positively and linearly related to total seasonal rainfall only in 1986/87 and 1989/90, when linear regression on rainfall accounted for about 46% of the variance of site mean grain yields. In the very wet 1987/88 season, because of waterlogging at some sites and no limitation in the water supply, yield showed little relation to rainfall. But in the other dry season, 1988/89, the utilization of soil water stored from the high rainfall in 1987/88, confounded with rotation effects, made the yield response to total seasonal rainfall insignificant. However, over the four-year data set the general yield-rainfall trend is better described by a quadratic equation. Fitted equations show that the maximum biological yield is obtained between 500-600 mm rainfall in each rotation. Summer crops (water melon) provide better growth conditions for the subsequent wheat crop in lower rainfall situations, but the advantage is lost as the rainfall increases. A comparison of equations fitted to the two extremes, the zero-fertilizer check and the $N_{120}P_{80}$ treatment, shows the general trend of the yield-rainfall relationship to be unaffected by fertilizer, but response to rainfall at the highest fertilizer rate becomes larger (Figure 3.3.2).

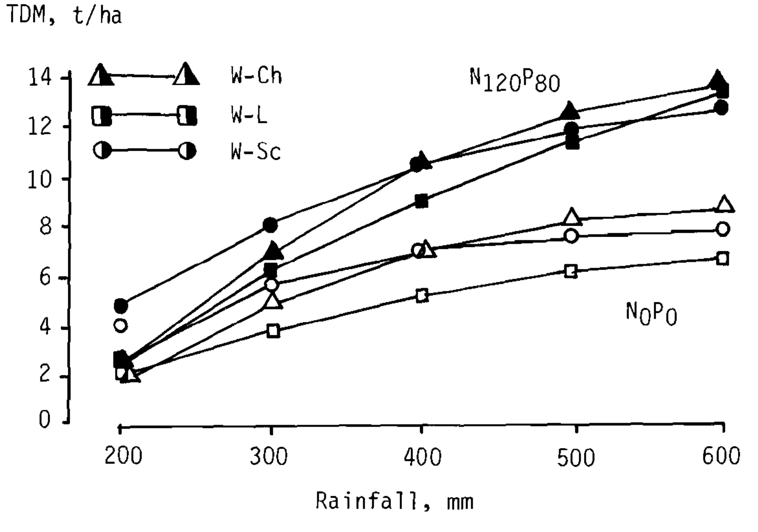


Figure 3.3.2 Relationships of total dry matter yield to rainfall under zero and high fertilizer regimes in wheat-lentil, wheat-chickpea and wheat-summer crop rotations separately. Fitted equations:

			R^2, %
W-L:	N_0P_0:	$Y = 28.44Q - 0.021Q^2 - 2753$	61.3
	$N_{120}P_{80}$:	$Y = 49.68Q - 0.029Q^2 - 6069$	84.4
W-Ch:	N_0P_0:	$Y = 50.24Q - 0.042Q^2 - 6350$	45.4
	$N_{120}P_{80}$:	$Y = 75.02Q - 0.059Q^2 - 1057$	67.2
W-Sc:	N_0P_0:	$Y = 29.79Q - 0.025Q^2 - 890$	36.8
	$N_{120}P_{80}$:	$Y = 48.20Q - 0.036Q^2 - 3213$	69.1

As rainfall distribution can be as important for crop growth as total rainfall amount, the seasonal total was divided into two sub-totals: rainfall received between October and January (Q_1) (sowing to tillering stage) and between February and May (Q_2) (tillering to maturity). Using the two sub-totals as separate linear terms in the regression increased the explanatory power of the equation by about 5% (Equations I and II). When we increased the complexity further, using monthly subtotals, R^2 was improved by another 4% (Equation III). These improvements indicate the importance of the distribution of the rainfall. Equations, based on data from all 70 sites, are:

Equation		R^2, %
$Y = 21.68\ Q - 0.017\ Q^2 - 3010$ ...	I	61.7
$Y = 15.96\ Q_1 + 251.11 Q_2 - 0.016\ Q^2 - 2273$ ...	II	66.4
$Y = 13.37\ Q_{Oct} + 4.76\ Q_{Nov} + 24.20\ Q_{Dec} + 9.72\ Q_{Jan} + 24.09\ Q_{Feb} + 19.32\ Q_{Mar} + 30.09\ Q_{Apr} - 22.36\ Q_{May} - 0.01\ Q^2 - 1810$ ...	III	69.9

where Y is grain yield (kg/ha), Q is total seasonal rainfall (October-May), Q_1 and Q_2 are the October to January and February to May sub-totals, respectively, and Q_{Oct}, Q_{Nov}, Q_{Dec}, etc. are the monthly sub-totals. All terms in each equation are statistically significant at the 1% level.

Mean yields were very little affected by the available-P and mineral-N contents of the soil, mainly because of the confounding effect of the rainfall. This can be understood better from the equations (over the 70 sites) given below:

Equation		R^2, %
$Y = 135.96\ NA - 2.36\ PA + 851$ ...	IV	17.4
$Y = 82.29\ NA - 43.59\ PA + 20.18\ Q - 0.016\ Q^2 - 3289$ ...	V	67.0

where Y is grain yield (kg/ha), NA and PA are the soil available-N and P (ppm) respectively and Q is the seasonal rainfall. All the coefficients in the equations are significant at 1%, except that of PA in equation IV.

The inclusion of rainfall in the regression increases R^2 by about four times. However, the quadratic regression on rainfall (I) has already given an R^2 value of 61.7%, which means that initial soil fertility can explain only an additional 5% of the variance. It would therefore be difficult to explain the site yield differences in terms of initial soil fertility levels.

Remarkable differences were found between sites, irrespective of rainfall amount, mainly as a result of rotation. Wheat preceded by a summer crop had a significantly higher mean yield than wheat in W-L and W-Ch rotations (Table 3.3.2). These results are in agreement with other studies showing that summer crops like melon do not utilize all the stored water in the profile, and the subsequent wheat crops are able to utilize it (ICARDA 1984; Cooper et al. 1987; Pala et al. 1987). As already seen in the regression of total dry matter on rainfall, summer crops gave advantage to subsequent wheat crops under lower rainfall conditions (Figure 3.3.2).

3.3.3.2 Crop Response to Fertilizer

Mean yields of grain and straw across the 70 sites showed highly significant responses only to N fertilizer (Table 3.3.3). However, although response to P was non-significant, there was still a trend of yield increase from P application. The maximum fertilizer rate ($N_{120}P_{80}$) gave increases of 35% in grain and 60% in straw over the control treatment, resulting in a reduction in harvest index from 35 to 31%. The 1000-grain weight decreased significantly with increasing rate of N application. This might be explained by the better performance of fertilized plants during early growth when there was no limitation of water or nutrients. In this case, vegetative growth is encouraged and the growing period is lengthened. As the season advances, the limitation of water becomes the determining factor of grain filling, and individual grain weight is reduced. Similar results have been reported for barley (Jones 1989).

Grain and straw yield responded positively to N fertilizer (except at 1 site in 1988/89 and 3 sites in 1989/90 where rainfall was

Table 3.3.3 Mean effect of fertilizer treatment over 70 sites on wheat grain and straw yield (kg/ha) and 1000-grain weight (g)

		P_2O_5, kg/ha				
	N, kg/ha	0	20	40	80	Mean
						**
Grain	0	1852	1959	1999	2031	1960
	40	2254	2291	2323	2443	2328
	80	2390	2413	2458	2481	2436
	120	2436	2426	2479	2459	2459
			NS			
	Mean	2233	2272	2315	2362	2296
						**
Straw	0	3493	3752	3770	3790	3701
	40	4469	4510	4566	4781	4581
	80	4902	4932	5133	5188	5039
	120	5327	5339	5422	5573	5415
			NS			
	Mean	4548	4633	4723	4833	4684
						**
1000-grain weight	0	32.5	32.3	32.7	32.9	32.6
	40	31.5	31.5	31.6	31.5	31.5
	80	30.9	30.6	30.5	30.6	30.7
	120	30.0	30.1	29.8	30.0	30.0
			NS			
	Mean	31.2	31.1	31.2	31.2	31.2

N x P interaction is not significant

the lowest), and those responses were significant at 38 and 61 out of 70 sites, respectively. But responses of grain and straw to P-fertilization were positive and significant at only 15 and 10 sites, respectively. Straw responses to N were more numerous than those of grain, mainly because of the good vegetative growth during the early rains but a reduced utilization of nitrogen during grain filling due to drought.

The frequency of significant responses to fertilizer in relation to site factors is shown in Table 3.3.4. The importance of N increases with increasing rainfall. It is lower in W-SC than in W-L or W-Ch

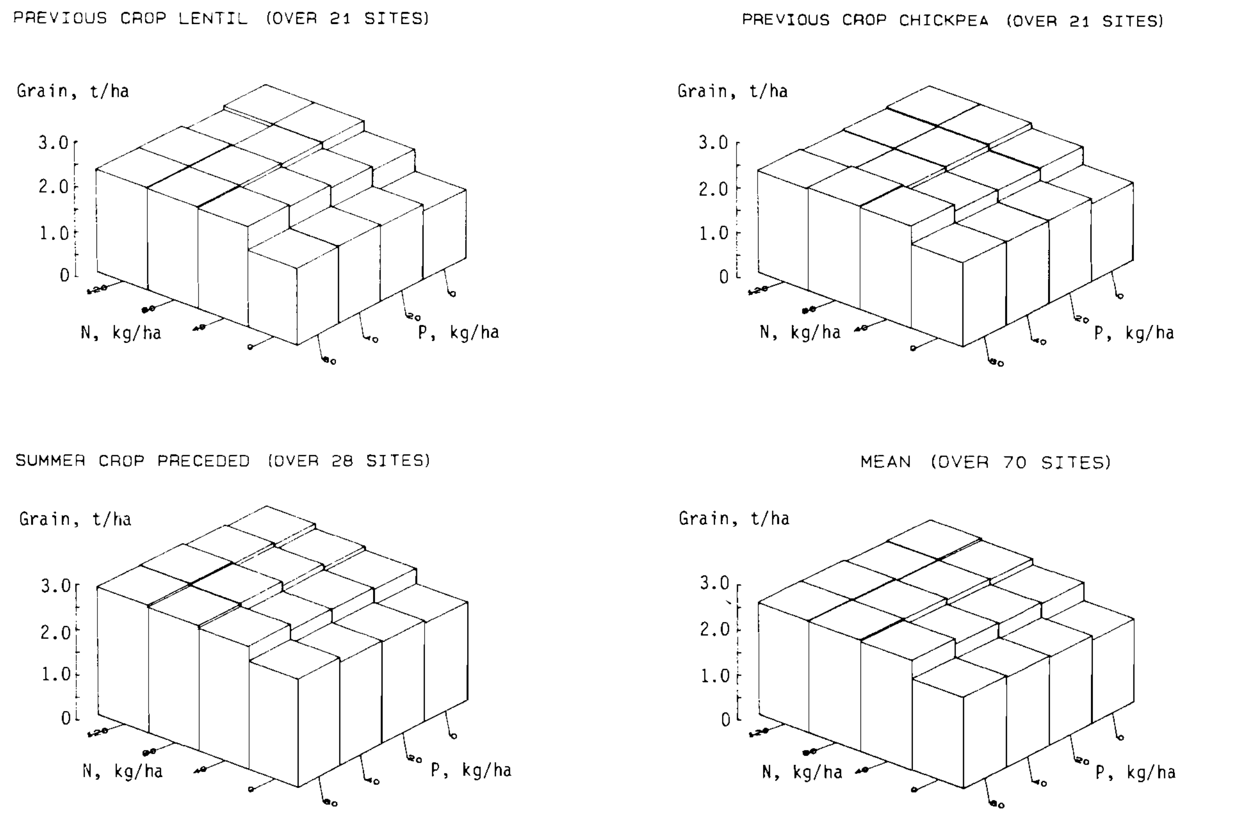
Table 3.3.4 Summary of the percentage distributions of significant responses to N and P fertilizers as affected by main site factors

Factor		Number of sites	Grain N	Grain P	Straw N	Straw P
All sites		70	54	21	87	16
Rainfall, mm	< 250	20	25	5	65	15
	251-400	25	60	28	92	12
	> 401	25	72	28	96	20
Rotation	W/L	21	52	14	71	5
	W/Ch	21	48	10	76	5
	W/SC	28	43	14	68	18
Available-P	< 5	32	63	22	84	22
	> 5.1	38	47	21	89	11
Mineral-N	< 10	39	59	23	89	21
	> 10.1	31	45	19	80	10

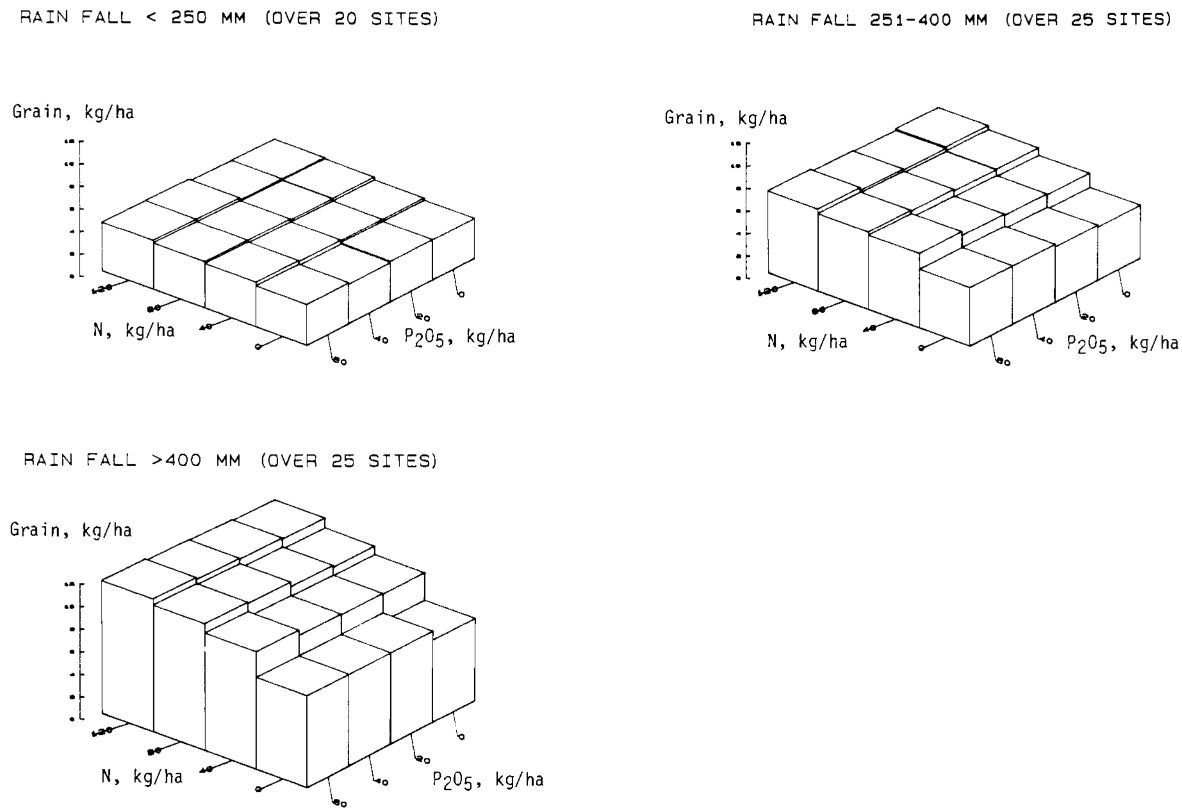
rotation, and it is higher when initial soil mineral-N at 0-60 cm depth is below 10 ppm. However, crop responses to P showed little relation to any of the site factors.

Mean grain yield responses to fertilizer N and P for different previous crops and rainfall groups are given in Figure 3.3.3 and 3.3.4. Nitrogen application (120 kg N/ha) increased wheat grain yield by 34, 22 and 19% over the zero control in W-L, W-Ch and W-SC rotations, respectively; and by 3, 24 and 32% in rainfall groups of < 250 mm, 250-400 mm and > 400 mm, respectively.

Significant interactions between N and P fertilizers were negligible. Analyses have therefore been focused on the main effects of N and P on wheat production under different conditions of rainfall, soil fertility status and preceding crop. However, the relationships between yield and these factors need to be quantified through best-fit equations, to give a better understanding of crop fertilizer response and to provide useful recommendations to decision makers and eventually to farmers.



<u>Figure 3.3.3</u> **Effect of previous crop on grain response to N and P fertilizers in NW Syria, 1986-1990**



<u>Figure 3.3.4</u> **Effect of rainfall on grain response to N and P fertilizers in NW Syria, 1986-1990**

When using regression analysis to obtain such equations, it is tempting to try to reduce the residual variation to a minimum, but only those variables that are meaningful should be retained in the equations. We have therefore, compared a series of equations in terms of their respective adjusted R^2 values (Table 3.3.5). These values show the percentage of variance explained for different data sets and different levels of soil available-P and mineral-N.

Equation (Ea), with terms for N and P and rainfall in both linear and quadratic forms, provides quite a high R^2 values for each data set or subset. However, the coefficients of the linear and quadratic P terms are not statistically significant. This agrees with the findings of Matar and Samman (1969) and the observation that the available-P status of farmers' fields in the wheat-based system has greatly increased over the last 20 years as a result of frequent application of P fertilizer (Jones et al. 1987). When we remove total seasonal rainfall from equation (Ea), R^2 values drop dramatically (Eb), but subsequent removal of P from Eb has little influence (Ec). R^2 values of (Ea) are quite similar to those of (Ed), in which P and N interactions with total seasonal rainfall are omitted. Again, removal of the P terms from (Ed) does not change the R^2 values very much; in fact, it even improves them slightly (Ee). Increasing the complexity of the equation again by adding terms for soil nutrient status increases R^2 values in some cases but not in others. It is therefore concluded that equation (Ee) is the most appropriate one for determining fertilizer recommendations for different rainfall conditions (Table 3.3.6).

Wheat response to applied N was also affected by soil nutrient content at planting and by previous crop, as shown in Figures 3.3.5 and 3.3.6 for total dry matter (total production and increase over control) at three standard rainfall values for two different states of soil nutrient availability: low available N (< 10 ppm), and high available N (> 10.1 ppm) and for three preceding crops, lentil, chickpea and summer crops. All crop responses to fertilizer increased with increasing rainfall. Wheat following summer crops outyielded wheat following lentil and/or chickpea under low rainfall conditions, and this

Table 3.3.5 Empirical equations and their respective R^2 values for different data sets

Data set	No. of sites	Adjusted R^2 (%)							
		Ea	Eb	Ec	Ed	Ee	Ef	Eg	Eh
Grain									
All sites	70	64.6	1.6	1.6	63.4	64.5	68.3	68.7	69.4
W-L	21	83.4	1.9	2.2	81.5	83.3	82.3	82.4	84.2
W-Ch	21	64.0	0.4	0.8	63.0	64.2	70.9	72.9	71.8
W-SC	28	60.9	1.5	1.6	60.0	60.7	60.9	61.0	61.7
PaNa	24	57.9	1.9	2.0	56.1	57.5	58.6	62.9	60.2
PaNA	10	78.4	5.0	5.6	76.9	78.3	78.8	79.4	80.3
PANa	15	55.7	1.8	2.3	53.0	55.9	56.2	59.2	58.9
PANA	21	75.4	0.0	0.4	74.9	75.5	76.1	81.2	76.6
Total Dry Matter									
All sites	70	65.4	5.3	5.3	63.8	65.2	69.7	69.8	71.2
W-L	21	80.5	6.3	6.5	77.9	80.4	78.9	78.9	81.4
W-Ch	21	61.2	3.7	4.1	60.2	61.4	70.2	72.0	71.3
W-SC	28	65.2	5.5	5.4	63.7	64.7	65.0	65.4	66.4
PaNa	24	62.9	6.0	6.0	60.1	62.4	62.5	68.1	65.1
PaNA	10	80.3	9.2	9.5	77.8	79.9	78.8	79.0	81.3
PANa	15	57.4	8.9	9.2	54.9	57.5	58.4	60.6	60.9
PANA	21	74.9	3.1	3.4	74.2	75.0	75.6	79.0	76.4

Ea: $Y = aN + bP + cNP + dN^2 + eP^2 + fQ + gQ^2 + hQN + iQP + const.$
Eb: $Y = aN + bP + cNP + dN^2 + eP^2 + const.$
Ec: $Y = aN + bN^2 + const.$
Ed: $Y = aN + bP + cNP + dN^2 + eP^2 + fQ + gQ^2 + const.$
Ee: $Y = aN + bN^2 + cQ + dQN + eQ^2 + const.$
Ef: $Y = aN + bN^2 + cQ + dQ^2 + eNA + const.$
Eg: $Y = aN + bN^2 + cQ + dQ^2 + eNA + fPA + const.$
Eh: $Y = aN + bN^2 + cQ + dNQ + eQ^2 + fNA + const.$

N and P represent rates of fertilizer N and P_2O_5 (kg/ha) applied, Q is total seasonal rainfall, NA is soil mineral-N, PA is soil available-P, and a, b, c, ... i, are derived coefficients different for each version of the equations.

advantage was kept under moderate rainfall but lost above 400 mm (for reasons given above). Yield increases over control were very similar in each rotation at low rainfall but became much larger in the wheat-lentil rotation at higher rainfall.

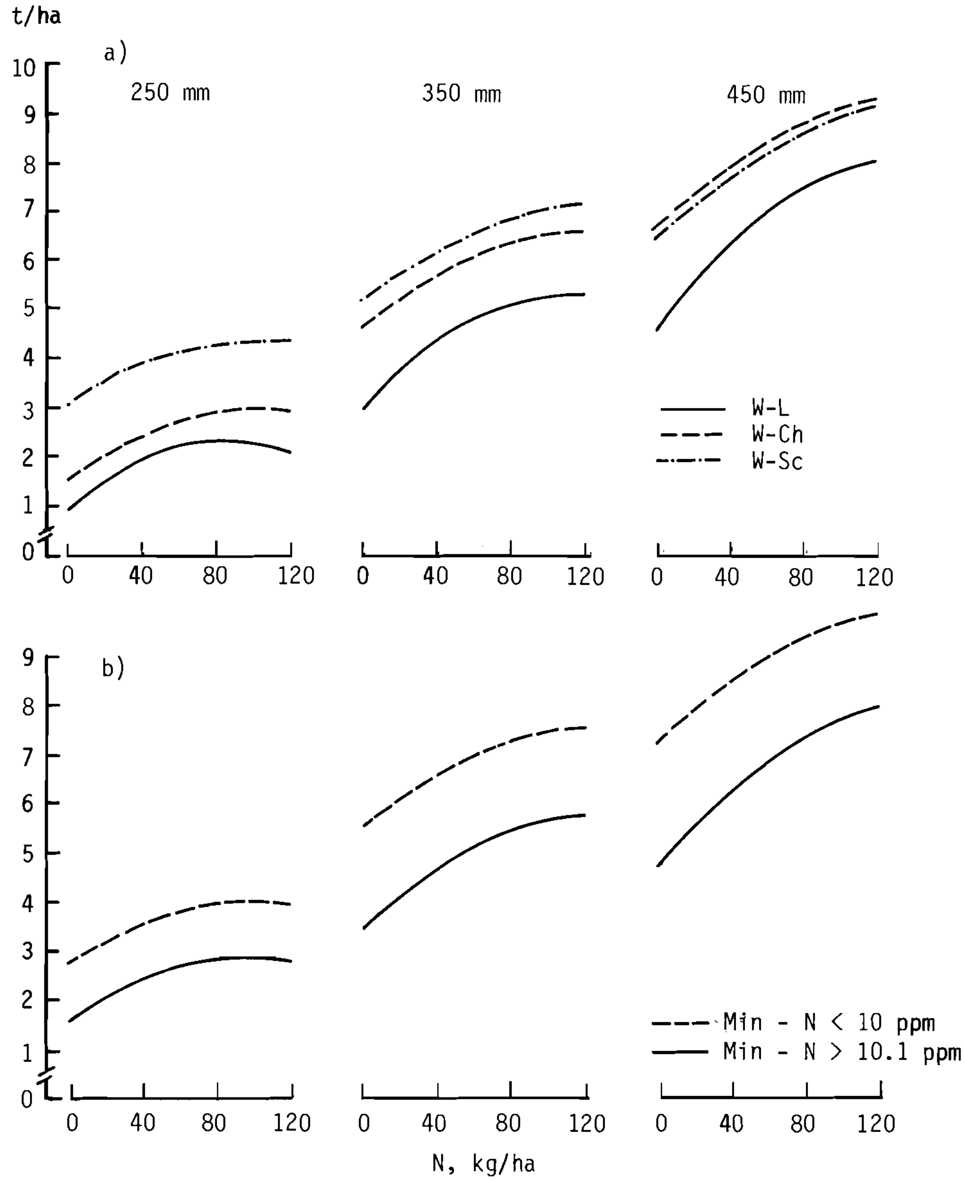
Table 3.3.6 Coefficients for the equation (Ee) for different data sets

Data Set	N	Q	NQ	N^2	Q^2	Const.	Adj. R^2 %
Grain							
All Sites	1.7442	20.2413	0.0239	-0.0538	-0.0167	-2814	64.5
Lentil	1.4615	10.8249	0.0326	-0.0737	-0.0043	-1625	83.3
Chickpea	1.6503	27.8983	0.0219	-0.0525	-0.0232	-4592	64.2
S. Crop	1.6642	18.0242	0.0199	-0.0399	-0.0151	-1940	60.7
PaNa	1.7702	14.7644	0.0276	-0.0551	-0.0120	-1803	57.5
PaNA	3.2225	24.7710	0.0230	-0.0524	-0.0250	-3197	78.3
PANa	-0.4522	20.1341	0.0319	-0.0655	-0.0166	-3122	55.9
PANA	1.2081	26.4535	0.0189	-0.0449	-0.0215	-3859	75.5
Total Dry Matter							
All Sites	9.9122	48.3069	0.0659	-0.1325	-0.0417	-5428	65.2
Lentil	8.9008	33.9333	0.0949	-0.1938	-0.0227	-4108	80.4
Chickpea	12.3210	61.8129	0.0511	-0.1179	-0.0524	-8579	61.4
S. Crop	7.0068	45.8766	0.0600	-0.0976	-0.0418	-3777	64.7
PaNa	5.5403	38.0197	0.0863	-0.1348	-0.0336	-3590	62.4
PaNA	7.5954	67.3028	0.0717	-0.1397	-0.0724	-7429	79.9
PANa	12.2231	44.5036	0.0700	-0.1652	-0.0370	-5731	57.5
PANA	10.0598	60.9126	0.0522	-0.1039	-0.0518	-7236	75.0

Upper and lower case print for PA and NA (available P and N in soil) indicate high and low values, viz. NA>10 ppm>Na and PA>5 ppm>Pa.

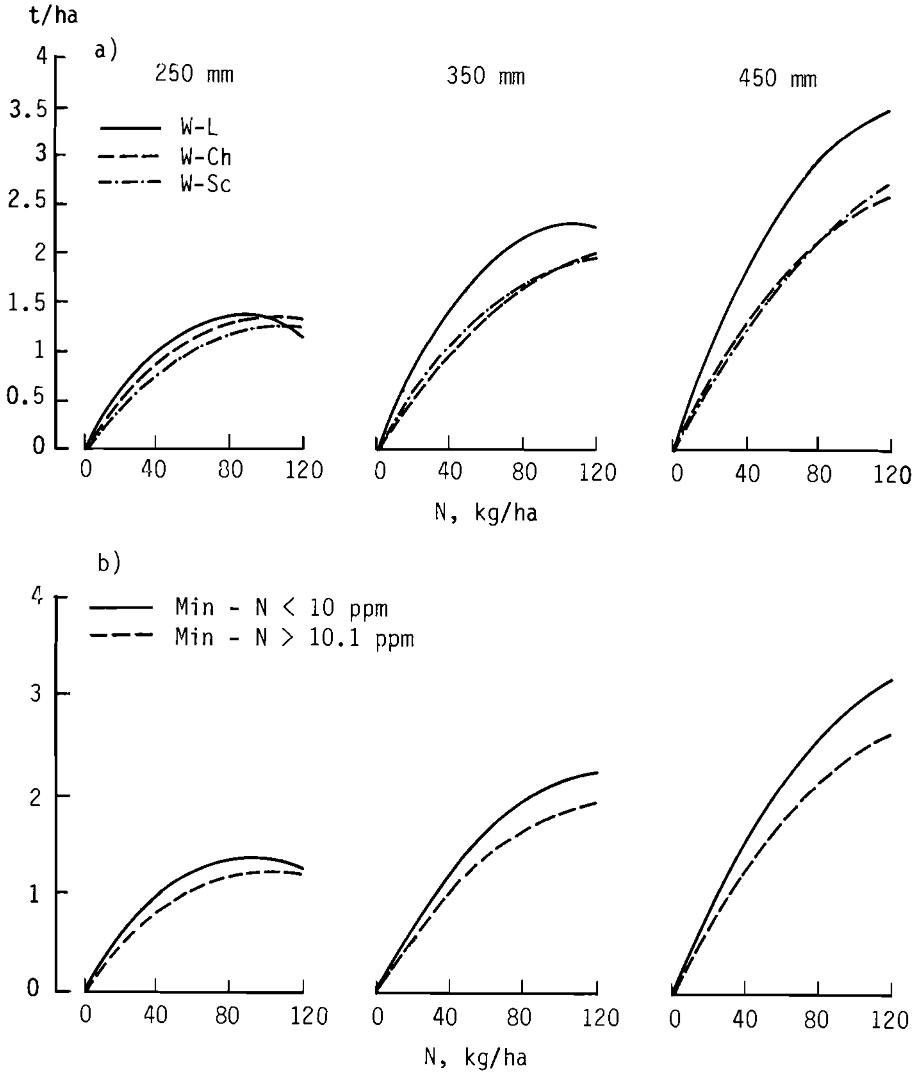
Sites with high mineral-N content gave higher total dry matter production at each rainfall level; and sites with lower mineral-N content gave larger responses to applied N with increasing rainfall. The present study shows nitrate-N to be a reliable guide to N fertilization of wheat. The optimal level of soil NO_3-N maximizing wheat yields is function of the target yields and the preceding crops (Matar et al. 1990).

In conclusion, P fertilizer has now only a small effect on wheat production, due to heavy previous applications by farmers over the last twenty years; consequently, there seems little point in applying the soil test for available-P. Use of phosphate fertilizer could now be



<u>Figure 3.3.5</u> Effect of previous crop (a) and initial soil nutrient content (b) on total dry matter response to N fertilizer at three rainfall levels (Drawn from equation Ee in Table 6.)

reduced to just a maintenance dose applied to maintain an optimum level of soil available-P. Long-term studies are currently being conducted at ICARDA to determine the optimum maintenance doses of phosphate for different soil and climatic conditions.



<u>Figure 3.3.6</u> Effect of previous crop (a) and initial soil nutrient content (b) on total dry matter response to applied fertilizer-N at three rainfall levels (total dry matter increase over zero fertilizer control)
(Drawn from equation Ee in Table 6)

In contrast, nitrogen fertilizer is very effective, but it interacts strongly with rainfall and the initial fertility of the soil. It follows that any economic N-application should be based on likely rainfall to be received in the growing season. One objective of the work is to improve the efficiency of fertilizer use by defining recommended rates in terms of seasonal conditions and soil nutrient status. Since most nitrogen is topdressed at the tillering stage, in late winter or early spring, there is scope to do this. At topdressing time, soil water storage is at its maximum for the season, and one can judge better how much nitrogen to apply. Analyses of long-term climatic records can be used to predict the probabilities of receiving different amounts of rainfall thereafter, and "best-bet" nitrogen topdressing requirements can be determined.

3.3.3.3 Economic Analysis

Economic analysis is as essential as biological analysis to any study of the effects of inputs like fertilizers on agricultural production. Farmers are interested in net benefits and in protecting themselves against risk. Good recommendations arise from evaluations of alternative technologies from the farmers' point of view. This section looks at partial budgets and the use of net benefit curves and marginal analysis to derive recommendations.

Partial Budget. In a partial budget analysis of the four-year data set (Table 3.3.7), values of net revenue and marginal net benefit/cost ratio were compared, for each fertilizer treatment in three crop rotations (W-L, W-Ch and W-SC) using 1989/90 prices of grain, straw and fertilizer. Net revenue values indicate that all fertilizer treatment rates were profitable. Marginal analysis showed that the optimum rate was 120 kg N/ha without P when the previous crop was either lentil or chickpea, but $N_{120}P_{40}$ when wheat followed a summer crop.

Technical and Economic Optima. Technical and economic input optima were calculated for seven defined environments (Table 3.3.8), by taking the partial derivative of the relevant response function for grain yield (see Table 3.3.5).

$$Y = aN + bQ + cNQ + dN^2 + eQ^2 + \text{Const.}$$

where N = N applied (kg/ha)
Q = Seasonal rainfall (mm)

Table 3.3.7 Calculated mean values of increase in net revenue and marginal net benefit:cost ratio for fertilizer use on wheat when the previous crops are: lentil, chickpea and summer crops separately

Previous crop	N/P_2O_5	Increased net rev. SYP/ha				Net benefit:cost ratio			
		0	20	40	80	0	20	40	80
Lentil	0	0	1379	1704	914	-	3.29	2.37	0.79
(21 sites)	40	6366	6904	7249	7866	5.09	4.38	3.85	3.17
	80	8999	8732	8987	9079	4.31	3.76	3.43	2.87
	120	9573	8399	9308	9724	3.55	2.97	2.91	2.58
Chickpea	0	0	1712	921	669	-	3.76	1.45	0.59
(21 sites)	40	5261	4577	4653	5719	4.66	3.47	2.92	2.55
	80	6886	6071	6120	6541	3.71	2.99	2.66	2.27
	120	7496	6937	6608	6689	3.04	2.60	2.28	1.95
Summer crops	0	0	882	1168	1842	-	2.43	1.77	1.45
(28 sites)	40	4317	4828	4906	6173	4.22	3.59	3.03	2.69
	80	5433	6295	7681	6914	3.21	3.07	3.11	2.37
	120	7062	7652	8198	7943	2.92	2.78	2.67	2.22

Technical optima (i.e. yield maxima) were found by equating the partial derivative to zero. For the economic optima, the partial derivative were equated to the price ratio, fertilizer: grain, using the government prices for the 1989/90 season. The calculation was made for three different rainfall amounts. Throughout, it is assumed 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.

Fertilizer rates for the technical optima are higher than those for the economic optima (Tables 3.3.8 and 3.3.9). However, the technical optimum is never a practical target, and it is the economic optimum that is of importance here. The following values were also calculated:

Table 3.3.8 Model specification and calculated mean technical optima (fertilizer rates maximizing yields) under different rainfall conditions

Model Specification	250 mm			350 mm			450 mm		
	At yield maximum N (kg/ha)	Grain yield (kg/ha)	Net revenue increase over zero fert. in grain equiv. (kg/ha)	At yield maximum N (kg/ha)	Grain yield (kg/ha)	Net revenue increase over zero fert. in grain equiv. (kg/ha)	At yield maximum N (kg/ha)	Grain yield (kg/ha)	Net revenue increase over zero fert. in grain equiv. (kg/ha)
1. W-L	65	1126	313	87	2199	562	109	3258	883
2. W-Ch	68	1174	242	89	2744	413	110	3895	630
3. W-SC	83	1898	276	108	2985	467	133	3820	707
4. PaNa	79	1479	341	104	2487	593	129	3325	914
5. PaNA	86	1817	384	108	3017	606	130	3766	879
6. PANa	57	1090	216	82	2329	438	106	3315	738
7. PANA	66	1607	196	87	3108	342	108	4218	527
8. All sites	72	1479	277	94	2700	475	116	3639	726

Rotations: W-L, wheta-lentil; W-Ch, wheat-chickpea; W-SC, wheat-summer crop.
PaNa, PaNA, PANa, PANA - as defined below Table 3.3.6.

Table 3.3.9 Calculated mean economic optima, assuming a marginal rate of return of 40 percent under different rainfall conditions

Model	250 mm				350 mm				450 mm			
	At yield optimum N (kg/ha)	Grain yield (kg/ha)	Increase in net revenue as grain equivalent (kg/ha)	Marginal benefit:cost ratio (%)	At yield optimum N (kg/ha)	Grain yield (kg/ha)	Increase in net revenue as grain equivalent (kg/ha)	Marginal benefit:cost ratio (%)	At yield optimum N (kg/ha)	Grain yield (kg/ha)	Increase in net revenue as grain equivalent (kg/ha)	Marginal benefit:cost ratio (%)
1	52	1113	198	194	74	2186	403	277	96	3245	680	360
2	49	1156	127	131	70	2725	257	187	91	3876	433	242
3	59	1874	137	119	83	2961	278	169	108	3795	469	220
4	61	1462	204	170	86	2470	406	240	111	3307	678	310
5	67	1799	234	178	89	2998	413	236	111	3748	642	295
6	42	1075	118	141	67	2315	292	222	91	3300	544	303
7	44	1586	88	101	65	3080	191	149	86	4196	355	197
8	53	1461	154	146	76	2682	308	207	98	3621	515	267

Calculations are based on relative price of fertilizer N to wheat grain of 1.4066

a. The predicted mean yield at the optimum N rate;

b. The resulting increase in net revenue (expressed in kg grain/ha) over 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.

Calculations of marginal benefit:cost ratio were extended for each of the 7 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 an N price up to 3 times higher than that of grain when rainfall equals 250 mm, and up to 4 and 6 times for 350 mm and 450 mm, respectively.

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3.4 Phosphate Studies

3.4.1 Predicting the Phosphate Sorption Characteristics of Soils of the WANA Region*

J. Torrent, E. Afif and A. Matar**

3.4.1.1 Introduction

The P quantity/intensity (Q/I) relationships of soils have been intensively investigated for the last 25 years. The Q/I curves, also called "adsorption isotherms" or, more properly, "sorption curves", provide data useful for P fertility management. For instance, the quantity of P sorbed at a phosphate equilibrium concentration giving near-maximum yield has been used to estimate the "external" phosphate requirement of a crop (Fox 1981). Another index derived from the

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** Professor of Soil Science (Córdoba), Graduate Student, and Soil Chemist (ICARDA).

sorption curve is the phosphate buffer capacity (PBC), i.e. the slope of the curve (dQ/dI) at a fixed concentration; this index is important in models predicting P uptake by plants (Barber 1984), and it helps to predict P fertilizer requirements when it is used together with soil test data (e.g. Holford 1980).

The determination of P sorption curves in the laboratory needs time and effort, since 10-12 duplicate points are usually needed. For routine purposes, one-point tests that estimate P sorption or PBC have been recommended (Bache and Williams 1971), although the information that they provide is limited. Alternatively, the P sorption properties can be estimated from other soil properties, provided that a significant relationship exists (for a group of soils) between these two groups of properties.

In this project we examined the possibility of estimating P sorption in soils of the WANA region from properties that can be determined in the laboratory on a routine basis.

3.4.1.2 Materials and Methods

The 21 soil samples used in this study were collected in different localities from Syria, Jordan, Tunisia and Pakistan, and ranged widely in those properties considered to be significant for P sorption, such as clay content, free iron oxides and calcium carbonate equivalent (Table 3.4.1). Soil analyses were carried out according to standard methods (Peña and Torrent 1990). Phosphate sorption curves were obtained according to Fox and Kamprath (1970) and sorption parameters were evaluated from the linear form of the Freundlich equation fitted to the sorption data points (usually 10-12) within the 0-3 mg P/l equilibrium concentration range.

3.4.1.3 Results and Interpretation

The amount of P sorbed at an equilibrium concentration of 0.2 mg P/l ($P_{0.2}$) was taken as an index of the P sorption capacity (this concentration is considered to give maximum yields for most important field crops). Table 3.4.2 shows the correlation of $P_{0.2}$ with several soil properties. The property best correlated with $P_{0.2}$ was **Fe_d** (Figure 3.4.1), which was able to explain 74% of the variance in sorption. In a stepwise regression analysis no other variables significantly increased the percentage of variance explained.

Table 3.4.1 Values (means and ranges) of soil properties

Property	Mean	Range
Clay (g/kg)	415	50 - 760
Organic matter (g/kg)	13	1 - 53
Total $CaCO_3$ (g/kg)	209	17 - 494
Active $CaCO_3$ (g/kg)	64	3 - 204
pH (water)	8.2	6.8 - 8.9
CEC ($cmol_c$/kg)	37.6	8 - 79
Fe_d (g/kg)*	13.2	1.3 - 53.2
Fe_o (g/kg)*	2.0	0.9 - 4.9
Olsen-P (g/kg)	4.7	2.1 - 9.7

* Fe_d = Citrate-bicarbonate-dithionite soluble Fe;
  Fe_o = Acid oxalate soluble Fe.

Table 3.4.2 Correlation between $P_{0.2}$* and selected soil properties

Property	Clay	Organic matter	Total $CaCO_3$	Active $CaCO_3$	pH	CEC	Fe_d	Fe_o
Correlation coefficient	0.48	0.10	-0.46	-0.35	-0.52	0.22	0.86	0.78

* $P_{0.2}$ = P sorbed at an equilibrium concentration of 0.2 mg P/l

The importance of iron oxides in P sorption has been suggested by regression analysis carried out in different groups of soils within the Mediterranean region (Peña and Torrent 1984; Ryan et al. 1985; Peña and Torrent 1990 and others). This is a consequence of the usually low amounts of other highly P-sorbing components (amorphous aluminosilicates, Al oxides, hydroxy-Al compounds) in these soils.

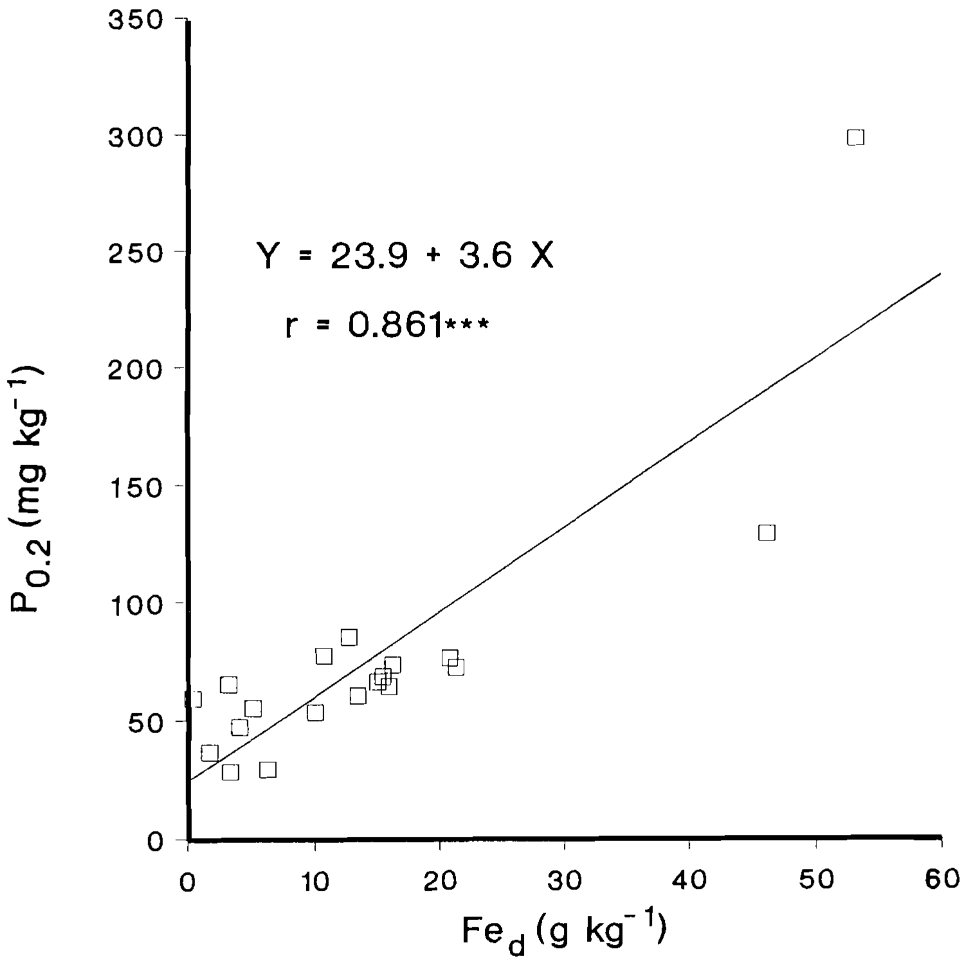

Figure 3.4.1 P sorption at 0.2 mg P L^{-1} equilibrium concentration against Fe_d

Although the noncrystalline Fe oxides (estimated by Fe_o) have larger specific surface area than the crystalline ones (estimated by the difference Fe_d - Fe_o) they seem, in most cases, to be less related to P sorption than crystalline oxides, probably because Fe_o is usually much lower than Fe_d - Fe_o. Some cases in which Fe_o has a better predictive value than Fe_d have, however, been reported (Ryan et al. 1985).

In the present (as in other) studies dealing with soils of widely ranging properties (Peña and Torrent 1990), $P_{0.2}$ was not highly correlated with clay content. In studies dealing with homogeneous groups of soils, this correlation was, however, high (e.g. Peña and Torrent 1984; Bakheit Said 1990). A likely reason is that, in these instances, a high covariance between clay and Fe_d was to be expected (or was actually found). In summary, Fe_d is a better predictor than clay for soils that do not conform to a certain soil type for which a previous study of P sorption versus soil properties has been carried out.

The minor influence of $CaCO_3$ on P sorption, as suggested by the present and other regression analyses (Bakheit Said 1989), apparently contradicts the "textbook" contention that calcareous soils have a high P-fixing capacity. Precipitation of Ca-phosphates can occur, however, at phosphate concentrations higher than those used in constructing the P sorption curves, such as those occurring near a P fertilizer granule. The manner in which fertilizers are applied (granules, powder, liquid) and the rate at which fertilizers are dissolved and diffuse through soil, among other factors, will notably influence the P concentration in the soil solution and the relative importance of true adsorption and true precipitation processes.

3.4.1.4 Conclusions and Further Research Work

The P sorption capacity of soils of the WANA region can be estimated from the Fe_d content of the soil, which can be determined in a reasonably short time and with little effort. More work is needed to establish the relationships between P sorption and Fe oxides (and perhaps some other commonly determined soil properties) in different groups of soils. These relationships, if significant, would provide a good tool in some aspects of P fertilization.

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3.4.2 Effect of Site, Crop Sequence and P-Fertilizer Regime on Soil Available-P Status

A. Matar, M. Jones, M. Pala

Phosphate deficiency is common in the predominantly calcareous soils of the WANA region. Large and economic responses to phosphate fertilizer can be achieved (Soils Directorate/ICARDA 1985-1989); but as costs rise, there is increasing incentive to seek greater efficiency in its utilization. Two points are of particular relevance:

i. added phosphates are transformed into unavailable forms in the soil through precipitation and/or adsorption on soil colloidal surfaces;

ii. over the last twenty years, large amounts of phosphate have been applied to arable soils in areas of wheat-based farming systems, beyond the needs of the crops. This has actually led to a build-up of phosphate availability, such that phosphate responses are now only rarely observed.

Important research objectives therefore are to determine the "maintenance rate of phosphate addition" that maintains an availability of phosphate in the soil adequate to optimize cereal and small legume production and to understand better the underlying processes determining that rate.

Long-term trials were started at three experimental sites (Breda, Tel Hadya and Jindiress) in 1986/87 to study the rates of change of available-P in soils (Olsen-P) in relation to (a) different initial values arising from the residual effects of previous P additions; (b) different annual rates of application, under a cereal/legume cropping sequence (Breda: barley/vetch; Tel Hadya: wheat/lentil; and Jindiress: wheat/chickpea).

The trials started with the creation of a range of soil available-P status by the application of 0, 50, 100, 150 and 200 kg P_2O_5/ha to large plots (main plots). In the following seasons, yearly rates of 0, 15, 30, 45 or 60 kg P_2O_5/ha were applied to every crop in the rotation (sub-plots). In all cases, the P fertilizer was broadcast on the soil surface and incorporated before sowing. All treatments were replicated twice at each site. A standard dressing of 60 kg N/ha was applied to all plots in the cereal crop phase.

Over the period, 1986/87 to 1989/90, seasonal rainfall ranged from 183 to 415 mm at Breda, 233 to 504 mm at Tel Hadya and 334 to 715 mm at Jindiress, with averages of 260, 332 and 501 mm, respectively, close to the long-term averages of 278, 330 and 447 mm. One may reasonably assume that total crop growth and total P uptake at each site over the four years were close to the average.

Soil available-P values were determined every season just before sowing (Figures 3.4.2, 3.4.3 and 3.4.4). They can be seen to depend on the size of the initial fertilizer application in 1986/87, on the annual rates of application and on the experimental site.

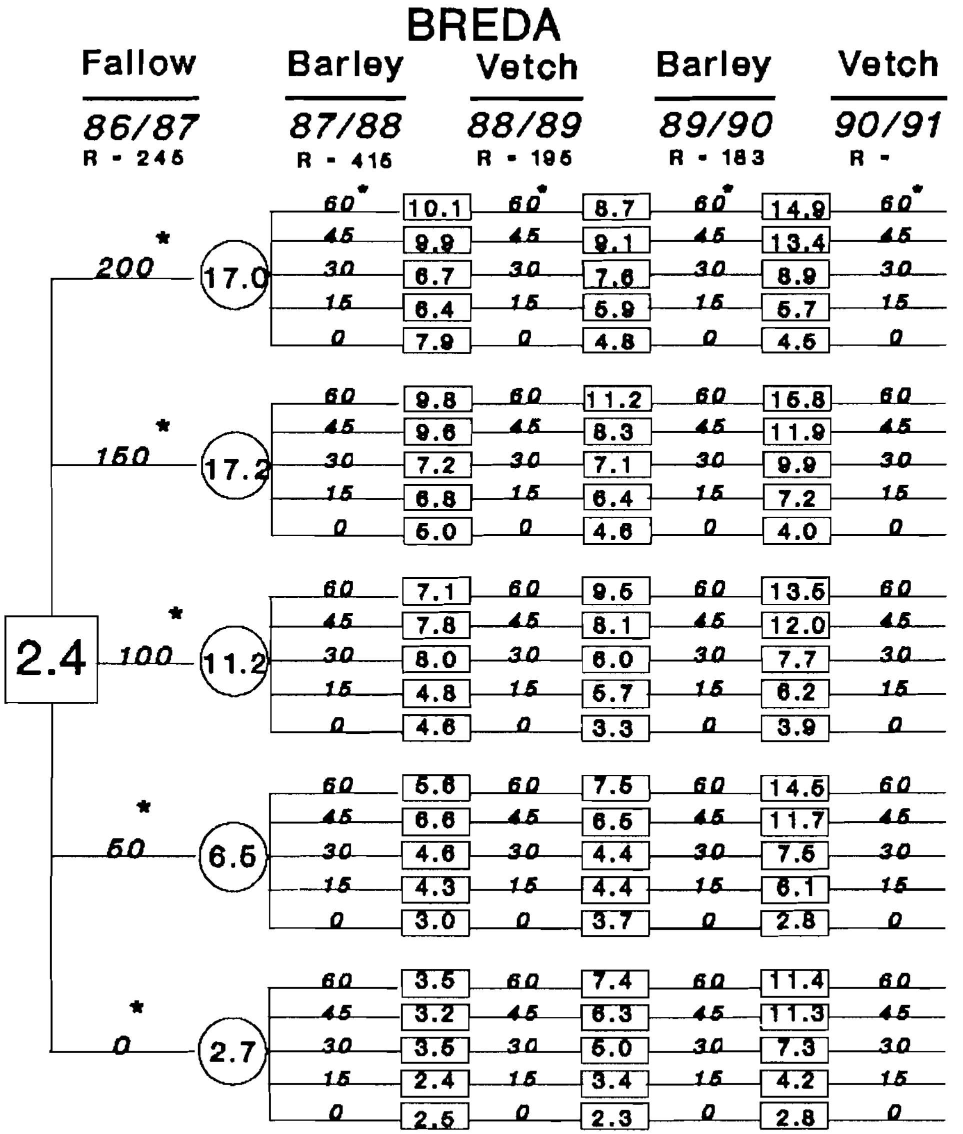
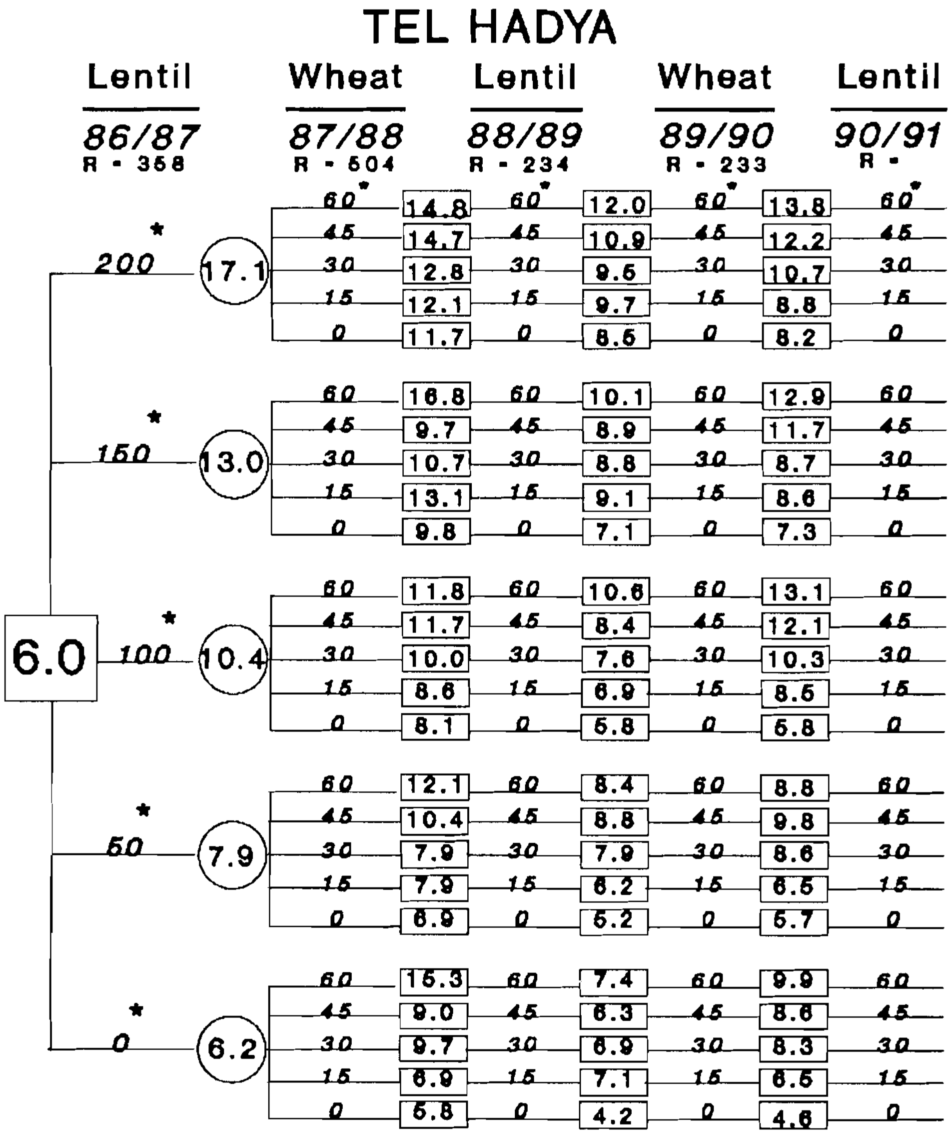


Figure 3.4.2 Changes in soil available P ($NaHCO_3$-P) with time in relation to rate of P applied at Breda

* Applied kg P_2O_5/ha
R=Seasonal rainfall in (mm)



<u>Figure 3.4.3</u> Changes in soil available P ($NaHCO_3$-P) with time in relation to rate of P applied at Tel Hadya

* Applied kg P_2O_5/ha
R=Seasonal rainfall in (mm)

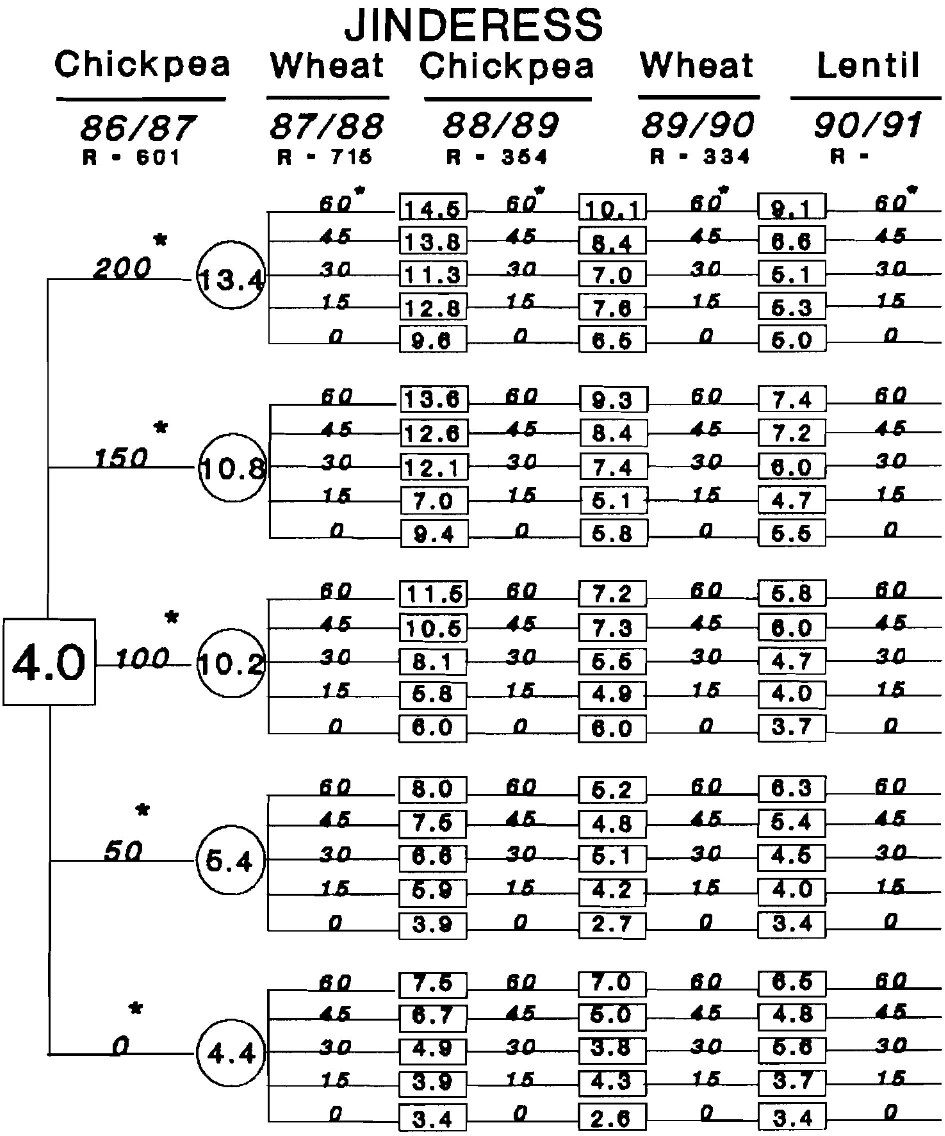


Figure 3.4.4 Changes in soil available P ($NaHCO_3$-P) with time in relation to rate of P applied at Jindiress
* Applied kg P_2O_5/ha
R=Seasonal rainfall in (mm)

The approximate annual rates of P required to maintain the level of 7 ppm Olsen-P that appears to be necessary for maximum yields of cereals or grain legumes (Matar et al. 1987) are presented in Table 3.4.3. Highest rates are at Jindiress, where 45 to 50 kg P_2O_5/ha/year are needed when the initial Olsen-P value is high (above 10 ppm) and more than 60 kg P_2O_5/ha when initial values are low. The annual requirement at Breda is much lower, 15 to 27 kg P_2O_5/ha, depending on the initial Olsen-P value. And the requirement is least at Tel Hadya, where no phosphate appears to be necessary for three seasons if the initial Olsen-P value is high (> 13 ppm).

Table 3.4.3 Maintenance rate of phosphate needed to maintain the available-P in soils at 7 ppm after 3 years of cropping at the three sites

Site	Initial (86/87) rate of P_2O_5 added, kg/ha	**Olsen available P ppm	Annual rate of P needed kg P_2O_5/ha
Breda	150-200	17-17.2	15-20
	100	11.2	22
	50	6.5	25
	0	2.7	27
Tel Hadya	200	17.1	0
	150	13.0	0
	100	10.4	8
	50	7.9	20
	0	6.2	25
Jindiress	200	13.4	50
	150	10.8	45
	100	10.2*	60+
	50	5.4	60+
	0	4.4	60+

* More than 60 kg P_2O_5/ha were needed at Jindiress to maintain an Olsen-P of 7 ppm when the starting Olsen-P was $\leq$ 10. ppm

** Prior to 1987/88 season, i.e. after one year

We may make two preliminary observations on these findings:

- There was no clear benefit (at least, over three years) from high initial phosphate rates (200 and 150 kg P_2O_5/ha) in terms of substantially lower maintenance-rate requirements.

- Site differences were larger than expected. Thus, although the immobilization rate of P in Breda and Tel Hadya soils had previously been shown to be very similar (ICARDA 1985) and crop P-uptake values were also similar, high levels of Olsen-P were apparently more easily maintained at Tel Hadya than at Breda. The required maintenance rate was highest at Jindiress, where total P-uptake was higher due to greater plant growth under higher rainfall and the immobilization rate is relatively high (ICARDA 1985).

This long-term experiment will continue for several more seasons with measurements on soil Olsen-P and total P-uptake by each crop.

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3.4.3 Direct and Residual Effect of Applied Phosphate on the Water-Use Efficiency, Yields and Nutrient Uptake of Lentil

A. Matar, D. Dermoch* and F. Jassem**

3.4.3.1 Introduction

Lentil is an important crop in the rainfed farming systems in the dry areas of WANA, where its grain is a valuable source of good quality protein in the diet. Lentil is grown in rotation after cereals on highly calcareous soils that are naturally low in native phosphorus.

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** Graduate Student at University of Aleppo

In Syria and elsewhere in the region significant responses of lentil to phosphorus application have been reported (Loizides 1970, Matar et al. 1987, 1990).

In 1986/87, an investigation of the response of food and forage legumes to P fertilization was started under more controlled conditions on Tel Hadya station. The legumes studied (faba bean, chickpea, pea, vetch and lentil) appeared to be almost equally responsive to both applied and residual phosphate (FRMP Annual Report 1988). Biologically speaking, residual and applied-P are likely to have a different "timing" of availability, and we would expect the relative importance of the two sources to depend not only on the characteristics of legume root development, but also on the soil type and on the particular seasonal temperature and rainfall distribution.

A detailed study was carried out for two seasons, 1987/88 and 1988/89, at three stations, Jindiress, Tel Hadya and Breda, to investigate the effect of the interaction between phosphate fertilization and water use on lentil yields and nutrient uptake under different soil and environmental conditions. The results will be used for an MSc thesis by Ms F. Jassem.

In the season preceding each experiment, the experimental area was divided into 5 large blocks of land which received varying rates of P-fertilizer (0, 50, 100, 150 and 200 kg P_2O_5/ha). This pre-treatment of the experimental area provided a range of residual available-P levels under which responses of lentil to newly applied P (0, 50 and 100 kg P_2O_5/ha) could be evaluated. Total biological yields and nitrogen and phosphorus uptake were determined at 5 or 6 stages of growth depending upon site and season. At harvest, grain and straw yields were recorded.

The present report focuses on three treatments in which the water content of the soil profile was measured every ten days: plots which received 100 kg P_2O_5 in the previous season (PR 100); 100 kg in the current season (PD 100) but none the previous season; and control, PO. Soil moisture was measured gravimetrically in the 0-15 cm soil layer and with a neutron probe at 15 cm intervals in the rest of the profile to 150 cm.

3.4.3.2 Effect of Phosphate Application on Growth and Yield of Lentil

The effects of newly applied phosphate and residual-P on the growth of lentil were monitored at various stages of plant growth from emergence to maturity. New phosphate (i.e. drilled with the seeds) had a positive and significant effect in both seasons at Breda, on total above-ground dry matter production, on plant P% and on total P uptake (TPU); but few responses were observed at Tel Hadya or Jindiress (Table 3.4.4).

However, it was remarkable that responses to phosphate residual from fertilizer applied in the year preceding lentil (wheat at Tel Hadya and Jindiress and fallow at Breda) and mixed with the plow layer by pre-seeding cultivation, proved to be more important and efficient, at Tel Hadya and Jindiress as well as at Breda (Table 3.4.4). The P% of lentil plant material was found significantly higher at all 3 sites in both seasons in the presence of residual-P. Furthermore, whenever a response to P was observed, that of the residual-P was found to be equal and sometimes superior to that of the newly applied-P in increasing dry matter accumulation or TPU. But both applied and residual P contribute to growth and P uptake by lentil, especially at the dry site, Breda.

Total dry matter (grain + straw) at harvest proved to be quite responsive to P application, especially to residual P, and wherever soil Olsen-P was low. That was true in the 1988/89 season when all 3 sites had soil available-P values less than 3.9 ppm, and at both Breda and Tel Hadya in 1987/88. But at Jindiress in 1987/88, with Olsen-P equivalent to 4.8 ppm, there was no response to P-application (Tables 3.4.5 and 3.4.6). Previous work had shown that a critical level of Olsen-P of about 5-6 ppm could lead to maximum production of lentil (Matar et al. 1987).

Table 3.4.4 Significance levels of the responses of total dry matter (TDM), P% in plant material and total P uptake (TPU) to residual or newly applied phosphate fertilizer at three stations in 1987/88 and 1988/89

Component	New P				Residual P			
	Stage of growth				Stage of growth			
	S1	S2	S3	S4	S1	S2	S3	S4
	1987/88							
Breda								
Total dry matter	xx	xx	xx	xx	NS	xx	x	x
P%	xx	xx	xx	xx	xx	xx	xx	xx
TPU	xx	xx	xx	xx	xx	xx	xx	xx
Tel Hadya								
Total dry matter	NS	x	NS	NS	NS	x	NS	x
P%	x	NS	NS	NS	NS	x	xx	NS
TPU	NS	NS	NS	x	NS	x	x	x
Jindiress								
Total dry matter	NS	x	NS	-	NS	NS	NS	-
P%	x	NS	x	NS	xx	xx	xx	xx
TPU	NS	x	xx	-	xx	NS	x	-
	1988/89							
Breda								
Total dry matter	xx	xx	xx	xx	xx	xx	xx	xx
P%	xx	NS	NS	NS	xx	xx	NS	NS
TPU	xx	xx	x	xx	xx	xx	xx	xx
Tel Hadya								
Total dry matter	NS	NS	NS	NS	NS	x	xx	x
P%	NS	NS	NS	NS	xx	NS	xx	xx
TPU	NS	NS	NS	NS	xx	xx	xx	xx
Jindiress								
Total dry matter	NS	NS	NS	NS	NS	NS	NS	NS
P%	NS	NS	x	NS	NS	xx	x	x
TPU	NS	NS	NS	NS	NS	NS	NS	x

S1=early; S2=advanced early; S3=full flowering; S4=early podding

Table 3.4.5 Effects of residual and newly applied phosphate on harvest total dry matter of lentil in 1987/88 at three stations

Newly applied P, kg P_2O_5/ha	Residual phosphate (kg P_2O_5/ha)					
	0	50	100	150	220	Mean
Breda						
0	6092	6740	6811	7300	7557	6900
50	7414	7410	7552	7846	7588	7569
100	7625	7726	7610	7294	7524	7556
Mean	7044	7292	7334	7480	7556	
Signif. level	New P (**); Residual P (*); Interaction (*)					
Tel Hadya[1]						
0	5188	6752	5988	7710	6661	6460
50	6057	6813	6323	7635	7193	6804
100	6032	7498	6424	7154	7974	7016
Mean	5759	7021	6245	7500	7276	
Signif. level	New P (NS); Residual P (**); Interaction (NS)					
Jindiress						
0	7694	7890	7855	7777	8204	7884
50	7888	7827	8044	8181	8060	8000
100	7739	8214	7543	7884	8022	7880
Mean	7773	7977	7814	7947	8095	
Signif. level	New P (NS); Residual P (NS); Interaction (NS)					

1. Tel Hadya field was moderately infected by Orobanche.

The response to a new application of P proved very significant (at 1% level) in both seasons at Breda only. By harvest, no effect of new P was evident at Tel Hadya or Jindiress. One could conclude that applying P with the seed is important at Breda because its immediate availability provides a boost to young seedlings. This leads to a better coverage of the soil surface and a reduced water loss by evaporation, which is especially important at Breda because it is the driest site.

Table 3.4.6 Effects of residual and applied phosphate on total dry matter at harvest of lentil in 1988/89 at three stations (Breda, Tel Hadya, Jindiress)

Newly applied P, kg P_2O_5/ha	Residual phosphate (kg P_2O_5/ha)					
	0	50	100	150	220	Mean
Breda						
0	1321	1497	1441	1845	2077	1636
50	1683	1818	1697	1977	2059	1847
100	1577	1762	1626	2032	1928	1785
Mean	1527	1692	1588	1951	2021	
Signif. level	New P (**); Residual P (**); Interaction (NS)					
Tel Hadya						
0	1664	1881	1920	2048	2001	1902
50	1588	1973	2105	1887	2274	1965
100	1609	1893	1698	2176	1961	1868
Mean	1620	1916	1907	2037	2079	
Signif. level	New P (NS); Residual P (**); Interaction (NS)					
Jindiress						
0	3248	3649	4198	3979	3991	3813
50	3617	3521	4114	3743	4038	3806
100	3640	3251	4242	3668	3531	3667
Mean	3501	3474	4185	3797	3853	
Signif. level	New P (NS); Residual P (*); Interaction (NS)					

The effects of phosphate application on lentil grain production were less straightforward. The grain yields were quite high, 2.2 - 2.5 t/ha, at all three sites, under the high rainfall of 1987/88 (414 mm at Breda rising to 715 mm at Jindiress) (Table 3.4.7). But increasing the rate of P, either in the current or preceding season, tended to reduce grain yield. The reason for this is not known, and a more detailed study is needed to interpret these results.

In 1988/89, rainfall was scarce: 194, 249 and 352 mm at Breda, Tel Hadya and Jindiress, with mean grain yields of 538, 653 and 1254

Table 3.4.7 Effects of residual and applied phosphate on grain yield of lentil in 1987/88 at three stations (Breda, Tel Hadya, Jindiress)

Newly applied P, kg P_2O_5/ha	Residual phosphate (kg P_2O_5/ha)					
	0	50	100	150	220	Mean
Breda						
0	2278	2415	2314	2376	2314	2339
50	2621	2451	2432	2322	2108	2387
100	2334	2369	2296	2181	2049	2246
Mean	2411	2412	2348	2293	2157	
Signif. level	New P (*); Residual P (**); Interaction (NS)					
Tel Hadya						
0	2081	2489	2114	2290	2310	2257
50	2383	2354	2321	2495	2048	2320
100	2218	2562	2167	2308	2537	2358
Mean	2227	2413	2201	2364	2354	
Signif. level	New P (NS); Residual P (NS); Interaction (NS)					
Jindiress						
0	2961	2765	2696	2675	2607	2741
50	2804	2283	2488	2646	2337	2511
100	2807	2794	2531	2300	2524	2591
Mean	2857	2614	2572	2540	2489	
Signif. level	New P (*); Residual P (*); Interaction (NS)					

kg/ha, respectively. The response of grain yield to residual-P was positive and significant at all three sites (Table 3.4.8); but no significant effect of new P was observed, except at Breda.

These results demonstrate again that response to P fertilization is relatively more important in dry years. In wet years root development is more extensive and the pool of available-P in the soil is effectively larger, which reduces the need for fertilizer P in all but the most P-deficient soils.

Table 3.4.8 Effects of residual and applied phosphate on grain yield of lentil in 1988/89 at three stations (Breda, Tel Hadya, Jindiress)

Newly applied P, kg P_2O_5/ha	Residual phosphate (kg P_2O_5/ha) 0	50	100	150	220	Mean
Breda						
0	417	474	407	587	652	507
50	547*	599*	494	581	625	569
100	477	553*	480	625	559	539
Mean	480	542	450	598	612	
Signif. level	New P (**); Residual P (**); Interaction (*)					
Tel Hadya						
0	582	646	655	737	680	660
50	547	696	690	638	772	668
100	560	624	596	739	631	630
Mean	563	655	647	705	694	
Signif. level	New P (NS); Residual P (*); Interaction (NS)					
Jindiress						
0	1039	1144	1220	1377*	1384*	1233
50	1213	1188	1293	1371	1415	1296
100	1191	1044	1350	1238	1346	1234
Mean	1148	1126	1287	1328	1382	
Signif. level	New P (NS); Residual P (**); Interaction (NS)					

3.4.3.3 Effect of Phosphate Application on Water Use by Lentil

Water use by the lentil crops in 1987/88 was similar at all 3 sites, with average values of 329, 344 and 374 mm at Breda, Tel Hadya and Jindiress, respectively; and water-use efficiency (WUE) was apparently unaffected by newly applied or residual phosphate (Table 3.4.9).

In 1988/89, WUE was slightly but significantly increased (5% level) by direct or residual P at Breda, and by the residual P only at Jindiress (Table 3.4.9). No significant effects were observed at Tel

Hadya. In general, improvements in WUE from phosphate application were found to be smaller for lentil than those found previously for barley (Cooper et al. 1987).

3.4.3.4 Relationships between water use, total dry matter, N and P uptake by lentil

A linear relationship was found, as expected, between water use by lentil and total biological yield, taken across all growth periods in both seasons and across all three sites, with R^2 values of 0.84 and 0.87 for P-fertilized and non-fertilized treatments (Table 3.4.10).

Table 3.4.10 Relationships between total dry matter production (TDM), total N and P uptake (TNU, TPU) and water use (WU) by lentil taken across various stages of growth and all sites and seasons 1987/88 and 1988/89 with (P+) or without direct P application (Po)

Dependent variable	Regression equations	R^2
TDM (Po)	= 20.28 WU - 1256.8	0.87**
TDM (P+)	= 21.60 WU - 1152.5	0.84**
TPU (Po)	= 0.042 WU - 2.31	0.81**
TPU (P+)	= 0.051 WU - 2.63	0.77**
TNU (Po)	= 0.429 WU - 20.23	0.88**
TNU (P+)	= 0.464 WU - 17.21	0.83**

Similar linear relationships also occurred between lentil water use and total P uptake and total N uptake calculated across all stages of plant growth in both seasons and at all 3 sites (Table 3.4.10). We may attribute this, in the case of P, both to direct effects of greater phosphate mobility and availability under wetter soil conditions and to the indirect effect of the biomass-water use relationship. In the case of N, the effect of moisture on root proliferation and depth may have been a significant factor. From regressions cited in Table 3.4.10, a general estimate of total P and N uptakes by lentil can be calculated from the volume of water use, and vice versa.

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3.5 Soil and Crop Nitrogen Dynamics

3.5.1 Soil Nitrogen Status in Two-Course Rotations: A Preliminary Assessment

A. Matar and H.C. Harris

Last year we reported in some detail on a two-course rotation trial at Tel Hadya in which wheat is grown in seven crop sequences (FRMP 1990). We indicated in that report that studies on the nitrogen balance of the rotations were to be started. Here we report on the results of analyses of soil nitrogen at the end of the summer of 1989.

3.5.1.1 Trial Design

Details of the design and management of the trial are given elsewhere (FRMP 1990). In brief, it is a phased entry two-course rotation trial with seven crop sequences. The sequences are wheat after: fallow (F), summer crop (water melon) (S), vetch (V), lentil (L), chickpea (C), medic (*Medicago* spp.) (M), and wheat (W). Because of drought in

1988/89 water melon was not planted and the plots were fallowed through the season. Four levels of nitrogen (0, 30, 60, and 90 kg N/ha) are applied to the wheat phase in a split-plot design. The plots are further split to accommodate three levels of management of the wheat stubble: heavy, moderate and zero grazing. The rotations were established in 1983/84, and the treatments were begun in 1985/86. Of the legumes, chickpea is combine harvested, lentil hand harvested, and both medic and vetch are grazed.

3.5.1.2 Soil Samples

Soils of all sub-sub-plots of two of the three replicates were sampled at the beginning of November 1989, before the start of the rainy season. Samples were taken from 0 to 20 cm depth; five samples from each sub-sub-plot were bulked and analysed, in duplicate, for NO_3^-, mineral N, and total N. These are referred to as the surface samples.

In the last week of November soil profiles were sampled, in 20 cm increments to a depth of 100 cm, in selected plots. The treatments selected were both phases of the heavily grazed sub-sub-plots in the wheat-fallow, wheat-chickpea, and wheat-medic rotations where 0 and 90 kg N/ha is applied in the wheat phase. These treatments are ones in which detailed soil water measurements are taken during the crop season.

3.5.1.3 Mineral Nitrogen in Surface Samples

After Wheat. In the surface samples the most significant source of variation was the fertilizer N applied in the wheat phase (Table 3.5.1). This was presumably due to inefficient uptake of N in the drought conditions of the preceding season, as the effect was shown in the N_{60} and N_{90} treatments (Figure 3.5.1). Stubble management did not affect the N status. There were, however, significant differences among the rotations (Figure 3.5.2). Most noteworthy was the increase in mineral N in the wheat-medic rotation (M), which is apparent at all levels of applied N, and in the wheat-vetch rotation (V), apparent at

Table 3.5.1 F-values of analyses of variance of mineral N, NO_3^-, and NH_4^+ in surface soil samples taken at the end of summer, 1989, from a two-course rotation trial at Tel Hadya

Source of Variation	d.f.	After Wheat Phase Min-N	NO_3^-	NH_4^+	After Phase 2 Min-N	NO_3^-	NH_4^+	Tabulated $F_{0.05}$
Replicate	1	2.88	4.38	0.30	4.06	14.44	0.80	5.99
Rotation	6	9.80	10.38	5.90	13.02	124.65	5.58	4.28
Error a	6							
Nitrogen	3	142.40	101.68	129.68	2.64	14.62	0.25	3.07
N x Rot	18	2.06	2.74	1.23	0.95	1.92	0.95	2.13
Error b	21							
Grazing	2	0.68	0.15	1.85	2.39	0.98	1.46	3.15
G x Rot	12	0.65	0.38	1.12	0.39	0.60	0.67	1.92
G x N	6	0.48	0.22	1.08	0.84	0.86	0.61	2.25
G x Rot x N	36	0.47	0.39	0.66	0.72	0.71	1.01	1.62
Error c	56							

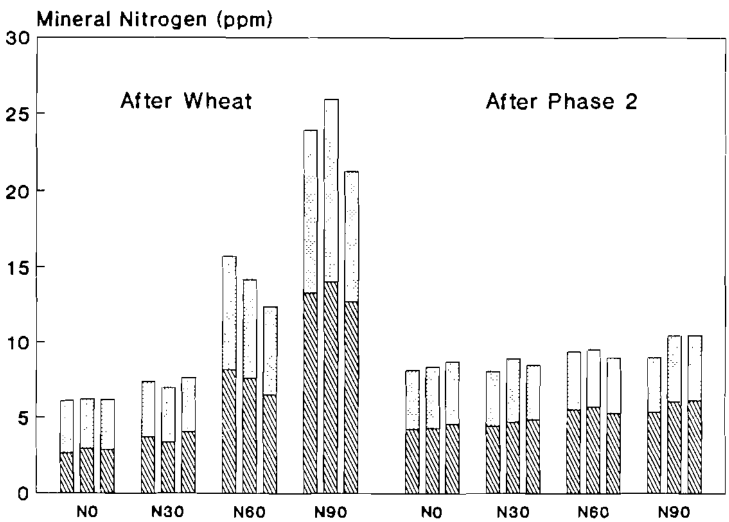

Figure 3.5.1 Total mineral nitrogen (ppm), NO_3^- (cross-hatched bars), and NH_4^+ (stippled bars) in surface soil (0-20 cm) in late summer, 1989, after wheat and after Phase 2 of crop rotations at Tel Hadya. The four rates of nitrogen are applied to the wheat phase only. The three bars within each N treatment represent, from left to right, heavy, moderate and zero grazing of wheat stubble.

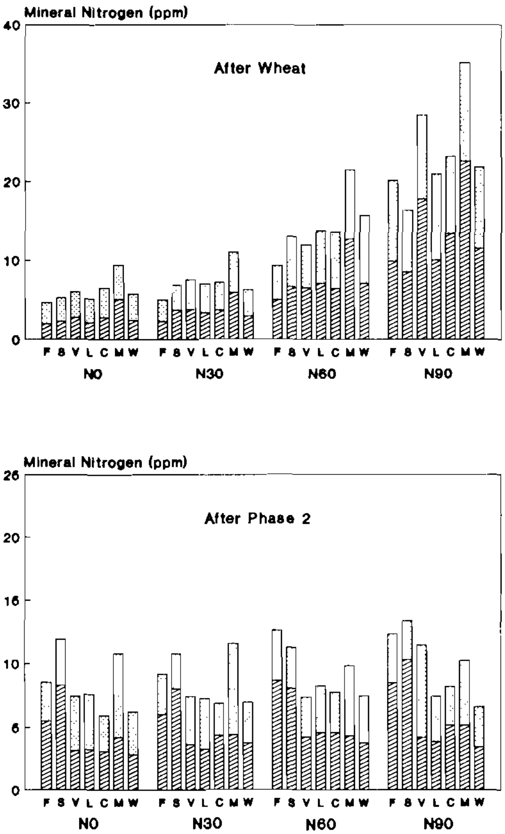

Figure 3.5.2 Total mineral nitrogen, $NO3^-$ (cross-hatched bars), and NH_4^+ (stippled bars) in surface soil (0-20 cm) in late summer, 1989, following both phases of seven crop sequences. F=Fallow; S=water melon; V=vetch; L=lentil; C=chickpea; M=medic; W=wheat.

90 kg of applied N. Most of the increase was present as NO_3^-. In three of the four nitrogen treatments there was least N present following wheat after fallow. These results are presumably related to the productivity of the preceding wheat crop. About three times as much nitrogen was removed from the wheat-fallow as from the wheat-medic rotation (Figure 3.5.3). Approximately 140 mm of additional water was available to wheat after fallow following effective fallow storage in the 1987/88 rainy season, which was exceptionally wet.

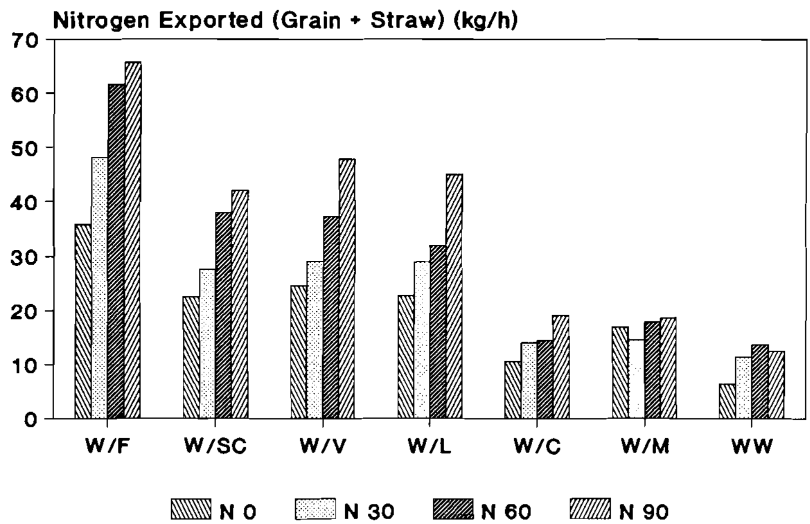

Figure 3.5.3 Nitrogen (kg/ha) removed in wheat grain and straw in seven crop sequences in the 1988/89 crop growth season.

After Phase 2. In the alternative phase, mineralization of nitrogen during fallowing is reflected in the values for the rotations with fallow (F) and water melon (S), the latter also fallowed in the 1988/89 season (Figure 3.5.2). In this phase too, there was more mineral N following medic in all N treatments, and vetch at N90, than in the other rotations with legumes. There is little evidence of residual effects of N applied in the wheat phase. Probably most of any fertilizer N unused by previous crops had entered the organic matter pool of the soil.

3.5.1.4 Mineral Nitrogen in Soil Profiles

The differences in soil mineral N contents in the top 100 cm of the profile showed the same pattern as seen in the surface samples. After the wheat phase the differences between the rotations in the N90 treatment were exaggerated by greater mineral N contents in the 20 to 40 cm layer in wheat-medic than in the other rotations (Figure 3.5.4).

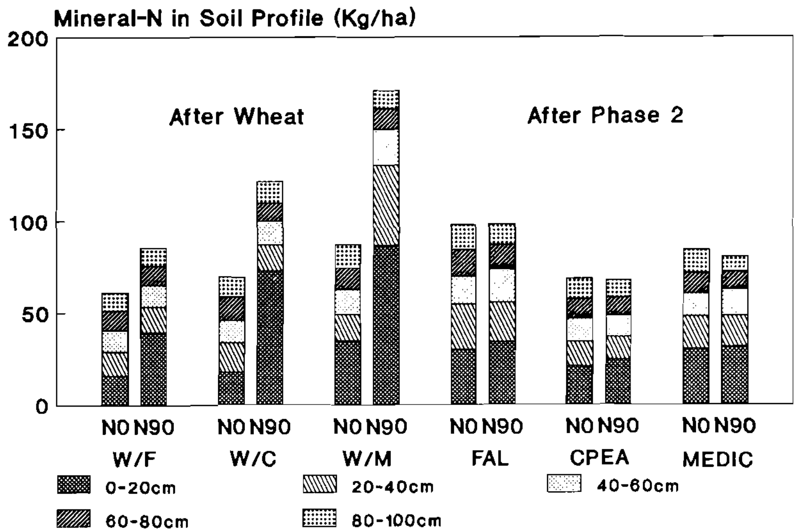

Figure 3.5.4 Mineral nitrogen (kg/ha) in the first 100 cm of the soil profile in both phases of selected rotations where zero or 90 kg N/ha is applied in the wheat phase.

The analysis showed the same concentrations in the 0 to 20 cm soil layer as for the surface samples, despite the fact that 45 mm of rain fell between the two soil samplings. It might have been expected that there would be a burst of mineralization following rain, but this did not happen. However the time between the samplings was short, and conditions were cold enough to limit microbial activity.

3.5.1.5 Total Soil Nitrogen and Organic Matter

Total soil nitrogen contents (ppm) (Kjeldahl method) and organic matter (%) in the surface samples were greatest in the wheat-medic rotation in both phases. There was no clear pattern amongst the remaining crop sequences (Figure 3.5.5).

3.5.1.6 Conclusion

These are the first nitrogen determinations made in this trial, and it

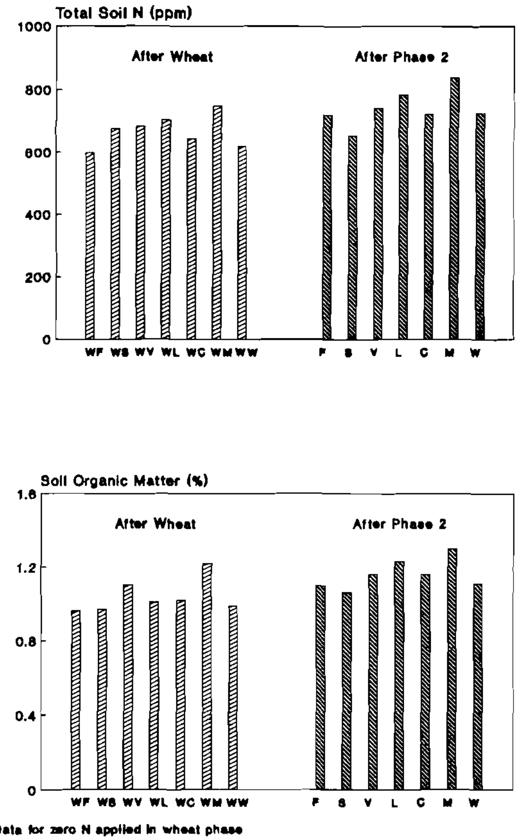

Figure 3.5.5 Total nitrogen (kg/ha) and organic matter (%) in the surface soil (0-20 cm) in seven two-course rotations. Data are for treatments where no nitrogen is applied.

is therefore not possible to draw firm conclusions from the data. It is tempting to suggest that three cycles of the wheat-medic rotation may have lead to an improvement in both the nitrogen and organic matter status of the soil. However, the data represent only a very small window in time in systems that are both dynamic and complex. Determination of mineralization potential of selected treatments is under way, and further detailed studies of nitrogen cycling and balances in the rotations have begun in conjunction with the Pasture, Forage and Livestock Program and with the Legume Program.

Reference

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3.5.2 Effect of Supplemental Irrigation and Nitrogen Fertilization on the Nitrogen Content of Grain Wheat

A. Matar and E. Perrier

3.5.2.1 Introduction

Supplemental irrigation can be used to alleviate climatic risk factors in semi-arid regions and so sustain higher and more stable yields. The increases in grain yields of wheat due to supplemental irrigation relative to the rainfed crop were found to be highly significant but depended on the rainfall conditions of the season (ICARDA Annual Report 1987).

However, the improvement of growth conditions achieved by supplemental irrigation affects not only yield magnitude but also its quality. To examine this, wheat grain from a supplemental irrigation trial conducted at Tel Hadya in 1988/89 was analysed for N-content (%). In that trial, a linesource sprinkler system was used to apply six levels of irrigation treatments (main plots) as follows:

1. Rainfed with no irrigation (I_0)
2. Irrigate to replenish 20% of water balance requirement (I_1)
3. Irrigate to replenish 40% of water balance requirement (I_2)
4. Irrigate to replenish 60% of water balance requirement (I_3)
5. Irrigate to replenish 80% of water balance requirement (I_4)
6. Irrigate to replenish 100% of water balance requirement (I_5)

Spring wheat varieties Cham 1 (durum), and Cham 4 (bread), were sown with a drill at 125 kg/ha (sub-plot). Four levels of N (urea) were applied: N_0 = none; N_1 = 50 kg N/ha, N_2 = 100 kg N/ha and N_3 = 150 kg N/ha (sub-sub-plots). Nitrogen was applied at the rate of 30 kg N/ha at sowing and the remainder at tillering. A blanket application of 100 kg P_2O_5/ha was applied broadcast to all plots at sowing. There were four replicates.

Wheat grain was sampled from all treatments and analysed for its N content using the Kjeldahl-method.

The quantities of supplemental water applied during 1988/89 season were equivalent to: 0, 31.5, 67.1, 104.9, 141.3 and 183.4 mm for treatments I_0 to I_5 respectively, and the total seasonal rainfall was 234.4 mm.

3.5.2.2 Results

Both wheat varieties gave positive and highly significant grain-yield responses to supplemental irrigation and N fertilization (Table 3.5.2). Furthermore, significant interactions were observed between N fertilizer and irrigation level and/or variety and N fertilizer. Under all irrigation treatments, maximum grain yields were given by 50 kg N/ha for Cham 1 and 100 kg N/ha for Cham 4.

Table 3.5.2 The effect of supplemental irrigation and N fertilization on the grain yields (t/ha) for Cham 1 and Cham 4 variety in 1988/89 at Tel Hadya, Syria

Irrigation treatments	Grain yields kg/ha									
	Cham 1 (durum)					Cham 4 (bread)				
	N applied (kg N/ha)					N applied (kg N/ha)				
	0	50	100	150	Mean	0	50	100	150	Mean
I_0 Rainfed	510	700	701	742	663	920	864	788	659	808
I_1 20% water bal.	854	832	836	812	834	1077	1058	864	833	958
I_2 40% water bal.	1354	1409	1766	1369	1475	1673	1696	1534	1702	1651
I_3 60% water bal.	1668	2055	2443	2033	2050	2273	2415	2408	2367	2366
I_4 80% water bal.	2541	2915	3394	2825	2919	2709	3267	3160	3302	3110
I_5 100% water bal.	3151	3830	3963	3584	3632	3498	4025	4210	4404	4034

LSD (.05) = 16.7 at same level of irrigation.

The effect of supplemental irrigation on wheat-grain N% and total N uptake (TNU) could be looked at from an intensity/quantity perspective. Grain N% (intensity) decreased consistently with

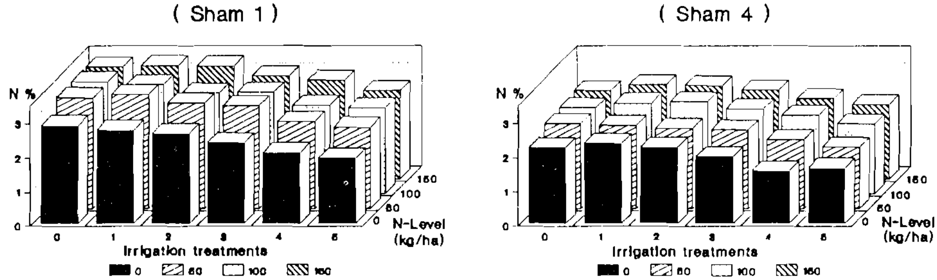

Figure 3.5.6 Nitrogen % in grain of wheat in relation to irrigation and N fertilization

increasing irrigation level but TNU (quantity) increased. The N% of Cham 1 grain dropped from 2.86 to 1.92 in going from the rainfed (I_0) treatment to the I_5 treatment, when no N fertilizer was applied. Corresponding figures for Cham 4 were 2.22 and 1.62 %N (Figure 3.5.6).

However, nitrogen fertilization improved grain N% (intensity) as well as total N uptake (quantity). Thus, the negative effect of supplemental irrigation on the N content of grain can be alleviated by use of N fertilizer. As Figure 3.5.6 shows, N fertilization improved the grain N% of unirrigated wheat and almost maintained the level of grain N% where high levels of irrigation were applied. Up to the I_4 treatment, the rate of N fertilizer which optimized grain production was also sufficient to maintain the %N content of the grain. However, a higher level of N fertilizer was needed when irrigation was applied to replenish the full water balance requirement (I_5).

Total N uptake into the grain (TNU) increased with irrigation level even in the zero N-fertilizer treatment (Figure 3.5.7). Evidently, the crop was able to take up more nitrogen in the presence of adequate moisture, possibly from increased mineralization of organic N and/or from a more extensive root system. With no or little irrigation (I_0 and I_1 treatments), nitrogen fertilization alone did not much increase grain TNU. Only by increasing the irrigation to the level I_2 level and beyond was TNU increased very significantly with N fertilization. The greatest TNU value was obtained when 100 kg N/ha were applied to Cham 1 and 150 kg N/ha to Cham 4.

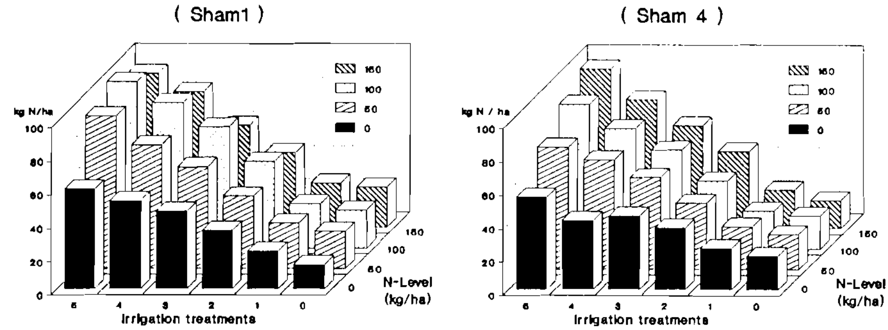

Figure 3.5.7 Total nitrogen uptake by wheat grain in kg N/ha in relation to irrigation and N fertilization

In conclusion, it should be pointed out that in seeking to increase wheat production by supplemental irrigation, it is important to be aware that protein content (on a % basis) may be decreased, and this has implications for the nutritive value of both grain or straw. Measures to increase wheat production through supplemental irrigation must go hand in hand with N fertilizer additions which optimize yield and maintain, if not improve, the quality of grain and straw.

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ICARDA 1987. Annual Report for 1986.

3.5.3 Effect of Site Factors and Fertilization on the Nitrogen Content of Barley

A.E. Matar and Z. Masri*

3.5.3.1 Introduction

In the four seasons, 1984-1988, a total of 75 NP fertilizer trials on barley (Arabi Aswad) were conducted jointly with the Soils Directorate in farmers' fields across northern Syria. Sites were selected each

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year to represent the main soil groups, the range of soil fertility levels and the predominant crop rotations. A summary of the yield data from these trials was reported last year (SD/FRMP 1989).

In the area of study, barley is produced mainly as feed for sheep, and for this purpose the nutritional quality of both grain and straw is important. Although nutritional quality is partly genetically controlled, it is also greatly influenced by climatic conditions, soil type, cultivation practices and any application of mineral fertilizers. In the present study the N contents of harvested barley grain and straw from selected treatments in all trials were determined, and the effects of site factors (soil type, initial available-N status and seasonal rainfall) and N and P fertilizers on N uptake and barley quality (protein content) evaluated.

Each trial comprised two replicates of a randomized complete block design with four rates of N (0, 20, 40 and 60 kg N/ha) in the form of ammonium nitrate and four rates of P (0, 30, 60 and 90 kg P_2O_5/ha) in the form of triple superphosphate. Protein content was determined in grain and straw from both replicates of the four treatments, N0P0, $N_{60}P_0$, N_0P_{90} and $N_{60}P_{90}$. Plant samples were dried at 70°C, threshed, and the grain and straw separately ground. These samples were wet digested using concentrated H_2SO_4 and a catalyst mixture (K_2SO_4 + 1% Se). Total N was analysed in the extract, and the protein content calculated by multiplying the N content by a factor of 6.25.

3.5.3.2 Results

In general, it was found that the protein contents of barley grain and straw were related to soil type or group, available-N status of the soil at sowing, fertilizer rate, rainfall amount and, indirectly, to the yield of barley obtained.

Effect of Seasonal Rainfall on Barley Protein Content (%). Low rainfall is the factor most limiting plant yields in the barley areas of Syria, but its effect on the protein contents of those yields tends to be the opposite. In the present data, negative relationships were observed between % protein contents of grain and straw and seasonal rainfall, in both unfertilized and fertilized treatments. Linear regression equations relating protein % of grain and straw to seasonal rainfall, for each soil sub-group separately and for all sites together, are summarized in Table 3.5.3. It was found that 39 and 35% of the variation in protein content (%) in grain and straw, respectively, could be explained by rainfall differences.

Table 3.5.3 Linear regressions equations and correlation coefficients relating protein content (%) in barley grain and straw as related to total season rainfall for various soil sub-groups, in the barley area of Syria

Soil sub-groups	Crop components	Fertilizer treatment	Linear regression Coefficient	Intercept	r
Xerochrepts	Grain	N_0P_0	-.01231	13.48	-0.57**
		$N_{60}P_{90}$	-.02100	17.93	-0.63**
	Straw	N_0P_0	-.00713	4.71	-0.59**
		$N_{60}P_{90}$	-.01188	6.89	-0.59**
Calciorthid	Grain	N_0P_0	-.02950	19.06	-0.69**
		$N_{60}P_{90}$	-.03631	23.35	-0.66**
	Straw	N_0P_0	-.01362	7.01	-0.49**
		$N_{60}P_{90}$	-.01669	8.87	-0.42**
Gypsiorthid	Grain	N_0P_0	-.02863	21.08	-0.79**
		$N_{60}P_{90}$	-.03056	23.11	-0.78**
	Straw	N_0P_0	-.01975	10.29	-0.57**
		$N_{60}P_{90}$	-.02431	12.08	-0.72**
All Soils	Grain	N_0P_0	-.02044	16.54	-0.62**
		$N_{60}P_{90}$	-.02663	20.22	-0.67**
	Straw	N_0P_0	-.01269	6.83	-0.54**
		$N_{60}P_{90}$	-.01688	8.81	-0.61**

** Significant at 1% level.

Effect of Soil Properties on Barley Protein Content (%). The response of grain and straw protein content to rainfall apparently differs between sub-groups of soil (Table 3.5.3). The protein % in barley grown on Xerochrept soils declined less with increasing rainfall than that in barley grown on Calciorthids or Gypsiorthids; however, barley grown on these latter soils has a higher protein % under dry conditions.

Protein contents were also found to be positively and highly correlated with the NO_3-N concentrations in the top 40 cm of the soil at sowing time (at 1% level). It was found that 41 and 22%, respectively, of the variation in protein % in the grain and straw of the barley in N_0P_{90} plots could be explained by the variability in soil NO_3-N content at sowing. The regression equations were:

Protein % (grain) = 10.213 + 0.0456 (NO_3-N) ppm
Protein % (straw) = 2.706 + 0.0397 (NO_3-N) ppm

Rainfall-Soil NO_3 Interaction Effects on Barley Protein Contents (%). Although protein % is inversely related to yield under conditions of increasing rainfall, it also depends on soil NO_3 status. The interaction between rainfall and soil NO_3 on the protein % of N_0P_{90} barley was found to be highly significant. Division of the sites into two groups, high (NO_3-N $\leq$ 8 ppm) and low (NO_3-N > 8 ppm) in available-N content gave significantly different protein-rainfall relationships (Figure 3.5.8). Under low rainfall conditions, the protein % of the grain was much higher in high NO_3-N soils, but under high rainfall (> 400 mm) it became almost the same in low and high NO_3 soil. The straw data show a similar trend. It seems that with increasing rainfall and in presence of P fertilization, the high NO_3 soils have greater yield potential, and the excess N absorbed is diluted and distributed over a much larger crop biomass than is the case in low NO_3 soils.

Histograms showing the mean variation in protein contents (%) of grain and straw across all sites and seasons, according to soil NO_3-N and seasonal rainfall, are plotted in Figures 3.5.9 and 3.5.10.

Effect of Fertilizer on Barley Protein Content (%). Protein-content responses to fertilizer application were seen in most of the trials. The equations in Table 3.5.3 provide a comparison of the effects of the N_0P_0 and $N_{60}P_{90}$ treatments in relation to rainfall. The effect of nitrogen fertilizer was positive and increased significantly the

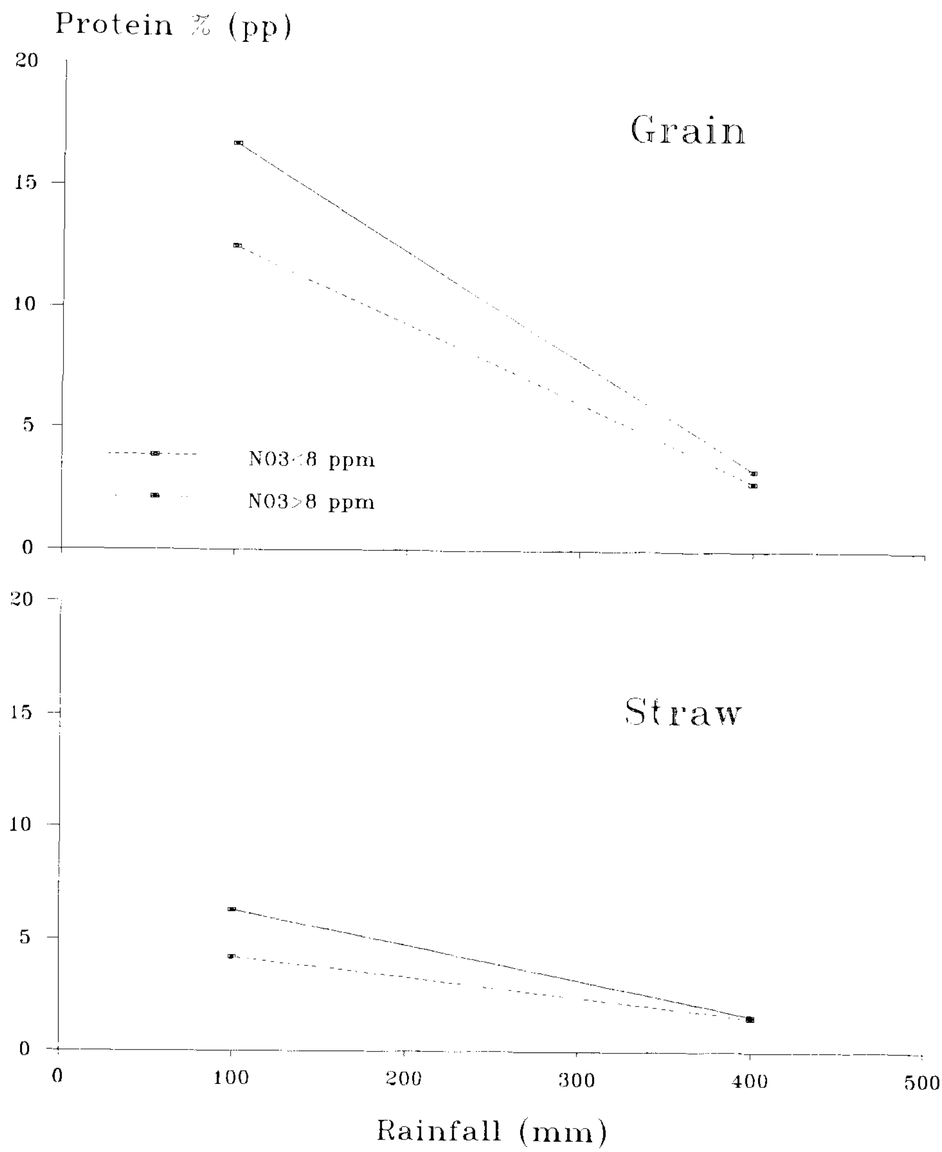

Figure 3.5.8 Effect of the interaction between rainfall and soil nitrate-N status at sowing time on the protein content of barley grain and straw

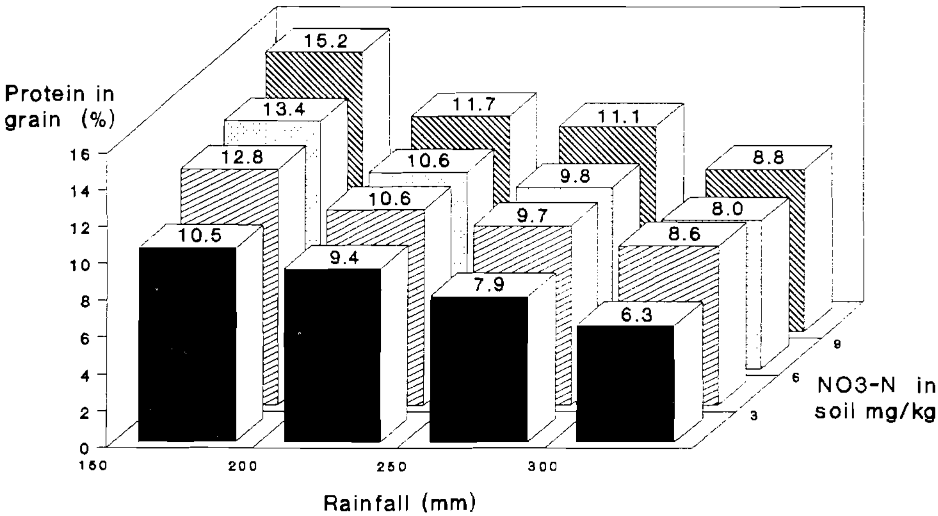

Figure 3.5.9 Effect of rainfall and 0-60 cm soil nitrate-N content at sowing time on the % protein content of barley grain.
[Soil fertilized with 90 kg P_2O_5/ha]

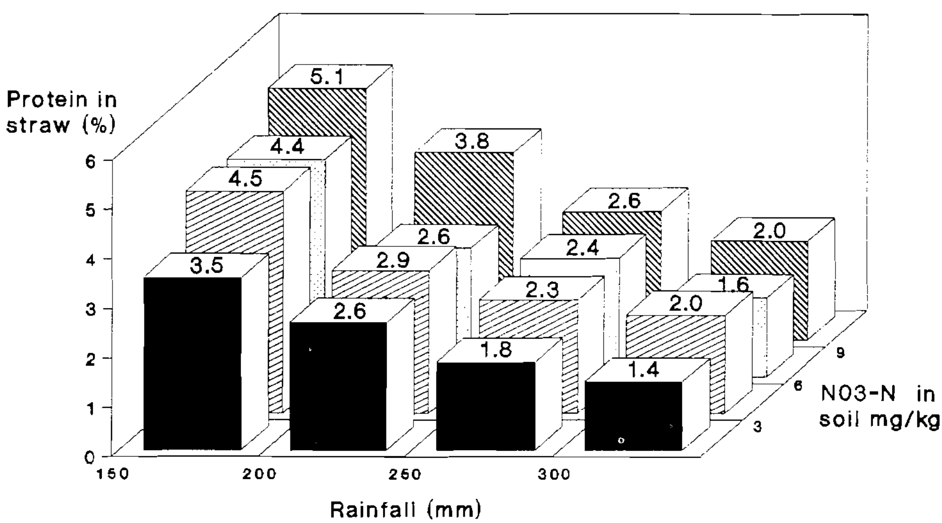

Figure 3.5.10 Effect of rainfall and 0-60 cm soil nitrate-N content at sowing time on the % protein content of barley straw.
[Soil fertilized with 90 kg P_2O_5/ha]

protein contents of grain in 42 out of 72 trials, but this was superimposed on strong background effects from seasonal rainfall and from the original nitrate-N status in soils at sowing time, as Figure 3.5.11 illustrates. It is noticeable that N fertilization consistently increased the protein % whether soil NO_3 was low or relatively high.

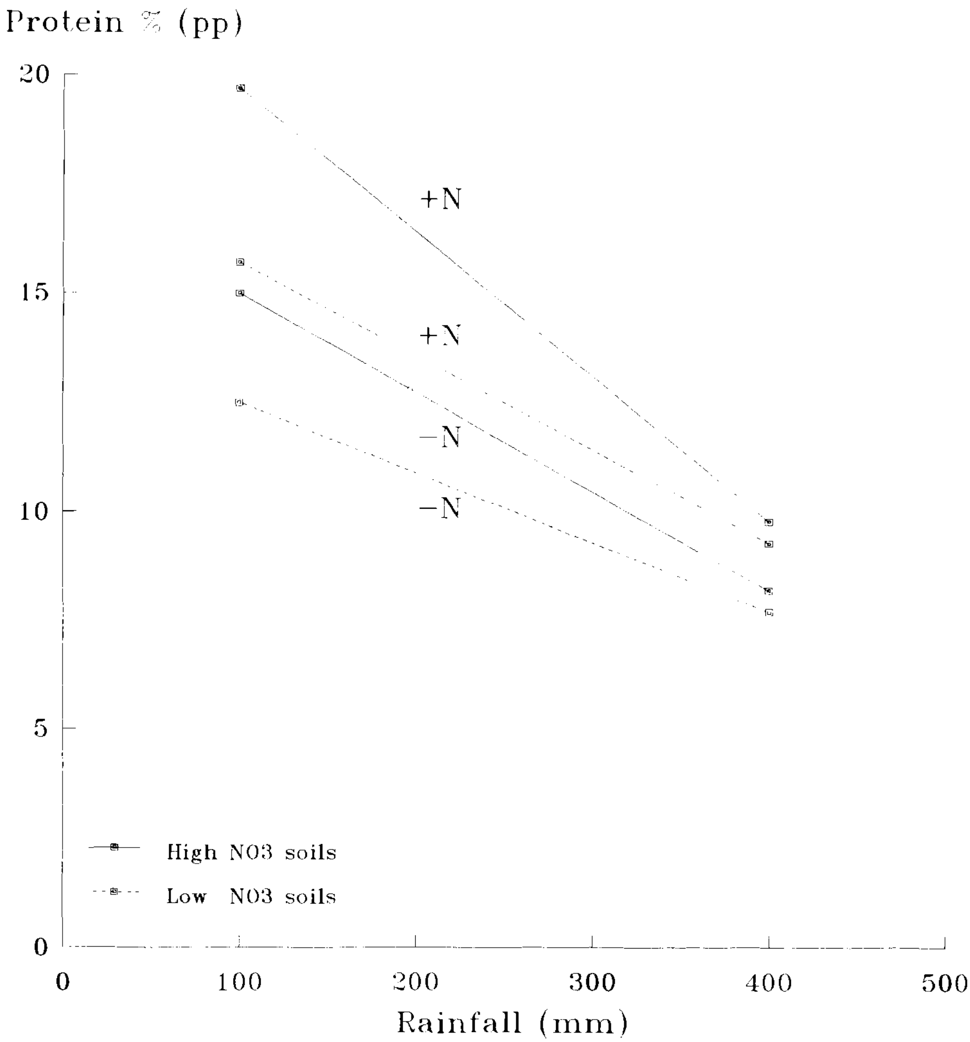

Figure 3.5.11 Response of barley grain protein content to rainfall, with (+N) and without (-N) 60 kg fertilizer N/ha, at two levels of sowing-time 0-40 cm soil nitrate-N content

The critical level of NO_3-N in soils leading to a maximum production of TDM or GY has previously been found to be about 7 ppm (Matar et al. 1987); and no significant increase in TDM or GY production from N fertilization has been observed at sites having NO_3-N exceeding 8 ppm. That shows that N can accumulate in barley grain, under conditions where no increase in dry matter yield is obtained. Furthermore, it was observed that application of 60 kg N/ha could moderate the drop in grain protein % under increasing rainfall conditions but not eliminate it completely.

Effect of Fertilizer on Total Protein Yield. The total protein yield of barley as related to fertilization was calculated for each soil group separately. Applying N and P together maximized protein yield in all cases (Figure 3.5.12). Protein production cannot be compared directly between the various soil groups, because of differences between them in mean rainfall and soil nutrient status. But it could be observed that application of P to gypsiferous soils increased protein production more than N application did because P availability was a much more severely limiting factor in these soils.

Protein Content vs Barley Yields. Negative correlations between grain and protein % are often observed, although total protein yield usually increases with total dry matter production. By considering the protein % in barley grain, taken across all sites and seasons, a greater negative correlation coefficient was observed with the N-fertilized plots ($r = -0.68^{**}$) than with non-fertilized, ($r = -0.38^{**}$) (Figure 3.5.13). The same negative correlations were observed with barley (Scholtz 1976), wheat (Terman et al. 1969) and other crops. It is expected that any factor that increases yield, without increasing the pool of available nitrogen in the soil, will tend to reduce the grain protein % by diluting the available N supply.

Thus a major (though hidden) benefit of fertilizer use on barley may be an increase in its nutritional qualities, in addition to any increase in total dry matter production. However, depending on rainfall, increases in grain and straw yields may reach a plateau at a

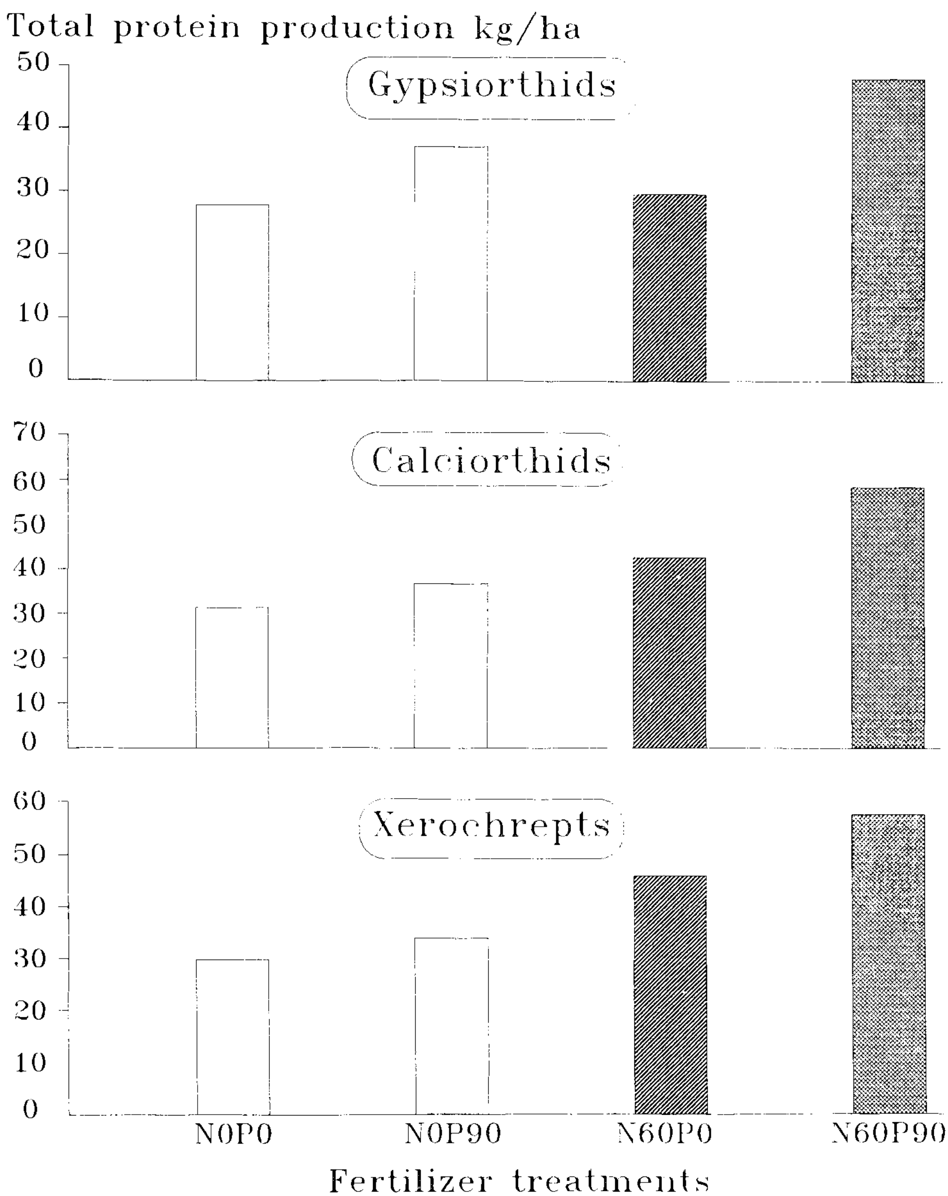

Figure 3.5.12 Effect of fertilizer treatment on total yield of protein by barley in three soil groups

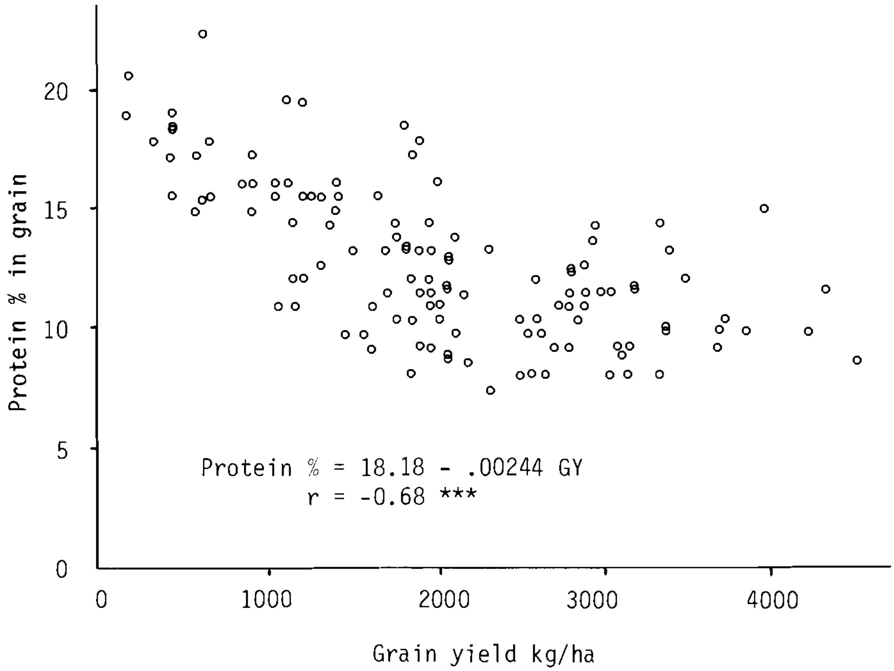

Figure 3.5.13 Relationships between grain protein content and grain yield of barley. (Data from four seasons and from two rates of fertilizer-N application, 0 and 60 kg N/ha)

relatively low rates of fertilizer N, while protein % continues to increase. Thus nutritional investigations will be required to ascertain the economic value of added protein yield obtainable above that achieved with the most economic N rate for maximum yield production. It may well be quite impractical to program higher protein yields of cereals through higher N fertilizer rates, given the increasing price of N fertilizers.

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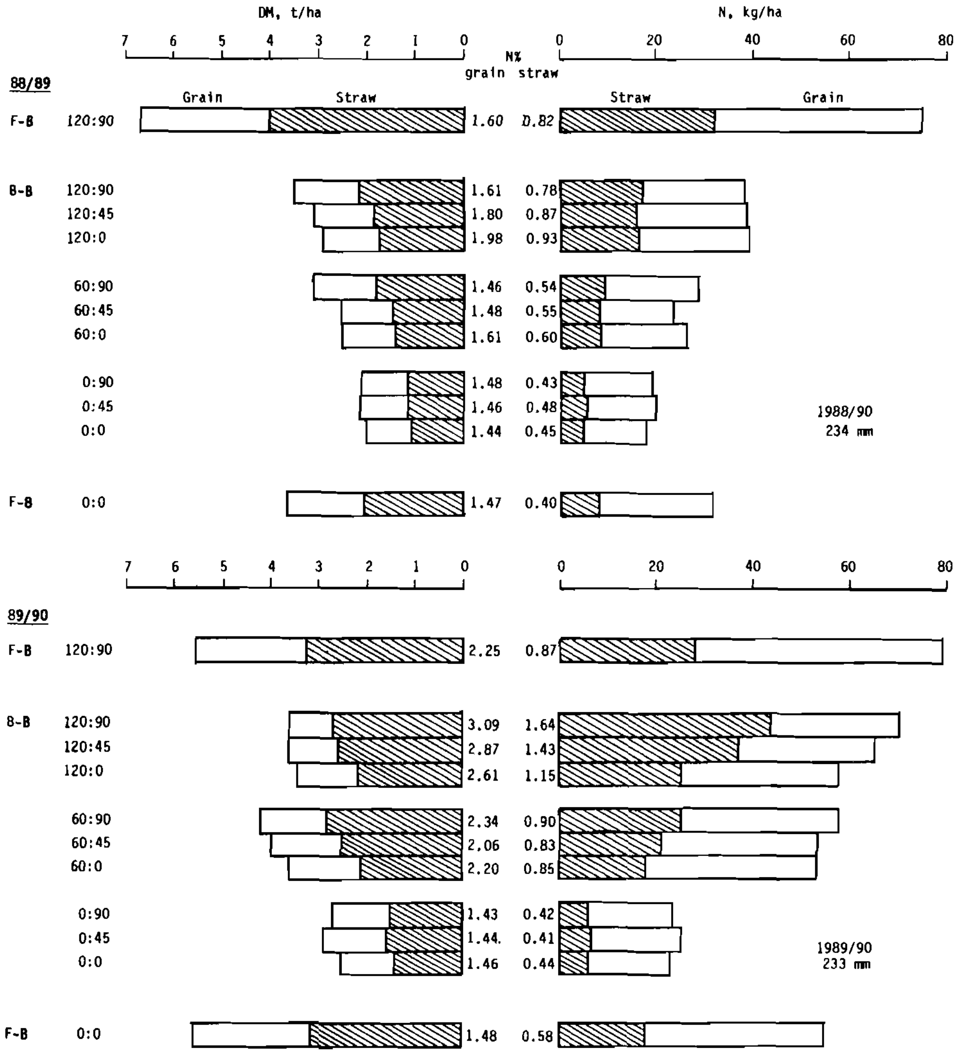
3.5.4 The Nitrogen Content of Grain and Straw of Monocropped barley at Tel Hadya and Breda

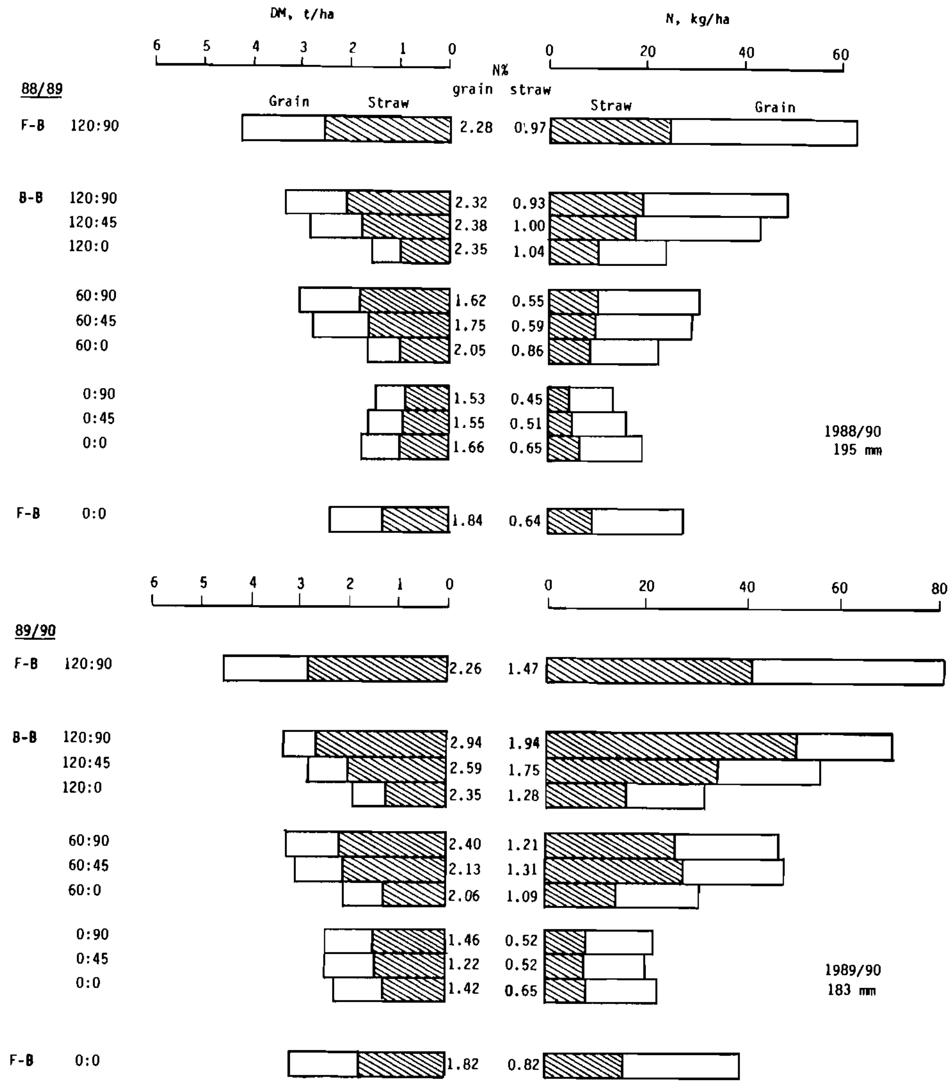
M.J. Jones

Although it is almost certainly desirable that barley should be grown in rotation with legumes or fallow, increasingly it tends to be grown annually on the same land without any fallow or break crop. To observe what happens in this situation, long-term "continuous barley" trials were set up at Tel Hadya and Breda in the 1986/87 season. In the majority of plots, barley is sown every year (B-B rotation) in plots carrying six replicates of nine fertilizer treatments, comprising three rates each of nitrogen and phosphate factorially combined. Other plots carry a barley-fallow rotation (F-B), with barley sown under zero and high NP fertilizer regimes only, for comparison. Here, Figures 3.5.14 and 3.5.15 show mean grain and straw values of dry yield, nitrogen concentration (%) and total nitrogen content for all treatments at both sites in 1988/89 and 1989/90.

Generally, fertilized barley in F-B rotation outyielded all other treatments in grain and straw production and total nitrogen content; and unfertilized barley in F-B rotation outyielded barley in B-B rotation at all rates of fertilization at Tel Hadya and at lower rates of fertilization at Breda. At both sites, the total nitrogen content of barley in F-B rotation was approximately equivalent to that achieved with 60 kg fertilizer-N/ha on continuous barley.



3.5.14 Yields, nitrogen concentrations (%) and total nitrogen contents of grain and straw, under different fertilizer treatments, in the third and fourth years of continuously cropped barley at Tel Hadya



3.5.15 Yields, nitrogen concentrations (%) and total nitrogen contents of grain and straw, under different fertilizer treatments, in the third and fourth years of continuously cropped barley at Breda

Percentage nitrogen concentrations of grain and straw were greatly affected by rotation, fertilizer rate and year. Altogether, grain values varied from 1.22 to 3.09 % N, and straw values from 0.40 to 1.94 % N. It should be remembered that both years were dry years, and this encouraged a higher concentration of nitrogen in plant material. Nitrogen fertilizer greatly increased grain and straw nitrogen concentrations, but this effect was much greater in B-B rotation, where growth was more drought-limited than in F-B rotation. Particularly in 1988/89 (following the heavy rains of 1987/88), barley grown after fallow benefitted from soil-stored moisture, although this factor was not quantified.

The differences in grain and straw "quality" implied by the N % values are very wide indeed. Low values were associated with an absence of N fertilization, but yet lower values would be expected in wetter years even where some nitrogen was applied. High values were associated with high rates of N fertilizer, particularly in B-B rotation, but also with the second of the two seasons, 1989/90. Rainfall was similarly low at both sites in both years but was better distributed in 1989/90. This almost certainly accounts for the greater dry matter production and some of the increase in total crop nitrogen, but it is not clear why percentage N concentrations were also higher. Late frosts limited grain yields of N-fertilized barley in B-B rotation at both sites in 1989/90, but since in only one or two treatments were yields actually lower than in 1989/90 it is difficult to ascribe high grain N concentrations to this factor.

3.6 Fallow Replacement Studies

3.6.1 Barley Productivity in the Medic-Barley Rotation Trial at Breda

M.J. Jones

This trial was set up at Breda in 1987 to investigate the potential of *Medicago* as an annual pasture replacing fallow in rotation with barley in dry areas. For comparison, three other rotations were included, barley-lathyrus, barley-fallow, and barley-barley. The trial comprises three replicates of both phases of each of the four rotations. In the medic-barley rotation, each plot is 1 hectare in size to permit realistic grazing management, and the initial sowings of medic comprised a mixture of species, so that a natural selection of the most appropriate material might occur during the course of the trial. Plots in other rotations are each 0.36 ha, and all plots are divided into 2 subplots to carry two rates of topdressed nitrogen, 0 and 20 kg N/ha, in the barley phase. Phosphate, 60 kg P_2O_5/ha, is also added, biannually to the barley phase at planting time.

A full comparison of these rotations will require examination of the productivity of both phases, separately and together, in both agronomic and economic terms. That cannot reasonably be done until two full cycles (4 years) have elapsed after the completion of the start-up year (1987/88). Meantime, however, it is interesting to take a preliminary look at the effect of rotation and fertilization on barley yields. Figure 3.6.1 summarizes rotation effects on barley grain and straw production in 1988/89 and 1989/90 (years 2 and 3). Both were very dry years, but the effect of fallow was very much greater in the second year. In neither year, were barley yields after medic significantly different from barley yields after lathyrus, but both were significantly lower than those after fallow. Barley after legumes significantly outyielded barley after barley in 1988/89 but not in 1989/90.

Effects of topdressed N-fertilizer were inconsistent. In 1988/89 no significant main effects were observed (Table 3.6.1), although a significant rotation x N interaction for grain implied that yields were decreased by added N except in barley-barley rotation where they were increased. But in 1989/90, grain yields were significantly decreased by added N across all four rotations while straw yields were increased. There were no interactions.

The main focus of interest in this trial is on the barley-medic rotation. The other rotations may be regarded as different forms of control treatment. On present evidence, medic may be seen as behaving similarly to the other legume, lathyrus, in respect of its effect on the barley phase of the rotation.

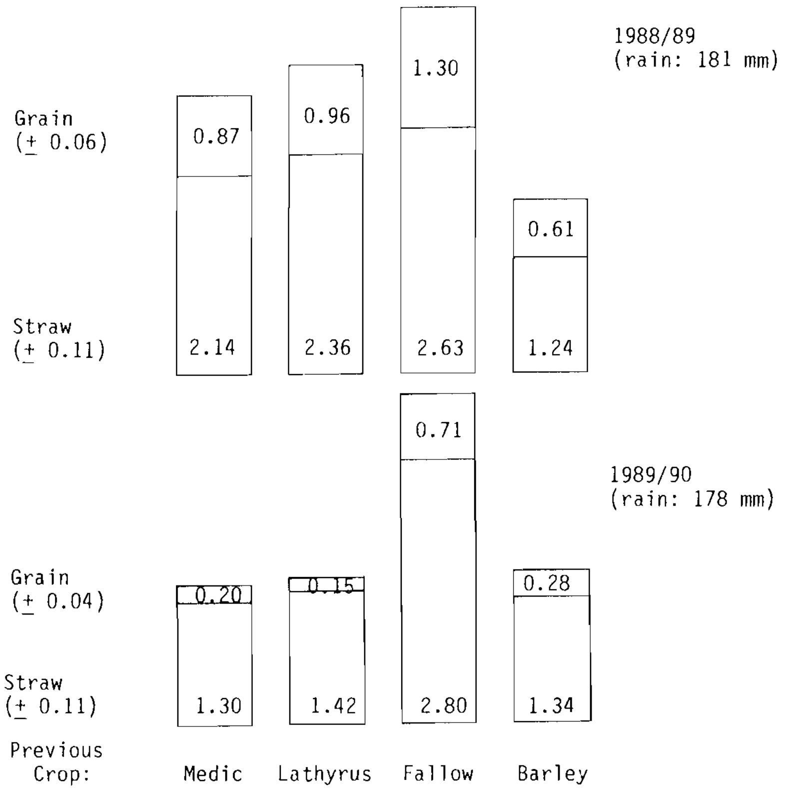


Figure 3.6.1 Effect of rotation (previous crop) on the yield (t/ha) of barley grain and straw in the second and third years of the medic-barley rotation trial at Breda. (Values are means of treatments with and without N topdressing)

Table 3.6.1 Barley grain and straw yields (t/ha), as affected by N-fertilizer topdressing

Fertilizer, kg N/ha	Grain		Straw	
	88/89	89/90	88/89	89/90
	NS	*	NS	*
0	0.97	0.39	2.04	1.58
20	0.90	0.28	2.14	1.85
SE of mean (±)	0.042	0.031	0.080	0.076

4. PROJECT 2. AGROECOLOGICAL CHARACTERIZATION FOR RESOURCE MANAGEMENT

Introduction

Long-term goals in this project are to help ICARDA and national programs to improve the efficiency, relevance and targeting of research through the application of techniques which both characterize agro-ecological variability and predict how such variability will interact with and modify the impact of new technology. We seek to 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 defined 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.

4.1 Spatial Weather Generation: More Examples from a Case Study in the Aleppo Area, NW Syria

W. Goebel

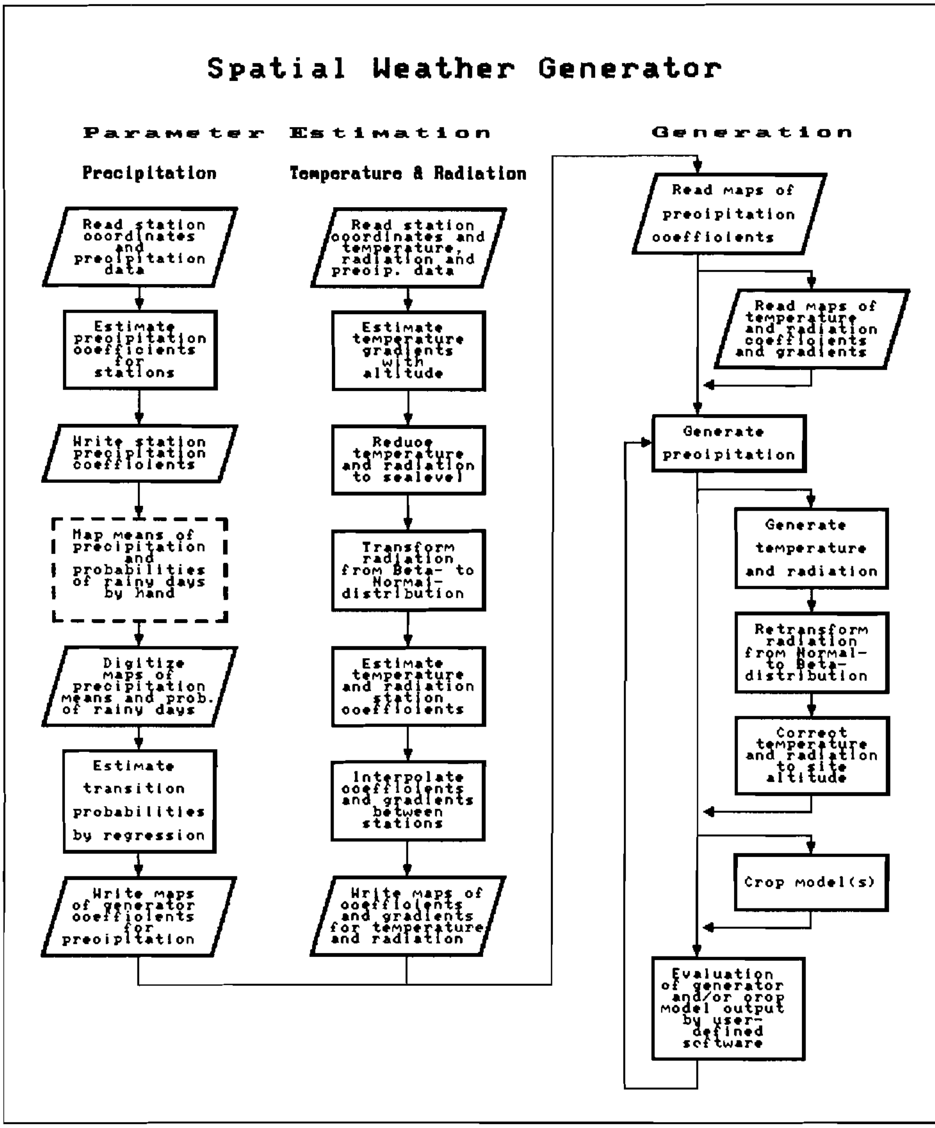
4.1.1 Methods

4.1.1.1 The Spatial Weather Generator

Since 1986 a spatial weather generator (SWG) has been under development at ICARDA. It consists of three main parts: a parameter estimation part, which reduces the original weather data to a set of coefficients for each weather station; a generator part, which in the strict sense stochastically reproduces synthetic sequences of data from the sets of coefficients. A third part, the interpolation of the coefficients between the stations, is added between parameter estimation and data generation. This permits the frequencies of climatic events (like dry spells or frosts, or the characterization of climatic conditions during certain periods of crop development) which are of significance for crop production to be mapped. In combination with a crop model, the spatial weather generator facilitates the analysis of how variations in climate across space affect crop performance.

The SWG presented here can generate rainfall, maximum and minimum temperatures and solar radiation (global shortwave irradiance). Its general organization is shown in Figure 4.1.1. In last year's annual report (ICARDA 1990), the methods used by the SWG for generating rainfall were discussed together with examples of its output and use. In this report, we present the SWG's techniques for generating temperature and solar radiation simultaneously, together with rainfall, and give examples of the use of that output, alone and in combination with the SIMTAG wheat model (Stapper 1984a,b).

The method which the SWG uses for simulating temperature and solar radiation is an adaptation of a method first proposed by Matalas (1967). It was first adapted to weather generation by Richardson (1981). Since then, the principle has been repeatedly used for this purpose (e.g. Richardson and Wright 1984; Woolhiser, Hanson and Richardson 1988; Richardson and Nicks 1990). It permits the simultaneous generation of variates from a number of variables which follow the Normal-distribution while preserving cross and serial correlations amongst them. Generator coefficients are the means and standard deviations of maximum and minimum temperature and solar radiation and, after the transformations described in Appendix 1, the cross correlations between the three variables, the lag-1 serial correlations and the lag-1 serial cross correlations.



<u>Figure 4.1.1</u> Generalized flowchart of the Spatial Weather Generator

The temperature and radiation coefficients are determined separately for each calendar month, and after the spatial interpolation, they are smoothed across the year with the help of cubic splines.* Means and standard deviations are furthermore calculated separately for wet and for dry days to take account of the effect of rainfall and the associated cloudiness on these variables. Not enough is known yet about the differences in the various correlation coefficients between wet and dry days in different climates to make a definitive judgement whether the use of separate sets of correlation coefficients for wet and dry days improves the quality of the generated data enough to warrant the additional effort for the spatial interpolation of the additional coefficients. For the U.S.A., Richardson and Wright (1984), Woolhiser, Hanson and Richardson (1988), and Richardson and Nicks (1990) used only a single set of correlation coefficients for both wet and dry days, for each calendar month. Experience so far seems to indicate that this is an adequate approach in many regions and not much is gained from using twice or four times as many correlation coefficients. Nevertheless, the SWG offers three options:

- a single set of correlation coefficients for all days,
- two sets of correlation coefficients for wet and dry days,
- four sets of correlation coefficients to allow for differences of serial correlations whether the previous day was wet or dry.

While the distribution of air temperature is reasonably well approximated by the Normal-distribution (except for the typical slight skewness of maximum and minimum temperature), Normal-distribution is a poor model for solar radiation, which by its nature can assume only values within a certain, relatively narrow range and whose distribution may be quite strongly skewed. Treating solar radiation as though it followed the Normal-distribution leads to the generation of impossible values, values which, for instance, are larger than the maximum

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* The smoothing method is similar to the one employed for precipitation coefficients. For details see last year's annual report (ICARDA 1990).

possible clear-day radiation or less than zero. If such impossible values are rejected or if they are replaced by the closest realistic values, the generated data no longer have the same means, standard deviations and correlation coefficients as the original data from which the coefficients were determined.

A Beta-distribution with an upper boundary that is a function of latitude and day of the year and a lower boundary arbitrarily set to 10% of the upper boundary value provides a better fit for solar radiation than the Normal-distribution. Two additional parameters determine the skewness of the Beta-distribution. To combine the advantages of the Beta-distribution (good fit) and of the Normal-distribution (preservation of correlations, simultaneous generation), the SWG transforms radiation values from Beta- to Normal-distribution before generator coefficients are estimated. The generated radiation values are then retransformed from Normal- to Beta-distribution.

To eliminate the effect of altitude, temperature and radiation data are reduced to sea-level values before the spatial interpolation of generator coefficients. As the temperature gradient with altitude varies from place to place, it is determined by linear regression of temperature on altitude using data from stations within a certain distance. This method fails in regions without marked altitude differences between stations. For such cases, the SWG offers two alternatives: to use two preselected stations, for instance those with the highest altitude difference within a certain perimeter to determine the temperature gradient or, as a last resort, to use a predetermined, fixed gradient (usually -0.5°C/100m). Radiation values are reduced to sea level by assuming that the increase in optical air mass would be proportional to the air mass which would fit between station altitude and sea level at given station temperature and temperature gradient.

The coefficients estimated from reduced temperature and radiation data can be interpolated across space much more easily than the original values. If the station network is reasonably dense, objective interpolation methods, such as Kriging (Delfiner and Delhomme 1975;

Burgess and Webster 1980a,b; Webster and Burges 1980; Ripley 1981), can be employed without the need for manual corrections. The temperature gradients used for the reduction of temperature and radiation are also mapped using the same methods. Together with a digitized contour map, the gradient maps serve to retransform the generated temperature and radiation values into values appropriate to site elevation.

4.1.1.2 SIMTAG

SIMTAG (SIMulation of Triticum Aestivum Genotypes) is a process-oriented wheat model which simulates crop growth and development on a daily time step. It was originally developed by M. Stapper at ICARDA between 1979 and 1982 (for details see Stapper 1984a,b). The version used for this study has been modified in such a way as to allow direct linkage to the SWG. A summary flowchart of the modified model is given in Figure 4.1.2.

4.1.2 The Study Area

The study area comprises the surroundings of Aleppo in Northwestern Syria (Figure 4.1.3). It extends from 35°30'N to 36°30'N and from 36°30'E to 38°00'E. The western rim of the area is dominated by ranges of hills stretching in North-South direction, whereas most of the remainder of the area has a flat to undulating topography, except for a hilly plateau in the center, southeast of Aleppo. This plateau is framed by two closed drainage basins on its southwestern and northeastern sides. Tel Hadya is situated close to the center of the southwestern basin. The lowest part of the northwestern basin is occupied by the salt lake of Jabboul. Rainfall is highest in the western hills and decreases rapidly towards the east and, to a lesser extent, towards the south (Figure 4.1.4). This pattern is disturbed only by the effect of the plateau in the center.

For this study, daily climatic data from the 19 meteorological and precipitation stations indicated in Figure 4.1.4 were used. For 14 of them temperature data, and for five of them solar radiation data,

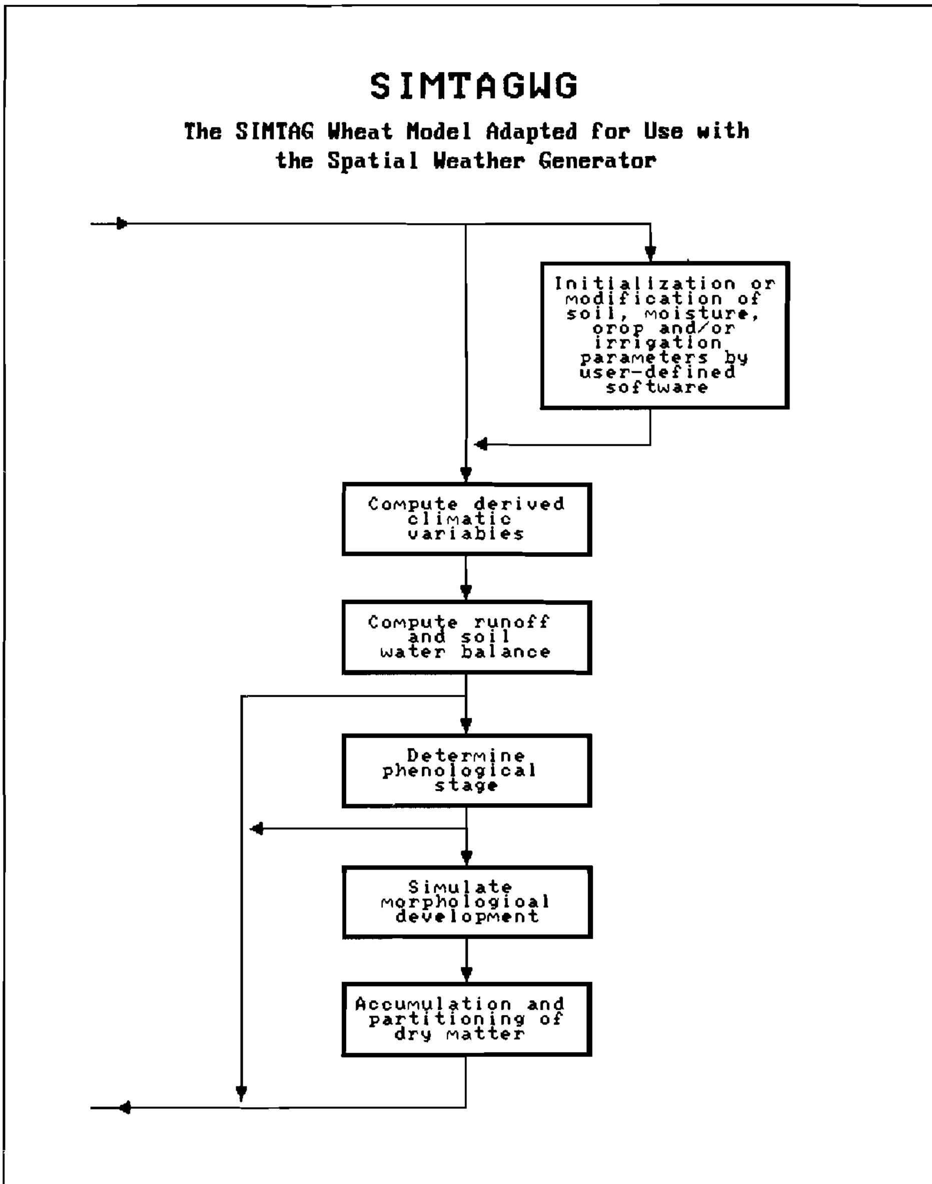

Figure 4.1.2 Generalized flowchart of the SIMTAG wheat model modified for integration with the Spatial Weather Generator

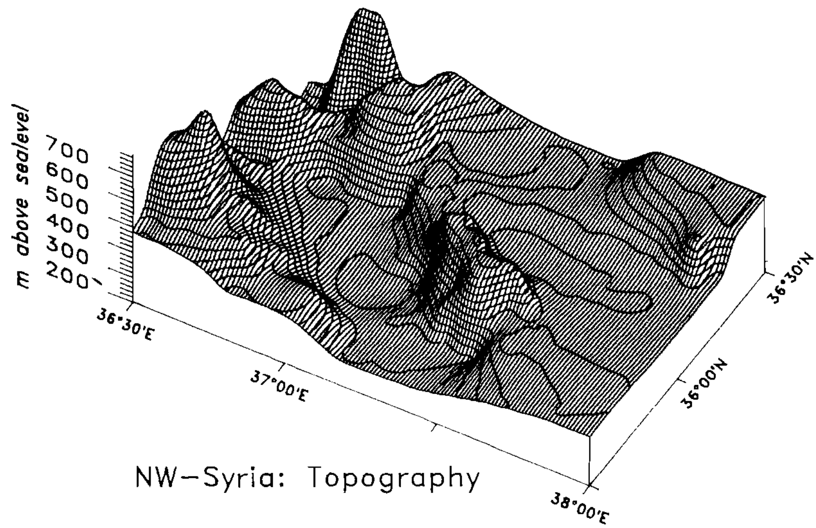

Figure 4.1.3 Major topographic features of the study area in Northwestern Syria

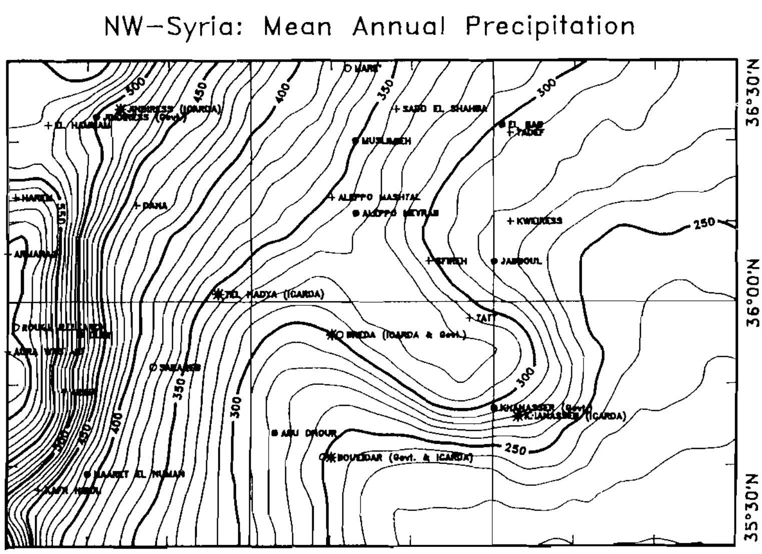

Figure 4.1.4 Mean annual rainfall (mm) and locations of the meteorological stations whose data were used in this study (✱ daily precipitation, air temperature and solar radiation, ● daily precipitation and air temperature, ○ daily precipitation, + monthly precipitation only). Following the last three seasons with below-average precipitation, the values on parts of the map may seem 10 to 15 mm to high.

were available. These data were supplemented with data from a number of stations outside the area in order to facilitate better interpolation of generator coefficients near the borders of the area, and by monthly data from a large number of precipitation stations.*

4.1.3 Results

Five hundred years of daily rainfall, maximum and minimum temperature and solar radiation were generated on a four by four minute-wide grid across the study area. One hundred of these years were used to simulate the growth of 99 crops of Cham 1 wheat in each grid cell. On a PC with a 386 processor and a 387 co-processor running at 25 MHz, the time required for the generation of one year of rainfall was found to be approximately 0.06 seconds, the generation of rainfall, temperature and radiation took about 0.7 seconds per year and, when the SIMTAG wheat model was linked to the generator, one year of weather generation and crop simulation took about 2.24 seconds.

A first set of diagrams (Figures 4.1.5 to 4.1.10) is concerned with thermal conditions during early crop development. Depending on the moisture availability during a 30-day period following germinating rains, seasons were divided into a group with favorable moisture conditions (≥ 30 mm of rainfall during these 30 days) and a group with unfavorable moisture conditions (< 30 mm). Germinating rains were defined as the first three-day period starting between 1 November and 1 January with 20 or more mm of rainfall.

It was shown in last year's annual report (ICARDA 1990) that early germinating rains are more likely to be followed by drought in the seedling stage ("dry starts") than are late germinating rains. Figures 4.1.5 and 4.1.6 show that the average starting dates of these two types of seasons are 10 to 14 days apart. Therefore, since average temperatures show a strong seasonal tendency to fall over the whole period from November to January, dry periods after germinating rains

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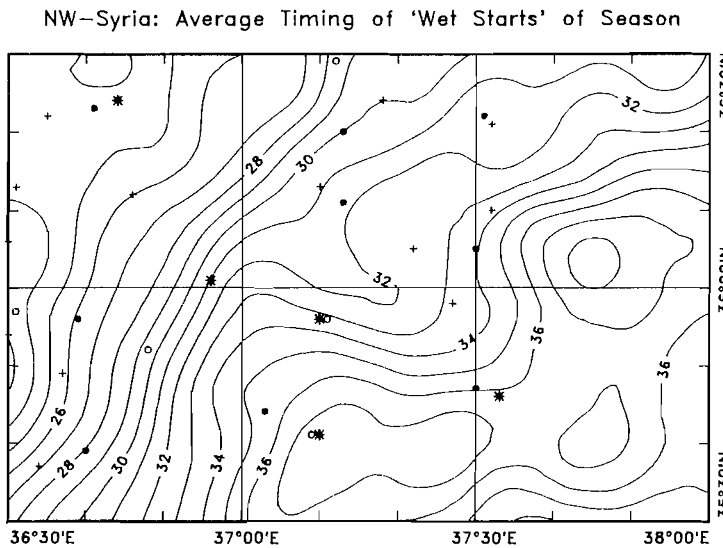
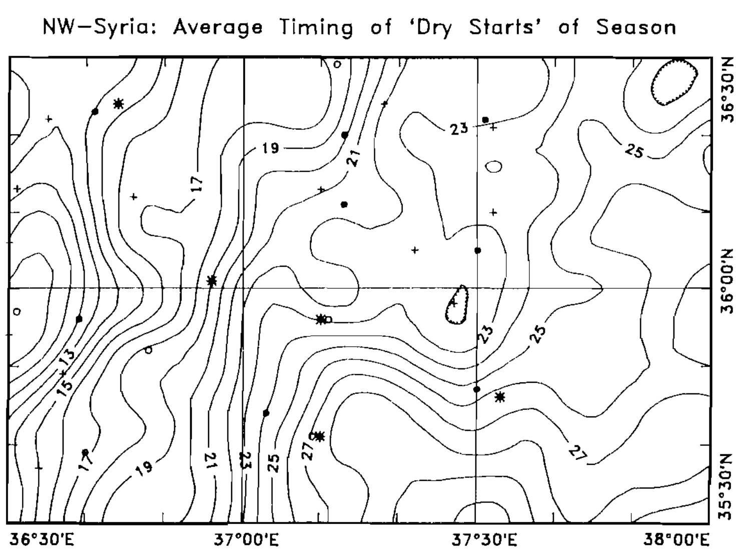
* ICARDA is indebted to the Syrian Meteorological Department which generously made data available for this study.



<u>Figure 4.1.5</u> Average timing of "wet" starts of season in days after 31 October. "Wet" starts are defined as germinating rains (≥20 mm precipitation in 3 days) followed by a period of 30 days with ≥30 mm of precipitation



<u>Figure 4.1.6</u> Average timing of "dry" starts of season in days after 31 October. "Dry" starts are defined as germinating rains (≥20 mm precipitation in 3 days) followed by a period of 30 days with <30 mm of precipitation

are more likely to be warm than cool. Continuing ample rainfall after germinating rains is more probable in seasons with a late start. By then, the general temperature level has dropped, so that on average such "wet" starts of the growing season are cooler than "dry" starts (Figures 4.1.7 and 4.1.8). The general steep decrease of temperature during the period from November to January completely masks the fact that, if they happen during the same time of the year, "dry" starts of season frequently are colder than "wet" starts which are characterized by moist, mild weather.

Figures 4.1.9 and 4.1.10 show how the number of favorable seasons with ample moisture supply at the beginning combined with temperatures permitting vigorous early growth decreases as one moves from the humid western hills towards the dry southeast, where the germinating rains tend to occur late and where, in those cases when they happen early, the risk is high that they are followed by a dry spell.

The following examples involve the simulation of rainfed wheat crops with SIMTAG. In order to show as clearly as possible the effect of climatic variability across space on crop growth, a number of generalizing assumptions were made:

- That the soil was uniform across the whole area, a calcic Rhodoxeralf from a profile at Tel Hadya research station being taken as reference. (This simplification was necessary also because information on many soils in the area is insufficient to estimate all the parameters required by the model.)

- That the soil moisture content was reinitialized at the beginning of every season with the same values, typical of conditions after a season with low rainfall or in rotation after a crop that strongly depletes soil moisture reserves.

- That there was no nutrient stress; SIMTAG at present does not permit the simulation of nutrient dynamics and fertilization.

NW–Syria: Mean Air Temperature in °C during 'Wet Starts' of Season

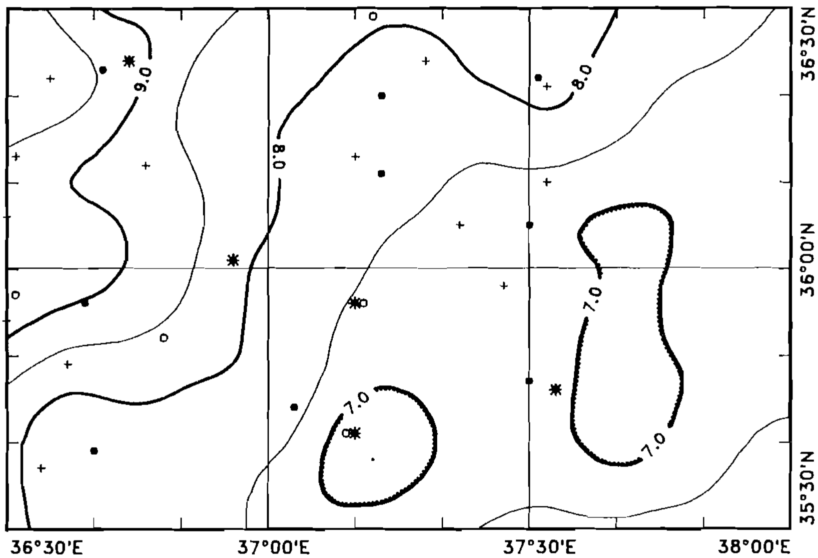


Figure 4.1.7 Average temperature during "wet" starts of season in °C (for further explanations see Figure 4.1.5)

NW–Syria: Mean Air Temperature in °C during 'Dry Starts' of Season

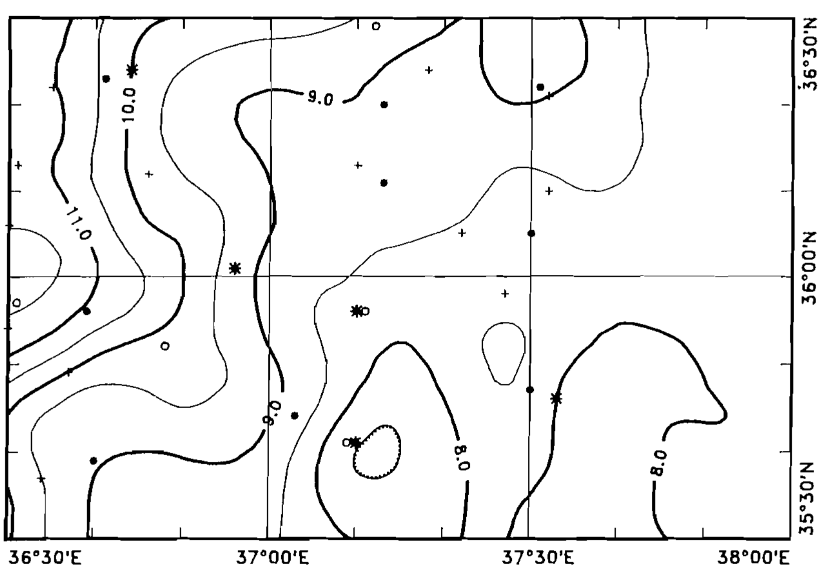


Figure 4.1.8 Average temperature during "dry" starts of season in °C (for further explanations see Figure 4.1.6)

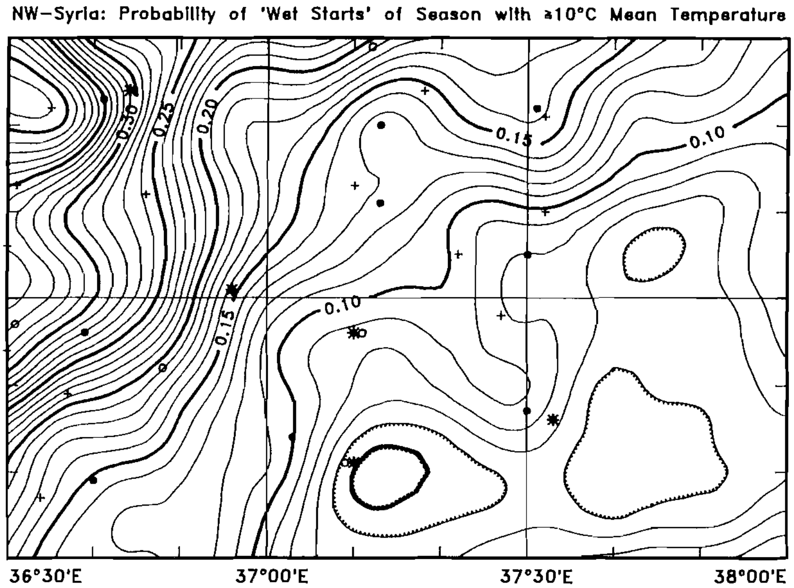


Figure 4.1.9 Probability of "wet" starts of season with a mean air temperature of ≥10 °C (for further explanations see Figure 4.1.5)

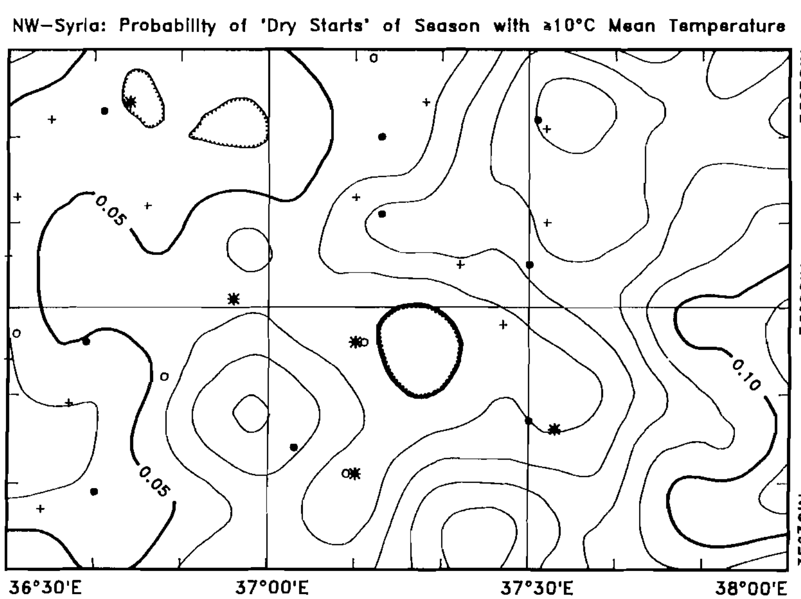


Figure 4.1.10 Probability of "dry" starts of the season with a mean air temperature of ≥10 °C (for further explanations see Figure 4.1.6)

- That a crop of Cham 1 wheat* was uniformly planted on 15 November at 5 cm sowing depth to give plant population of 300 plants/m^2.

Given these generalizations, any variability of simulated crop performance across space is the sole effect of spatial climatic variability.

Figures 4.1.11 and 4.1.13 are concerned with thermal conditions during the sensitive period of development from heading over anthesis until the onset of linear grain filling. Figure 4.1.11 shows the probability of frost during this stage of crop development. This probability is very low, below 2% (one year in fifty) in the wet and hilly areas in the west. It reaches a peak of 5 to 10% (about one year out of every fifteen) in the closed drainage basin around Tel Hadya, Breda and Abu Dhour, and decreases again to around 1-2% further east.

The reasons for this trend are the following. In the humid and relatively cool areas in the west, germination usually occurs during November. But development is relatively slow, delaying heading until late April or even May, when frosts are rare even at higher elevations. Frost risk is further reduced through the high probability, compared to other regions, of rainfall during this period, which lessens the danger of radiation frost. Further east, germination still frequently occurs in November. Higher daytime temperatures in spring, however hasten crop development, bringing heading forward to early April, a time when frost is more likely. Still further east, the model predicts a further increase in development rate, as evidenced by the average growing period length (Figure 4.1.12), which decreases from over 170 days in the west to below 150 days in the east. But at the same time, germination is frequently delayed until December due to a delay in the germinating rains. The timing of anthesis therefore does not change much more as one moves further east. But April minimum temperatures show a slightly increasing trend in the same direction, so that the risk of frost is diminished.

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* The genetic coefficients were determined and generously made available for this study by Dr H.C. Harris.

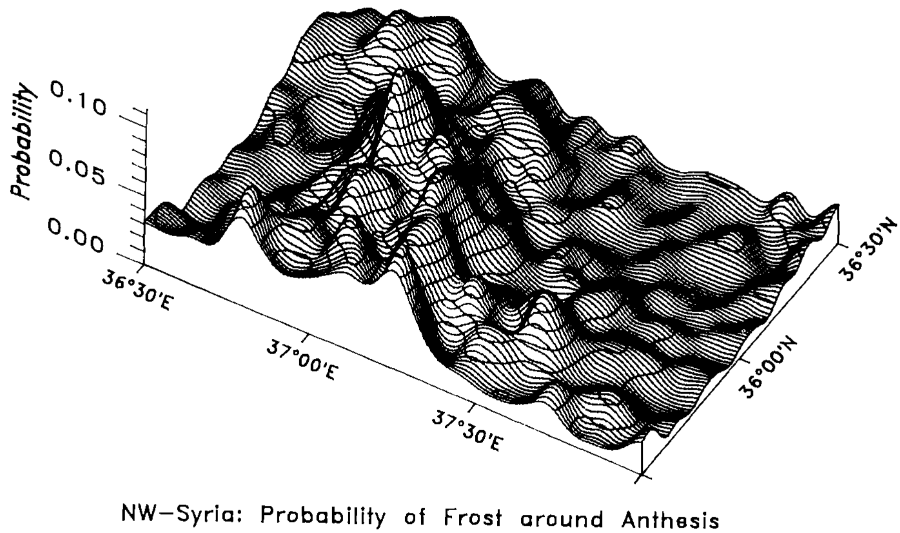

Figure 4.1.11 Probability of frost during the period from heading through anthesis until the start of linear grain filling for Cham 1 wheat planted on 15 November

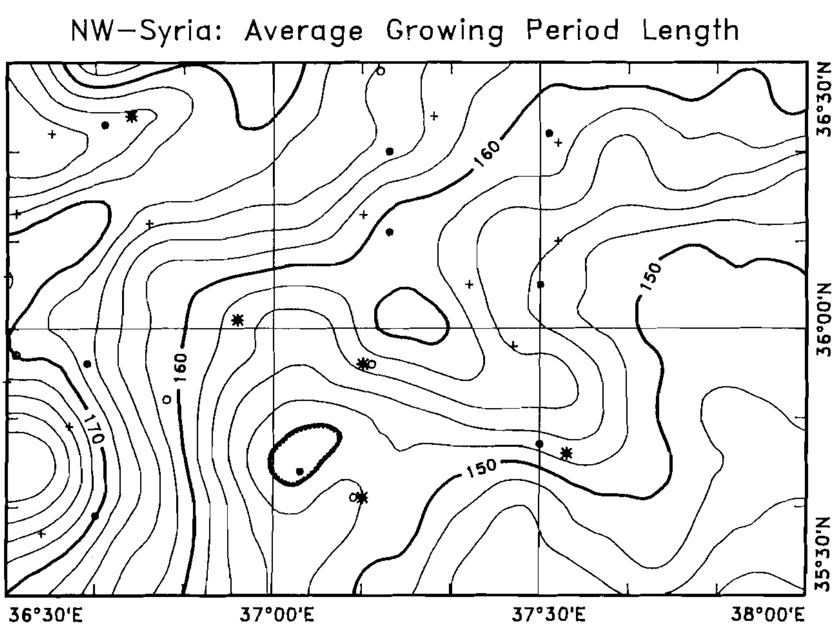

Figure 4.1.12 Average growing period length in days from germination to maturity of Cham 1 wheat planted on 15 November

NW–Syria: Mean Max. Temperature around Anthesis Exceeded Once in Five Years

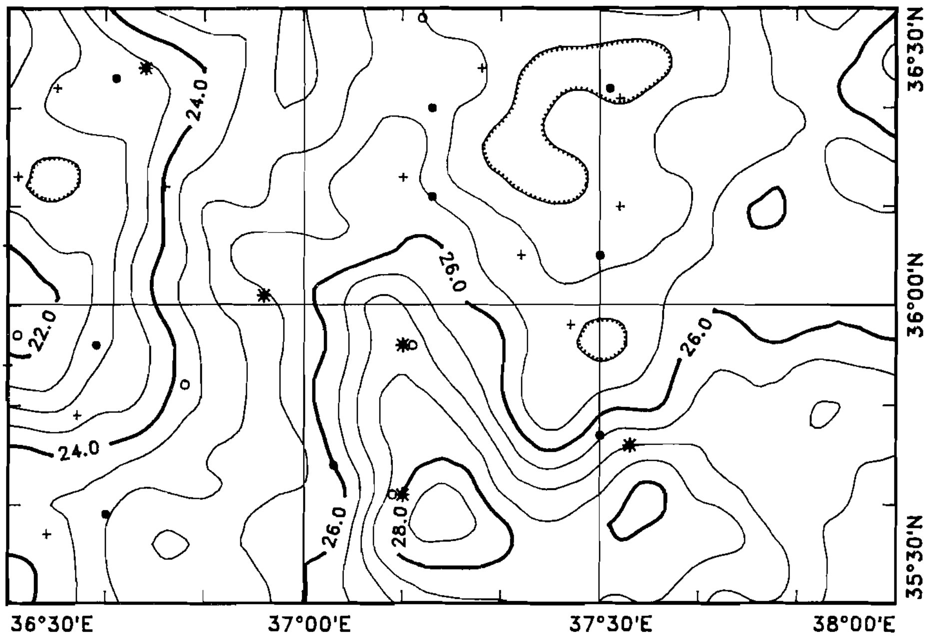

Figure 4.1.13 Mean maximum temperature (°C) exceeded in one year out of five during the period between heading and start of linear grain filling of Cham 1 wheat planted on 15 November

Figure 4.1.13 shows, for the same period, the mean maximum temperature expected to be reached once in five years. Across the whole area, the values stay well below the critical temperature level of 30 to 33°C, indicating that damage due to excessive heat around anthesis time will be a rare exception. Together with the map of frost risk, this illustrates how well adapted the crop is to the region. Its development rate is regulated so that it evades both types of temperature stress optimally: anthesis is late enough to reduce frost risk and at the same time early enough to avoid heat damage.

The next examples compare predictions of grain yield and total above-ground dry matter of Cham 1 wheat obtained by two different methods:

- Simulations with the SIMTAG model as described above,

- Predictions from multiple regression models based on the results of on-farm agronomy trials in 70 locations over 4 years and presented elsewhere in this report (see section 3.3).*

The regression models link grain yield and total dry matter to monthly rainfall total from October to May and to the square of the sum of these totals. In order to make the predictions from the regression and simulation models as comparable as possible, the fully fertilized treatment of the on-farm trials (120 kg/ha N and 80 kg/ha P_2O_5) was selected. Regression coefficients and R^2 values are given in Table 4.1.1. Both kinds of models were driven by the same 100 years of generated data, rainfall data only for the regression model, and rainfall, temperature and radiation data for the simulation model.

Figures 4.1.14 and 4.1.15 show the average above-ground dry matter obtained from simulation and regression respectively. Figures 4.1.16 and 4.1.17 show the average predicted grain yields, while Figures 4.1.18 and 4.1.19 depict the grain yields expected to be surpassed in

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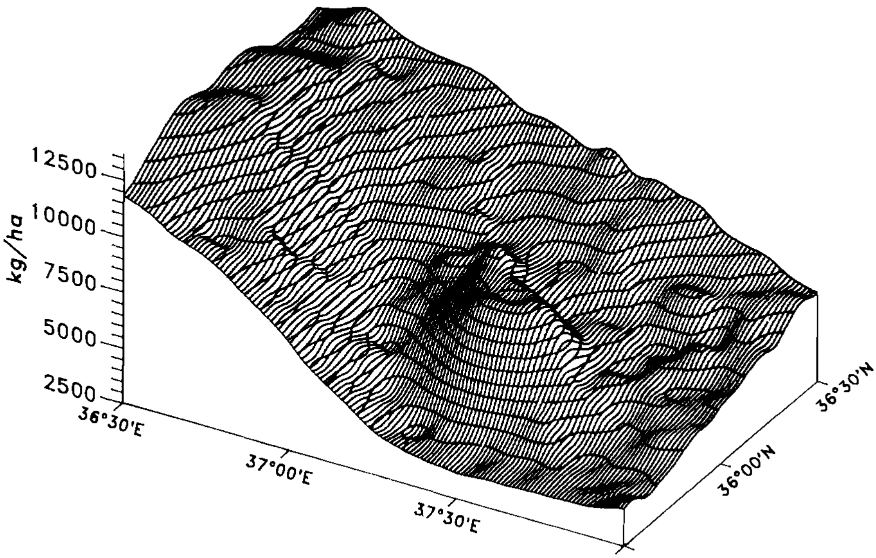
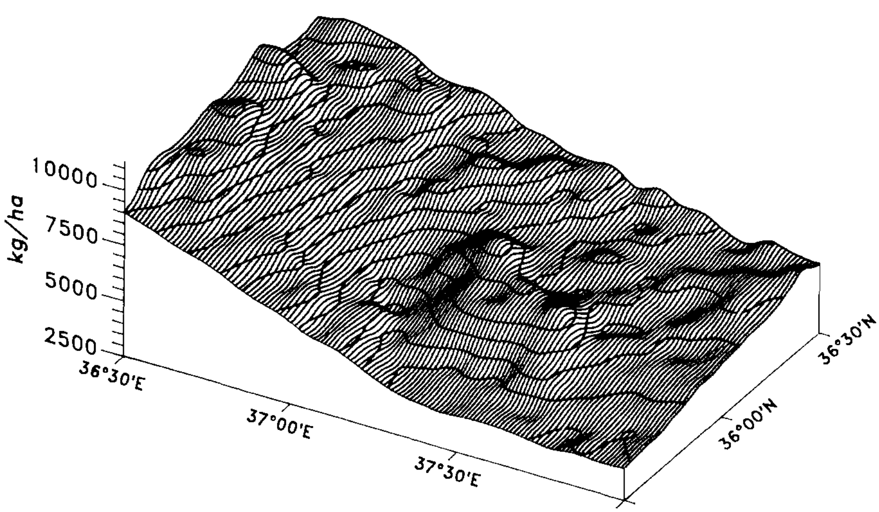
* I would like to thank Dr M. Pala for allowing me to use the results of his analysis.



NW–Syria: Average Total Dry Matter of Wheat Predicted by SIMTAG

Figure 4.1.14 Average total above-ground dry matter (kg/ha) of Cham 1 wheat planted on 15 November as predicted by simulations with SIMTAG, assuming a uniform calcic rhodoxeralf as soil. The plant density after emergence was assumed to be 300 plants/m^2



NW–Syria: Average Total Dry Matter of Wheat Predicted by Regression

Figure 4.1.15 Average total above-ground dry matter (kg/ha) of Cham 1 wheat planted on 15 November and fertilized with 120 kg/ha N and 80 kg/ha P_2O_5, as predicted by regression

NW–Syria: Average Grain Yield of Wheat Predicted by SIMTAG

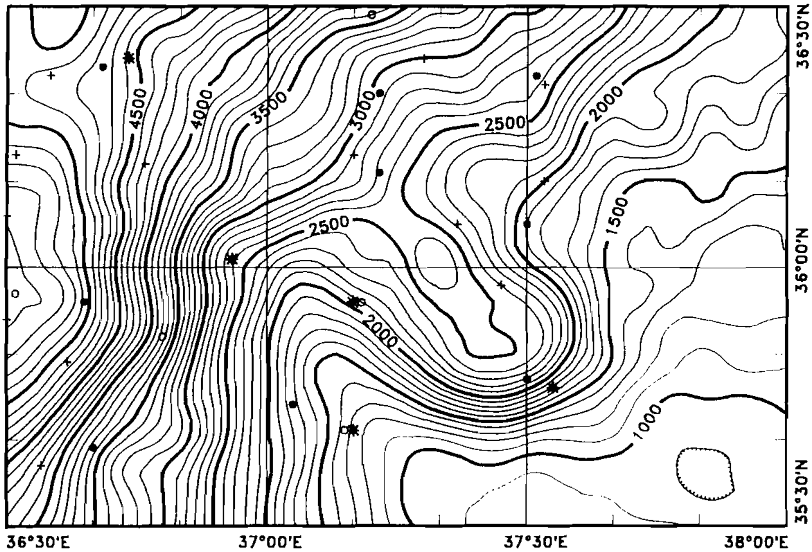


Figure 4.1.16 Average grain yield (kg/ha) of Cham 1 wheat as predicted by simulations with SIMTAG (for further explanations see Figure 4.1.14)

NW–Syria: Average Grain Yield of Wheat Predicted by Regression

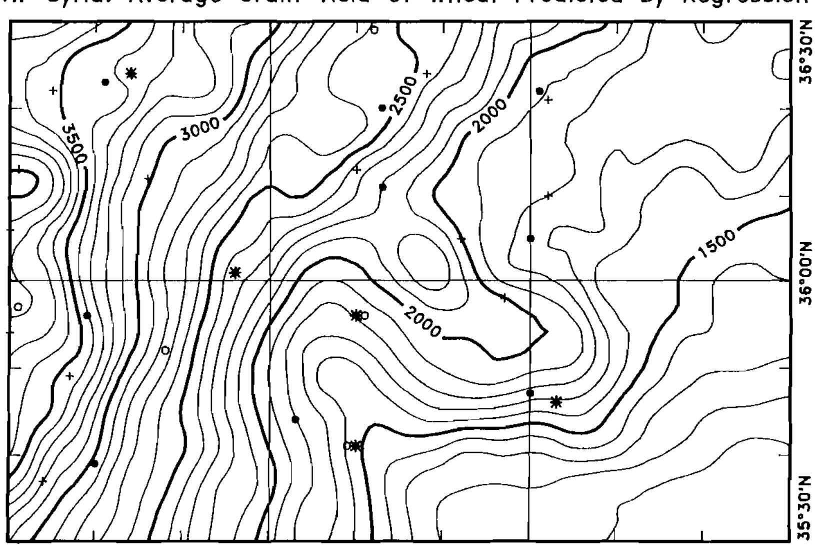


Figure 4.1.17 Average grain yield (kg/ha) of Cham 1 wheat as predicted by regression (for further explanations see Figure 4.1.15)

NW-Syria: Grain Yield of Wheat Expected in 4 Years out of 5 According to SIMTAG

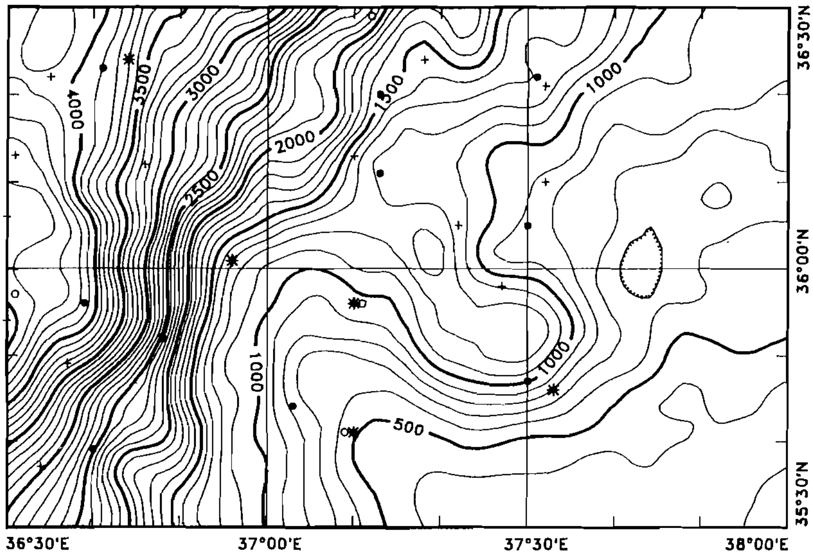


Figure 4.1.18 Grain yield (kg/ha) exceeded in four years out of five by Cham 1 wheat as predicted by simulations with SIMTAG (for further explanations see Figure 4.1.14)

NW-Syria: Grain Yield of Wheat Expected in 4 Years out of 5 by Regression

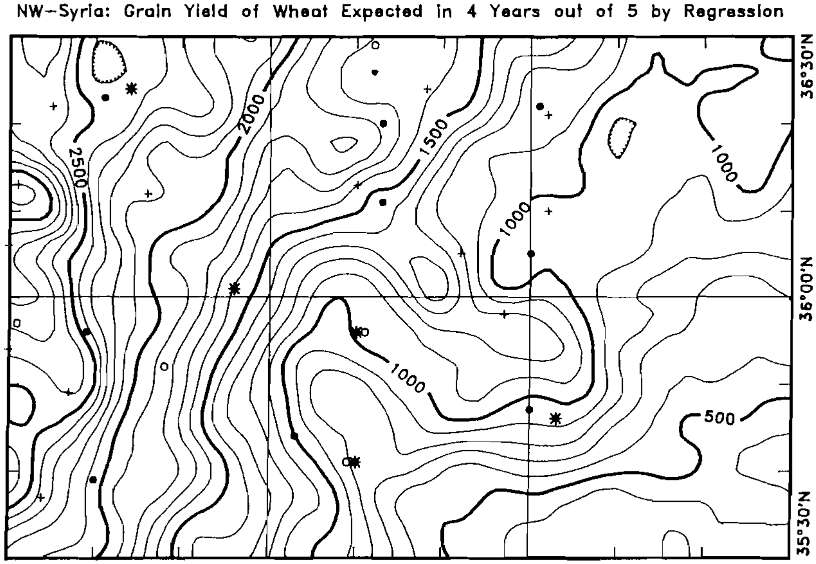


Figure 4.1.19 Grain yield (kg/ha) exceeded in four years out of five by Cham 1 wheat as predicted by regression (for further explanations see Figure 4.1.15)

Table 4.1.1 Regression coefficients for the prediction of wheat grain yield (kg/ha) and total dry matter (kg/ha) from monthly rainfall totals (mm)

Variable	Coefficients for grain yield	Coefficients for total dry matter
(Constant)	-1776.232	-2905.625
Square of Oct to May rainfall	-0.01214	-0.03203
October rainfall	18.61437	49.36714
November rainfall	3.09768	13.23568
December rainfall	23.01561	58.05962
January rainfall	12.16893	26.00895
February rainfall	22.65823	64.49828
March rainfall	21.04174	57.40239
April rainfall	28.78702	59.16906
May rainfall	-18.57090	-56.24252
Adjusted R^2	0.76	0.78

(Data courtesy of Dr M. Pala)

four years out of five. It is evident that the trends shown by the isolines in all of these figures are very similar to the isohyets of annual rainfall (Figure 4.1.4). The similarity between maps generated by both models and the rainfall map is evidence of the overriding importance of moisture availability as the limiting factor for crop growth in the area. Yet there are significant differences.

The predictions for dry matter agree only at the very low end of the scale (about 4 t/ha). With increasing growth potential, the predictions from the regression model lag behind those from the simulation model. This difference exceeds 20% in the most productive area in the west (13.5 t/ha versus 11 t/ha). The predictions for average grain yield also agree fairly closely at the dry end of the spectrum in the southeast, but also in some of the area with a medium potential, as around Tel Hadya, where both models predict an average grain yield of around 2.3 t/ha. At the high-yielding end, the simulation model predicts 30% higher yields than the regression model.

The difference between the models is even greater if one looks at the yields expected to be reached in four years out of five. Here the yields given by the simulation model are over 40% ahead of those from the regression model in the western hill areas, whereas in the dry southeast the two models again agree closely.

Several factors are known or suspected to contribute to the observed differences between the models:

- The predictions of the wheat regression model are extrapolations and therefore, strictly speaking, not valid in the barley-growing areas at the dry end of the spectrum.

- The regression model is based on data from a variety of soils, some of them holding less plant-extractable water than the Tel Hadya soil whose data were used for the simulation.

- The regression model assumes the same fertilizer rate every season. In the best seasons with ample, optimally distributed rainfall the nitrogen fertilization does not fully exploit the potential of the crop. SIMTAG on the other hand assumes no nutrient constraints whatsoever.

- The regression model still predicts some yield even in the driest of seasons, whereas SIMTAG simulates a complete crop failure under conditions of extreme moisture stress. Such conditions occur in the low rainfall part of the study area fairly frequently (in this simulation up to around 15% of the seasons).

These points together explain why the simulation model is more sensitive to variations in growing conditions than is the regression model.

Yet available data from ICARDA's research stations at Jindiress and Kafr Antoon (northeast of Jindiress) indicate that the predictions of the regression models for grain yield and dry matter agree more closely with reality than those predicted by SIMTAG for these locations. It is suspected that SIMTAG overestimates the green area of Cham 1 in areas at the humid end of the spectrum, thereby accumulating more dry matter, which in turn leads to an overestimation of grain yield (since grain yield is strongly correlated with total dry matter at anthesis). Whether this is due to a problem in the model or to difficulties in correctly estimating the genetic parameters for Cham 1 is not clear and deserves further attention. On the other hand, SIMTAG seems to perform as well as or better than the regression models in the part of the area with about 350 mm or less annual rainfall.

The last example presented here (Figure 4.1.20) compares fertilizer efficiencies on barley and wheat. A thousand years of precipitation data were generated and used to determine the efficiency of 80 kg N and 40 kg P_2O_5 per ha on wheat and on barley under rainfed conditions using the regression models developed by M. Pala (see section 3.3 of this report) and M. Jones (ICARDA 1990, in particular page 46, Table 3.1.6, equation a). Based on this and assuming equal costs, isolines of equal economic returns per unit of applied fertilizer were plotted for various ratios of prices for wheat and barley grain ranging from 1:1 to 2:1. The boundaries of the agricultural stability zones (ICARDA 1979) were plotted based on the same rainfall data. The map shows that barley uses fertilizer at the chosen production intensity more efficiently than wheat everywhere except in the wetter part of zone 1 (1a and 1b inside the area circled by the 1.0 contour). With an increasing price differential for wheat grain, the line where returns from the two crops for applied fertilizer are equal is pushed towards the drier areas.

During recent years, wheat/barley price ratios have fluctuated between about 1.2:1 and 1.5:1 (Merz 1990). Under these conditions, the contour line of equal returns from the two crops to applied fertilizer fluctuates around the boundary between stability zones 1b and 2 and is on average situated inside zone 2, near its wet end. Higher price differentials for wheat grain can push this line further towards the dry end, but never realistically much beyond the middle of zone 2. It

NW-Syria: Wheat/Barley Price Ratios for Equal Returns from Fertilizer

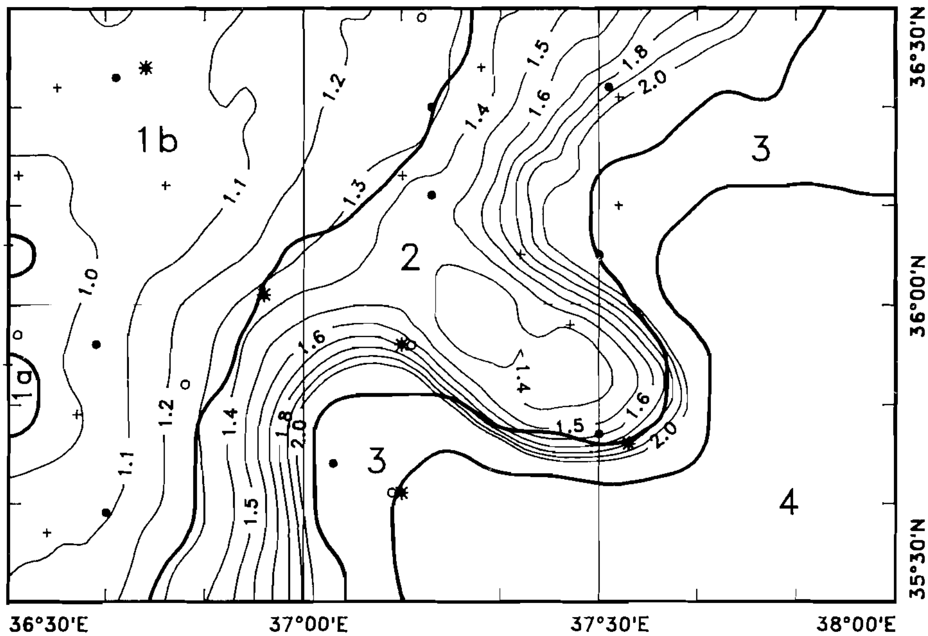


Figure 4.1.20 Isolines of equal returns per unit of fertilizer from wheat and barley grain assuming different price ratios between 1.0:1 and 2.0:1 (thin lines) and agricultural stability zones (solid lines). A fertilizer level of 80 kg/ha N and 40 kg/ha P_2O_5 was assumed for both crops

may be worth noting that the transition from the mainly wheat producing area to the predominantly barley growing area coincides fairly closely with the line where, under average price conditions, the returns from fertilizer applications are equal for both crops.

4.1.4 Appendix 1: Summary of methods employed by the SWG for temperature and radiation generation

4.1.4.1 Multivariate procedure for modelling temperature and solar radiation

The procedure is adapted from Matalas (1967) and assumes Normal-distribution of the variables. Daily maximum and minimum temperatures are taken to be normally distributed, solar radiation is first transformed in order to make it more compatible with Normal-distribution (see section 4.1.4.2). The variables are described by their arithmetic means, standard deviations, cross-correlation coefficients, lag-1 serial correlation coefficients and lag-1 serial cross-correlation coefficients. These descriptors are calculated separately for wet days and for dry days, for every calendar month. Optionally four sets of correlation coefficients can be employed (for wet days after wet days, after dry days; for dry days after wet days, after dry days). Another option is to use only one set of correlation coefficients for all days, no matter whether they are dry or rainy.

If, for any chosen calendar month, x_{ik} denotes daily values of maximum temperature (i=1), minimum temperature (i=2) and transformed solar radiation (i=3) on day k and n_i the number of observations, then the cross-correlations c_{ij} between two variables as indicated by subscripts i and j are

$$c_{ij} = \frac{n_{ij} \sum_{k=1}^{n_{ij}} x_{ik}\, x_{jk} - \left(\sum_{k=1}^{n_{ij}} x_{ik}\right)\left(\sum_{k=1}^{n_{ij}} x_{jk}\right)}{\sqrt{\left(n_{ij} \sum_{k=1}^{n_{ij}} x^2_{ik} - \left(\sum_{k=1}^{n_{ij}} x_{ik}\right)^2\right)\left(n_{ij} \sum_{k=1}^{n_{ij}} x^2_{jk} - \left(\sum_{k=1}^{n_{ij}} x_{jk}\right)^2\right)}}$$

Of course, $c_{12}=c_{21}$, $c_{23}=c_{32}$, $c_{13}=c_{31}$ and $c_{11}=c_{22}=c_{33}=1$.

The cross correlation coefficients are assembled in a matrix $\mathbf{M_o}$:

$$\mathbf{M_o} = \begin{bmatrix} 1 & c_{12} & c_{13} \\ c_{12} & 1 & c_{23} \\ c_{13} & c_{23} & 1 \end{bmatrix}$$

The lag-1 correlation coefficients r_{ij} are computed from

$$r_{ij} = \frac{(n_{ij}-1)\sum_{k=2}^{n_{ij}} x_{ik}\, x_{j,k-1} - (\sum_{k=2}^{n_{ij}} x_{ik})(\sum_{k=2}^{n_{ij}} x_{j,k-1})}{\sqrt{((n_{ij}-1)\sum_{k=2}^{n_{ij}} x^2_{ik} - (\sum_{k=2}^{n_{ij}} x_{ik})^2)((n_{ij}-1)\sum_{k=2}^{n_{ij}} x^2_{j,k-1} - (\sum_{k=2}^{n_{ij}} x_{j,k-1})^2)}}$$

where the index k-1 indicates a lag of one day. If $j=i$, r_{ij} is the lag-1 serial correlation coefficient for variable $i=j$, else r_{ij} is the lag-1 cross-correlation coefficient with variable j lagged one day behind variable i.

The lag-1 correlation coefficients are assembled in a matrix $\mathbf{M_1}$:

$$\mathbf{M_1} = \begin{bmatrix} r_{11} & r_{12} & r_{13} \\ r_{21} & r_{22} & r_{23} \\ r_{31} & r_{32} & r_{33} \end{bmatrix}$$

Matrices $\mathbf{M_o}$ and $\mathbf{M_1}$ are transformed into two matrices A and B using the following formulae:

$$\mathbf{A} = \mathbf{M_1}\, \mathbf{M_o}^{-1}$$

$$\mathbf{BB^T} = \mathbf{M_o} - \mathbf{M_1}\, \mathbf{M_o}^{-1}\, \mathbf{M_1}^T$$

where the superscripts T and -1 denote the transpose and the inverse of the matrices.

B is obtained from BB^T through a Choleski-decomposition (for details see Hartung and Elpelt, 1986).

If X_k denotes a vector of the standardized residuals of maximum temperature, minimum temperature and transformed solar radiation on day k and ϵ is a vector of three independent variates from the standard Normal-distribution, then the relation between the residuals on day k and day k-1 is given by

$$X_k = AX_{k-1} + B\epsilon_k$$

Multiplication of the residuals X_i with the appropriate standard deviation and addition of the corresponding mean then yields the generated values of maximum temperature (i=1), minimum temperature (i=2) and transformed radiation (i=3) for day k.

$$x_{ik} = X_{ik}\, s_{ik} + m_{ik}$$

4.1.4.2 Transformations of solar radiation values

As the Normal-distribution provides only a poor fit for solar radiation, which varies only within a certain range determined by latitude of a given site, the calendar date and the elevation, the radiation data are transformed to approximate a Normal-distribution more closely before the coefficient estimation. The inverse transformation is then applied to the generated radiation data.

The radiation data are assumed to follow a Beta-distribution (for details on Beta-distributions see Johnson and Kotz, 1970, pp. 37-56) with an upper boundary b determined as function of latitude and date with the help of a subroutine based on the SIMTAG wheat model (Stapper, 1984a). The lower boundary of values, a, is taken to be 10% of b. For each day, standardized radiation value r′ is obtained from the original value r by

$$r' = \frac{r-a}{b-a}$$

From the Beta-standardized radiation values of dry days and of wet days during each calendar month, the shape parameters p and q of the corresponding Beta-distribution can then be estimated as:

$$p = m'^2 \ (1-m')/s'^2 - m'$$
$$q = m' \ (1-m')^2/s'^2 + m'-1$$

where m′ and s′ are mean and standard deviation of the standardized radiation values.

For every radiation value r′, the corresponding probability is obtained by integration of the Beta-density function:

$$P_{r'} = \frac{1}{B(p,q)} \int_{o}^{r'} t^{p-1} \ (1-t)^{q-1} \, dt$$

where B(p,q) is the Beta-function. Since

$$B(p,q) = \frac{\Gamma(p) \ \Gamma(q)}{\Gamma(p+q)} ,$$

it can be approximated by using Hastings′ formula (for details see ICARDA 1990):

The integration is done with the Gaussian quadrature method. The transformed integral of the Beta-density function is

$$P_{r'} = \frac{r'}{2B(p,q)} \int_{-1}^{1} \left(\frac{r'(1+t)}{2}\right)^{p-1} \left(1- \frac{r'(1+t)}{2}\right)^{q-1} dt$$

The probability P_r' (as computed under the assumption that radiation follows a Beta-distribution) is then equated to the probability P_{rT} from a Normal-distribution of transformed radiation values r_T:

$$P_r' \text{ (Beta)} = P_{rT} \text{ (Normal)}$$

Since the means and standard deviations (now not Beta-standardized!) are known, it is possible to compute values r_T from a Normal-distribution which have the same probability of being reached as the values r' from a Beta-distribution. For every value r' there is a corresponding value r_T.

For values of $P_{rT} > 0.5$, r_T can be efficiently approximated with another of Hastings' approximation formulae (Hastings 1955; Hartung, Elpelt and Klossener 1987):

$$r_T = \left(t - \frac{a_0 + a_1 t + a_2 t^2}{1+b_1 t+b_2 t^2+b_3 t^3}\right) s + m$$

where $t = \sqrt{-2 \log (1-P_{rT})}$

$a_0 = 2.515517$ $a_1 = 0.802853$ $a_2 = 0.010328$

$b_1 = 1.432788$ $b_2 = 0.189269$ $b_3 = 0.001308$

and s and m are standard deviation and arithmetic mean respectively.

For probabilities less than 0.5, P_{rT} is replaced by $1-P_{rT}$ and s is multiplied by -1.

The reverse transformation from Normal- to Beta-distribution of the generated values is a reversal of the described steps. Hastings' formula for approximating the probability P_{rT} from a value $r_T > m$ is

$$P_{rT} = 1 - \frac{1}{2\pi} e^{-x^2/2} (a_1 t + a_2 t^2 + a_3 t^3 + a_4 t^4 + a_5 t^5)$$

where $t = \frac{1}{1+b(r_T-m)/s}$

$$b = 0.2316419 \qquad a_1 = 0.31938153$$
$$a_2 = -0.356563782 \qquad a_3 = 1.781477937$$
$$a_4 = -1.821255978 \qquad a_5 = 1.330274429$$

If $r_T < m$, then $t = \frac{1}{1+b(m-r_T)/s}$

and the equation yields $1-P_{rT}$, which has to be subtracted from 1 to obtain P_{rT}.

r′ from a standardized Beta-distribution is obtained by integration of the Beta-density function. Finally, r is obtained from

$$r = a+(b-a)r'$$

4.1.4.3 Spatial interpolation of temperature and radiation coefficients

Station temperature and radiation data are reduced to sea level before the actual interpolation. The temperature gradients are determined by either linear regression of temperature on altitude based on the data of all stations within a chosen perimeter, or calculated from the temperature difference between two preselected stations.

With the linear regression method, the gradients g per 100 m are obtained from

$$g = \frac{n \sum_{i=1}^{n} h_i t_i - \left(\sum_{i=1}^{n} h_i\right)\left(\sum_{i=1}^{n} t_i\right)}{n \sum_{i=1}^{n} h_i^2 - \left(\sum_{i=1}^{n} h_i\right)^2} * 100$$

and the temperatures, T_o at sea level are

$$T_o = \frac{\sum_{i=1}^{n} t_i}{n} - g \frac{\sum_{i=1}^{n} h_i}{100n}$$

where n is the number of stations, t_i are the station temperatures and h_i are the altitudes of the stations above sea level in m.

Radiation values are reduced to sea level by reducing them proportionally to the increased air mass which would have to be traversed between station altitude and sea level.

The reduced radiation in MJ/m^2 at sea level is

$$R_o = R_h-(R_x-R_c)(1-10^y/760)$$

with $y = (53010.4+212.04T_h-h(1-1.0602g))/(18400-73.6T_h-0.368hg)$

where R_h is the radiation measured at station altitude, R_x is the extraterrestrial radiation, R_c is the maximum possible clear day radiation at sea level after Stapper (1984a), T_h is the mean temperature at station altitude in °C, h is the elevation of the station in m, and g is the temperature gradient in °C/100 m.

The spatial interpolation is done on the coefficients calculated from reduced temperature and radiation by Kriging (for details see Ripley 1981, Burgess and Webster 1980a,b; Webster and Burgess 1980; Delfiner and Delhomme 1975). Widely available software packages, Surfer (Golden Software, n.d.) and GEO-EAS (Eglund and Sparks 1988) have been found adequate for the task.

After generation, the temperature and radiation values are retransformed according to the local elevation:

$$T_h = T_{og} + hg/100$$

and

$$R_h = R_{og} + (R_x - R_c)(1 - 10^z/760)$$
with $z = (53019.4 + 212.04T_{og} - h(1-1.0602g))/(18400 + 73.6T_{og} - 0.368hg)$

where T_h is the temperature at altitude h, T_{og} is the value generated from the interpolated coefficients at sea level, g is the temperature gradient per 100 m, R_h is the radiation at altitude h, R_{og} is the generated radiation value, and R_x and R_c are the extraterrestrial and maximum clear-day radiation at sea level, respectively.

4.1.4.4 Generation of random numbers from the standard Normal-distribution

The random numbers from the standard Normal-distribution which are required for the generation of temperature and radiation values are obtained by the Box-Muller method (Box and Muller 1958; Rubinstein 1981):

$$C_1 = \sqrt{-2 \log U_1} * \cos (2U_2)$$

where U_1 and U_2 are two uniform(0,1)-variates. A second standard Normal-variate is obtained from the same two uniform(0,1)-variates as

$$C_2 = \sqrt{-2 \log U_1} * \sin (2U_2)$$

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4.2 Two Years' Results from Diagnostic Agronomy Trials in the Mafraq Area, Northern Jordan

M. Oglah, A. Jaradat, R. Tutwiler and M. Jones

4.2.1 Introduction

The first objective of the multidisciplinary program begun by JUST and FRMP in 1988 was to characterize the agricultural production systems of the 'marginal zone' of rainfed agriculture (200-300 mm mean annual rainfall) in Jordan. The Mafraq area was selected as being representative. It lies between the Syrian border to the north, the Zarqa valley to the south, and the Hejaz railway and the Ramtha-Jerash road to the east and west, respectively, an area of approximately 1000 km^2.

Last year's report outlined the geography of the area and the history of its agricultural settlement and summarized the analyses of two years' farm survey work (Jaradat, Oglah and Tutwiler 1990). Farms were grouped according to rainfall zone, farm size, enterprise mix, total income and off-farm income; and four main production strategies were identified, CL (cereals + livestock), CLO (cereals, livestock, olives), CO (cereals + olives) and C (cereals only). The main conclusion was that, for improvement, the key on-farm element to focus on is the livestock-crop interface. Almost all farmers with livestock identified feed supply as their principal problem. They wished to increase the productivity of their arable land specifically to lessen their dependence on external feed sources.

Concurrently with the farm survey work, a series of agronomy trials were started. Described as diagnostic, they were seen as complementing the survey work by exploring possible options for improved productivity of arable land for feed supply. They examined the potential under farmers' field conditions in this zone of various fodder legumes and of an improved barley cultivar and improved inputs and management practices for barley. Here we give a preliminary summary of the first two years' results.

4.2.2 Trial details

Trials were planted along a rainfall transect running approximately southeast from Ramtha, at three sites in 1988/89 and five sites in 1989/90 (Table 4.2.1). Only one site, Balama, was common to both years, but JUST (88/89) is seen as equating with Ramtha (89/90), and Rihab (88/89) is very close to Deir Waraq (88/90). Soils (at the 1988/89 sites) have been described as predominantly deep vertisols developed on hard limestone under a xeric soil moisture regime, having a high water-holding capacity.

Table 4.2.1 Trial sites and October-March rainfall totals

		Rainfall, mm
88/89	JUST (= Ramtha)	148
	Balama	162
	Rihab	158
89/90	Ramtha	327
	Balama	150
	Deir Waraq (= Rihab)	150
	Faa	150
	Noeimeh	250

Each site carried two trials:

Fodder legume trial. The aims were to measure and demonstrate the productivity of forage legumes in this environment and to compare a range of cultivars. There were eight cultivars in 1988/89 (3 *Vicia sativa*, 1 *V. narbonensis*, 1 *V. dasycarpa*, 2 *Lathyrus sativus* and 1 *L. ochrus*.), to which one *Vicia ervillia* cultivar was added for the 1989/90 trials. Each trial comprised three replicates of the eight (nine) genotypes fully randomized, with a plot size of 10 x 1.5 m. Seed was sown in December by Øyjord plot-drill into a harrowed seedbed with diammonium phosphate fertilizer (DAP) at 100 kg/ha. To estimate productivity, samples were taken for biomass (total dry matter) at the "grazing stage", early to mid-April, and for grain and straw at maturity.

Barley trial. The aim was to compare a local barley (Arabi Abiad) with an improved cultivar (WI 2269), under different management conditions. Each trial comprised a full factorial combination of the two cultivars with (a) seed drill vs broadcasting, (b) with and without 100 kg DAP/ha, and (c) with and without herbicide, erbitox (2,4 D), sown in 10 x 1.5 m plots. As with the fodder legumes, samples were taken at the grazing stage and maturity, but only mature-stage data are reported here.

4.2.3 Results of Forage Legume Trials

Legume yields reflected seasonal rainfall (Table 4.2.2). Means of grazing-stage dry matter values clustered between 1.3 and 1.9 t/ha for the six sites with rainfall around 150-160 mm but rose to 2.6 t/ha at 250 mm (Noeimeh) and nearly 4 t/ha at 327 mm (Ramtha), an approximately linear rate of increase of about 1 t/ha/100 mm. Vicia narbonensis (67) was the highest-yielding cultivar in five of the eight trials and gave the highest yield mean, followed by V. dasycarpa (683). Yields of these two cultivars showed high variability (CV approx. 50%), arising - like the high yield means - from a greater responsiveness to increasing rainfall. The two Lathyrus sativus cultivars were much more stable (CV less than 30%). This was due to relatively low yields under high rainfall rather than to relatively high yields at low rainfall. Vicia ervillia, grown only in the second year, also appeared rainfall-responsive, and, over five sites, its yield mean (2.55 t/ha) was exceeded only by those of V. narbonensis and V. dasycarpa (3.00 and 2.65 t/ha, respectively).

Legume yields at maturity are summarized in Tables 4.2.3 and 4.2.4. Greatest total dry matter production continued to come from V. narbonensis, but the superiority of that cultivar was less marked at this stage, particularly in the first season, when L. sativus (347) produced the most material at two of the three sites. Over the two seasons together V. narbonensis had the highest mean harvest index, around 28%; but that of V. ervillia was higher in 1989/90 (mean, 35%). That of V. dasycarpa was consistently low, around 15%. This genotype is best utilized for grazing, but seed production would be a problem in this environment.

Mean yields of fertilized barley (from the barley trial at the same site) are included in Tables 4.2.3 and 4.2.4 for comparison. Barley, which tended to have a higher harvest index, produced more grain than any legume at every site, but it was out-produced in total dry matter by several legume cultivars at Noeimeh and Deir Waraq in 1989/90. For animal feeding, straw is particularly important and

Table 4.2.2 Grazing stage yields of 9 forage legume genotypes in eight trials in northern Jordan, 1988/90 and 1989/90, total dry matter/ha

Variety	Acc'n Nº	1988/89 JUST	Balama	Rihab	1989/90 Ramtha	Balama	D. Waraq	Faa	Noeimeh	Mean	CV %
V. sativa	708	1.55	1.20	1.05	3.82	1.32	1.46	1.26	2.02	1.71	53
V. sativa	2541	1.74	1.43	1.19	3.57	1.80	2.08	1.24	2.17	1.90	40
V. sativa	715	1.94	1.44	1.21	3.79	1.49	1.84	1.25	2.45	1.93	45
V. narbonensis	67	2.11	2.39	1.54	5.58	1.97	2.86	1.61	2.99	2.63	50
V. dasycarpa	683	1.40	1.67	1.29	4.42	1.82	1.99	1.75	3.25	2.20	49
L. sativus	347	1.57	1.81	1.42	2.97	1.86	1.93	1.46	2.07	1.89	26
L. sativus	311	1.73	1.82	1.65	3.17	1.55	1.93	1.42	2.11	1.92	29
L. ochrus	101	1.61	1.43	1.24	3.56	1.77	1.29	1.28	4.04	2.03	55
V. ervillia		-	-	-	4.47	2.21	1.25	2.05	2.79	(2.55	47)
MEAN		1.71	1.65	1.32	3.93	1.75	1.85	1.48	2.65		
Rainfall, mm		148	162	158	327	150	150	150	250		

Table 4.2.3 Means of total dry matter (TDM) at maturity and grain yield of 8 forage legume genotypes at 3 sites in northern Jordan, 1988/89 (with means from adjacent barley trials included for comparison)

Variety	Acc'n Nº	JUST TDM	JUST Grain	Balama TDM	Balama Grain	Rihab TDM	Rihab Grain	Means TDM	Means Grain	HI, %
V. sativa	708	1.85	0.40	1.22	0.18	1.23	0.18	1.43	0.25	17.7
V. sativa	2541	2.58	0.62	1.44	0.27	1.55	0.36	1.86	0.42	22.4
V. sativa	715	2.20	0.44	1.65	0.24	1.53	0.32	1.79	0.33	18.6
V. narbonensis	67	3.43	0.85	1.81	0.70	1.94	0.40	2.39	0.65	27.2
V. dasycarpa	683	1.69	0.22	1.68	0.22	1.69	0.40	1.69	0.28	16.6
L. sativus	347	2.43	0.57	2.45	0.73	2.22	0.57	2.37	0.62	26.3
L. sativus	311	2.90	0.71	2.31	0.35	1.92	0.50	2.38	0.52	21.9
L. ochrus	101	1.68	0.17	1.55	0.25	1.45	0.21	1.56	0.21	13.5
Barley *		4.73	0.96	3.32	0.93	3.13	0.82	3.73	0.90	24.2

* Means of all fertilized plots

Table 4.2.4 Means of total dry matter (TDM) at maturity and grain yield of 9 forage legume genotypes at 4 sites in northern Jordan, 1989/90 (with means from adjacent barley trials included for comparison)

Variety	Acc'n Nº	Ramtha TDM	Ramtha Grain	Balama TDM	Balama Grain	Noeimeh TDM	Noeimeh Grain	Deir Waraq TDM	Deir Waraq Grain	Means TDM	Means Grain	HI, %
V. sativa	708	6.42	1.60	1.47	0.16	1.93	0.26	1.95	0.44	2.94	0.62	20.9
V. sativa	2541	6.03	1.50	2.61	0.79	3.32	0.72	2.06	0.63	3.51	0.91	26.0
V. sativa	715	6.80	1.35	2.33	0.81	2.54	0.38	2.05	0.45	3.43	0.75	21.8
V. narbonensis	67	7.91	2.27	3.02	1.01	3.16	0.75	3.44	1.06	4.38	1.27	29.0
V. dasycarpa	683	6.01	0.74	2.13	0.47	3.60	0.50	1.54	0.24	3.32	0.49	14.7
L. sativus	347	5.77	1.25	2.70	0.73	2.15	0.16	3.45	0.67	3.52	0.70	20.0
L. sativus	311	5.95	1.23	2.95	1.00	2.89	0.23	3.50	0.58	3.82	0.76	19.0
L. ochrus	101	6.04	1.40	2.59	0.63	3.54	0.50	1.55	0.42	3.43	0.74	21.5
V. ervillia		6.59	2.05	2.97	1.32	2.37	0.81	1.42	0.55	3.34	1.18	35.4
Barley *		8.99	3.23	5.01	2.50	2.87	1.10	2.79	1.25	4.92	2.02	41.1

Four sites only, because Faa was prematurely grazed off.
* Means of all fertilized plots.

comprises 60-80% of the biomass of these crops at maturity. It is therefore particularly interesting that the yield means of the four 1989/90 trials show that three of the legumes produced as much straw as did the barley:

	t/ha
Barley	2.90
Vicia narbonensis	3.11
Lathyrus sativus (347)	3.06
Lathyrus sativus (311)	2.82

Although these materials were not analysed chemically, legume straws are generally superior to barley straw in terms of nitrogen content and feed quality. If they can also be produced in similar quantities, their value to the livestock producer is undeniable.

4.2.4 Results of Barley Trials

A summary of the main treatment effects at the three 1988/89 sites shows that only one factor, fertilizer, had any major effect (Table 4.2.5); and there was a similar pattern in the 1989/90 season. This

Table 4.2.5 Main factor effects on barley yields at three sites in 1988/89: total dry matter and grain yield

	JUST		Balama		Rihab	
	TDM	Grain	TDM	Grain	TDM	Grain
Yields, t/ha:						
Cultivar: Arabi Abiad	4.71	0.89	2.79	0.76	2.80	0.73
WI 2269	4.46	0.91	2.51	0.71	2.70	0.74
Fertilizer: nil	4.50	0.89	1.97	0.54	2.37	0.65
100 kg DAP/ha	4.73	0.96	3.32	0.93	3.13	0.82
No herbicide	4.71	0.96	2.58	0.73	2.69	0.73
Herbicide	4.46	0.84	2.71	0.74	2.82	0.74
Broadcast	4.46	0.87	2.68	0.74	2.82	0.75
Seed drill	4.71	0.93	2.62	0.73	2.68	0.72
Percentage effect of improved practices:						
Cultivar	−5	+2	−10	−7	−4	+1
Fertilizer	+5	+8	+69	+72	+32	+26
Herbicide	−5	−12	+5	+1	+5	+1
Seed drill	+5	+7	−2	−1	−5	−4
4 practices combined *	+3	−2	+64	+82	+17	+29

* Not fully additive because of some interaction between treatments

result demonstrates the importance of testing each factor separately. The full package of four improved practices (cultivar, fertilizer, herbicide and seed drilling) gave yields greatly increased over those of control at one site and moderately increased at another, but at both sites approximately similar increases could have been obtained from the fertilizer component alone. The testing and demonstration of packages only may often lead to the recommendation of unnecessarily complex and expensive packages.

Tables 4.2.6 and 4.2.7 summarize cultivar and fertilizer effects, respectively, on a site-by-site basis. Differences between cultivars were almost negligible. There was a slight tendency for Arabi Abiad to produce more total dry matter under low-yielding conditions, while WI 2269 produced 10% more at the one relatively wet site (Ramtha, 1989/90), but the 8-site means were virtually identical. In respect of grain, Arabi Abiad gave a slightly higher mean yield, but the difference -- less than 5% --- would almost certainly not be statistically significant.

Table 4.2.6 Barley genotype comparison at eight sites: yield means, across ± fertilizer treatments, of total dry matter and grain (t/ha)

		TDM		Grain	
	Site	Arabi Abiad	WI 2269	Arabi Abiad	WI 2269
1988/89	JUST	4.71	4.46	0.89	0.91
	Balama	2.79	2.51	0.76	0.71
	Rihab	2.80	2.70	0.73	0.74
1989/90	Ramtha	7.50	8.31	2.77	2.96
	Balama	4.47	4.55	2.36	2.21
	Deir Waraq	2.37	2.17	1.08	0.89
	Faa	1.92	1.81	0.79	0.63
	Noeimeh	2.19	2.31	0.90	0.82
	MEANS	3.59	3.60	1.29	1.23

Table 4.2.7 Barley response to fertilizer (100 kg DAP/ha) at eight sites, mean yields across two genotypes, total dry matter and grain (t/ha)

	Site	TDM		Grain	
		-F	+F	-F	+F
1988/89	JUST	4.50	4.73	0.89	0.96
	Balama	1.97	3.32	0.54	0.93
	Rihab	2.37	3.13	0.65	0.82
1989/90	Ramtha	6.82	8.99	2.50	3.23
	Balama	4.01	5.01	2.08	2.50
	Deir Waraq	1.76	2.79	0.71	1.25
	Faa	1.62	2.11	0.67	0.75
	Noeimeh	1.63	2.87	0.63	1.10
	MEANS	3.09	4.12	1.08	1.44

Fertilizer gave yield increases of more than 20% at six sites out of eight in respect of grain, and at seven sites in respect of total dry matter. The one site, JUST, at which little fertilizer response was observed, was the only one not located on a farmer's field and may well be atypical. Over the eight sites together, mean increases were approximately 33% for both grain and total dry matter.

One advantage often claimed for improved cultivars is that they are more responsive to inputs like fertilizer. That was not the case in these trials, which showed almost no interaction between cultivar and fertilizer use. Among the 1989/90 sites, at Ramtha, the wettest site, in the absence of fertilizer the improved cultivar produced 10-12% more total dry matter than the local variety but this difference was little changed by fertilizer (Table 4.2.8). At the other four sites yield and fertilizer response differences were negligible or slightly in favor of Arabi Abiad. Over the five sites, mean increases from fertilizer were 37 and 38% for total dry matter and 36 and 34% for grain (for Arabi Abiad and WI 2269, respectively).

Table 4.2.8 Effect of genotype on barley response to fertilizer (100 kg DAP) at five sites in 1989/90 only; total dry matter and grain (t/ha)

	TDM				Grain			
	Arabi Abiad		WI 2269		Arabi Abiad		WI 2269	
	-F	+F	-F	+F	-F	+F	-F	+F
Ramtha	6.44	8.56	7.21	9.41	2.44	3.09	2.55	3.37
Balama	3.97	4.98	4.05	5.05	2.08	2.65	2.08	2.35
Deir Waraq	1.93	2.81	1.59	2.76	0.80	1.35	0.60	1.15
Faa	1.65	2.20	1.59	2.03	0.75	0.83	0.58	0.67
Noeimeh	1.57	2.81	1.68	2.93	0.64	1.16	0.61	1.03
MEANS	3.11	4.27	3.22	4.44	1.34	1.82	1.28	1.71

4.2.5 Conclusions

First, it is clear that forage legumes can be productive in this environment. Both seasons were very dry, but there were no crop failures. A mean grazing-stage dry matter yield from the six lowest rainfall sites (mean, 153 mm) of 1.63 $\pm$ 0.19 t/ha is remarkably good and shows remarkably low variation. Vicia narbonensis and V. ervillia appeared to be the most promising of the cultivars tested, particularly for grain production; but V. dasycarpa is also a good cultivar for grazing-stage utilization; and V. narbonensis and the two Lathyrus sativus cultivars all produced as much straw as barley in the 1989/90 season.

The barley trials demonstrated the overriding importance of fertilizer in this area. Nevertheless, the other three factors tested should not be written off prematurely. Only one improved cultivar, WI 2269, was tested against the local barley; other improved cultivars might perform more impressively, especially in more favorable rainfall seasons. Similarly, herbicide did not increase yields, but then weeds are only a minor problem in dry seasons. Seed drilling gave no advantage over broadcast seeding; yet, the success of a broadcast crop depends very much on the quality of the seedbed and the method of covering. If these are satisfactory, there is no reason for any relative yield loss. However, one sees many badly broadcast crops in Jordan, over which the seed drill would almost certainly bring an improvement.

It is planned to continue these trials for one more season.

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

Elizabeth Bailey

4.3.1 Introduction

The drier areas of West Asia and North Africa are characterized by a fragile and limited natural resource base, uncertain and fluctuating environmental conditions, and low production potential. These areas contain some of the poorest farmers facing some of the harshest conditions in the region.

Agricultural systems that have evolved over time to cope with the problems of farming in such variable environments are traditionally of low intensity and low productivity, but are well adapted to the environment. However, rapidly expanding populations and other recent changes in the external environment are forcing changes in production practices that now threaten the natural resource base.

The rising demand for food has led to intensified land use, the expansion of cultivation into more and more marginal areas, and overgrazing of natural rangelands. While such strategies may offer short-term gains in output, they increase the variability and risks in production. The increasing pressures on soil, water and natural vegetation seriously threaten their potential for future productive utilization. The consequences are potentially disastrous. The deterioration of the productive base threatens the standard of living of the indigenous population and the long-term viability of agriculture in these areas.

Dryland resource degradation is ultimately the result of human decision making. Individual land users make management decisions in response to a range of perceived constraints and incentives. Understanding land users' perspectives and why observed actions are being taken will assist in identifying the causes of degradation. Given the central role of individual land users' decision making in resource management, the people concerned must actively participate in every step from problem diagnosis to technology development and evaluation. Sustainable production systems can be developed only if the benefits are clear to the individual land users involved.

4.3.2 The Dryland Resource Management Project

The development of sustainable agricultural systems must be achieved through the efficient management and conservation of existing resources thus ensuring that increases in productivity can be maintained in the long-term.

The successful design of improved technologies and management systems will depend on an understanding of existing systems, how they have evolved, and how producers are adjusting to a changing environment. Such an understanding requires in-depth studies of the interrelationships between agricultural practices and the wider physical, biological, social and economic environment.

Toward this end, in 1990 ICARDA initiated a new regional project, the Dryland Resource Management Project. The project is coordinated by scientists in the Farm Resource Management Program and is supported by Ford Foundation.

The project will produce a series of studies that offer a critical assessment of existing systems of agricultural production and resource management in dry areas, and their impact on the natural resource base, with a view to formulating recommendations for improvement. Each study has two objectives: (1) to describe and analyze current resource management practices and local land users' perceptions for the purpose of developing alternative management practices, and (2) to initiate within the national programs multidisciplinary activities addressing the problems of land users in the drier areas.

The studies will be conducted by multidisciplinary teams of national scientists in several countries in the region. These studies are viewed as the first phase in the process of developing sustainable agricultural production systems in marginal areas. The results from these studies will play an important role in guiding future research and development. Following this first phase of research, NARS will be able to prescribe further programs of activity for testing and evaluating appropriate new technologies and management strategies.

4.3.3 Project Composition

The three year (1990-1992) project will have three major components.

1. A preliminary meeting will be held in June 1991 at which participating national teams will present case study plans and methodological approaches will be discussed.

2. Case studies will then be conducted simultaneously in each country. National scientists will assume primary responsibility for designing, conducting, and analyzing the case studies with regular consultation and support by ICARDA scientists.

3. Upon completion of the case studies, ICARDA will host a presentation workshop in which the results of each case study will be given, general conclusions discussed, methodologies assessed, and recommendations for follow-on work formulated. Results from the case studies and discussions at the workshop will be collated and edited by ICARDA for publication.

The value of this region-wide, yet nationally specific, approach has a number of dimensions. Scientifically, the data bases and analyses from the local studies will allow national programs and international research organizations to address location-specific problems and, at the same time, will provide the means for characterizing the resource management practices and problems on a region-wide basis. For national agricultural research institutions, the case study activities and the trans-national meetings will encourage a regional consensus on the importance of the problems in the drier areas and appropriate ways to seek solutions in a cooperative manner. By the end of the three-year project, national teams of scientists with an awareness of the problems of resource degradation and an enhanced capacity for applied multidisciplinary research will be operational.

4.3.4 Nature and Scope of Case Studies

The overall objective of the project is to produce a series of studies that offer a critical assessment of existing systems of agricultural production and resource management in dry areas and their impact on the natural resource base, with a view to formulating recommendations for improvement.

The studies will be conducted within a systems framework but focused on particular problems of resource management and degradation. In conducting these studies, the researchers will, wherever possible, draw upon existing research in the study area.

The aim of these studies is not only to analyze how the activities of the local population (and others) are affecting the natural resource base, but also how the deterioration of natural resources are affecting the activities and welfare of the local people. Thus, the collection and analysis of information will be designed to meet the following objectives:

- identify current processes of degradation arising from existing production practices;

- investigate farmers' awareness and perceptions of such degradation;

- analyze the way in which resource management strategies are evolving, and under what pressures, clearly identifying the driving forces (infrastructural, economic and social) behind these changes, and their effects on the natural resource base;

- analyze and assess existing systems of resource management in terms of farm structure, enterprise mix, capital and labour requirements, and technological skills.

- identify, within the context of present resource capacities, farmers' production priorities and, within the wider economic environment, constraints and incentives to sustainable increases in productivity and farm income.

- recommend appropriate technologies or management practices for future testing and evaluation.

These case studies can be viewed as the first phase in a collaborative process of developing sustainable agricultural production systems in marginal areas. Outputs from each case study, to be presented at the final workshop, will include:

- Analysis of existing resource management;

- Evaluation of existing technology and management strategies:
  - farmers existing technology and management practices;
  - technology and management practices that have already been tried or tested in the area;
  - potential alternative technologies or management strategies;

- Assessment of the requirements of alternative technologies and management strategies, eg., changes required in production practices, in management practices, in social organisation (communal management), in government policy, etc.

- Proposals for technology development and testing with full participation of local communities.

4.3.5 Participating National Teams

Details for a study in southern Jordan and in southern Tunisia have already been finalized. Arrangements for studies in Syria, Libya and Yemen are currently being developed. Other countries may become involved in the project

4.3.5.1 Jordan

The case study in Jordan will be conducted by a team of scientists from The University of Jordan and the National Centre for Agricultural Research and Technology Transfer (NCARTT). Based on the hypothesis that the productivity of the range as it is currently utilized is not sustainable, the objective of the study is to establish the differences between alternative forms of rangeland management in terms of their effect on rangeland resources, and in relation to the local land users' production aims and perspectives.

The case study will be located in south Jordan, in a transect which runs east and west of Lajoun range reserve, and includes a spectrum of land use management systems: open rangeland, government range reserve, cooperative range reserve, and arable (barley producing) areas. The case study will utilize and build upon existing research being conducted in this area, to achieve the following:

1. Describe the existing situation in the open range, and explain the reasons for the current situation:

- what is the resource situation: condition and composition of the natural vegetation;
- who are using the resources and what are their production aims;
- how are they using the resources:
    - grazing
    - ploughing for barley

- productivity of the rangeland - dry matter production
  - animal feed value
- land users' perceptions of the current situation

2. Examine existing alternative management strategies:

   a) Government range reserve
   b) Cooperative range reserve

- what is the resource situation in the reserves, in comparison to the open range;
- who are using the resources: who has access to the reserves;
- how are they using the resources: numbers of animals, grazing days, etc.;
- productivity of the reserves, in comparison to the open range;
- local land users' perceptions/opinions of these reserves.

3. Examine interactions/linkages within and between systems:

- rangeland users may be from sedentary (arable) areas or may be transhumant sheep owners;
- utilization of the range is related to the feed cycle and the availability of alternative feed: barley production, concentrates, alternative grazing sources.

4.3.5.2 Tunisia

The case study in Southern Tunisia will be conducted by a multi-disciplinary team of scientists from the Departement des Sciences du Milieu, the Departement Sciences Vegetale, the Departement des Sciences Animales, and the Departement des Sciences Humaines of the Institut des Regions Arides (IRA), Medenine.

The case study will be located in the region running south from Gabes to the Libyan border, bounded by the sea to the east and the Matmata mountains in the west. The region is divided into two major agro-ecological zones: the Jeffara plain and the Matmata mountains.

The study area should incorporate a transect from the mountain area to the Jeffara plain.

The Jeffara plain can be divided into three major agricultural zones: extensive rangeland (pasture), an expanding cultivated area (cereals and arboriculture), and intensive agriculture around oases. The plains were originally under communal tribal land occupied by nomadic pastoralists. With land reform, there has been an increase in cultivated area, particularly the area planted to olive trees. The reduction in available grazing has forced changes in the traditional livestock production system. The major problem of resource degradation in the plains is the increasing desertification (windblown sand and shifting dunes) attributed to the expansion of the cultivated area (notably of barley) and overgrazing of rangeland.

Within the Matmata mountains, agriculture is supported by traditional methods of water harvesting ("jessour") involving small dams and terraces. This system of jessour, by retaining run-off water, contributes to a reduction in the degrading effects of water erosion. The run-off water also contains sediment which is deposited as a layer of alluvium behind the dams. However, studies by IRA have shown that there are weaknesses in the design and construction of the jessour system; one in ten years dams are destroyed by floods. Furthermore, increasing population combined with limited resources is resulting in out-migration from the region.

It is envisaged that parallel studies will be conducted in the Matmata mountains and the Jeffara plain, focused on very different resource management problems, but where possible identifying interrelationships between the two zones.

5. PROJECT 3. ADOPTION AND IMPACT OF TECHNOLOGY

Introduction

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

1. To help biological scientists design technologies which can be easily adopted by farmers through the collection and implementation of information on the needs and constraints of farmers.

2. To help to derive ways to introduce new practices into farming systems of the region.

3. To describe ways to estimate the impact of new technology, and to identify benefit and problems arising from new practices and their implications for technology design.

4. To assess, within the region, trends in crop production, policies affecting agriculture, labor supply and other sociological and economic factors directly affecting agriculture.

5.1 Adoption of Winter-Sown Chickpeas in Syria: 1989/90 Season

Richard Tutwiler and Ahmad Mazid

5.1.1 Advantages of Winter Chickpea Varieties

The first winter-sown chickpea variety in Syria, Ghab 1, was released in 1982. It was followed by a second variety, Ghab 2, in 1986. Both varieties offer the potential of considerably increasing national chickpea productivity. The Syrian local chickpea variety is traditionally sown in the spring because it is susceptible to <u>ascochyta</u>

blight, a disease which is promoted by humid and moderately cold conditions. Although spring planting allows escape from conditions most conducive to blight development, late planting also means that the reproductive stage of spring chickpea falls at a time when rainfall is minimal and temperatures are high (ICARDA 1987). Consequently, yields are low and unstable.

The new winter-sown varieties were developed to be resistant to both ascochyta blight and cold. In over ten years of scientific trials, both on-station and on-farm, winter-sown chickpeas have consistently outyielded the local spring-sown cultivars. The yield difference is usually between 50% and 100% (ICARDA 1987). The higher yields are due to a longer growing season; better utilization of moisture during growth and maturation; a higher germination rate; more favorable soil moisture and temperature conditions during reproductive growth; better nodulation; and less damage from insect pests (ICARDA 1981).

Advancing the planting date of chickpeas by as much as four months in Syria's Mediterranean climate has the obvious advantage of giving the crop an opportunity to receive more precipitation. Generally speaking, the rains begin in October and continue until February-March, when they become markedly less frequent. The rainy season ends in the spring, and it is not unusual to experience late-season droughts and high temperatures. However, there are dangers inherent in winter sowing. Ascochyta is an ever-present threat, but killing frosts can occur as well. Syria's highly variable rainfall pattern produces some years in which a good start in October-November is followed by an absence of rain in December-January, sometimes continuing longer. In such years, winter-sown chickpeas would germinate and emerge, only to die or fail to mature due to the mid-season drought.

The Syrian and ICARDA scientists who developed the new varieties were well aware of these climatic problems, and therefore breeding and agronomic research stressed the importance of resistance to blight and cold tolerance, together with cultural practices to reduce the risks of variable rainfall within a season. It was clearly recognized that weather factors, no matter how carefully they may be anticipated, cannot be completely overcome. Nonetheless, research has proven that over a multi-year period the new varieties should outperform the local spring chickpeas considerably, both in terms of yield and economic return.

Concurrently with agronomic trials, winter-sown chickpeas were assessed for economic feasibility using partial budgeting techniques. Careful records of variable costs were kept and these were compared to those for spring chickpea. In each year that this was done, the net return from winter chickpeas was substantially higher than for the local spring variety, although the actual difference varied somewhat from year to year and from location to location. For example, in 1985/86, a year of average rainfall but spring drought, winter chickpea gave an average net revenue 68% higher than spring chickpea. In 1988/89, a year of drought, the winter varieties averaged net revenues 48% higher. The differences in income benefits were due largely to yield differences. Production costs were much the same for both types, but with one important exception. Weeds that emerge with winter rainfall are destroyed during the tillage and planting operations of spring-sown chickpeas, but producers of winter-sown varieties must somehow control weed infestations within the growing crop. Since this is usually done by hand, costs for weed control in winter chickpea are typically two to three times higher than for spring chickpea. These additional production costs, however, were more than compensated for in terms of net revenue by the yield advantage.

With such favorable profit margins, it was thought that many farmers would want to adopt the new winter-sown varieties. A substantial increase in Syrian chickpea production could therefore be anticipated in the near future.

5.1.2 Characteristics of Syrian National Chickpea Production

According to statistics published by the Syrian Ministry of Agriculture and Agrarian Reform (MAAR), spring-sown chickpeas are the country's second most important rainfed food legume crop, following only lentil in terms of production value and area planted. This has been the case for the past twenty years. Over the same period, the place of chickpea in terms of percentage of area planted to rainfed crops has remained relatively constant at about 2% of total annual rainfed crop area. However, because there has been a dramatic increase in the total area planted to rainfed crops, the trend in annual area sown to chickpea shows an increase of 60% since 1967, representing an average growth rate of 3% per annum. Annual production, however, has trended upwards at an average rate of only 1.1% per annum. Both these figures obscure the reality of significant annual variations about trend in both actual area planted and production realized (see Figures 5.1.1 and 5.1.2).

Despite the difference in units of measurement, the patterns of variation in production and area shown in Figures 5.1.1 and 5.1.2 are remarkably similar. With one exception (i.e. 1973) the variations are the same in direction, if not in magnitude. Production figures are the product of area and yield. The latter is shown in Figure 5.1.3. In general, the pattern is similar. There are considerable annual variations in yield, but there are more differences in the directions of variation about the trend when yield is compared to production than when area and production are compared to each other. In contrast to area and production, yield is trending downward at an average rate of -1.29% per annum. Thus, although there has been a noticeable trend towards increasing area planted to chickpea, the trend in increased production is less noticeable due to the downward trend in yield. It was initially to reverse this downward trend that the new winter varieties were developed.

Much of the annual variation in chickpea yields, and perhaps the longer-term downward trend, might be attributed to rainfall patterns. For example, a 1979 study of rainfed agriculture in Syria showed a correlation of $r = 0.83$ between a national annual rainfall index and chickpea yields (ICARDA 1979). Because of the earlier planting and more efficient use of available soil moisture, annual winter chickpea yields should be less subject to minor variations in rainfall than

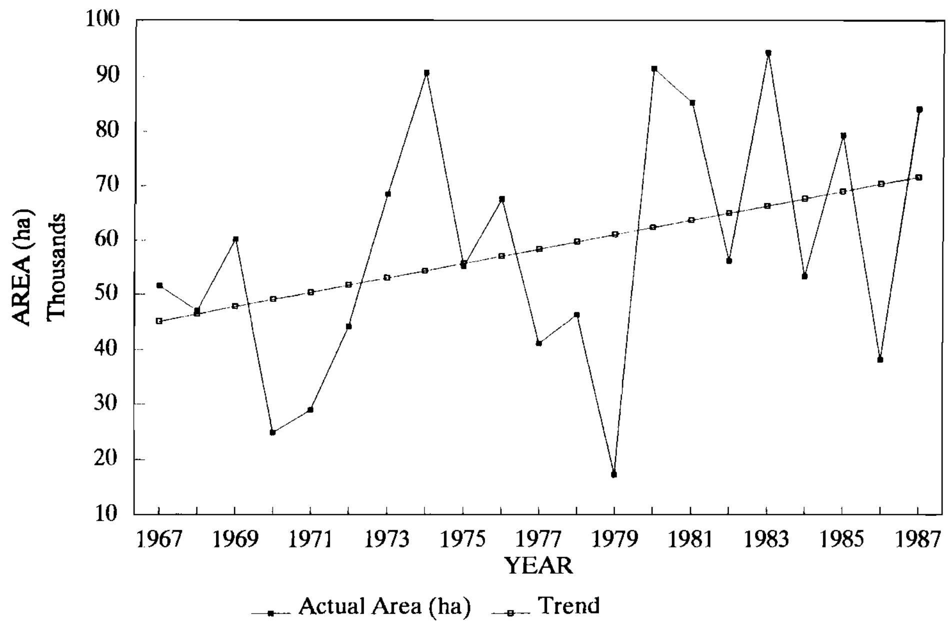


Figure 5.1.1 Chickpea: actual area and trend
Area = 45108 + 1325t

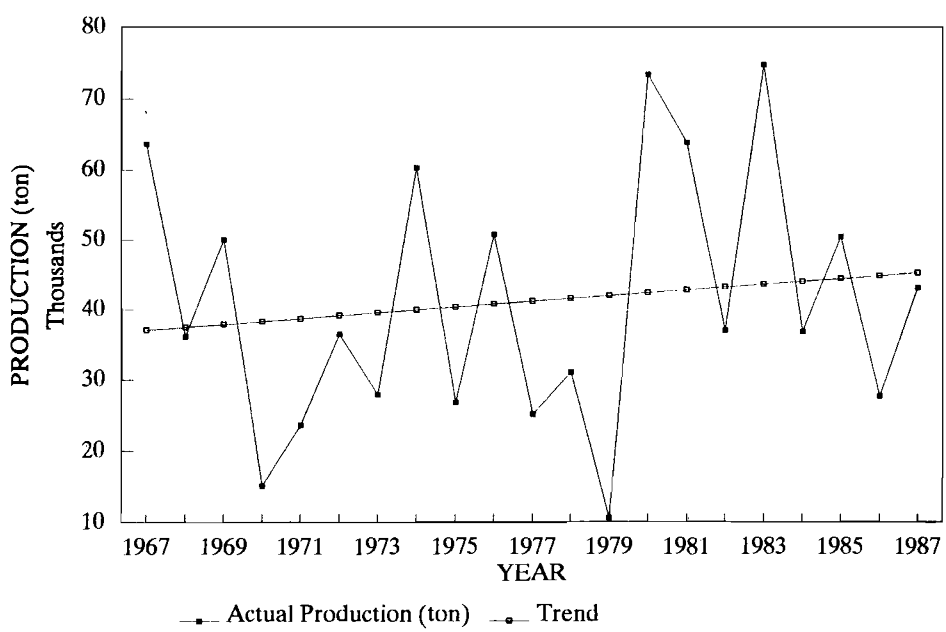


Figure 5.1.2 Chickpea: actual production and trend
Production = 37060 + 407t

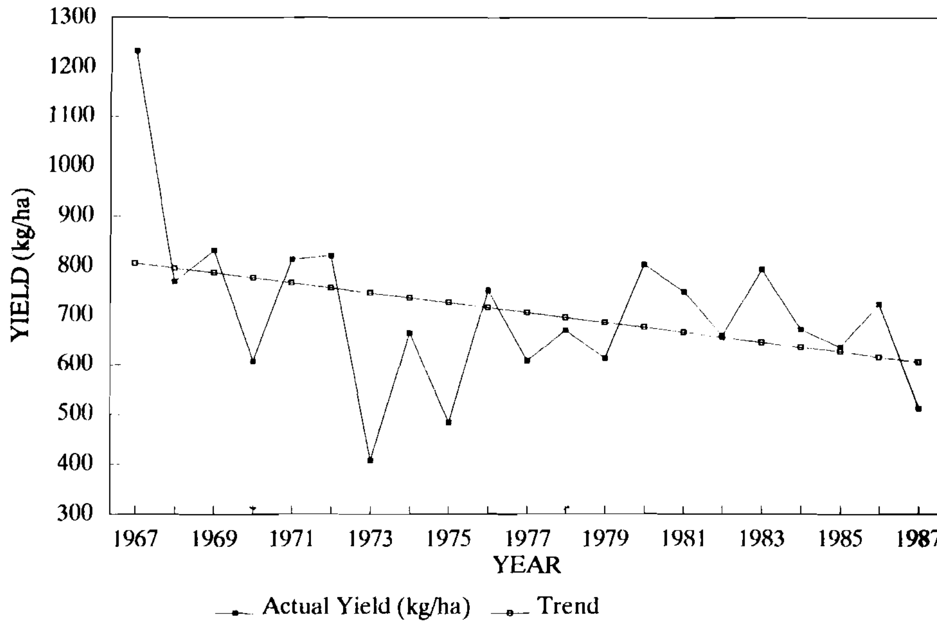


Figure 5.1.3 Chickpea: actual yield and trend
T+Yield = 806 - 10t

spring chickpea yields. Coefficients of variation (CV's) in winter-sown varieties have been lower than in spring-sown checks in agronomic trials (ICARDA 1984). Moreover, winter sowing may encourage the cultivation of chickpeas in drier areas where they are not now grown.

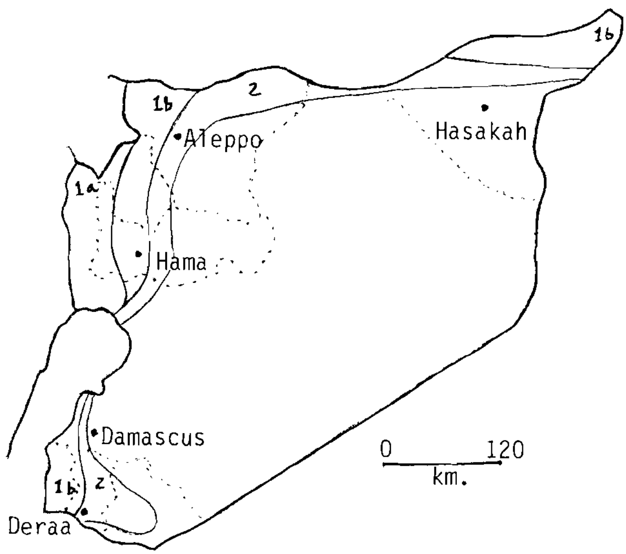
The relationship between rainfall and spring chickpea yields may not be unidimensional. A comparison of CV's of yields among rainfed crops in drier areas of Syria shows spring chickpea has the lowest (22%) among lentil (35%), barley (58%) and wheat (37%). During the same period of comparison, the CV for precipitation was 27% (ICARDA 1979).

A comparison of CV's of area planted and yield supports the view that rainfall has a relatively greater impact on the variability of area planted than on yield variation per se. For most rainfed winter crops, one would expect yield to vary more from year to year than area planted, because planting is done at the start of the rainy season according to the farmer's production strategy and resource availability, without knowledge of future rainfall. However, in the case of spring chickpea (c.f. Figures 5.1.1 and 5.1.3), the CV for area planted, 1967-87, is 39% while the CV for yields during this period is only 24%.

This somewhat anomalous circumstance is directly related to the place of chickpea in the rainfed farming system. Spring chickpea is largely dependent upon stored soil moisture. The decision to plant and how much to plant will depend on rainfall already received, and not, like winter planted crops, on expectations of rainfall. Yields of spring chickpea may be less variable because, in dry years, some farmers may simply choose not to plant, thereby saving the costs of production and avoiding the risks of crop failure. The existence of this option for spring but not winter chickpea has important implications for the adoption of the winter-sown varieties, for the substitutability of winter-sown for spring-sown chickpea, and thus for the goals of reducing annual variations in area planted and increasing national chickpea production.

5.1.3 Spring Chickpea in the Farming System

Farm surveys and official government statistics indicate that chickpea continues to be overwhelmingly a rainfed crop. It was estimated in 1981 that only 5% of total production was under irrigation, and there is little indication that this figure has changed ten years later. The principal production areas fall within two of the rainfall-based agricultural stability zones established by the government. Zone 1 has a mean annual rainfall of over 350 mm and is located along the coastal plain, the coastal mountains, and the Jawlan plateau. It also includes a sub-zone (zone 1b) to the east of the coastal range and in the northeast corner of the country which receives mean annual rainfall of 350-600 mm and no less than 300 mm in two-thirds of the years recorded (see Map). Zone 2 is adjacent to zone 1 and has an annual rainfall of 250-350 mm with no less than 250 mm falling during two-thirds of the years.



Location of Stability Zones and Chickpea
Producing Areas

Both zones are characterized by the predominance of cereals and food legumes in their rainfed farming systems, although tree crops especially olives, nuts, and some fruits are becoming increasingly important. Within the two zones, there are two geographical areas which together constitute about 95% of the chickpea area. These are the Southwest, in particular the provinces of Deraa, Sweida, and Quneitra, and the Northwest, especially Idleb province, western Hama and Homs provinces, and western and northern Aleppo province.

Until about 1979, when there was a devastating drought in southern Syria, almost three quarters of the mean area planted to chickpea was in the southwestern region, and Deraa province (i.e. the Hauran plain) alone accounted for 43% of the national total. A study conducted before the drought (SPC 1979) argued that the reasons for the imbalance between the southwest and northwest were basically economic: lower production costs and slightly higher value per 100 kg of production resulted in much higher gross margins and net earnings for southwestern producers than for their northwestern counterparts. When southwestern and northwestern producers were averaged together, the result was still "exceptionally high" gross margins and net earnings compared to other rainfed crops (SPC 1979: III-26). Unfortunately, this study has not been repeated, and whether chickpea continues to be such a relatively profitable crop is not known.

One reason for chickpea's presumed profit advantage has been its place in the farming system. Chickpea is planted in the spring as part of either a two-course or three-course rotation. Especially prevalent in the Hauran is a chickpea-wheat-fallow rotation (El-Mott 1984). More common in the northwest is a chickpea-summer crop-wheat rotation or, more simply, a two-course chickpea-wheat rotation. Because it is planted in the spring after the critical rainfall months of December-February have passed, the farmer can adjust chickpea planting decisions according to received rainfall. If insufficient rains have fallen to produce the farmer's idea of an acceptable chickpea yield, then fallow can be substituted for chickpea. The costs of land preparation, seeding, and fertilization are therefore saved without loss. By leaving the intended chickpea field fallow, the farmer preserves the option of growing a modest summer crop (often melons) on residual moisture should heavy late rains fall in March and April after the chickpea planting date has passed. In essence, chickpea (like a summer crop) has much lower risk in terms of crop failure or economic loss than, say, cereals which must be planted before the winter rains.

There is the additional economic advantage of low weed-control costs. Weeds can present a serious problem for winter crops because, like the crops themselves, weeds benefit from the rain falling during the winter months. Their period of greatest growth coincides with that of the winter crops. A spring chickpea producer destroys most of the winter weeds when the field is prepared for seeding, leaving only the lesser spring weeds to contend with during the chickpea growing season. This can save considerable labor costs over winter crops.

Traditional spring-sown chickpeas, although they could never supplant the dominant position held by cereals in the rainfed farming system, are a desirable crop because of the lower risk attached to planting decisions, the lower implied costs of production, and their high utility and market values. Like cereals, chickpeas are a consumer staple. Unlike cereals, however, their market position has remained strongly tied to local supply and demand factors. Government intervention and international commodity market influence has been low. According to a published government report (SPC 1979), in the mid 1970's the average price producers received was about double the announced price and less than one percent of national production was purchased by government institutions. This situation appears to have changed in the 1980's, probably because of substantial rises in announced prices. Chickpea can also have an important by-product value, as chickpea straw is often fed to animals.

There have been some noticeable shifts in national chickpea production patterns over the past twenty years. The rising trend in area planted with a simultaneous decline in average yields has been noted. There has been also a relative change in production areas. Annual average area planted in the southwest has fallen slightly, but between 1971-75 and 1982-87 the average annual area in the northwest grew dramatically, with an increase over the period of 74%. At present, slightly over 37% of national chickpea area is in the northwest. More dramatically, the northeastern region, located in Hassakeh province in the trans-Euphrates Jezirah, has developed as a production area.

The reasons for the shift in emphasis away from the southwest are not very clear, but three factors may have been important. The first is yield performance. Average annual yields in the southwest have declined more steeply than the national average, whereas average annual yields in the northwest and Hassakeh province have shown a fairly level trend (although with the usual considerable annual fluctuations). The second factor is mechanization. The terrain in the southwest is difficult. Situated amid ancient lava flows, the land is rough and full of stones. Mechanization of chickpea land preparation, seeding, and harvesting has not developed there as quickly as in the northwest and, especially, the northeast. Thus, relative to the southwestern producing area, harvesting costs are often lower in the northwest and northeast. The third factor may have been the success of a government program to replace fallow with winter crops in the southwest.

In summary, spring chickpea presents planners and decision-makers with something of a problem. Long-term national production is almost stagnant (at an annual trend of 1.1%), but the coefficient of variation over time is very high at 46%. Actual production has been as high as almost 64,000 tons (1981) and as low as 11,000 tons (1979). This can be attributed more to annual variations in area planted than to yield fluctuations, but there is an ominous long-term declining trend in yields. The immediate reaction is to seek a way to reverse the yield trend and, while so doing, reduce the annual variations. If this can be done, then there will be obvious benefits to farmers and the national economy.

However, there is a second problem which equally needs a solution. Variation in area planted is one of the key contributors to national production instability. Although there is a trend towards more land being devoted to chickpea, this is more a reflection of the geographical expansion of the rainfed farming system than an indicator of the intensification of production and greater utilization of resources. Land not otherwise planted to spring chickpea, once rotational factors are accounted for, is probably either being fallowed until the next winter season or being held in "temporary" fallow to see if enough rain will fall in the spring to grow a modest summer crop.

For planners, consumers, and economists alike, the problem of annual chickpea area presents a real challenge. But at the farm level, it may not be viewed as a problem or a challenge. If the farmer is practising the traditional wheat-based farming system, then spring chickpeas act as a desirable buffer against the risk of economic loss due to the unpredictability of the winter rains. In fact, being able to vary the area planted to spring chickpeas from year to year as a protection against loss from crop failure is one of the major benefits the crop gives the farmer. A predictable yield, even if low, may be preferred to an unpredictable yield, no matter how potentially high.

5.1.4 General Release and Assessment of Adoption Potential

The years immediately following the release of the new varieties were devoted to a controlled seed multiplication program using private farmers under contract to the General Organization for Seed Multiplication (GOSM). The program's purpose was to accumulate sufficient seed stocks for general release of certified seed. Multiplication was done on plots of one to twelve hectares. The results were successful. Yields were high, there were no major incidences of diseases or pests, and analyses showed high profit margins (ICARDA 1988a, 1988b, 1990). At the beginning of the 1989/90 growing season sufficient seed stocks had been accumulated, and the new seed varieties were made available for sale to the general public through GOSM. Announcements concerning the new varieties and their availability were widely disseminated through the mass media and the extension service. At the same time, the Socio-Economic Studies and Training Section of the Syrian Scientific Agricultural Research Center, together with ICARDA scientists, organized a farm-level survey to assess the performance of the new technology under farmer conditions and to obtain an evaluation from the farmers themselves of the potential for adoption and positive impact.

The sample of farmers to be surveyed was drawn from lists of farmers growing winter chickpea in the 1989/90 season provided by the Ministry and GOSM. Due to limited research resources, it was not possible to include in the sampling universe farmers who had obtained seeds outside official release channels, such as those who may have received seeds from farmers participating in past on-farm trials with the Ministry and ICARDA. Nonetheless, the lists of farmers purchasing seeds did constitute an appropriate and adequate starting point for establishing a baseline for evaluating the adoption process.

The sample chosen contrasted farmers on the basis of their prior experience: those growing winter chickpea for the first time in 1989/90 (67% of the sample) and those already with a year or more of previous experience (33% of the sample). This latter group contained mostly farmers who had been part of the seed multiplication program. About a third of the entire sample was also growing spring chickpea. Most of these were in the group of first year winter chickpea producers.

The sample was distributed over three provinces: Aleppo, Hama, and Hassakeh. Given limited resources, some major areas (particularly the Southwest) had to be excluded from the initial survey. But Hassakeh was included for two reasons: first, there had been a dramatic expansion of spring chickpea here in recent years; and second, research trials indicated Hassakeh had great potential for maximizing winter chickpea performance and impact. Moreover, Ministry officials indicated that they hoped to target Hassakeh as a new area for chickpea production in the future.

The survey questionnaire focussed on five subject areas: the place of chickpea in the farming system; cultivation practices; production economics; crop performance and yield; and farmer evaluation of adoption potential. Interviewing was done following the harvest.

5.1.5 Adoption Categories and Rates within the Sample

To allow discussion of factors that may either encourage or hinder the adoption and beneficial impact of winter-sown chickpea, the survey sample was divided into two basic adoption categories: adopters and non-adopters, with each category sub-divided on the basis of number of years experience growing winter chickpeas. An adopter is defined as a farmer who has had one or more years' experience with the new variety and plans to produce it again in the 1990/91 season. A non-adopter has one or more years' experience, but does not plan to produce the crop again. Based on the relative sizes of these categories, it is possible to establish a 1989/90 baseline for adoption rates (Table 5.1.1).

The overall ratio is 47% adopters and 53% non-adopters. Over two-thirds of the non-adopters have experience only of the 1989/90 season. About three-fifths of the adopters have just one year's experience, but they found the new variety successful enough to plan to produce it again in the next year. By comparing first-year adopters with first-

Table 5.1.1 Sample Distribution (number of farmers by adoption category and location)

Location	Adoption Categories				Total Farmers
	Adopters		Non-Adopters		
	2 or more yrs	1st year	1st year	2 or more yrs	
Hama	2	5	18	7	32
Aleppo	12	15	19	7	53
Hassakeh	6	11	5	2	24
Total Farmers	20	31	42	16	109

year non-adopters within the sample, the initial (or first year) adoption rate was 42% in 1989/90. In comparison, the adoption of winter-sown chickpea was sustained through the 1989/90 season by 56% of farmers with two or more years' experience growing the crop. The higher rate of continued adoption after the initial year's experience is not surprising. Similarly, it is also not surprising that numbers of initial adopters abandon the crop after more than one year's experience. The challenge is to determine the reasons behind initial and sustained adoption decisions.

5.1.6 1989/90 Yield Performance

The starting point for assessing adoption decisions is yield performance, since the principal purpose of winter sowing is to raise productivity per hectare. Agronomic studies in Syria of various winter chickpea production packages, like those of spring chickpea, have established that weather conditions are the most important determinant of yield (Pala and Mazid 1990). The weather conditions during the 1989/90 growing season varied considerably over the survey area (see Figure 5.1.4 and note that Kamishli represents the chickpea growing area of Hassakeh province). Total rainfall ranged from an average of 235 mm in Hama province to 282 mm for Aleppo to 463 mm in Hassakeh. Although temperatures were mild in Hassakeh with occasional frosts in December and January only, in Aleppo and Hama there were recurrent hard frosts beginning in November and running through to March. Hama was

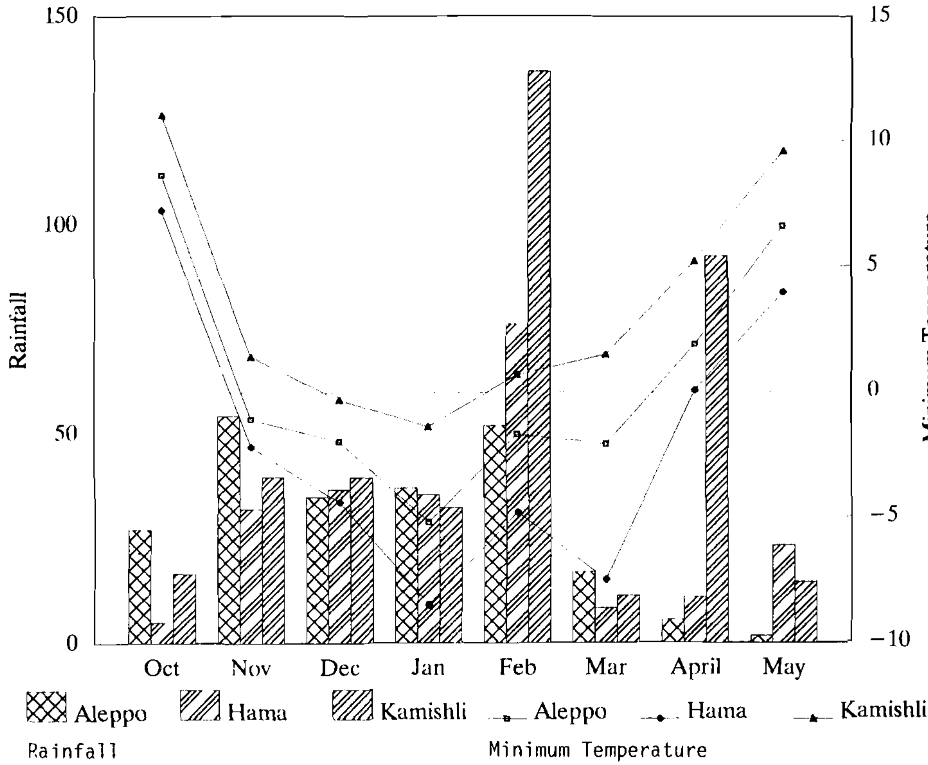


Figure 5.1.4 1989-90 climatic conditions in survey areas

the most affected by late frosts, with a low of -8°C in late March. The combination of low rainfall and late frosts, though curtailing disease and pest development, nonetheless made 1989/90 an unfavorable year for both winter-sown and spring chickpeas in Hama and much of Aleppo provinces.

In recent years, national mean spring chickpea yields have been between 600 and 800 kg/ha, but within the surveyed provinces only Hassakeh achieved this range for spring chickpea in 1989/90. Hama and Aleppo reported mean values of 335 kg/ha and 563 kg/ha, respectively. Worse frosts in Hama than in Aleppo, together with slightly lower rainfall, reportedly accounted for the difference between them.

Winter chickpea producers, on the whole, did better than their spring counterparts. Reported average winter chickpea yields for Hama, Aleppo, and Hassakeh were 355 kg/ha, 849 kg/ha, and 1,474 kg/ha, respectively. The average of all winter chickpea producers was 850 kg/ha. There is no evidence to suggest that the differences in winter chickpea yield among Hama, Aleppo, and Hassakeh were due to better management in Hassakeh. In fact, Hama and Aleppo producers devoted more time, energy, and money to tillage, fertilization, and weed control than did Hassakeh farmers. Unfortunately, in 1989/90, the weather was working against them.

Given the pattern of yields, it would be expected that first year winter chickpea farmers in Hassakeh would be more likely to grow the new variety in 1990/91 than would their Hama and Aleppo counterparts. Indeed, 69% of first year Hassakeh producers expressed their intention to adopt the new varieties, in contrast to only 22% in Hama. In Aleppo, the initial adoption rate was 44%. There was a similar, although more muted, reaction among winter chickpea producers with more experience. Only 22% of Hama producers with two or more years' experience will continue in 1990/91. The figures are 63% in Aleppo and 75% in Hassakeh.

5.1.7 Economic Returns

Yield advantages can be offset by lower selling prices and higher production costs. The survey data allowed the calculation of average gross revenues, variable production costs, and gross margins (net revenues) for winter chickpea producers in the three provinces. A separate study provided comparative spring chickpea figures for Aleppo and Hassakeh provinces. These are presented in Table 5.1.2. Although the figures are not available for spring chickpea in Hama, it is safe to say that these producers suffered loss and, probably, losses similar to those incurred by neighboring winter producers.

Several observations can be made. First, the prices farmers received varied among provinces and between spring and winter

Table 5.1.2 Economic comparison of winter and spring chickpeas, 1989/90 (by location)

	Hama		Aleppo		Hassakeh		Average for all winter
	Winter	Spring	Winter	Spring[1]	Winter	Spring[1]	
Grain yield (kg/ha)	355	335	849	563	1474	759	850
Price (SYP/kg)	17.0	na	15.2	16.6	14.2	12.8	15.5
Revenue (SYP/ha)[2]	6509	na	13043	9653	20755	9697	12938
Variable costs (SYP/ha)[3]	7372	na	9370	6502	6185	5154	8151
Gross margin (SYP/ha)	-863	na	3673	3151	14570	4543	4787

Notes: 1. Spring chickpea figures based on data collected by Mustafa Darwich in separate study and provided for comparative purposes.
2. Refers to potential revenue from grain sales at farm gate prices, does not include possible revenue from straw sales or grazing residues.
3. Variable costs do not include ground rent or capital depreciation; unpaid family labor is included as imputed value based on prevailing wage rates.

chickpeas. The differences reflect both government pricing mechanisms and the supply and demand factors affecting the proportion of chickpea sold in the private sector. Second, average production costs differ considerably from one province to another and for winter and spring chickpea. Spring chickpea costs are lower than winter chickpea costs in Aleppo and Hassakeh (spring chickpea costs are not available for Hama), but winter chickpea costs in Hassakeh, on the average, were lower than average spring chickpea costs in Aleppo. This reflects the pattern seen in the average yields by location, and emphasizes the profitability of both winter and spring chickpea in Hassakeh as opposed to either type of chickpea in the other locations.

Looking at gross margins by adoption category (Table 5.1.3), it is immediately apparent that the more successful winter chickpea producers tend to adopt the new technology. Both categories of adopters have much higher average gross margins and higher yields (although they also accepted higher costs) than first year non-adopters and spring chickpea producers in Aleppo and Hassakeh. One interesting tendency is for farmers with two or more years of experience growing winter chickpea, whether adopters or not, to make higher investments in the crop than those growing it for the first time. Perhaps this indicates more confidence in the performance of the new varieties and, thus, a willingness to accept a higher cost risk. Unfortunately, a higher level of cost investment was not always reciprocated with a higher net return. This was especially the case in Hama and Aleppo in 1989/90.

Table 5.1.3 Adoption categories and distribution of benefits, 1989/90

	Adoption Categories			
	Adopters		Non-Adopters	
	After 2 or more years	After first year	After first year	After 2 or more years
Proportion of total sample	18%	29%	38%	15%
Average yield (kg/ha)	1328	976	537	795
Average costs (SYP/ha)	8920	8285	7165	9469
Average gross margin (SYP/ha)	11318	6869	825	2507

Table 5.1.4 shows the relative distribution of variable costs for each location, adoption category, and farm size grouping. The figures are percentages of average total costs per category. Thus, although Hassakeh farmers devoted 45% of their expenditures to planting (cost of seeds and planting), because their total costs were lower, the actual cost (SYP) was similar to the cost incurred by Aleppo farmers who averaged only 29% of their expenditures for planting. Fertilizing costs were substantially higher in Hama than in Hassakeh and Aleppo, both in relative and absolute terms. Indeed, in actual money terms, Hama producers spent almost three and half times as much as Hassakeh

Table 5.1.4 Distribution of costs within farm categories (in percentages of total variable costs per ha)

Categories	Til.	Plant.	Fert.	Weed control	Disease + pest	Harvest	Total cost (SYP/ha)
Hama	11	39	28	9	0	13	7372
Aleppo	10	29	18	9	2	32	9370
Hassakeh	9	45	9	7	0	30	6585
Adopters	9	35	19	6	2	29	8920
First year adopters	10	34	15	10	1	30	8285
First year non-adopters	11	35	24	7	1	22	7165
Non-adopters	10	34	17	10	2	27	9469
≤ 35 ha	11	32	22	9	1	25	8213
> 35 ha	9	38	16	7	1	29	8087
Total average	10	35	19	8	1	27	8151

Til.= Tillage; Plant.= Planting; Fert. = Fertilizing

farmers on fertilizing their winter chickpea crop. Hama harvest costs were half those of Hassakeh and one-third those of Aleppo because of the dismal harvests in Hama. Hassakeh farmers spent less on harvesting than Aleppo farmers because they used combine harvesters whereas in Aleppo harvesting by hand predominated. Weed, disease, and pest control measures represented relatively small expenditures for all categories. This was perhaps the only "benefit" from the adverse climatic conditions in Hama and Aleppo.

Farmers who grew both winter and spring chickpea in 1989/90 were asked if there were any additional inputs applied to winter chickpea not applied to spring chickpea. Differences were not in kind, but rather in degree of application. Half the respondents used a higher rate of phosphate and about a third said either higher labor use or herbicide use for weed control and harvesting (Table 5.1.5). Only 17% of respondents said there were no differences between winter and spring production practices and costs. Two-thirds of these respondents were first year non-adopters.

Table 5.1.5 Additional practices used for winter chickpea (frequency mentioned, in percentages)

Additional practices	Adopters: 2 or more yrs	Adopters: 1st year	Non-Adopters: 1st year	Non-Adopters: 2 or more yrs	Total sample
Higher rate of phosphate	60	57	17	60	51
Higher labor use	20	50	17	40	34
Higher herbicide use	50	43	17	0	34
Higher seed rate	40	21	17	40	29
Higher use of pesticides	10	14	0	40	14
No difference	20	0	67	0	17

Note: Sample is farmers growing both winter and spring chickpea in 1989/90.

Table 5.1.6 summarizes the disposal of the 1989/90 winter chickpea harvest. Some 35% was sold to government buying agencies (the General Organization for Seed Multiplication and/or the Cereals Office), with 58% sold in the private sectors, 1% kept for home consumption, and 6% kept as stocks for next year's seed or future sale. Adopters with two or more years' experience tended to favor private market outlets (even though the prices offered by government were slightly better than the private sector), and they also kept a higher percentage as stocks. This reflects the fact that these experienced producers are often commercial growers, whereas first year producers are more tentative and tend to prefer a contractual marketing arrangement with the government.

It may be noted that a government report has stated that ten years ago only one percent of national spring chickpea production circulated through the government marketing organizations.

5.1.8 Location, Land Use, and Farm Size

Most studies of the adoption of improved agricultural technologies assume that the critical factor in the decision to adopt is economic return. At least initially, economic return is strongly associated with yield performance. Later in the adoption process the effects of

Table 5.1.6 Disposal of 1989/90 winter chickpea harvest (% of production by farmer categories)

Farmer categories	Sold: to govnt.[1] %	Sold: to govnt.[1] SYP/kg[2]	Sold: to market %	Sold: to market SYP/kg	Kept on-farm: consump. %	Kept on-farm: stocks %	Average production (kg)
Hama	45	16.0	50	20.8	1	4	913
Aleppo	85	15.1	12	15.4	1	2	4,326
Hassakeh	22	15.4	70	13.3	1	7	38,964
Adopters	13	15.4	77	14.8	1	9	31,771
First year adopters	58	15.3	37	16.3	3	2	9,367
First year non-adopters	63	15.3	36	14.3	0	2	4,082
Non-adopters	55	15.6	40	13.7	1	3	6,125
Size ≤ 35 ha	55	15.3	40	13.4	1	4	1,844
Size > 35 ha	33	15.4	60	14.8	1	6	20,255
Total sample average	35	15.4	58	15.0	1	6	10,964

Notes: 1. Government buyers were GOSM and Cereals Office.
2. Official government prices set at 16 SYP/kg for clean standard seed and 13 SYP/kg for ordinary seed. Determination made at sale.

the higher yields of early adopters on prices may hinder subsequent adoption by others. Early adopters can also create extra demand for inputs, thus raising production costs for later, potential adopters (Lipton and Longhurst 1989). Indications are that the adoption of new technology rarely, if ever, proceeds uniformly through a farming population. Early on in the process, adoption "lead areas" emerge in which there are a higher incidence of initial and sustained adoption, while other areas lag behind. Similarly, the early adopters often display characteristics in common which distinguish them from later adopters and/or non-adopters in both the lead and lag areas.

The results of the survey would seem to indicate that in 1989/90 location had a decisive effect on adoption rates for winter chickpea. Hassakeh rates were well above those for Aleppo and Hama. This can readily be interpreted as the effects of climatic conditions on yields and consequently on economic returns. When farmers were asked why they chose to grow winter chickpea in 1989/90, the overwhelming response was an expected high yield. This was equally the case in all locations (see Table 5.1.7). However, expectations were not so uniformly achieved. They were fulfilled in Hassakeh for the most part, less so in Aleppo, and hardly at all in Hama. It could be expected that farmers with two or more years' experience of the new varieties in Hama and Aleppo might have a longer term perspective than their first-year colleagues, and indeed the rejection rate among these farmers was less than the first-year growers. But attrition among early adopters was still marked in Aleppo and Hama. Earlier studies of technology adoption, and of improved varieties in particular, showed overwhelmingly that larger farmers adopted earlier and could sustain the consequent necessary shifts in farm resource allocations much better than could the later-adopting small farmers. In fact, one common criticism of the "green revolution" is that the adoption of modern varieties and packages by large farmers in lead areas actually had a detrimental effect on subsequent adoption and the ability to sustain innovation by small farmers. Larger farmers are said to have better access to reliable information, credit, and other facilities. They are likely to have greater economic security and can therefore assume the higher level of risk associated with early adoption (Harriss 1982).

The survey results would seem to be in line with this view. The average farm size of adopters is over twice that of non-adopters (Table 5.1.8). Moreover, early adopters (i.e. those with two or more years' experience) have a higher average farm size than first year adopters. But these figures should not be used to argue that winter chickpea adoption is closely related to large farm size, as qualitative differences exist between large and small farmers.

There are three reasons why it is too early in the process to conclude that small farmers will necessarily lag behind large farmers. First, about 43% of the large farmers in the sample are located in Hassakeh, and the yield performance in that province may be of overriding influence, at least in 1989/90. The adoption rate of large farmers in Hama is actually lower than that of small farmers, who

Table 5.1.7 Reasons for growing winter chickpea in 1989/90 (frequency mentioned, by location and farm size, in percentages)

	Location			Farm Size		Total sample
	Hama	Aleppo	Hassakeh	≤35 ha	>35 ha	
High yield	97	79	83	89	82	85
High net benefit	41	30	38	35	35	35
Possibility for mechanical harvest	19	17	83	18	46	32
Frost resistant	47	34	0	40	20	30
Early maturity	22	36	0	29	19	24
Disease resistant	16	34	0	22	20	21

Table 5.1.8 Arable land use, 1989/90 (average in ha and % of arable)

Farms	Cereals		Chickpea			Other		Fallow		Total
			Total		(winter)					
Location										
Aleppo	25.5	44%	10.5	18%	(6.9)	20.7	36%	0.9	2%	57.6
Hama	12.5	43%	6.6	23%	(4.8)	9.3	32%	0.5	2%	28.9
Hassakeh	103.1	44%	53.8	23%	(49.6)	75.4	32%	2.5	1%	234.8
Farm Size										
≤ 35 ha	8.9	41%	5.4	25%	(4.6)	6.9	32%	0.6	2%	21.8
> 35 ha	69.2	44%	32.6	21%	(27.0)	52.3	34%	1.7	1%	155.8
Adoption Category										
Adopters	62.3	48%	26.1	20%	(20.1)	42.5	32%	0	-	130.9
1 yr adopters	48.7	42%	23.6	20%	(19.3)	42.0	36%	2.5	2%	116.8
1 yr non-adopters	26.3	44%	16.0	27%	(14.2)	16.4	27%	1.1	2%	59.8
Non-adopters	22.7	42%	8.4	16%	(7.2)	22.5	42%	0	-	53.6
Entire Sample	38.8	44%	18.7	21%	(15.7)	29.4	33%	1.1	2%	88.0

Notes: Cereals refers to wheat and barley.
Other crops includes: other legumes (lentil, faba bean, forage legumes); tree crops (vines, olives, nuts, fruits); oil seed crops (soya, sunflower)

seemed more willing to stay with the new varieties despite the very bad 1989/90 yields in that province. There was no noticeable adoption pattern for farm size in Aleppo.

Secondly, large farmers were, in effect, pre-selected to receive the new technology before small farmers by the official seed-multiplication policy for winter chickpea. For at least five years GOSM and ICARDA directed their efforts at multiplication to large plots, often of ten hectares or more, and contracts were made with large farmers who had sufficient land for this purpose.

The third factor to consider is the place of chickpea in the land use patterns of large and small farmers in the various locations surveyed (Table 5.1.8). It should be remembered that most of the sample was located in zone 1b and therefore has similar long-term rainfall patterns and, hence, similar land use patterns. On the basis of proportion of land devoted to various crops, there are no large differences among the various categories. Aleppo farmers tend to be slightly more diversified, and they have proportionately about 5% less land in chickpeas and more in other non-cereal crops. What is striking, however, are the average farm size differences among the provinces. Much of the statistical difference in farm size between adoption categories is due to the size of farms in Hassakeh, the location where winter chickpea was such a success in 1989/90.

Given the existing land use patterns, it is interesting to consider what options farmers have for expanding winter chickpea cultivation. The most obvious possibility is substituting winter for spring chickpea. This would mean an average potential ceiling of 20% to 21% of farm area for winter chickpea. A second possibility is to eliminate fallow and substitute winter chickpea. The survey data clearly show that fallow is only a small percentage of arable land, and it is unlikely, even if all fallow land were to be planted in winter chickpea, that large production increases would be achieved. Available farm level information does not provide any clues to the possibility of substituting winter chickpeas for other field crops such as cereals, lentils, or oilseed crops. Presumably, farmers have good reasons, economic or otherwise, for devoting a high percentage of their land to cereals.

There are, however, some clues as to the substitutability of winter for spring chickpea. Among the sample farmers in 1989/90, winter chickpea constituted 84% of land sown to chickpeas. Despite the fact that 53% of the farmers say they will not grow winter chickpea in 1990/91, the proportion of winter chickpea will increase to 90% of the total chickpea land grown by adopters and non-adopters together in 1990/91. Why is this? There are two reasons. First, winter chickpea adopters intend to increase their chickpea area by substituting winter for spring varieties and also to marginally increase their total area planted to chickpea. Second, the non-adopters are not only stopping production of winter chickpea, but they are also sharply reducing the total area they plant to spring chickpea. If farmers do as they have stated, then area planted in chickpea in 1990/91 will represent a reduction of 22% of the 1989/90 area, but winter chickpea will be a higher proportion of the total than in the previous year (see Table 5.1.9). Whether or not the process of substituting winter for spring chickpea will help stabilize the annual total chickpea area can only be answered in future years.

Table 5.1.9 Estimated changes in chickpea area, 1989/90 to 1990/91

Categories	% Change Winter Area	% Change Spring Area	Total Sample Average
Adopters	+38%	-80%	+11%
1 yr Adopters	+48%	-72%	+26%
1 yr Non-Adopters	-100%	-17%	-91%
Non-Adopters	-100%	+75%	-75%
Aleppo	-28%	-44%	-33%
Hama	-87%	-50%	-77%
Hassakeh	-3%	-81%	-9%
≤ 35 ha	-70%	-62%	-69%
> 35 ha	-7%	-54%	-15%
Total Sample	-16%	-56%	-22%
	winter	**spring**	**total**
Average area 1989/90	15.7 ha	3.2 ha	18.7 ha
Average area 1990/91	13.2 ha	1.4 ha	14.6 ha

5.1.9 Farmer Evaluations

Surveyed farmers were asked a series of evaluative questions designed to elicit their comparison of winter and spring varieties. Responses were then compiled by the frequency they were mentioned, for the total sample and for each adoption category (Table 5.1.10). Two thirds of the farmers producing both winter and spring chickpea noted the more vigorous growth of the winter varieties. This included some 50% of the first year non-adopters, noticeably the most skeptical group regards the merits of winter chickpea. Higher yields were mentioned by 63%, but in this case only 17% of first year non-adopters agreed. Slightly over half the farmers asked responded that winter chickpeas gave a higher net revenue, had better frost tolerance, and had a more assured yield. Not unexpectedly, although there are some exceptions, non-adopters were less enthusiastic about winter chickpea qualities than were adopters. Also, first year non-adopters were the group most hesitant about expressing opinions, whereas all the first year adopters believed they could comment on the positive characteristics of the new varieties.

Table 5.1.10 Advantages of winter chickpea compared to spring chickpea (frequency mentioned, in percentages)

Characteristics	Adopters		Non-Adopters		Total sample
	2 or more yrs	1st year	1st year	2 or more yrs	
More vigorous growth	60	79	50	60	66
Higher yields	70	79	17	60	63
Earlier harvest	80	68	50	38	59
Higher net revenue	70	57	17	60	54
Better frost tolerance	60	64	33	40	54
More assured yield	70	50	17	80	54
More straw yield	40	64	33	20	46
Better resistance to disease	60	36	50	40	46
Better seed quality	30	36	17	40	31
Do not know	20	0	50	20	17

Note: Sample is farmers growing both winter and spring chickpea in 1989/90.

Farmers were also asked to evaluate the characteristics of the two winter varieties, Ghab 1 and Ghab 2. Table 5.1.11 shows the pattern of their responses. The "neutral" and "don't know" answers have been omitted to highlight the contrasts between positive and negative evaluations. As far as seed size is concerned, 70% of Ghab 1 producers responded positively and only 16% gave a negative response. However, Ghab 2 received a much lesser vote of confidence on seed size. Frost tolerance was an important issue, especially in the 1989/90 season. About half the Ghab 1 growers were positive and 29% were negative. Again, Ghab 2 received a lesser rating. Both varieties were given good marks for resistance to blight, wilt, and the parasitic plant orobanche, although it should be noted that neither winter or spring chickpea suffered severely from these during the 1989/90 season.

Table 5.1.11 Positive and negative responses in varietal comparison of Ghab 1 and Ghab 2 (frequency mentioned, in percentages)

	Ghab 1		Ghab 2	
Characteristics	Positive	Negative	Positive	Negative
Seed size	70	16	50	25
Frost tolerance	49	29	35	33
Blight resistance	57	20	57	13
Wilt resistance	56	21	55	15
Orobanche resistance	59	16	65	5

When asked for their comments on the major problems they encountered in producing winter chickpea in 1989/90, surprisingly few farmers complained of anything other than climatic conditions (see Table 5.1.12). Only 35% of adopters with two or more years experience cited climatic conditions as a problem, but the first year and two or more year's experience non-adopters did so with frequencies of 68% and 63%, respectively. Because of the adverse weather, weed control was not as costly in 1989/90 as could be expected in better seasons, and this is reflected in the farmer's responses. On the whole, there seemed to be few technical or economic problems for winter chickpea producers other than, of course, the low rainfall and severe late frosts in Hama and Aleppo.

Table 5.1.12 Problems encountered by winter chickpea farmers, 1989/90 (frequency mentioned by adoption category, in percentages)

Problems	Adopters: 2 or more yrs	Adopters: 1st year	Non-Adopters: 1st year	Non-Adopters: 2 or more yrs	Total sample
Climatic conditions	35	52	68	63	56
Economic factors (costs)	35	23	22	19	24
Weed control [1]	25	16	7	31	17
Rotation [2]	10	7	7	6	7
Labor availability	0	0	7	19	6
Input availability	15	0	2	6	5
Other factors	10	13	12	0	10
Do not know	0	7	2	0	3

Notes: 1. Refers to lack of availability of effective chemical herbicide.
2. Refers to perceived negative effect of winter chickpea on next season's crop.

5.1.10 Farmer Views on Adoption

The basic incentive farmers recognize for adopting winter-sown chickpea is high yields (Table 5.1.7). Two other, slightly more sophisticated, incentives expressed by a lower proportion of farmers are high net revenues and the possibility of mechanical harvesting. The latter is particularly keenly felt in Hassakeh, where large farms and fields combine with the vigorous growth and tall stature of winter varieties to encourage harvest mechanization with its substantially lower per hectare costs. In any event, the consensus among farmers in all locations and in both size groupings is that economic return is the principal motivation for adoption.

Determining the economic threshold for adoption is a difficult exercise, and it would require a much larger data set than currently available. Each farmer has unique economic circumstances, requirements, objectives, and expectations. Moreover, although there may be patterns and commonalities among groups of farmers, these should be expected to vary among locations, farm size, land uses, etc. Table 5.1.3 provides some clues. The net revenue threshold for adoption in 1989/90 appears to lie somewhere between 2500 and 6800 Syrian pounds per hectare, but this figure would obviously vary from year to year depending on the season and the comparative performance of spring chickpea. For example, in Aleppo, where the net revenue differences between winter and spring chickpea were relatively slight, the adoption rate was markedly lower than in Hassakeh. In addition, net revenues (and risks) from winter chickpea would have to be compared with those of other crops in the farming systems. The question of winter chickpea adoption is not only the issue of substitutability with spring chickpea. Because winter sowing requires a land use decision and allocation of resources early in the season before the rains, it is better understood as a separate crop in terms of management and adoption rather than simply a variation, albeit an improved one, of spring chickpea.

Farmer responses to a question on factors acting to limit the area they grow or have grown to winter chickpea are given in Table 5.1.13. This question was designed to get at the subject of expanding winter chickpea area beyond that planted in the initial adoption year. Only 6% of farmers had no answer. The responses of the rest were well distributed among various constraints. The most important of these would appear to be low selling prices. This reinforces the impression given by both their initial reasons for producing winter chickpeas and their adoption decisions following harvest. Economic return will be the key variable influencing the future course of winter chickpea in Syria.

The proper interpretation of the small seed size response is not clear. It was the second most commonly mentioned constraint, but non-adopters mentioned this more than did adopters. Small seed size is

Table 5.1.13 Factors limiting area sown to winter chickpea (frequency mentioned, by adoption category, in precentages)

Constraints	Adopters: 2 or more yrs	Adopters: 1st year	Non-Adopters: 1st year	Non-Adopters: 2 or more yrs	Total sample
Low selling prices	45	36	31	25	34
Small seed size	25	16	31	44	28
Rotation or plan[1]	20	13	14	13	15
Seed availability	25	7	10	0	10
Weed control[2]	10	13	0	0	6
Other factors	0	13	21	13	14
Do not know	0	7	12	0	6

Notes: 1. Refers to competition for land allocated by farmer to other crops, principally cereals, or to land and input allocations made by national agricultural plan.
2. Refers to lack of availability of effective chemical herbicide.

probably not the reason they chose to not adopt. Rather, the reason is a relatively lower economic return than possible from other alternatives. It could be argued that seed size affects prices and therefore has a negative effect on economic benefit, but selling prices in 1989/90 do not support this argument (see Table 5.1.6).

When farmers were asked their opinion of constraints to adoption by other farmers, the most popular response was that other farmers did not know about winter chickpeas (Table 5.1.14). Whether they would adopt if they did know was another question which received a mixed response. Farmers assumed that if other farmers experienced high yields and good economic returns, then logically they would adopt.

5.1.11 Conclusions

At the beginning of this report the problem posed by spring chickpea to national agricultural planners and farmers alike was described as low

Table 5.1.14 Factors limiting adoption of winter chickpea by other farmers (frequency mentioned, by adoption category, in percentages)

Constraints	Adopters		Non-Adopters		Total sample
	2 or more yrs	1st year	1st year	2 or more yrs	
Winter sowing unknown	35	58	45	31	45
Low selling prices	30	26	21	56	26
Small seed size	15	16	24	19	19
Low knowledge of production practices	30	19	10	0	15
Seed shortage	10	7	7	0	6
Other factors	5	10	10	13	9
Do not know	0	3	17	13	9

productivity and highly variable annual areas planted. This creates a situation of uncertain production from one year to the next. Although spring planting allows farmers to escape the risk of crop failure due to poor rainfall, it also means they must accept lower production levels and a less than optimal land use intensity. Since economic pressure on land is increasing dramatically, the economic benefit farmers can obtain from chickpea is arguably in decline relative to other crops in the farming system.

Winter-sown chickpeas promise to solve these problems because of their higher yield potential and more productive use of land. In principle, winter-sown varieties could serve as a mechanism for stabilizing the area planted, allowing planners and farmers alike to allocate resources in a more rational manner than presently possible. However, even if winter sowing stabilizes crop area, there remains the question of whether it will stabilize yields and economic returns. With spring planting, in a dry year a farmer may decide not to plant. He gets no yield, but neither does he lose an investment. With winter planting, there can be no such guarantee. Nonetheless, pre-release experiments and verification trials indicate that the higher yields obtained in most years could outweigh the risk of losing planting investments in very dry years. Whether or not farmers share this logic can only be established by continuing the adoption monitoring in future years.

The present study is only a start. Perhaps its most important conclusion is the significance of annual variations in climatic conditions on adoption. One year is not an adequate test, or even an adequate sample, of farmer adoption response. The shortage of rain and the late frosts, particularly in Hama province distorted adoption responses by masking performance differences between winter and spring chickpea. Similarly, the favorable weather in Hassakeh probably painted too rosy a picture of the new varieties. Finally, climatic conditions did not allow an adequate test of the effects of weeds and/or diseases and pests. Before more definitive conclusions can be drawn, survey data from additional seasons must be collected.

Nevertheless, the 1989/90 season allows some interesting observations. First, both adoption patterns and farmer responses to evaluative questions indicate a very strong inclination to judge winter chickpea on the basis of economic return. Yield is not the objective, per se. Rather, farmers are interested in monetary returns. There is little indication, if any, that production for household use is an important factor in the adoption process. The second observation is related to the first. In terms of volume of production, winter chickpea is being immediately adopted as a commercial crop, primarily by large-scale farmers. Whether or not economies of scale are involved cannot be judged from existing data, but larger scale producers in 1989/90 had slightly lower per hectare costs and spent proportionately less on weed control and harvesting. Caution should be taken by noting that the coincidence of large scale cultivation, high yields, and high adoption rate in Hassakeh may be only fortuitous, at least in 1989/90.

A third observation is that farmers appear to be using slightly different evaluation criteria depending upon their years of experience with winter chickpea. In the first year of cultivation, a high yield is very important for deciding to adopt. The implicit comparison is with spring chickpea. However, the second season's outcome may be judged not so much on yield as on net revenue. Other, more subtle variables come into the calculation. Prices, seed and input availability, seed quality, land use allocations, weed control, etc. are important factors to consider, both from the standpoint of continuing winter chickpea and deciding planting areas.

The initial survey results would seem to indicate that early in the adoption process winter chickpea serves as a substitute for spring chickpea. However, once the substitution takes place, then the choice for winter chickpea becomes subject to different issues, broader than chickpea itself and extending to the place of chickpea in the farming and market systems. Ultimately, the spread of adoption may depend mainly on the comparative advantage of chickpea and other food legumes vis-a-vis alternative crops in the farming system. A hint of this important area for research was given by the farmers themselves when they identified low selling prices as a constraint to expanding winter chickpea area. They were not referring to winter versus spring chickpea prices, but rather to chickpea prices in general as being too low to sustain present production area. Not coincidentally, non-adopters, when taken as a whole, do not intend to plant as large a chickpea area in 1990/91 as they did in 1989/90. The largest factor contributing to an overall decline in chickpea area in the sampled farmers is the decline in spring chickpea among non-adopters. Winter chickpea adopters are slightly increasing their area planted to the new varieties and, therefore, their chickpea area in general.

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5.2 Monitoring Winter Chickpea Adoption in Morocco

R. Tutwiler, M. Amine

Winter-sown chickpeas were formally introduced to Moroccan farmers in 1987 when two locally adapted varieties derived from ICARDA material, ILC 482 and ILC 195, were inscribed in the official catalogue and approved for commercial production. In order to test the receptivity of farmers to the new technology, the Department of Plant Production (DPV), the National Institute of Agricultural Research (INRA), the Extension Service (DVRA), and ICARDA began a joint program of farmer-managed on-farm trials throughout the country. In the first season, 1987/88, some 33 trials were installed in 9 regions comparing the new varieties with the local spring-sown chickpeas. The results were yields significantly higher than the local varieties in almost all areas. Particularly noteworthy was the success of winter chickpea in southern regions where traditional spring chickpea has declined in past years due to consistently low yields and diseases.

A much larger program of on-farm work was conducted in the 1988/89 season. A total of 104 trials were initiated in 19 regions.

Unfortunately, climatic conditions were unfavorable in many areas. Reasonable rains early in the season were followed by a prolonged drought. In April there were heavy rains, creating a combination of humidity and temperature very conducive to the development of ascochyta blight. Blight ravaged the majority of the trials. As a result, yields were generally much lower than in the previous year. In comparative terms, the new varieties only marginally out-performed the local spring chickpea check. The overall average yield of ILC 482 was 530 kg/ha. ILC 195 was slightly more resistant and gave 670 kg/ha. Average yield of the local spring variety was 500 kg/ha.

Concurrently with the trials program, DPV, DVRA, and ICARDA conducted a survey to gain an initial idea of farmers' reaction to the new technology. The purpose was to identify the principal constraints to adoption of winter chickpea in four representative regions: Fes-Taounate and Khemisset in the north and Settat and Safi provinces in the south. The sample consisted of 112 farmers, divided into those who had already adopted winter chickpeas (i.e. grown the new varieties for more than one year and not as part of the trials program); those who participated in the 1988/89 trials; those who had grown winter chickpeas and rejected the new varieties (i.e. non-adopters); and neighboring farmers who had seen the new varieties growing but had not grown them themselves. The results of the 1989 survey were reported last year. Overall, farmers accepted the idea of winter sowing and appreciated its advantages, both in terms of better water-use efficiency and the likelihood of higher yields. They were, however, extremely cautious about the small seed size and consequent, possibly adverse, market prices of the released varieties. Other factors included higher weed control costs, but those were somewhat offset by earlier harvesting and the potential for the mechanical rather than hand harvesting of winter chickpeas.

Another purpose of the 1989 survey was to create a baseline for charting the adoption process. As in most other WANA countries, the Moroccan national statistical data base has as its purpose the monitoring of national patterns of commodity production. Information at the level of individual farmers is not generally available in usable form. Therefore, we needed to establish a baseline description of chickpea producers and potential producers before proceeding to identify adoption rates and impact patterns. We based our 1989 survey sampling strategy on this goal.

The adoption study was continued in 1990, and the first, very preliminary calculations of adoption rates based on farm-level reporting can be made. Several indicators of adoption have been derived from the decisions made by baseline farmers over the three-season period 1987-90. In interpreting the results, however, certain conditions must be acknowledged. The baseline is calculated from a limited sampling universe. We assume that our baseline, which is drawn initially from only four provinces, is representative of chickpea producers in those provinces. We assume that the ecological and socioeconomic diversity in the sample bears a reasonable resemblance to the diversity in Morocco as a whole, at least in so far as these patterns relate to existing and potential chickpea producers.

The sample is restricted to farmers with at least one year's initial experience producing winter chickpea. Adoption is defined as the decision to produce winter chickpea for at least a second year. The first year may be done with or without participating in the demonstration program, but the second year of production must be done independently. Discontinuing use of the new varieties after one year is non-adoption. Discontinuing after two or more years is defined as dis-adoption.

Table 5.2.1 presents the baseline sample distribution by location and adoption category. Also given is the incidence of ascochyta blight in 1988/89 as a percentage of winter chickpea fields affected. On the basis of farmer distribution, the overall adoption rate in 1990 was 43% of the 98 farmers in the baseline. The rate of adoption by participants in the 1988/89 trials program was 42%, and the dis-adoption rate among adopters following the blight epidemic was 29%.

An indication of the impact of the 1988/89 blight can be gained by comparison of adoption rates, including dis-adoption, in low and high

Table 5.2.1 1990 situation: Farmer distribution by location and category

Location	Adoption Category Non-adopters[1] I	II	III	Adopters[2] III	II	Total farmers	Ascochyta (% fields in 1989)
Fes - Taounate	5	4	1	4	9	23	7%[3]
Khemisset	4	12	1	2	3	22	44%
Safi	4	3	3	13	6	29	27%
Settat	6	9	4	3	2	24	90%
Total	19	28	9	22	20	98	

Notes:

1. Non-adopters categories are I=pre-1989 trials participants
   II=1989 trials participants
   III=dis-adopters after 1989
2. Adopter categories are: III=pre-1989 trials participants and spontaneous adopters
   II=1989 trials participants
3. Although blight was recorded as significant in only 7%, pod borer, wilt, and hail together damaged at least another 50% of winter chickpea fields in Fes-Taounate.

incidence areas. In Fes-Taounate and Safi (areas of low incidence), 62% of farmers with at least one year's experience had adopted the new varieties. But in the highly afflicted areas of Khemisset and Settat, the rate in 1990 was down to 22%. The adoption rate combining all areas fell from a healthy 62% prior to the epidemic in 1989 to 43% in 1990.

Clearly, winter chickpea suffered a setback in Settat and Khemisset. Intuition suggests yields played a big part. In Settat, the area worst hit by ascochyta, 1988/89 trials participants received only 370 kg/ha from ILC 482 and ILC 195 when averaged together, whereas their local check plots averaged 470 kg/ha. When trials farmers are averaged with adopters in Settat, the overall yield for winter chickpea varieties was 800 kg/ha, but spring chickpea producers in Settat reported 1,160 kg/ha. Khemisset told a similar story. In the trials spring gave double the winter yield, and even when the most successful winter adopters are included, spring still outyielded winter by 30%.

These comparisons reveal an interesting pehnomenon. There is a marked tendency, even under harsh disease conditions, for winter chickpea adopters to obtain higher yields than trials participants. For whatever reason, and one suspects better management derived from greater experience may play a role, the adopters sometimes were able to realize a substantial yield advantage over spring chickpea even in Settat and Khemisset. This phenomenon may help to explain why the dis-adoption rate following the blight was lower than the non-adoption rate among trials participants.

Weeds were another factor discouraging adoption and also encouraging some adopters to abandon the new technology. The high costs of hand-weeding in Khemisset meant that 9 out of 15 trials participants suffered economic loss. Given this result in 1989, it is hardly surprising that only 8% of trials participants in Khemisset decided to adopt the new varieties in 1990.

Fortunately, the situation in Safi and Fes-Taounate was much brighter. In these regions the new varieties were a qualified success in 1989 and enjoyed respectable adoption rates. Despite the blight and other diseases and pests and even considering weed problems in Fes-Taounate, winter chickpea substantially outyielded the spring variety and gave a much better economic return in both regions.

An important part of the story is not revealed in yield and economic return comparisons. This is the perceived problem of small seed size in the two released varieties. Trials participants, adopters, and non-adopters in both survey years consistently expressed the importance of developing and releasing new winter chickpea varieties with larger sized seeds. The reason is consumer preference in Morocco and the consequent effect on market prices. In response to this finding, the national program for food legumes and ICARDA scientists have focussed efforts on developing and releasing new, larger-seeded winter varieties with considerable success. Whether or not the new varieties and better climatic conditions than those experienced in 1989 will have a positive effect on raising adoption rates will be discovered in the next few years as the program for monitoring winter chickpea adoption in Morocco continues.

5.3 Supplemental Irrigation Project: from Research to Extension

A.B. Salkini and E. Perrier

5.3.1 Introduction

Syria, a net exporter of wheat until the 1960s, imported about 40% of its wheat needs in the mid-1980s and will import 55% and 74% of its domestic requirements of wheat by the year 2000 and 2020, respectively, if current trends of domestic supply and demand continue. With the exception of Pakistan and Turkey, all the countries of West Asia and North Africa have a wheat deficit problem similar to that of Syria.

About 6000 years ago supplemental irrigation (SI) started in the uplands and foot-hill regions near many small rivers and streams in the Near East. These efforts were devoted to the production of cereal grains, mainly wheat and barley. Even now these traditional practices remain in use.

Supplemental irrigation can alleviate climatic risk in semi-arid regions by increasing choices for soil and crop management. To achieve maximum yield in this environment, say more than 5 t/ha, a rainfed wheat crop requires at least 450 mm of water. With a stable water supply, the technology exists to increase yields; for example, the world's record wheat yield on a farmer's field was 14.1 t/ha, accomplished in Washington State, USA, using conventional irrigation (Perrier and Salkini 1991).

Supplemental irrigation is used in areas where a crop can be grown by natural rainfall alone but additional water stabilizes and improves yield (Withers and Vipond 1974). Whether to irrigate or not is decided purely on the estimated profitability of doing so, which underscores the importance of scheduling SI by minimum not maximum crop water requirements. In addition, irrespective of seasonal rainfall, SI provides conditions suitable for using high inputs, such as high yielding varieties, fertilizer, herbicides, etc., as well as more intensive cropping.

For Syria, and for many WANA countries, it has been realized that the adoption of SI technologies, on as large an area of rainfed wheat as soil and water resources permit, could be the most promising way to achieve self-sufficiency, or, at least, to bridge a sizeable part of the wheat-balance gap.

ICARDA in cooperation with the Syrian Ministry of Agriculture and Agrarian Reform (MAAR) started, in 1985/86, a research program on the supplemental irrigation of rainfed winter crops with a particular focus on wheat. Applying the farming systems research approach, the program has included (1) diagnostic surveys to understand the present farming systems of rainfed and supplementally irrigated wheat, and to identify major constraints to SI development; (2) basic research to characterize and quantify the complicated inter-relationships between climate, soil, water and plant; and (3) on-farm research and demonstration fields to verify and test the basic findings of on-station research.

This report summarizes the major findings of four years (1985/86-1988/89) research on SI of wheat conducted at Tel Hadya Research Station (36°.56′ E; 36°.01′ N; elevation 284 m; and long-term annual rainfall 338 mm). Both agronomic and economic results are highlighted. Major findings of several formal and informal surveys are also presented; and the particular importance of the agricultural extension role in guiding farmers on supplemental irrigation scheduling is emphasized. A more detailed and comprehensive report on the agronomic and socio-economic impact of supplemental irrigation on rainfed wheat production systems will be published, in a separate document, later this year.

5.3.2 Details of Trials on SI of Wheat, Tel Hadya, 1985-1990

The 1985/86 and 1986/87 trials used a split block design in 4 replicates with the SI treatments comprising the main plots: rainfed, irrigated to replenish 100%, 66% and 33% of water-balance (WB) requirements. The sub-plots carried, in 1986, four rates of nitrogen: 0, 70, 140, 210 kg N/ha, and, in 1987, four wheat varieties: two bread wheats, Cham 4 and Mexipak; and two durum wheats, Sebou and Cham 1. At planting time, phosphate fertilizer was applied at the rate of 80 kg P_2O_5/ha. Because rainfall was inadequate, an irrigation for germination was applied, 30 mm to the whole trial in 1985, 20 mm in 1986 but excluding the rainfed plots.

In the 1987/88 and 1988/89 seasons a linesource sprinkler system was used and the SI treatments were: rainfed, irrigated to replenish 20%, 40%, 60%, 80%, and 100% of WB requirements. Varieties Cham 1 and Cham 4 were drilled at 125 kg seed/ha; and four rates of nitrogen, 0, 50, 100, 150 kg N/ha, were applied.

5.3.3 Results and Discussion

5.3.3.1 Supplemental Irrigation Requirements of Rainfed Wheat

At a very early stage of the SI project, a probability analysis combined with a water-balance analysis of climatic data and soil and plant characteristics was conducted for a time series of 23 years of Aleppo data (agroclimatic zone 2)*, to give a rough estimate of SI schedules of rainfed wheat. The analysis showed that wheat would have required in the 23 years analysed:

no irrigation in one year;
one irrigation of 870 m^3/ha in four years;
two irrigations of 1800 m^3/ha in 10 years;
three irrigations of 2210 m^3/ha in three years;
four irrigations of 3100 m^3/ha in four years;
five irrigations of 3480 m^3/ha in one year (Salkini and Perrier 1988).

[Note: 1 mm rainfall $\approx$ 10 m^3/ha]

It should be noted, however, that these SI requirements are calculated (1) to replenish 100% of the water-balance, whereas research

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* Agroclimatic zone 2 covers rainfed areas of 250-300 mm rainfall, and not less than 250 mm in 66% of the years observed (AASA 1986).

has shown that the 100% WB requirements are needed only in below-normal rainfall seasons; in normal and above-normal rainfall seasons optimum yields are obtained from giving 40-60% of these requirements; and (2) for agroclimatic zone 2 (42% of total rainfed wheat area); yet more than 44% of the rainfed wheat area is located in zone 1* where SI requirements are lower than those of zone 2.

Field trials, on-farm trials, and farm surveys conducted during 1985/86-1989/90 indicated that:

- In agroclimatic zone 1, wheat requires one irrigation in wet (above-normal) seasons; two irrigations in normal rainfall seasons, and three irrigations in dry (below-normal rainfall) seasons.

- In zone 2, wheat requires 2, 3, and 4 irrigations in wet, normal and dry seasons, respectively.

- Distribution, as well as volume, of annual rainfall affects SI scheduling in terms of timing, frequency, and volume. For example, the annual rainfall at Tel Hadya for 1985/86 and 1986/87 seasons was exactly the same (315 and 316 mm, respectively). The best irrigation treatment for each of these seasons was 33% WB, i.e. irrigation to replenish 33% of WB requirements. However, 1500 m^3/ha (given in 4 irrigations), and 600 m^3/ha (given in 2 irrigations) were required to achieve 33% WB requirements for the two seasons, respectively (Table 5.3.1).

- Regardless of the stochasticity of the rainfall patterns, SI was needed in each of the four seasons, especially in spring (late March-early May), which coincides with the most water-sensitive stages of growth, flowering and grain-filling. Even in the wettest season of 1987/88 (504 mm rainfall, i.e. 149% of the long-

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* Agroclimatic zone 1 covers rainfed areas of more than 350 mm annual rainfall, and not less than 300 mm in 66% of the years observed (AASA 1986).

term average) two irrigations of 750 m^3/ha total were given in spring to realize optimum yield.

Table 5.3.1 Rainfall and supplemental irrigation given to optimum treatments (1985/86-1988/89)

	Rainfall (mm)	Water added at Germination (mm)	SI (mm)	Total water (mm)
1985/86	315	30*	120	465
1986/87	316	20**	40	376
1987/88	504	0	75	579
1988/89	234	0	183	417
Av. 4 years	342	12.5	104.5	459
SD	114.7	15.0	61.7	87.7

* given to all plots including rainfed
** given to supplemental irrigation plots only

- Early season irrigation (for germination) depended on the early rains. It was required in the first two seasons, but not in the last two. However, such an irrigation, if needed, has a considerable impact on yield.

5.3.3.2 Impact of Supplemental Irrigation on Yield

It can be concluded generally (from research data, surveys and secondary sources) that in the rainfed wheat-growing areas of zones 1 and 2, yields can be increased from an average of 1.5 t/ha to about 5.0 t/ha by supplementing rainfall with 600-1800 m^3/ha of irrigation water.

In four years research at Tel Hadya, grain yields averaged 2.63 t/ha (SD 1.85) for rainfed wheat and 5.36 t/ha (SD 1.12) for SI wheat. Straw yields averaged 2.89 t/ha (SD 1.45) and 7.32 t/ha (SD 1.69), respectively. However, it should be noted that the relatively high yield average of rainfed wheat derived from (1) the exceptionally high yield of 5.04 kg/ha grain and 9.4 t/ha straw in the very wet season of

1987/88; and (2) the germination irrigation given to the rainfed plots in 1985/86 (Table 5.3.2).

Table 5.3.2 Yields of rainfed and optimum supplemental irrigation treatments (1985/86-1988/89)

	Grain yield (t/ha)		Straw yield (t/ha)	
	Rainfed	SI	Rainfed	SI
1985/86	2.97	5.82	3.71	6.68
1986/87	1.78	5.35	4.62	8.00
1987/88	5.04	6.44	9.40	9.25
1988/89	0.74	3.83	2.98	5.33
Av. 4 years	2.63	5.36	5.17	7.32
SD	1.85	1.12	2.89	1.69
CV %	70%	21%	56%	23%

Differences between treatments are very significant for grain yield t = -5.84, sig. level = 0.01; for straw, t = 2.7, significant at 0.074 level

Supplemental irrigation reduced yield fluctuation and variability. Coefficients of variation (CV) of the four-year yield means of the rainfed crop were 70% for grain and 56% for straw compared with 21% and 23% for SI grain and straw.

It seems that Deficit Irrigation (i.e. replenishing part, not all, of the WB requirement and thereby subjecting the crop to some water-stress) can be adopted on rainfed wheat without serious reduction in yield, at least, in normal or wet seasons. At Tel Hadya, in three out of four seasons there were no significant yield differences between treatments that received only a proportion (33-40%) of the WB requirement and those that received 100%. The differences were significant only in the dry season of 1988/89 when the rainfall was 69% of the long-term annual average (Perrier and Salkini 1991).

Regardless of differences in rainfall patterns and irrigation schedules, over the four years there was a positive relationship between total water (rain or rain plus SI) received and yield (Figure

5.3.1). This relationship is presented in the following regression equation.

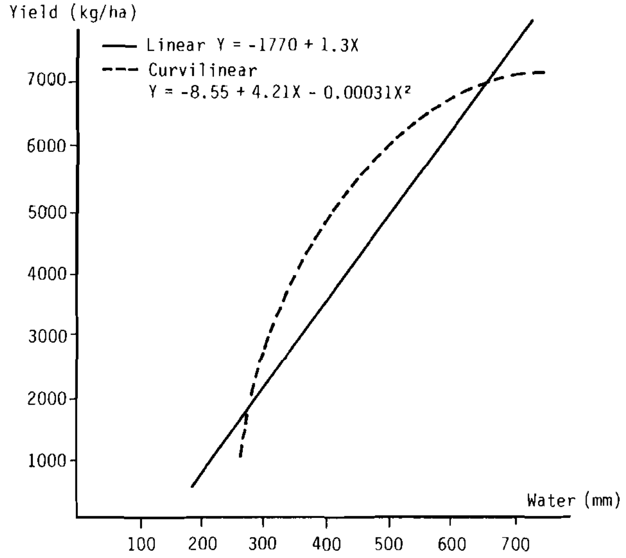

Figure 5.3.1 Relationship between wheat yield and water

Grain yield (kg/ha) = - 1770 + 1.3 total water (m^3/ha)

[r = 0.92 r^2 = 0.85 sig. level = 0.000]

which was obtained by regressing yields of 20 observations of both rainfed and SI treatments on the amounts of water received, rain only for rainfed and total water (rain + SI) for SI treatments.

However, presenting the relationship between yield and water in a linear equation oversimplifies the real world. The same relationship can be more realistically presented as a quadratic, curvilinear model:

$$Y = - 8055 + 4.21 W - 0.00031 W^2$$

Multiple r = 0.96 r^2 = 0.93 Adjusted r^2 = 0.92

sig. level = 0.001

where: Y = grain yield (kg/ha); and W = Water received (m^3/ha).

As expected, a linear relationship was found between rainfed wheat yield and rainfall. The lowest rainfed yields (0.74 t/ha grain and 2.98 t/ha straw) were obtained in the lowest rainfall season of 1988/89 (243 mm). Yields increased as rainfall did, and highest yields (5.04 t/ha grain and 9.40 t/ha straw) were obtained in the exceptionally high rainfall season of 1987/88 (Tables 5.3.1 and 5.3.2, Figure 5.3.2).

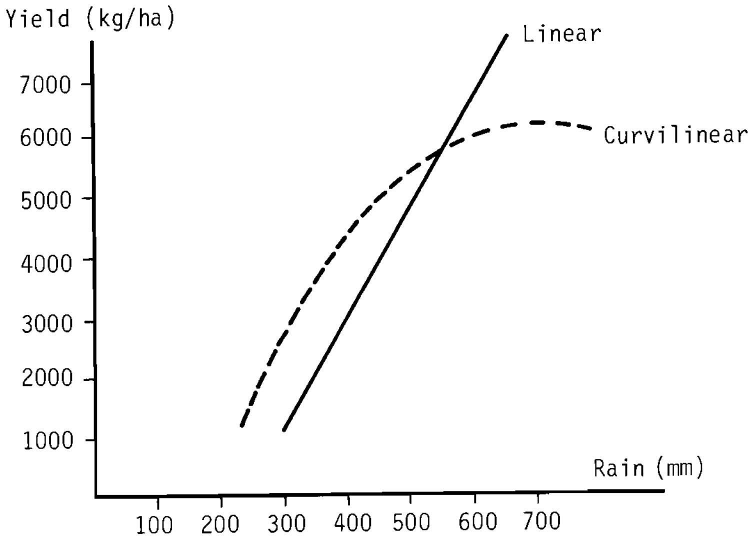

Figure 5.3.2 Relationship between rainfed wheat yield and rainfall

Simple regression analysis gave the following positive linear relationships:

Rainfed grain yield (kg/ha) = - 3967 + 1.93 rainwater (m^3/ha)
[$r = 0.98$ $r^2 = 0.97$ sig. level = 0.0068]

Rainfed straw yield (kg/ha) = - 3317 + 2.43 rainwater (m^3/ha)
[$r = 0.95$ $r^2 = 0.90$ sig. level = 0.02]

[Note: 1 mm rainfall $\cong$ 10 m^3/ha]

There was also a positive relationship between yield of SI treatments and rainfall, and this is difficult to interpret. On the assumption that SI eliminates the effects of low rainfall on yield by adding water, there should be no relationship between yield and rainfall; rather it should be between total water (rain + SI) and yield. Yet, a positive relationship between yield of SI treatments and rainfall (regardless of irrigation given) was found. The lowest yields of SI crops (3.83 t/ha grain and 5.33 t/ha straw) were for the driest season, 1988/89. As rainfall increased, yields of SI plots increased accordingly, and the highest yields (6.44 t/ha grain and 9.25 t/ha straw) were obtained in the wettest season, 1987/88 (Tables 5.3.1 and 5.3.2, Figure 5.3.3). These simplified linear relationships are presented in the following linear equations:

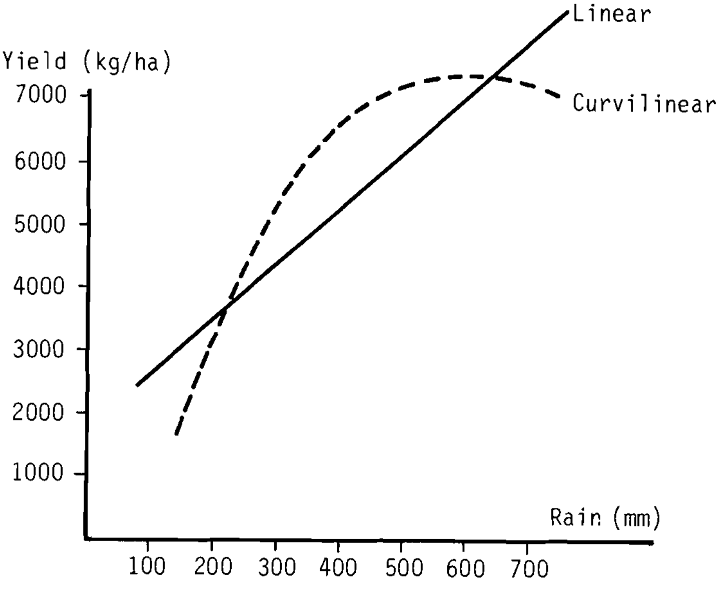

Figure 5.3.3 Relationship between supplementally irrigated wheat yield and rainfall

SI grain yield (kg/ha) = 2054 + 0.88 rainwater (m^3/ha)
[$r = 0.90$ $r^2 = 0.81$ sig. level = 0.05]

SI straw yield (kg/ha) = 2681 + 1.32 rainwater (m^3/ha)
[$r = 0.89$ $r^2 = 0.79$ sig. level = 0.05]

The varieties, Cham 1 (durum wheat) and Cham 4 (bread wheat), were the most responsive to supplemental irrigation. However, more research is still required in this respect, as the four varieties were compared for only one season.

For nitrogen application, it was found that moderate rates (70-100 kg/ha) are optimum, as the yield differences between moderate rates and high rates (150-210 kg/ha) were insignificant.

5.3.3.3 Economic Implications of Supplemental Irrigation on Rainfed Wheat

The low SI requirement of wheat and its high water-use efficiency (WUE) (Table 5.3.3) were reflected in high economic returns for SI. One cubic meter of rainwater produced, on average, 2.11 kg dry matter (0.69 kg grain and 1.42 kg straw), equivalent to a gross revenue of 3.78 Syrian lira (SYP), whereas one cubic meter of SI produced, on average, 5.27 kg dry matter (2.97 kg grain and 2.30 kg straw), equivalent to 13.35 SYP.* Taking the cost of water, in 1988, to be 1.23 SYP/m^3, the net revenue was 12.12 SYP/m^3 of SI water. Profitability of SI has increased considerably in the last two years, as the 1990 prices of wheat grain and straw are about double those of 1988*. Estimated net revenue for one cubic meter of SI, based on 1989/90 prices, is about 26.90 SYP (Table 5.3.4).

However, in practice, farmers' net revenue from water used for SI of wheat is much less, due to (1) lower yield levels, and (2) much higher application rates of SI. It has been found that farmers, on average, obtain yields of SI wheat 22% lower than those of research, while they apply more than treble (328%) the optimum amount of SI water (Table 5.3.5 and 5.3.6, Figure 5.3.4).

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* Prices used are 3.90 SYP/kg grain, and 0.77 SYP/kg straw as estimated by the farm survey conducted in 1988; corresponding prices for 1990 is 8.50 SYP/kg grain and 1.50 SYP/kg straw.

Table 5.3.3 Water-use efficiency of wheat for rainfed and optimum SI treatment (1985/86-1988/89)

	kg grain/m^3		kg straw/m^3		kg dry matter/m^3	
	Rainfed	SI	Rainfed	SI	Rainfed	SI
1985/86	0.86	2.38	1.08	2.48	1.94	4.86
1986/87	0.56	5.95	1.46	5.63	2.02	11.58
1987/88	1.00	1.87	1.87	-0.20	2.87	1.67
1988/89	0.32	1.69	1.27	1.28	1.59	2.97
Av. 4 years	0.69	2.97	1.42	2.30	2.11	5.27
SD	0.31	2.01	0.34	2.48	0.54	4.41

Table 5.3.4 Economics of SI application on wheat 1985/86-1988/89

	85/86	86/87	87/88	88/89	Av. 4 years	89/90*
kg Grain/m^3 of SI	2.38	5.95	1.87	1.69	2.97	2.97
kg Straw/m^3 of SI	2.48	5.63	-0.20	1.28	2.30	2.30
Total	4.86	4.58	1.67	2.97	5.27	5.27
Grain price (SYP/kg)	1.50	2.60	3.75	5.75	3.40	8.50
Straw price (SYP/kg)	0.55	0.85	1.10	1.50	1.00	1.50
Grain value from m^3 of SI	3.57	15.47	7.00	9.72	8.94	25.25
Straw value from m^3 of SI	1.36	4.78	-0.22	1.92	1.96	3.45
Total value from m^3 of SI	4.93	20.25	6.78	11.64	10.90	28.70
Cost of 1 m^3 SI	0.34	0.50	1.25	1.50	0.90	1.80
Profit from 1 m^3 SI	4.59	19.75	5.53	10.14	10.00	26.90

* Prices of 1989/90 and the 4 years average yields are used

Table 5.3.5 Water application of wheat: research vs farmer

	Research (m^3/ha)		Farmer		
Rainfall	(1) opt.	(2) max.	m^3/ha	% of (1)	% of (2)
High	850	2125	2730	320	128
Low	1834	1834	5780	315	315
Normal	1050	3150	3890	370	123
Average 3 season	1245	2370	4090	328	172

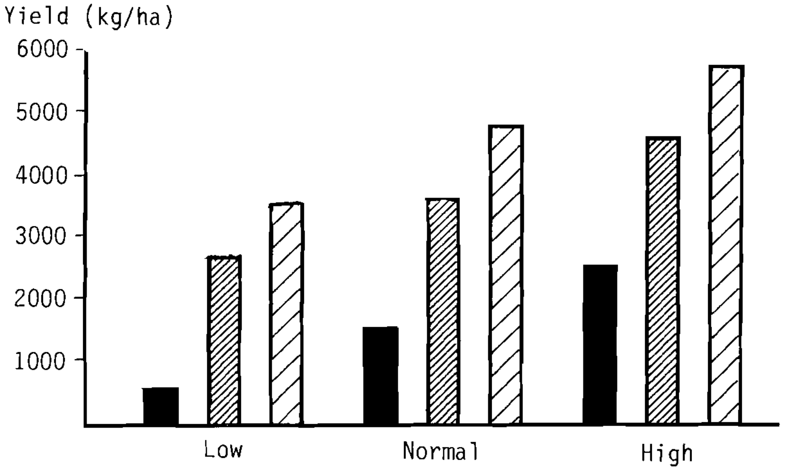

Figure 5.3.4 Wheat yields obtained: research vs. farmers

Farm survey and research data showed that, in normal seasons, in terms of 1988 prices, per hectare net profit gained by research could be as much as 425% of that gained by farmers (10900 SYP/ha and 2560 SYP/ha, respectively). Moreover, in low-yielding seasons (of about 2760 kg/ha yield average) farmer investment in SI for wheat may result in monetary losses (-720 SYP/ha). Yet, in such seasons, rainfed wheat production may produce greater losses (Table 5.3.6 and Figure 5.3.5).

Table 5.3.6 Comparison of per hectare profitability of SI and rainfed wheat: research vs. farmer

	High	Low	Normal	Av. 3 season
Research				
Profit 1 kg (SYP)	2.57	1.73	2.31	2.28
Yield (kg/ha)	5640	3450	4720	4620
Total profit (SYP/ha)	14495	5970	10900	10530
Farmer, SI				
Profit 1 kg (SYP)	1.35	-0.26	0.71	0.72
Yield (kg/ha)	4500	2760	3600	3620
Total profit (SYP/ha)	6075	-720	2560	2610
Farmer, rainfed				
Profit 1 kg (SYP)	2.45	-2.55	1.66	1.56
Yield (kg/ha)	2490	560	1610	1540
Total profit (SYP/ha)	6100	-1430	2670	2400

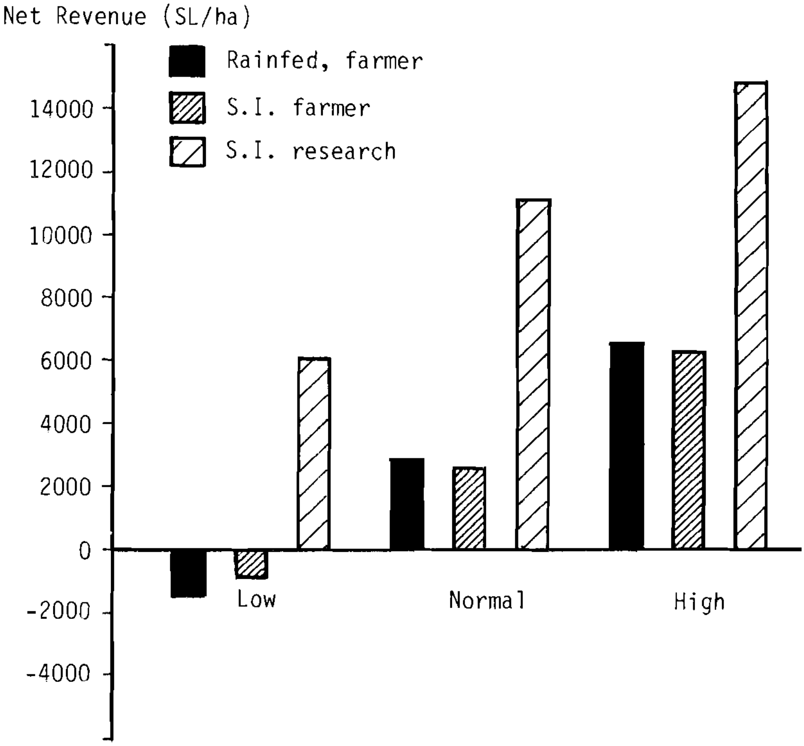

Figure 5.3.5 Profitability of wheat production: research vs. farmers

In fact, the above situation has been drastically adjusted by the huge recent increase in the official price of wheat (218% in two years).

Investment in SI of wheat has become more attractive for farmers. Even so, there is potential for much greater profits; from water saving, using scientific and simple methods for irrigation scheduling; from savings in other inputs, particularly seed and nitrogen fertilizer; and from potential yield increase as well. Estimated extra benefits of research practice over farmers' practices could be about 7800 SYP/ha and 14330 SYP/ha according to 1988 and 1990 prices, respectively (Table 5.3.7). Hence, the importance of the role agricultural extension could play in transferring improved SI techniques.

Table 5.3.7 Potential extra benefits from SI research practices over current benefits of farmers' practices

Item	Quantity	Extra benefit (SYP/ha)	
		1988 prices	1990 prices
I. DIRECT BENEFITS:			
1. Water saving (70%)	2845 m^3	3500	5260
2. Savings in N (42%)	110 kg	180	520
3. Savings in P_2O_5 (20%)	45 kg	80	250
4. Savings in seed (20%)	35 kg	140	300
5. Yield increase (28%)	1000 kg	3900	8000
Total Extra Benefits		7800	14330
II. INDIRECT BENEFITS:			
Water saved can be used to increase SI wheat area by 200%.			

5.3.3.4 Overall Impact of SI on Rainfed Wheat-Based Farming Systems

Where SI has been introduced into rainfed wheat-based farming systems a great agricultural, economic, and social impact has resulted. With SI, fallowing is eliminated and the cropping intensity increased from about 83% for rainfed systems to more than 110%. Cropping patterns are changed; and, new, highly profitable cash crops, such as vegetables, cotton, maize, etc., introduced. Pre-hectare net income is increased substantially, more than 5 times that of rainfed systems, as reported by farmers. With SI, rural families have better living conditions and general welfare. Migration, temporary and permanent, decreased to a minimum, or even ceased in same cases (FSP 1986).

5.3.4 Extension of SI Technologies

After four years of research, on station and on farmers' fields, it became necessary to verify, test, and demonstrate SI techniques to a wide range of farming communities. To do this, the cooperative project between DIWU (Directorate of Irrigation and Water Use) and ICARDA was extended to include the Directorate of Agricultural Extension (AE).

Nine Field Demonstration Tests (FDT) were carried out in 1989/90, in the major wheat-producing areas of the different agroclimatic zones of Aleppo Province (Figure 5.3.6). The FDT aimed (1) to familiarize farmers with new, simple and improved SI techniques; (2) to test the practicality and applicability of simplified scientific ways to schedule SI (water-balance method); and (3) to verify research findings on DEFICIT IRRIGATION (50% vs 100% of WB requirements) under different agroclimatic and socio-economic environments.

Each FDT was supplied with a Class A evaporation pan and rain gauge, and an area of one hectare was divided into 3 plots: rainfed, 100% WB irrigation requirement, and deficit irrigation (50% WB). Two training courses were provided to train AE agents on "SI Technologies and Scheduling" (12 agents) and on "Computer Use for WB Calculations and SI Scheduling" (3 agents).

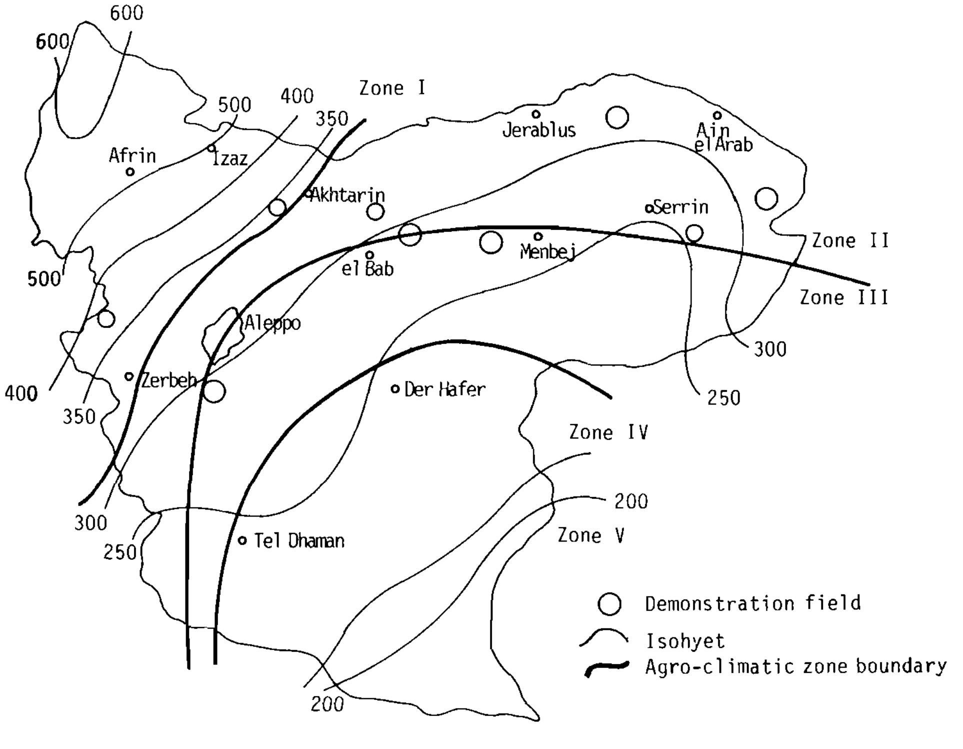

Figure 5.3.6 Demonstration fields in Aleppo province, 1989/90

Despite some difficulties (communication with remote sites, inaccuracy of some weather data at a few sites), the first year experience of FDT was successful in meeting the objectives listed above. SI scheduling and yield data were completed for seven out of the nine FDT (Table 5.3.8). The results may be summarized:

Table 5.3.8 Grain yield and water applied of seven demonstration fields by treatment, variety and site (1989/90)

	100% WB		50% WB		Rainfed
	kg/ha	m^3/ha	kg/ha	m^3/ha	kg/ha
Um Housch [1]	4320	1350	3790	675	1620
Kebbaseen [1]	5250	2200	4500	1100	750
Abu Kalkal [1]	4320	2500	3960	1250	450
El Kubba [1]	5040	2250	4320	1125	300
Bozhic [2]	5400	3000	4320	1500	grazed
Susian [2]	5250	3000	4500	1500	750
Karakuzac [2]	5445	3060	4125	1530	grazed
av. 7 sites	5003		4216		553
SD	485		270		568
CV%	10%		6%		103%

Differences between treatments were very significant as F = 189.56, sig. level = 0.000.
Differences between the two varieties were non-significant.
1. Variety Research 1; 2. Variety Cham 1

1. As 1989/90 was a dry season (rainfall 60-70% of the long-term average), yield differences between treatments were very significant (F = 189.56, sig. level = 0.000). Average yields (amounts actually obtained by farmers, not sample estimates) were 553 kg/ha (SD 568) for rainfed plots (excluding two sites that were grazed), 4216 kg/ha (SD 270) for deficit irrigation treatments (50% of WB), and 5003 kg/ha (SD 485) for non-deficit irrigation treatments (100% WB).

2. Between-sites variability was huge for the rainfed treatment (CV 103%) but small for deficit irrigation and non-deficit irrigation treatments (6% and 10%, respectively).

3. In agreement with research results, FDT showed that in dry seasons, wheat should be irrigated to replenish 100% of WB requirement, because deficit irrigation, under such conditions, may reduce significantly SI profitability. Gains from water saved by using deficit irrigation averaged about 3045 SYP/ha, but losses due to yield reduction were estimated at about 6296 SYP/ha, making a net loss of 3251 SYP/ha.

   Nevertheless, it must be highlighted that deficit irrigation (about 1240 m^3/ha on average) increased yields over those of rainfed wheat by 660% and also reduced yield variability considerably. In other words, an extra investment of about 3000 SYP/ha in deficit irrigation produced an extra gross revenue of about 31,000 SYP/ha. Whether farmers have to apply deficit, or non-deficit, irrigation in dry seasons depends on water availability and scarcity, and on the opportunity cost of not using the water on other crops.

4. The FDT compared two varieties, Research 1 and Cham 1. Research 1 yielded more than Cham 1 under below-normal rainfall conditions (780 kg/ha and 250 kg/ha, respectively). However, Cham 1 was more responsive to SI. It yielded 13.4% and 4% more than Research 1 in non-deficit and deficit irrigation conditions, respectively, the interaction between variety and irrigation treatment being significant at 0.06 significance level.

FDT will continue for 4-6 more years to verify crop performance under deficit irrigation conditions under a range of weather conditions, and to provide experience to AE agents on SI scheduling. This experience is the core element for a successful transfer and adoption of SI technologies by farmers. Under the highly variable rainfall of Mediterranean environments, each year has its own SI schedule. Farmers are not able to determine this scientifically themselves. So, the only possible method is to schedule SI on as many FDT as possible, and to transfer their schedules to neighboring wheat producers by personal contact or, more effectively, by local broadcasts of mass media, radio or TV.

References

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Perrier, E.R. and Salkini, A.B. 1991. Verification of Supplemental Irrigation of Spring Wheat, In Perrier and Salkini (eds) "Supplemental Irrigation" (in press).

Salkini, A.B. and Perrier, E.R. 1988. Supplemental Irrigation and its impact on wheat production economics in Syria. Paper presented in the VIII Conference of Arab Agricultural Engineers Union, Khartoum (in Arabic).

Withers, B. and S. Vipond. 1974. Scheduling Irrigation with limited water, 5th Annual High Plains Grain Conference, Texas.

6. TRAINING AND AGROTECHNOLOGY TRANSFER

M. Bakheit Said

During the 1989/90 season FRMP staff conducted a number of training activities which included group training both at main station and in-country, degree-related and non-degree individual training and other miscellaneous training activities.

6.1 Group-Training Courses

Long-Term Training Course in Fallow Replacement

This course was conducted at Tel Hadya, in collaboration with the Pasture, Forage and Livestock Program, during the period 18 March to 18 April 1990. The objectives were to review the advantages and disadvantages of fallowing in dry, rainfed, arable farming systems and the options for its replacement, to provide a thorough introduction of those pasture and forage legume species that appear to offer greatest potential for fallow replacement and to promote contacts between ICARDA and national programs in this field. The course was attended by 7 participants, from Syria, Libya, Jordan, Iran, Afghanistan and Algeria.

ICARDA/IFDC Training Course in Development of Effective Fertilizer Recommendations for the Mediterranean Region

ICARDA and IFDC joined efforts to hold a 3-week training course at Tel Hadya on the "Development of Effective Fertilizer Recommendations for the Mediterranean Region" during the period 18 February to 8 March 1990. The objectives were to review recent advances in soil and crop science in order to increase the participants' knowledge of factors affecting crop response to fertilizer, to ensure that the necessary techniques for processing, analyzing and interpreting data from trials are understood, to practise the various methods used in developing targeted fertilizer recommendations and to promote contact and information exchange between ICARDA and national programs in this field. The course was attended by 8 participants, from Syria, Jordan, Libya, Tunisia and Algeria.

Crop Modelling

The course participants were collaborators from Morocco and Turkey of the ICARDA/IDRC Project "Agroecological Characterization". The objectives were to train national staff in the theoretical background and practical applications of crop models to enable them to apply them critically to their agencies' needs. The course was held at Tel Hadya on 6-17 May and was attended by 7 participants, from Morocco (3) and Turkey (4).

Spatial Weather Generation Course

This course was again for collaborator participants from Morocco and Turkey of the ICARDA/IDRC "Agroecological Characterization" project. The objectives were to train national staff in the theoretical background and practical application of weather generation methods to facilitate their collaboration in the validation process and to help them make efficient use of the methods to meet their agencies' needs. The course was held at Tel Hadya during the period, 20 May - 28 June, immediately following the previous course, and was attended by 7 participants, from Morocco (4) and Turkey (3).

Survey Methods and Data Collection Course

This course was conducted jointly with the socio-economic section of the Directorate of the Agricultural Research at Douma during the period 16-23 July. It was attended by 14 Heads of Agricultural Research Stations in Syria and included the pretesting of a questionnaire to be used in the 1990 survey of winter chickpea adoption in Aleppo, Idleb, Hama and Hassakeh provinces.

Evaluation Strategies for Supplemental Irrigation

This was an in-country training course conducted in Tunisia on 22-31 January and sponsored by ICARDA/CCDD/INAT. The course covered aspects of soil physics, agricultural engineering and crop growth simulation using the CERES model. It was attended by 22 Tunisian participants.

On-Farm Methodology for Technology Transfer

This course aimed to strengthen the Mashreq countries' capacity for on-farm research and technology transfer. It was held in Jordan during the period 4-11 March 1990 and was attended by 12 participants, from Jordan (4), Iraq (4) and Syria (4). It was co-sponsored by ICARDA/UNDP and AFESD.

Group training course activities also included: a short course for Aleppo province extension agents on supplemental irrigation technology held on 16-27 September; and, the third sub-regional farm survey methods training course in Morocco on 3-13 December, attended by participants from Libya, Tunisia, Algeria and Morocco.

6.2 Individual Training

There are currently (end of 1990) seven students, and the eighth finished his work in October (Table 6.2.1). However, FRMP hopes to take, during 1991, five more students, including four from the region and one from China. The latter is interested in agroecological characterization.

Table 6.2.1 Individual training, degree-related

Name	Country	Degree	Cooperating University	Topic
M.S. Issa	Syria	MSc	Aleppo	Wheat yield variability
M. Saade	Syria	PhD	Michigan	Fertilizer allocation in Syria
E. Afif	Syria	PhD	Córdoba	P behavior in soils
M. Khazmeh	Syria	MSc	Damascus	Adoption of medics
O.H.E. Ibrahim	Sudan	MSc	Gezira	Crop water use (Wheat)
A. Mikhaeil	Syria	MSc	Aleppo	Soil fertility
M. Darwich	Syria	MSc	Cukurova	Economics of chickpea production
M. Shahine	Syria	MSc	Aleppo	Crop rotations

FRMP provided individual, non-degree training to 15 trainees in various topics and for varying durations (Table 6.2.2).

Table 6.2.2 Individual training, non-degree related

Name	Country	Subject	Duration
L. Medaa (Ms)	Syria	Fertilizer allocation	6 months*
M. H. Nagi	Syria	Tillage/moisture conservation	9 months*
Z. Zahir	Syria	On-farm fertility trial	1 year*
A. Droushiotou (Ms)	Cyprus	Methods of N analysis	2 weeks
C. Kali (Ms)	Cyprus	Methods of N analysis	2 weeks
A. Nemmeh	Syria	Methods of N analysis	1 week
L. Mahmoud (Ms)	Syria	Determination of micronutrients	1 week
S. Soumi (Ms)	Syria	Methods of N analysis	1 week
S. Talab	Syria	Methods of N analysis	1 week
G. Younis	Syria	Economic analysis	3 weeks
B. H. Al-Warih	Syria	Data entry and analysis	2 months
S. A.R. Salti	Syria	Data entry and analysis	2 months
M. A. Saed	Syria	Computer use for supp. irrig.	1 week
J. Roumie	Syria	Computer use for supp. irrig.	1 week
M. F. Amer	Syria	Computer use for supp. irrig.	1 week

* Continuing from last season

6.3 Miscellaneous Activities

FRMP, as in previous seasons, encouraged the attachment of visiting scientists from the region to the program for varying periods of time to work on collaborative research problems. In this connection a senior scientist from the Syrian Soils Directorate joined the program for 4 months and worked on the development of a framework for the economic allocation of fertilizer across crops and zones. He was assisted by a trainee from the same national department and a FRMP PhD student. In addition, an agricultural economist and visiting scientist from Aleppo University joined the program to review current knowledge of management strategies and ownership patterns of marginal grazing areas. This information is essential for the extension of our research from the station to communally owned land.

APPENDIX A

FARM RESOURCE MANAGEMENT PROGRAM

Staff List for 1990

Peter Cooper [1]	Program Leader - Soil Physicist
Hazel Harris	Soil Water Conservation Scientist
Michael Jones	Barley Based Systems Agronomist
Abdallah Matar	Soil Chemist
Thomas Nordblom [2]	Agricultural Economist
Mustafa Pala	Wheat Based Systems Agronomist
Eugene Perrier [1]	Water Management Agronomist
Mohamed Bakheit Said	Senior Training Officer
Richard Tutwiler	Social-Economist
Wolfgang Goebel	Post-Doc Fellow/Agroclimatologist
Ammar Wahbi [1]	On-Farm Agronomist-Barley/Livestock Systems
Ahmed Mazid	Agricultural Economist
Abdul Bari Salkini	Agricultural Economist
Elizabeth Bailey	Visiting Scientist/Agricultural Economist
Maurice Saade [1]	Postgraduate Research Student/Economist
Sobhi Dozom	Research Associate I
Mahmoud Oglah	Research Associate I
Ciro D'Acunzo [1]	Associate Expert/FAO
Shi Zuntong [1]	Visiting Scientist/China
Afif Dakermanji	Training Assistant
Sonia Garabed	Research Assistant II
Rafik Makboul	Research Assistant II
Leith el-Mahdy	Research Assistant II
Zuhair Arous	Research Assistant II
Atef Haddad	Research Assistant II
Haitham Halimeh	Research Assistant II
Nerses Chapanian	Research Assistant II
Mohamed Salem	Research Assistant II
Ghalia Martini	Research Assistant II
Hassan Jokhadar	Research Assistant II
Mohamed Samir Masri	Research Assistant II
Shahba Morali	Research Assistant II
Hisham Salahieh	Research Assistant II
Mohamed Tahhan	Research Assistant I
Pierre Hayek	Research Assistant I
Sabih Dehni	Senior Research Technician I
Malika Abdul-Ali	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 Kharbotly [1]	Research Technician II
Issam Halimeh	Research Technician II
Dolly Mousalli	Research Technician II
George Estephan	Research Technician II

Bernadette Jallouf [3]	Research Technician I
Mohamed Zeki	Research Technician I
Nabil Musattat	Research Technician I
Shereen Baddour	Research Technician I
Ghassan Kanjo	Research Technician I
Raala El Naeb	Research Technician I
Ghazi Yassin	Research Technician I
Ali Haj Dibo	Research Technician I
Hayel El Shaker	Assistant Research Technician
Jihad Abdullah	Assistant Research Technician
Marica Boyagi	Senior Secretary III
Katia Artinian	Secretary II
Zukaa Istanbouli	Secretary I
Samir Baradai [1]	Driver II
Mohamed Elewi Karram	Labourer II

1. Left in 1990
2. Transferred to PFLP
3. Joined and Left in 1990

APPENDIX B

PUBLICATIONS

This year we record only those publications and presentations that were made in 1990 or in late 1989 (and therefore unrecorded in our previous report) and only those publications published or accepted for publication in 1990.

Books

Ryan, J. and Matar, A. (editors), 1990. Soil test calibration in West Asia and North Africa. Proceedings of 3rd Regional Workshop, Amman, Jordan, September 1988. 243 pp. ICARDA-167 En.

Tully, D. (editor), 1990. Labor and Rainfed Agriculture in West Asia and North Africa. 200 pp. Kluwer Academic Publishers, Dordrecht, Netherlands.

Tully, D. (editor), 1990. Labor, Employment and Agricultural Development in West Asia and North Africa. 214 pp. Kluwer Academic Publishers, Dordrecht, Netherlands.

(Summaries of the eight case studies that comprise this second book were presented in FRMP Annual Report for 1989).

Journal Papers and Articles

Bailey, E. and Boisvert, R.N. 1989. "A comparison of Risk Efficiency Criteria in Evaluating Groundnut Performance in Drought Prone Areas". <u>Australian Journal of Agricultural Economics</u> 33, 153-69.

Bailey, E. and Boisvert, R.N. "Estimating Yield Response of Groundnuts to the Amount of Timing of Water Applications". <u>Journal of Production Agriculture</u> (forthcoming).

Matar, A., Pala, M., Beck, D. and Garabet, S. 1990. Nitrate-N test as a guide to N fertilization of wheat in the Mediterranean region. <u>Communications in Soil Science and Plant Analysis</u>, <u>21</u>, 1117-1130.

Matar, A., Beck, D., Pala, M. and Garabet, S. Mineralization potentials in selected Mediterranean soils. Communications in Soil Science and Plant Analysis (forthcoming)

Matar, A., Saxena, M. and Silim, S. Effects of residual and direct phosphate application on P uptake and yields of lentil in a

Mediterranean climate. Accepted for publication in Fertilizer Research.

Matar, A., Torrent, J. and Ryan, J. Soil and fertilizer phosphorus and crop responses in the dryland Mediterranean zone. Chapter to appear in Advances in Soil Science, Bob Steward (editor).

Mazid, A. 1990. Changes in lentil production technology in Syria, LENS, Vol 17, Nº 2.

Mazid, A. and Erkan, O. Barley production functions as descriptors of impact of technology on yield in southeast Turkey and northern Syria. Journal of Agriculture Faculty, University of Cukurova (Turkey) (forthcoming).

Tutwiler, R. 1990. "Agricultural Labor and Technological Change in the Yemen Arab Republic", in Tully, D. (ed). Labor and Rainfed Agriculture in West Asia and North Africa Kluwer Academic Publishers: Dordrecht, pages 229-252.

Presentations at Meetings

Cooper, P.J.M. and Bailey, E. "Livestock in Mediterranean Systems. A traditional Buffer against Uncertainty: Now a Threat to the Agricultural Resource Base". Paper presented at the 10th Agricultural Symposium, Risk in Agriculture, World Bank, Washington, D.C. 9-10 January 1990.

Jones, M.J. "Land Management and Sustainable Agricultural Development in West Asia and North Africa: an ICARDA View". Paper presented at International Symposium, Soil Constraints on Sustainable Plant Production in the Tropics, Kyoto, Japan, 14-16 August 1990.

Jones, M.J. "Cereal Production and Its Relationship to Livestock: The Point of View of the Agronomist". Paper presented at International Symposium, L'Elevage dans les Systèmes Céréaliers Méditerranéens, Rabat, Morocco, 7-10 October 1990.

Matar, A. "Soil Testing as a Guide to Fertilization in the Mediterranean Region. Paper presented at International Fertilizer Congress, Nicosia, Cyprus, 21-27 October 1990.

Pala, M. "Agronomic Aspects of Plant Nutrition Management under Rainfed Agriculture -- ICARDA Experience". Paper presented at 10th Session of FAO Regional Commission on Land and Water Use in the Near East, Amman, Jordan, 10-14 December 1989.

Tutwiler, R. "Yemeni Agriculture: Structural Change and Development Choices". Paper presented at Conference "Contemporary Yemen: Process of Change", London School of African and Oriental Studies, University of London, 21-23 May 1990.

APPENDIX C

LIST OF FIELD TRIALS AND EXPERIMENTAL ACTIVITIES IN FRMP CORE PROGRAM, 1990

PROJECT 1. MANAGEMENT OF SOIL, WATER AND NUTRIENTS

Improved efficiency of fertilizer use

SWAN-2B	Nitrogen use efficiency of durum and bread wheat lines
SWAN-	Plant analysis as a guide to N fertilization of cereals
SWAN-8A	Dependence of soil critical levels of phosphate on soil properties using two crop indicators - wheat and lentil
SWAN-8B	Loss of phosphorus availability in selected Mediterranean soils in relation to soil properties at constant temperature and water stress
SWAN-9	Rate of change of available P in soils in relation to residual and yearly application of phosphate under a cereal/legume cropping sequence
SWAN-10	P-adsorption isotherms in calcareous soils

Cereal crop management interaction

SWAN-4B	Barley genotype x management study
SWAN-4C	Wheat cultivar x management study

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 (6th year)
SWAN-13	The effect of stubble burning and seedbed preparation systems on a wheat/lentil rotation
SWAN-14	The productivity of farming systems (6th year)
SWAN-14A	Barley tillage/stubble mulch trial (2nd year)

Soil conservation

SWAN-35	Ghrerife atriplex hedge/barley trial (1st year)
SWAN-36	Wind erosion monitoring and modelling study

Improved production practices for food legumes

SWAN-16A	The effect of tillage, row spacing and weed control on winter-sown chickpeas
SWAN-20A	Mechanization of chickpea operations

Forage agronomy trials

SWAN-21	Forage legume potential in dry areas

SWAN-22 Vetch utilization trials

Water management studies

SWAN-23A Supplemental irrigation of wheat: nitrogen and variety effects (CERES-N validation)
SWAN-23B The performance of durum and bread wheat genotypes under different moisture regimes
SWAN-24 Research managed supplemental irrigation of wheat
SWAN-25 Research managed supplemental irrigation of lentils
SWAN-26 Supplemental irrigation (SI) of wheat and barley in Libya

Fallow replacement

SWAN-27 Legume/barley rotation trial - "Old rotation" [terminated]
SWAN-28 Forage crop/barley rotation trial - "New rotation" (9th year)
SWAN-29 Continuous barley trials (5th year)
SWAN-31 PFLP/FRMP medic/barley rotation trial (4th year)

Studies on oil crop production

SWAN-32 Sowing date studies for rape-seed varieties
SWAN-33 Supplemental irrigation of sunflower: variety and plant density effects
SWAN-34 The performance of rape-seed varieties under different moisture regimes

PROJECT 2. AGRO-ECOLOGICAL CHARACTERIZATION FOR RESOURCE MANAGEMENT

ACRM-2 Spatial climate model
ACRM-3 SIMTAG
ACRM-4 Simulation of supplemental irrigation farming using a modification of the CERES-wheat model and the ICARDA weather generator
ACRM-6 Prediction of crop-environment interactions
ACRM-7 CERES barley model validation and calibration
ACRM-11 Improving dryland farming systems in the arid zones of Jordan
ACRM-12 Dryland resource management and the improvement of rainfed agriculture in the drier areas of West Asia and North Africa
ACRM-13 Validation of Merz's method to generate correlated crop yields

PROJECT 3. ADOPTION AND IMPACT OF TECHNOLOGIES

ADIM-2 Economic factors influencing adoption of new technology in dry areas: a case study of fertilizer use on barley in northern Syria
ADIM-3 Factors affecting the adoption and impact of supplemental irrigation
ADIM-7 Evaluation of socioeconomic implications of lentil harvesting mechanization research
ADIM-10B Adoption of winter-sown chickpea in Morocco
ADIM-10C Adoption of winter-sown chickpea in Syria
ADIM-11 Economic evaluations of trial data on agronomic practices for cereals and food legumes

ADIM-12 Diagnosis of lentil production in Morocco
ADIM-13 Adoption and impact of improved wheat production technology in Syria
ADIM-14 Field demonstrations of supplemental irrigation of wheat
ADIM-15 Farm survey of supplemental irrigation of wheat and barley in Libya

TRAINING AND AGROTECHNOLOGY TRANSFER

المركز الدولي للبحوث الزراعية في المناطق الجافة
ايكاردا
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ICARDA-221/1300/July 1991