FARM RESOURCE MANAGEMENT PROGRAM

Annual Report for 1995

About ICARDA

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

The mission of the CGIAR is to contribute, through its research, to promoting sustainable agriculture for food security to alleviate poverty and hunger in developing countries. The CGIAR conducts strategic and applied research, with its products being international public goods, and focuses its research agenda on problem-solving through interdisciplinary programs implemented by one or more of its international centers, in collaboration with a full range of partners. Such programs concentrate on increasing productivity, protecting the environment, saving biodiversity, improving policies, and contributing to strengthening agricultural research in developing countries.

In the context of the challenges posed by the physical, social and economic environments, ICARDA's mission is to improve the welfare of people in the dry areas of the developing world by increasing the production and nutritional quality of food while preserving and enhancing the resource base. ICARDA meets this challenge through research, training, and dissemination of information in partnership with the national agricultural research and development systems.

ICARDA serves the entire developing world for the improvement of lentil, barley and faba bean; all dry-area developing countries for the improvement of on-farm water-use efficiency, rangeland and small-ruminant production; and the West Asia and North Africa region for production enhancement of bread and durum wheats, chickpea, and farming systems. ICARDA's research provides global benefits of poverty alleviation through productivity improvements integrated with sustainable natural-resource management practices.

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

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

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

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

FRMP REPORT 1995

1. INTRODUCTION

1.1 Content of this Report

The general purpose of agriculture at the national level is to produce commodities -- crops and animals -- for feeding and clothing the people and for creating national revenue by export. However, at the level of the individual farm the view is different. Each farmer does more than simply grow wheat or cotton, or raise sheep. He optimizes his many farming activities in the best way he can to provide himself and his family with a safe and acceptable livelihood. He will usually grow different crops on different fields each year. If he also has animals, he will try to integrate crop and animal production activities so that they help each other: for example, forage crops and crop residues as feed for animals; and animal manure as fertilizer for the crops. These integrated mixtures of agricultural activities are termed farming systems.

The nature of the farming system practised on any farm is determined partly by the wider social, economic and political environment -- or human society -- to which it belongs. For instance, what are the local traditions and skills, what are the prices offered for particular commodities, and what are the local policies and regulations governing farming?

Equally, in each place, the farming system depends also on the local biophysical resources: for example, what are the rainfall (and other climatic) limitations; is irrigation water available; what is the quality of the soil; for animals, what is the availability and quality of grazing land?

If agricultural research is to help farmers to be more productive (and to be more <u>sustainably</u> productive), it must take account of all these factors. It must look at how the many different farm activities fit together, and how they might be better integrated to become more productive. It must also examine how these activities match the climatic potential and how they utilize the natural resources -- soil, water and grazing lands -- so that more productive <u>but</u> non-damaging ways of utilizing those resources can be shown to farmers.

It is these broad issues -- of farming systems and their utilization of the natural resources -- that provide the agenda for farm resource management research within ICARDA's Farm Resource Management Program (FRMP). Its scope may be summarized as

- climate and land (soil, water, vegetation)
- farming systems that utilize these resources
- social, economic and policy contexts

<u>and</u> their interactions,
especially as they affect productivity and the conservation of the natural resource base.

The concept is

PRODUCTION

depends on

FARMING SYSTEMS

which depend on the

NATURAL RESOURCE BASE

and FRMP's concern is particularly with the system and resource base upon which production is founded. Research aims are broadly:

- to promote the effective and sustainable utilization of soil, water and vegetation;
- to identify biophysical and socio-economic constraints to productivity and ways to relieve them;
- appraise the effectiveness of new inputs and technologies, in their biophysical and socioeconomic context.

Under ICARDA's current Medium Term Plan (1994-1998), FRMP research activities are organized within the following five Projects:

: Agro-ecological characterization
: Resource conservation and management
: Agronomic management of farming systems
: Socio-economics of natural resource management
: Production systems, adoption and impact.

In each project, activities comprise research conducted directly by ICARDA scientists <u>and</u> also many collaborative projects conducted by National Program scientists, in which the ICARDA scientists are partners.

This Report covers activities conducted, completed or summarized during the calendar year 1995, and for the first time it is formulated in terms of the five Projects listed above. As in previous years, the Report does not seek to summarize all ongoing activities, many of which have a fairly long-term perspective; rather, to provide examples of such work and a record of activities that have reached a suitable stage for summarizing. The Report has been written during 1996, which is proving to be a year remarkably busy in events highly competitive with report writing. As a result, we are later and perhaps a little less full in our technical coverage than usual. We will seek to catch up, in both respects, when we report 1996.

1.2 Staff News

There were remarkably few staff changes during 1995. We were delighted by the return of Dr Aden Aw-Hassan, previously an FRMP Rockefeller fellow in the Cairo office, as the new coordinator of DRMP (Dryland Resource Management Project, see 5.2, below); but appointments to the two vacant posts of agroclimatologist and soil conservation/land management specialist were delayed until 1996. Dr Hazel Harris returned for a short period as a consultant and, among other things, contributed to the planning workshop for the new long-term trials in Egypt (see 3.3); and Dr Michel Wakil made brief reappearances during the year from his parallel careers in McGill and Aleppo Universities to keep several support staff busy and maintain our contact with the problems of using brackish groundwater (see 3.2).

We were also very pleased to welcome three new support staff to the Program during the course of the year: Hala Khawam, as assistant to Abelardo Rodriguez in agricultural economics; Ahmed Hamoud, as a meteorological recorder with Wolfgang Goebel; and Maher Hamoudeh, to strengthen Theib Oweis' field team in water studies. Not least, we were glad to see Mustafa Darwich back in FRMP, working with Rick Tutwiler as a technical consultant on the Mohassa project, filling the place of Joanna Haider, whose sad loss early in 1995 we reported last year.

1.3 The Weather in Northern Syria during the 1994/95 Cropping Season

The growing season of 1994/95 started with an exceptionally rainy period from mid-November until the beginning of December. This wet and mild start to the season was followed by a December with near-normal rainfall and fairly cool temperatures below the long-term average for the month. January rainfall was about average during the first two decades, but from then on mostly dry weather prevailed until April, when two events, one at the start, the other in the middle of the month brought unusually abundant rainfall for this time of the year. With the exception of a cold spell during the third decade of January, the air temperature was slightly above average from the end of December until the third decade of March, slightly below average from then on until mid-May. The last rains of the season fell at the end of May and the start of June.

The wet period at the start of the season helped crops all across northern Syria to establish well. The problems came from the rather dry spell extending from the third decade of January until early April or mid-April. While the April rains came early enough to benefit wheat and legumes in the wetter part of the area, including Tel Hadya and Jindiress, they came too late to benefit the crops at the drier sites, like Breda and Buider, which were already maturing. The result was a wide yield gap between wetter and the drier areas. For barley, the spatial picture was similar, though for different reasons. Because of the inherently early maturity of this crop, the late rains came too late to have any impact on yield even at sites like Tel Hadya. If anything, they caused some yield loss due to lodging. But the temperature distribution throughout winter and spring permitted the crop to take optimal advantage of the moisture stored in the soil during the initial wet period in autumn. This stored moisture was sufficient for high yields in the more humid zone but not in drier areas.

Table 1.1 Monthly precipitation (mm) for the 1994/95 season

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	TOTAL
<u>Jindiress</u>													
1994/95 season	0	25	151.3	75.9	85	32.8	58.2	58	27.6	5	3.4	0	522.2
Long term average (35s.)	1.5	29.6	57.3	91.4	85.0	74.7	61.9	41.1	22.5	4.0	0.1	1.4	470.5
% of long term average	0	84	264	83	100	44	94	141	123	125	34	0	111
<u>Tel Hadya</u>													
1994/95 season	1.3	15.7	98.1	45.1	42.4	16.5	24.5	48.3	19.5	1.5	0.0	0.0	312.9
Long term average (17s.)	0.5	24.8	50.0	52.2	62.8	57.3	39.3	25.6	16.5	2.7	0.0	0.8	332.4
% of long term average	260	63	196	86	68	29	63	189	118	56	-	0	94
<u>Breda</u>													
1994/95 season	12.2	2.2	59.8	48	35.2	18.2	14.8	31.8	15.2	6.8	0.0	0.0	244.2
Long term average (37s.)	1.6	14.4	30.0	50.0	47.5	40.0	32.2	28.6	16.3	1.4	0.0	0.0	262.0
% of long term average	762	15	199	96	1.12	46	46	111	93	485	-	-	92
<u>Boueidar</u>													
1994/95 season	8.7	5.1	79.4	27.3	30.6	11.6	12.2	22.6	1.4	4.2	0.0	0.0	203.1
Long term average (22s.)	0.5	17.7	27.4	35.4	42.3	36.1	26.2	16.6	9.6	7.0	0.1	0.0	218.9
% of long term average	1740	29	290	77	72	32	47	136	15	60	0	-	93
<u>Ghrerife</u>													
1994/95 season	1.8	3.8	45.8	38.6	30.7	10.3	18.8	23.8	2.8	4.2	0.0	0.0	180.6
Long term average (10s.)	0.5	25.8	29.9	37.3	46.5	42.8	31.4	11.4	16.4	2.9	0.0	0.0	244.9
% of long term average	360	15	153	103	66	24	60	208	17	145	-	-	74
<u>Terbol</u>													
1994/95 season	4.6	11.2	151.2	177.8	73.2	46.4	46.2	19.4	0.6	0.0	0.0	0.0	530.6
Long term average (14s.)	0.4	24.1	73.1	102.5	118.3	104.2	89.0	22.8	16.4	2.4	0.2	0.0	553.4
% of long term average	1150	46	207	173	62	45	52	85	4	0	0	-	96

Table 1.2 Monthly air temperature (°C) for the 1994/95 season

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
<u>Jindiress</u>												
Mean max.	36.6	30.7	17.7	9.7	11.2	15.2	16.2	20.3	28.5	32.9	34.2	34.5
Mean min.	21.6	17.4	8.9	3.1	5.6	4.2	4.2	7.5	12.1	18.1	21.6	22.7
Average	29.1	24.0	13.3	6.4	8.4	9.7	10.2	13.9	20.3	25.5	27.9	28.6
Abs. max.	34.0	38.1	29.0	13.8	15.8	19.1	21.9	27.0	38.3	38.0	38.6	39.7
Abs. min.	18.0	12.2	1.0	-4.8	-1.0	-1.6	-0.3	0.3	6.2	12.4	18.0	20.8
<u>Tel Hadya</u>												
Mean max.	37.3	30.3	17.8	9.6	12.2	16.5	18.9	23.1	31.6	35.7	35.9	37.3
Mean min.	19.9	14.8	7.4	1.6	3.7	2.7	3.4	6.9	11.5	18.6	21.4	22.6
Average	28.6	22.6	12.6	5.6	8.0	9.6	11.1	15.0	21.5	27.1	28.7	29.9
Abs. max.	41.8	36.3	28.5	12.4	17.0	21.8	23.9	30.4	41.8	41.2	38.8	40.5
Abs. min.	14.9	8.0	-2.0	-6.6	-1.2	-2.9	-2.1	0.7	4.7	11.8	17.0	19.2
<u>Breda</u>												
Mean max.	35.8	28.6	16.0	8.0	9.1	14.0	17.7	22.1	30.4	34.7	35.1	36.1
Mean min.	18.6	14.7	6.7	1.6	2.7	2.1	3.2	7.2	12.0	17.5	19.3	19.4
Average	27.2	21.6	11.4	4.8	5.9	8.1	10.5	14.7	21.2	26.1	27.2	27.7
Abs. max.	41.6	35.0	26.8	10.9	14.8	19.1	23.1	29.8	41.6	40.6	38.3	40.0
Abs. min.	13.9	10.2	-0.8	-5.3	-2.0	-3.0	-2.8	-0.8	4.0	12.2	16.4	17.0
<u>Boueidar</u>												
Mean max.	35.4	26.9	16.0	7.6	13.4	16.4	18.5	22.7	31.8	35.8	35.9	37.3
Mean min.	17.1	11.9	6.0	0.9	6.5	4.1	3.4	7.8	13.0	17.3	19.1	18.9
Average	26.3	19.4	11.0	4.3	9.9	10.3	11.0	15.3	22.4	26.6	27.5	28.1
Abs. max.	41.0	33.5	24.9	11.3	19.8	19.8	25.0	30.1	41.2	41.5	39.6	41.7
Abs. min.	13.6	7.4	-0.5	-4.1	0.9	-2.0	-2.4	0.0	5.1	13.0	16.2	15.4
<u>Ghrerife</u>												
Mean max.	36.0	28.9	16.1	5.3	10.2	14.6	19.0	23.2	31.5	35.5	35.5	36.7
Mean min.	20.7	16.3	7.2	-0.9	3.8	3.9	6.3	10.6	15.5	19.5	21.2	21.2
Average	28.3	22.6	11.6	2.2	7.0	9.3	12.7	16.9	23.5	27.5	28.3	29.0
Abs. max.	41.2	35.3	27.2	10.7	15.8	20.1	26.3	31.1	41.0	41.0	38.6	41.6
Abs. min.	16.9	11.7	1.0	-7.8	-1.2	-0.6	1.8	3.0	6.5	13.8	18.8	18.8
<u>Terbol</u>												
Mean max.	33.4	27.7	15.1	9.6	12.4	13.1	17.0	20.5	28.3	32.6	31.7	33.7
Mean min.	11.5	7.7	3.5	-2.5	-2.5	-0.3	0.9	3.2	7.5	10.2	12.5	11.5
Average	22.5	17.7	9.3	3.6	5.0	6.4	9.0	11.8	17.9	21.4	22.1	22.6
Abs. max.	39.3	33.0	27.0	16.5	18.0	19.0	23.5	28.5	38.0	38.0	36.0	37.0
Abs. min.	7.0	3.0	-2.5	-7	-6.5	-4.0	-5.0	-3.0	-0.5	6.0	9.0	5.0

Table 1.3 Frost events during the 1994/95 season

	Nov	Dec	Jan	Feb	Mar	Apr	May	Season
Jindiress								
No. of frost days	-	8	1	3	1	-	-	13
Abs. min. (°C)	-	-4.8	-1.0	-1.0	-0.3	-	-	-4.8
Tel Hadya								
No. of frost days	2	9	5	4	3	-	-	23
Abs. min. (°C)	-2	-6.6	-1.2	-2.9	-2.1	-	-	-6.6
Breda								
No. of frost days	3	10	6	8	3	2	-	32
Abs. min. (°C)	-0.8	-5.3	-2.0	-3.0	-2.8	-0.8	-	-5.3
Boueidar								
No. of frost days	2	13	-	4	3	1	-	23
Abs. min. (°C)	-0.5	-4.1	-	-2.0	-2.4	0.0	-	-4.1
Ghrerife								
No. of frost days	-	20	5	2	-	-	-	27
Abs. min. (°C)	-	-7.8	-1.2	-0.6	-	-	-	-7.8
Terbol								
No. of frost days	6	25	28	20	10	8	1	98
Abs. min. (°C)	-2.5	-7.0	-6.5	-4.0	-5.0	-3.0	-0.5	-7

Table 1.4 Frost events at 5 cm above the ground during the 1994/95 season

Abs. min (°C)	Nov	Dec	Jan	Feb	Mar	Apr	May	Season
Tel Hadya								
Frost days	2	12	8	9	6	1	-	38
Abs. min (°C)	-3	-7	-3	-4	-3.3	0	-	-7

2. PROJECT 1: AGROECOLOGICAL CHARACTERIZATION

INTRODUCTION

Agroecological characterization is essentially the description of agricultural production environments and their interaction with the production systems (and their components) utilizing those environments. Its principal purpose is to provide information and guidance to other research, planning and development departments in their general task of increasing agricultural output and enhancing the welfare and prosperity of farming communities. Its activities include, on the one hand, the collection, processing and integration of climatic, biophysical and, in some cases, socioeconomic information to build accessible, spatially referenced data bases; on the other hand, to describe and explore dynamically, through modelling, the interactions between environments and specific crops (and varieties), cropping systems and management practices. This latter approach has an inherent reciprocality: environments may be characterized in terms of the crops and systems that best fit them; but, equally the requirements that characterize those crops and systems may be used to identify the environments that best suit them. The knowledge generated may help both the design of new technologies (eg crop varieties and production systems) and the targetting of technologies, old and new, to locations that seem likely best to utilize them.

Models of crops and cropping systems are essential tools in this process. Last year we reported: first, how linkage of a weather generator model, summarizing past weather behaviour over a defined area, linked to a wheat growth simulation model, SIMTAG, could be used on a real-time basis to forecast upcoming yields in the target area; secondly, how CropSyst, a management-oriented cropping systems simulation model, had been used to generate a spatially-referenced 30-year output of wheat yields for northwest Syria, taking account of soil type and rainfall zone. This year we report a comparison of these two models, SIMTAG and CropSyst, in respect of their ability to simulate the performance of Cham 1, a durum wheat cultivar, under different irrigation and fertilization treatments, against historical field trial data from Tel Hadya from the period 1989-1992. Results show that both models satisfactorily replicated selected growth parameters over the three seasons, but CropSyst predictions of grain yield were closer to the real values. The next task is to evaluate, and apply, these models over a wider area.

2.1 Comparisons of CropSyst and SIMTAG Simulation Models for Durum Wheat Grown under Different Water and Nitrogen Regimes at ICARDA Research Farm

Introduction

Wheat is the most important staple food crop of West Asia and North Africa (WANA). In Syria, it is grown from the wettest to the driest areas. In wetter areas (over 325 mm mean annual rainfall), wheat is the dominant crop and is in rotation with food legumes and summer crops such as water melon, sesame, cotton, cucurbit. However, the farming systems of the area have to cope with problems of highly variable, and frequently deficient, rainfall (Cooper *et al.* 1987). Water is the primary resource determining agricultural productivity. Supplementary irrigation, ie, supplementation of deficits with minimum quantities of water, is one way to increase productivity and sustain the food requirements of the rapidly increasing populations in the WANA region (Perrier and Salkini 1991).

The impact on productivity of water availability cannot be analyzed independently of weather, soil characteristics, field hydrology, crop characteristics and rotation, among other factors. To develop best management practices (BMPs), it is necessary to integrate these factors into a comprehensive cropping systems approach. A successful method of determining BMPs would provide valuable information to meet the growing demand for agricultural products while minimizing the environmental impact of agricultural activities. However, this information can hardly be obtained by simple reliance on conventional field experimentation.

Computer simulation models, able to capture the long-term effects of weather fluctuations and the effects of various soil properties and management practices on the soil water balance, nutrient dynamics, and crop growth, further our understanding of cropping system performance under different water regimes. Such models should also lead to improvements in the efficiency of decision making for water management.

In anticipation of future applications of simulation models in the region, the objective of this study was to evaluate two models, SIMTAG, developed at ICARDA (Stapper 1993) and CropSyst, developed in Washington State University (Stockle *et al.* 1994; Stockle and Nelson 1994), for their abilities to simulate growth, yield, and nitrogen use of the durum wheat cultivar, Cham 1, grown under different water regimes at Tel Hadya.

The experiment

The field data used for model validation were obtained from a line-source sprinkler experiment (Perrier and Salkini 1991) conducted at ICARDA headquarters, Tel Hadya, during the 1989/90, 1990/91 and 1991/92 seasons using a strip block design with 3 replications. Cham 1, a durum wheat cultivar, was tested under 3 rates of water and 2 rates of N fertilizer in a wheat-chickpea rotation.

In this experiment, the water treatments corresponded to rainfed (W0), 60 (W60), or 100% (W100) replenishment of the deficit when the extractable soil water content in the root zone was depleted to about 50% of the maximum water-holding capacity. The N treatments were zero N application (N0) and 100 kg N/ha (N100). The total amount of water applied for W100 plots were 259, 168 and 208 mm in the 1989/90, 1990/91 and 1991/92 seasons, respectively. The corresponding amounts for W60 plots were 129, 118 and 111 mm, respectively.

Access tubes were inserted in each plot for soil moisture measurements with a neutron probe. Initial soil moisture was measured before sowing, and subsequent measurements were taken every 15 days at early growth stages, and every 7-10 days later in the season, at each 15 cm soil layer down to 150 cm depth. Soil samples were taken just before sowing to determine the initial soil mineral-N (NH_4-N and NO_3-N) and organic matter content, which are inputs necessary for both models to run. Crop samples (0.3 m^2) were obtained at the following growth stages: seedling, tillering, stem elongation, booting, anthesis, dough development and maturity. These samples were used to determine aboveground biomass, green area, and plant N content throughout the growing season.

The soil of the experimental field is classified as a Typic Chromoxerert, a sub-order of Vertisol soil group (FAO), or Calcixerollic Xerochrept, with a depth of more than 1 m. It contains about 25% calcium carbonate, 67% clay, 25% silt and 8% sand, and has a pH of 8 throughout the profile. The lower limit of plant extractable soil water (Permanent Wilting Point) is 22%, and the drained upper limit of soil water (Field Capacity) is 38%, averaged across the profile. Bulk density of the soil ranges between 0.9 g/cm^3 at the surface and 1.3 g/cm^3 in deeper soil layers. It is representative of many of the soils used for cropping in the region, self-mulching clays that are plastic when wet and crack extensively when dry (Cooper *et al.* 1987).

Daily weather data has been collected routinely as needed by simulation models.

The models

a) *CropSyst*: is a management-oriented cropping systems model able to simulate a range of weather/management scenarios on the basis of data from only a few experiments. It is a multi-year and multi-crop daily time step model that simulates the soil water budget, soil-plant nitrogen budget, crop canopy and root growth, dry matter production, grain yield, residue production and decomposition, and soil erosion. Management options include: cultivar selection, crop rotation (including fallow years), irrigation, nitrogen fertilization, tillage operations and residue management. Soil characteristics, initial conditions of available moisture N and organic matter, and daily weather data are essential inputs. The cultivar input parameters used may be either those typical for the crop species or values determined from the experimental data or by calibration (Table 2.1.1). However, the detail of the model has been reported elsewhere (Stockle *et al.* 1994; Stockle and Nelson 1994; Pala 1995).

The evapotranspiration routine may be selected from three reference evapotranspiration simulation models depending on the available weather data, viz:

Simple ET model: precipitation, max. and min. temperatures.

Priestley-Taylor model: precipitation, max. and min. temperatures, solar radiation.

Penman-Monteith model: precipitation, max. and min. temperatures, solar radiation, max. and min. relative humidities, wind speed.

b) *SIMTAG:* is a wheat model, Simulation of Triticum Aestivum Genotypes (Stapper 1993, Stapper and Harris 1989), capable of simulating the growth of bread wheat and durum wheat genotypes. It combines a water-balance module with modules for the simulation of phasic development, growth and yield formation of the crop. The simulation runs on a daily time step and is driven by values of precipitation, maximum and minimum air temperature, and global solar radiation. The data used can be observed weather data or synthetic weather data from a weather generator, to which the model can be linked.

The water-balance module requires information on the soil depth, the fraction of the soil moisture content accessible to the crop by soil layer, and the initial, saturation, and air-dry moisture content values of the particular soil. It simulates run-off, infiltration, deep drainage, and soil moisture redistribution between layers. Potential evapotranspiration is estimated from air temperature and global radiation using a method derived from the Priestley-Taylor Model

Table 2.1.1. Cham 1 crop parameters used for CropSyst model

Growth Parameters	Cham 1
Biomass-transpiration coefficient (kPa kg/m^3) (*)	5.00
Light to above ground biomass conversion (g/MJ)	3.00
At/Pt ratio where canopy growth ceases	0.95
Maximum water uptake (mm/day)	9.00
Critical leaf water potential (J/kg)	-1333
Wilting leaf water potential (J/kg)	-2000
Unstressed harvest index (HI) (**)	0.45
HI sensitivity to water stress during flowering (*)	0.20
HI sensitivity to water stress during grain filling (*)	0.20
Translocation factor (*)	0.30
Crop Phenology	
GDD emergence (°C-d) (**)	100.00
GDD flowering (°C-d) (**)	460.00
GDD grain filling (°C-d) (**)	530.00
GDD physiological maturity (°C-d) (**)	770.00
Base temperature (°C)	0.00
Cutoff temperature (°C)	35.00
Phenological sensitivity to water stress	2.00
Day length (photo-period) for insensitivity (hours)	20.00
Day length (photo-period) to inhibit flowering (hours)	8.00
Crop Morphology	
Maximum rooting depth (m) (**)	1.20
Maximum leaf area index (LAI) (m^2/m^2) (**)	4.00
Fraction of max. LAI at physiological maturity	0.80
Specific leaf area (m^2/kg) (*)	16.00
Leaf stem partition	2.00
Leaf duration (deg-days) (*)	700.00
Extinction coefficient for solar radiation	0.53
Leaf duration sensitivity to water stress	1.00
ET crop coefficient (*)	1.25
Nitrogen parameters	
Max. plant N content at early linear growth (kg/kg) (**)	0.014
Min. plant N content at early linear growth (kg/kg) (**)	0.007
Max. plant N content at maturity (kg/kg) (**)	0.012
Max. N content of standing stubble (kg/kg)	0.006

(*) Calibrated parameters
(**) Parameters determined from data

and partitioned into estimates of evaporation from the soil surface and plant transpiration, depending on the wetness of the soil surface, the size of the transpiring plant surface, and the root density in the various soil layers.

The simulation of the phasic development of the crop is based on photothermal time using base temperatures increasing from 0 to 8 °C with crop development. The onset of flowering is additionally modified by the vernalization requirement of the variety, which is one of the coefficients describing the genetic make-up required as input. Other genetic coefficients used to define crop development are photoperiod sensitivity, critical photoperiod length, and photo-thermal time to floral initiation and to anthesis. The crop input parameters for Cham 1 used in the present study are given in Table 2.1.2.

Table 2.1.2. Cham 1 crop parameters used for SIMTAG model

Parameters	Value
Variety number/kernel size group	17
Vernalization sensitivity factor	0.003
Photoperiod sensitivity factor	0.35
Critical photoperiod	5.0
Thermal time between emergence and floral initiation	280
Thermal time between emergence and anthesis	570
Phyllochron factor	1.13
Grain growth factor	0.127

Dry matter accumulation and redistribution of assimilates, ie growth and yield formation, are regulated by another set of genetic coefficients. The phyllochron interval determines the rate of leaf appearance, and thereby the size of the assimilating surface. Yield formation is based on the dry matter accumulated until anthesis and on the variety-specific traits kernel size and grain-filling rate which, together with the number of kernels per spike, determine what portion of the assimilates can be converted into grain yield under the climatic conditions prevailing during grain-filling. The number of kernels per spike is determined partly genetically and partly by climatic conditions during anthesis. The critical value of dry matter at anthesis is the resultant of the interactions of many factors, including the size of the assimilating surface, the time available for photosynthesis, which again depends on the rate of phasic development, and of the photosynthetic rate, which is reduced during periods of moisture stress according to the stress intensity.

The crop-management data used by the model comprise: variety, sowing date and sowing depth, and the plant density after emergence. The model was developed and calibrated with data from small plot trials, mainly from Syria and areas with Mediterranean-type climate, but also with data sets from other wheat-growing environments around the world. It does not require recalibration for use in different environments. The model assumes optimal nutrient availability and a disease- and pest-free stand. For the correct prediction of yields on large plots, the outputs need to be modified to reflect yield reductions due to imperfect management, nutrient stress, and variable soil conditions, as well as losses from diseases pests, and imperfect harvesting techniques.

Results and discussion

The correct simulation of wheat growth and yield under the harsh conditions prevailing at the study site is not a trivial matter. Yet it is important, if computer-based analytical tools are to be applied to evaluate management options in the region. On the other hand, the variability inherent in agronomic field research must be kept in mind when comparing field and simulated data.

Weather conditions: The 1989/90 cropping season was extremely dry, with a total rainfall of 233 mm (about two thirds of the long-term average), poorly distributed.

The 1990/91 season had a total rainfall of 293 mm (about 11% below the long-term average). A long dry spell during October-November jeopardized crop emergence, requiring the addition of 35 mm of irrigation water to all experimental plots.

The 1991/92 cropping season had a total of 353 mm of rainfall, 7% above the long-term average but poorly distributed (88% of the total rainfall fell during October to February). Temperatures, especially in spring, were lower than the long-term average, and so was evaporative demand, resulting in higher yields.

Crop data: A seasonal summary of data collected during the three years of the experiment is shown in Table 2.1.3. In general, total aboveground biomass and grain yield responses to N fertilization increased with increasing amount of water applied. Total aboveground biomass responded positively to N fertilization for all water rates in all the seasons except for the rainfed plots of 1989/90.

Table 2.1.3. Observed and simulated data of ET (mm), biomass (kg/ha), grain yield (kg/ha), N uptake (kg N/ha) for Cham 1 durum wheat in 3 seasons

Observed data	**Cum. ET,**	**Biomass**	**Grain yield**	**Cum. N uptake**
1990-W100-N100	423.3	8871	3870	87.2
1990-W60-N100	298.6	7308	1910	72.3
1990-W0-N0	197.9	3218	279	26.7
1991-W100-N100	404.4	10192	2349	109.0
1991-W60-N100	325.7	8655	1364	91.0
1991-W0-N0	280.9	5956	1550	35.5
1992-W100-N100	391.2	11437	4829	120.9
1992-W60-N100	288.0	9703	3660	115.0
1992-W0-N0	264.8	7086	2504	55.0
Simulated by	***Cum. ET,***	***Biomass***	***Grain yield***	***Cum. N uptake***
1990-W100-N100	421.5	8760	3598	94.9
1990-W60-N100	286.1	5013	1906	65.7
1990-W0-N0	163.3	3059	916	25.3
1991-W100-N100	365.1	9082	3407	104.7
1991-W60-N100	325.1	8369	2433	101.6
1991-W0-N0	253.4	5606	1659	39.1
1992-W100-N100	401.8	11618	4890	137.9
1992-W60-N100	336.4	10168	3139	129.5
1992-W0-N0	240.6	7304	2432	55.6
Simulated by	**Cum. ET,**	**Biomass**	**Grain yield**	**Cum. N uptake**
1990-W100-N100	372.1	9441	2158	89.0
1990-W60-N100	301.5	7064	1189	71.5
1990-W0-N0	200.6	3172	539	43.1
1991-W100-N100	363.2	11200	4229	101.7
1991-W60-N100	328.8	10181	3171	93.1
1991-W0-N0	261.2	7903	1548	76.4
1992-W100-N100	368.8	11056	3461	99.3
1992-W60-N100	350.1	10263	2867	92.9
1992-W0-N0	266.3	8273	1680	78.5

Grain yield increased in response to N application in the 1989/90 and 1991/92 seasons for all water regimes except the rainfed plots. However, grain yield decreased when N was applied in the 1990/91 season. The anomalous negative response of grain to high N may have arisen because the irrigation was not applied correctly due to persistent high wind. Application was over a prolonged period in small quantities, and the date recorded is about the mean of that period.

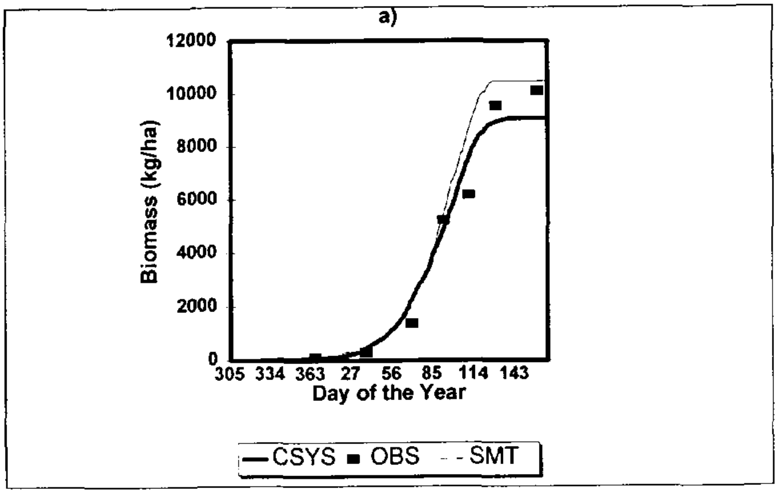
Evapotranspiration ranged between 198 and 423 mm across the seasons (Table 2.1.3). Obviously, water use increased with increasing amount of water applied.

N uptake ranged between 26 and 120 kg N/ha, increasing with increasing rate of water application.

Comparison of model performance: Comparison of the CropSyst with SIMTAG model was made for 9 (100 kg N/ha for W60 and W100, and 0 N for rainfed plots were used) out of the 18 combinations of 3 growing seasons, 3 water treatments, and 2 nitrogen treatments described above, each including the fluctuation of aboveground biomass, cumulative ET and cumulative N uptake throughout the season. Aboveground biomass, grain yield, cumulative evapotranspiration (ET), and cumulative crop N uptake at harvest were also compared.

To evaluate the ability of CropSyst and SIMTAG to track the aboveground biomass, ET, and N uptake progression throughout each growing season, the experimental data points were plotted against the daily simulated data for each treatment. An example is presented in Figure 2.1.1 for the 1990/91 season. Most simulations were similar to this example, with a few cases better or slightly worse. In general, the models tracked changes in biomass, ET and N uptake well throughout the season. This is an important result, because it shows the reliability of the models, when correctly calibrated, in predicting these quantities at harvest time, which is usually the information utilized in the long-term analysis of management practices.

Observed and simulated aboveground biomass, grain yield, cumulative ET and cumulative N uptake at harvest are compared in Figure 2.1.2. Statistical analysis of this information is presented in Table 2.1.4. For both models, the simulated aboveground biomass followed closely the 1:1 line when plotted against the experimental data (Figure 2.1.2a). The statistical analysis also confirmed that both models predicted wheat biomass reasonably well, showing a high index of agreement (d), and root mean square error (RMSE) corresponded to 11 and 13% of the observed mean values for CropSyst and SIMTAG, respectively.



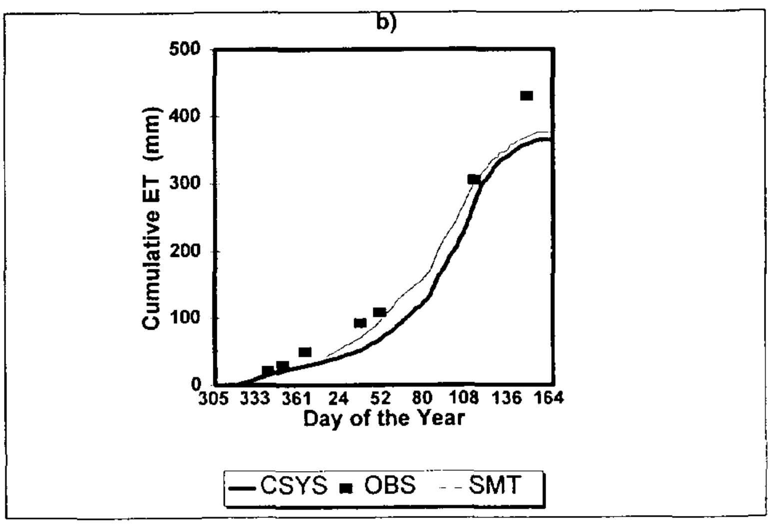


Figure 2.1.1 Distribution of the daily simulated data compared with the observed data obtained at different times during the 1990/91 growing season of Cham 1 durum cultivar, treatment W100/N100, (a) aboveground biomass, and (b) cumulative ET, where (___) represents simulation by CropSyst, (■■) represents observed data points, and (---) repesents simulation by SIMTAG model

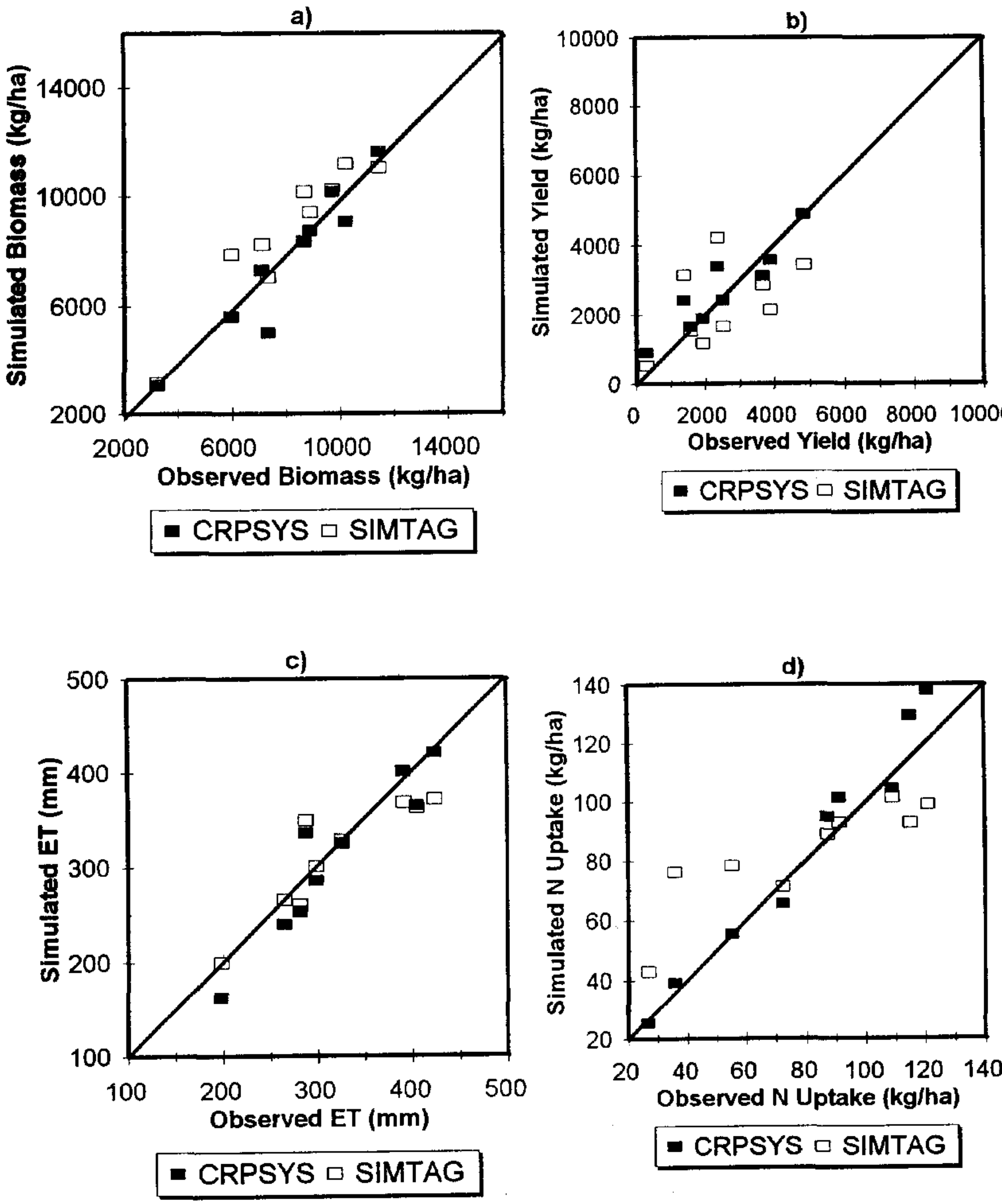


Figure 2.1.2 Comparison of CropSyst with SIMTAG under 100 kg N/ha application for W60 and W100 water regimes, and N-0 under rainfed (W0)

Table 2.1.4. Statistical summary comparing observed data vs. simulations of CropSyst CRSYS) and SIMTAG for biomass (BY), grain yield (GY), cumulative ET and cumulative N uptake (NUP) for Cham 1 durum cultivar

Yield parameters	n	Slope	Const	Adj. r^2	Obs. Mean kg/ha	Sim. Mean kg/ha	RMSE kg/ha	RMSE /Obs. Mean	d (**)
BY-CRSYS	**9**	**1.03**	**-667**	**0.90**	**8047**	**7664**	**884**	**0.11**	**0.97**
BY-SIMTAG	9	0.97	945	0.90	8047	8728	1021	0.13	0.95
GY-CRSYS	**9**	**0.77**	**795**	**0.85**	**2479**	**2709**	**581**	**0.23**	**0.94**
GY-SIMTAG	9	0.44	1214	0.28	2479	2316	1225	0.49	0.72
ET*-CRSYS	**9**	**1.06**	**-28**	**0.89**	**319**	**310**	**27**	**0.085**	**0.965**
ET*-SIMTAG	9	0.72	81	0.81	319	313	32	0.099	0.935
NUP-CRSYS	**9**	**1.13**	**-6**	**0.97**	**79**	**84**	**9**	**0.11**	**0.98**
NUP-SIMTAG	9	0.46	46	0.75	79	83	20	0.25	0.83

*) ET values are in mm.
* *) Index of agreement (d), as defined by Willmott (1982), where $0<d<1$, with a value of 1 indicating perfect agreement between observed and predicted values.

The grain yield predicted by CropSyst seems to be closer to the 1:1 line than that of SIMTAG (Figure 2.1.2b). The statistical analysis showed a reasonable agreement between observed and predicted grain yield data, with the index of agreement of 0.94 for CropSyst. However, SIMTAG could provide an index of agreement of only 0.72. The RMSE values corresponded to 23 and 49% of the observed mean values for CropSyst and SIMTAG, respectively, showing the superiority of CropSyst over SIMTAG for the most important yield component (Table 2.1.4).

The predicted ET at harvest was very close to the actual ET values for both models (Figure 2.1.2c). The index of agreement was 0.97 for CropSyst and 0.94 for SIMTAG with very similar RMSE values.

For N uptake, the prediction of CropSyst was closer to the 1:1 line than that of SIMTAG (Figure 2.1.2d), and statistical analysis confirmed that CropSyst predicted crop N uptake reasonably well. The index of agreement was very high (0.98) and the RMSE value low (11% of the observed mean). SIMTAG, which does not attempt to model N-dynamics in the soil, provided a lower index of agreement value (0.83) and higher RMSE (25%) (Table 2.1.4).

Conclusions

The response of wheat to water and nitrogen management, has been documented in previous studies (Perrier and Salkini 1991; Ryan and Matar 1992). Although valuable, these results are site and year specific and need to be extrapolated in time (long-term responses) and to other regions in order to be more useful. This study suggests that the use of crop modeling, after proper calibration and validation, may be a feasible approach for such extrapolations.

Present results indicate that CropSyst and SIMTAG satisfactorily replicate the field changes throughout the season in aboveground biomass, ET, and N uptake of durum wheat, Cham 1, for 9 of the 18 combinations of 3 growing seasons, 3 water rates and 2 nitrogen levels until el Hadya conditions; and aboveground biomass, grain yield, ET, and N uptake at harvest values were also simulated reasonably well by both models. However, CropSyst was found superior to SIMTAG in predicting grain yield, the most important crop parameter for farmers. Future research will aim to evaluate these models for a wider area. ***(M. Pala and W. Goebel)***

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3. PROJECT 2: RESOURCE CONSERVATION AND MANAGEMENT OF NATURAL RESOURCES

INTRODUCTION

The rationale for this Project, given in the ICARDA Medium Term Plan (1994-1998), is the serious stress suffered by the natural resource base on which agriculture in West Asia-North Africa depends. Much soil is lost annually to erosion by wind and water, aquifer levels are dropping and rangelend vegetation is degrading under the pressure of overgrazing. Thus, new technologies to increase system productivity must take into account the fragile environment on which they will depend for their success and on which they will have an impact; and that environment itself, and its interaction with users and their technologies, urgently requires research attention.

The attention given by FRMP scientists in recent years to technical aspects of resource conservation and management has been focussed mainly on water, which has rapidly become one of the most urgent agricultural issues in the WANA region and many dry areas further afield. This focus was reflected in the special chapter of our 1993 Report on 'Groundwater and Supplemental Irrigation' and in the review of 'Water Harvesting' in our 1994 Report; and it is continued in the three activities reported in the present chapter. However, Program interest in the broader land and soil conservation issues of resource management has meanwhile been maintained under a socio-economic flag (5.2, below) and, further, will be greatly strengthened technically in 1996 by the appointment of a soil conservation/ land management specialist.

Of the three sections of the present chapter, the first (3.1) picks up on the story of water-harvesting. One important conclusion of our review in 1994 was that "the technical success of water harvesting in any location depends on the existence of a real resource, and its size and reliability". For this, appropriate site appraisals are needed and "the research required might be termed 'development of resource appraisal methodologies'". Now we are able to report progress in one such methodology: satellite imagery of a pilot area of the Syrian steppe, processed, analysed and checked for ground truth, has been linked in a geo-information system to a digital terrain model computed from a topographic map, to identify areas suitable for the development of micro- and/or micro-catchments. It is anticipated that from this approach a general methodology will be developed, that matches water-harvesting criteria to a spatially referenced set of land, rainfall, crop and socio-economic data, suitable for application in other arid regions with similar conditions.

The second section (3.2) continues a series of reports on the quality of water used for supplemental irrigation in Syria and its effect on soil and crop performance. The results presented here highlight the apparent influence of soil texture on the relationship between quality of irrigation water and wheat yield. Threshhold water salinity values, below which yields decline, appear lowest on clay soils and highest where soils are loams or sandy loams, with an area of clay loam to loam soils intermediate. It is concluded that, where it is planned to use brackish sources for irrigation, appropriate water quality criteria need to be established to take account of local soil conditions.

Water quality is also an important factor in the work summarized in the third section (3.3). Here, however, the emphasis is on the long-term effects of using different quantities and qualities of water, as well as other inputs, on fully irrigated crops in intensive production systems in Egypt. Such systems are under continual pressure to raise their already very high levels of output, notwithstanding decreases in the quality and/or quantity of the available water; and there are well-justified fears for their ultimate sustainability. Long-term trials have been set up at several key sites, to monitor crop performance and soil and water quality under controlled conditions over time, and to relate trends in these parameters to different crop rotations and the inputs applied to them. It is also planned to monitor farmers and farmers' fields in villages adjacent to each experimental site, to provide complementary information on what is happening over a wider area and under farmer management. This dual approach is seen as providing a possible model for future agricultural resource management research elsewhere.

3.1 Planning Water Harvesting Systems Using Remote Sensing and GIS

Introduction

Dry areas occupy over 95% of the total lands of WANA. By definition, these areas have low annual rainfall and limited renewable water resources. The dry areas' share of the world's available fresh water is very small. Renewable water resources in WANA comprise about 1,250 cubic meters (m^3) per capita, compared with about 7,420 m^3 for the world and 15,000, 20,000, and 23,000 m^3 per capita for Europe, North America, and Latin America, respectively (World Resources Institute 1995). In many countries of the Middle East, available water will barely satisfy basic human needs in the next century (The World Bank 1994).

The demand for water in these areas continues to grow, as human populations and incomes rise. Presently, over 75% of the available water in dry areas is used for agriculture. However, competition for water among various sectors increasingly deprives agriculture of substantial amounts every year. In the dry areas, most hydrological systems are already stretched to the limit, yet more food production is required with less water. Such an objective cannot be attained without substantially increasing the efficiency of use of the available water resources (Tribe 1994).

One of the most inefficiently used resources in dry areas is rainfall. Amounts are low, erratic, and poorly distributed, but the gross annual volume of rainwater received by the vast dry areas is substantial. In many countries it adds up to more than all usable conventional water resources. Much of the rainfall, however, is lost to the atmosphere, either directly in evaporation or indirectly through runoff, with little or no agricultural benefit.

Three rainfall zones may be identified in the dry areas of WANA. At the dry end, where lands receive less than 100 mm mean total annual rainfall, no sustainable agriculture can be supported without full irrigation, and much of the land is actually desert. In contrast, at the wet end, where annual rainfall exceeds 300-350 mm, rainfed cropping is practiced with the application of supplemental irrigation for improving and stabilizing yields where water is available. The third zone, the steppe, which lies in between and receives 100 to 300 mm mean annual rainfall, is the focus of the present work. It has the following characteristics:

a) Total annual rainfall amounts are inadequate for economic crop production.

b) Rainfall distribution is suboptimal. (In fact, most rain comes in sporadic storms which are unpredictable and leave frequent drought periods during the growing season. The occurrence of such periods causes severe moisture stress for growing crops, with crop failure in most years.)

c) Storms with very high intensity are not unusual. When they fall on the crusted, low infiltration rate soils, which are characteristic of this area, runoff occurs and water flows to other areas depriving the land of its share of rainfall.

As a result, most rainwater in this zone is rapidly lost to evaporation. Even that part which flows on the surface as runoff, usually runs to natural sumps where it evaporates or loses its good quality. Research has shown that in the steppe of the eastern Mediterranean region, less than 5% of the rainfall may be used productively by poor rangelands or infiltrate to the groundwater.

Water harvesting, defined as "the process concentration of rainfall into smaller areas, through runoff, and storing it for beneficial use" (Oweis and Taimeh 1996), is an important option for enhancing rainfall effectiveness in this zone and for improving its management for sustainable agricultural production (Critchley and Siegert 1991). Furthermore, experience has shown that rainfed agriculture in this zone is not feasible without the use of water harvesting (Bruins *et al.* 1986).

Unfortunately, many modern water harvesting (WH) projects in dry areas have had little success (Reij *et al.* 1989). Reasons include deficiencies in planning, design, implementation, and also neglect of local socio-economic aspects in several cases. Selection of appropriate sites and suitable methods under the prevailing conditions are among the most important prerequisites for successful WH systems. At a small scale, field investigation is the preferred method for planning and design, since it provides detailed and more reliable information. However, planning WH at a large scale, through field visits, is often tedious and costly, and it may often be hampered by a lack of basic data and infrastructure. Essential information includes topography, vegetative cover, drainage systems, rainfall patterns, land use, soils, and land tenure. Without such information, no WH system can be planned and implemented successfully. It is not unusual to find that, although substantial investments have been made on building WH projects, they are still not functioning several years later. However, studies in other areas such as West Africa, have shown that such difficulties may be overcome by using available remotely-sensed data. Tauer and Humborg (1992) have successfully used remote sensing and GIS as tools for the identification of sites suitable for runoff irrigation in the Sahel zone.

Objectives

The general objective of this study is improved agricultural production to help combat desertification in the steppe zone of WANA by more efficient utilization of rainfall through properly planned water harvesting. Specific objectives include:

1. Identification of potential sites and suitable methods of WH at a pilot site in central Syria.
2. A general methodology for dry areas, by which remotely sensed data and GIS, together with minimum field investigation, can be used to identify and assess sites with potential for WH and advise on the appropriate methods of utilization.

Project Pilot Site

An area of central Syria covering about 33,000 square kilometers (km^2) between latitudes 33.8°N and 35.5°N and between longitudes of 36.8°E and 38.8°E was chosen for this study. This area is covered by the Landsat Thematic Mapper scene of Path 179 and row 36 (Figure 3.1.1). The region is sparsely populated, but with major settlements in Salamiyeh, Palmyra and Quaryatain. There are also scattered minor settlements and small villages mostly in the southern part of the target area. The infrastructure is very poor, especially in the northern part of the area, where only one paved road from Salamiyeh runs to Esriye. No detailed information on topography, soils, rainfall, or socio-economics is available for the area.

The climate in the Syrian steppe is characterized by cold and occasionally rainy winters and dry, hot summers. Mean daily temperature varies from as low as 6°C in January to over 32°C in August. Precipitation occurs during the months from November to April with an annual mean ranging between 350 mm in the northwest to less than 100 mm in the southeast of the project area. Rainfall is highly variable in space and in time and falls as scattered storms, often with an intensity high enough to cause substantial runoff.

Agriculture in this area consists mainly of poor range grazing (about 90% of the project area is rangeland) with some barley and forages in lower-lying areas with more fertile soils. There are also a few small areas of pomegranate, apricot and olive orchards, in addition to vegetables, irrigated with the limited available groundwater.

Soils of the area are classified, according to the FAO system, as Aridisols and Entisols (Ilaiwi 1985; Soil Department of Syria 1990). They have very low organic matter (1 to 2%) and few pedogenic horizons. One common feature is the presence of a surface crust, consisting of a pavement of embedded pebbles,

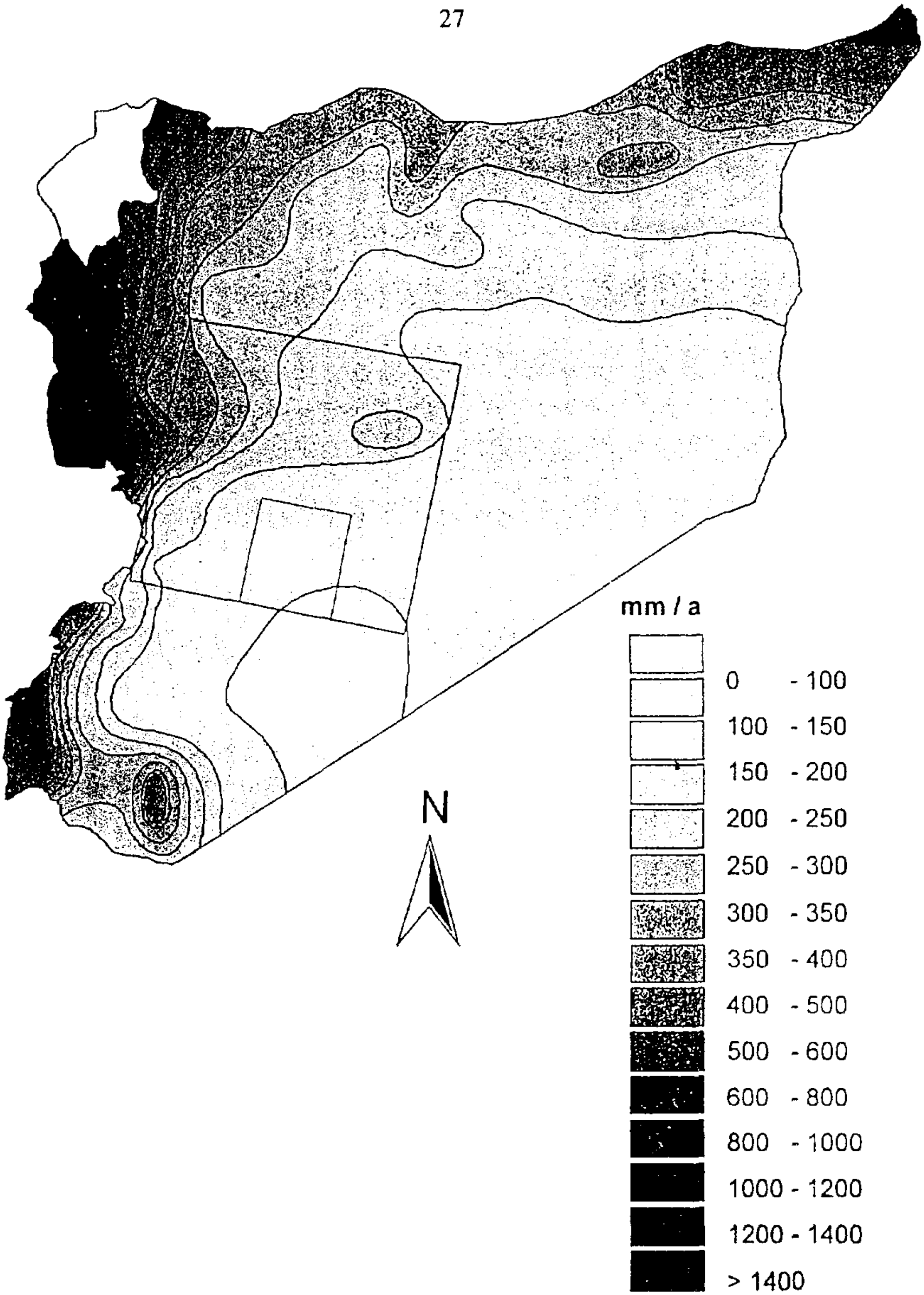

Figure 3.1.1 Study pilot site in Central Syria with landsat scene and rainfall isohyetes

the so-called desert pavement, which impedes infiltration. Some wide plains are often inundated after rainstorms in spring, and the lower slopes of the mountains are dominated by Torrifluvents with a thick horizon of alluvial sediments of loamy fine sand. These soils are relatively enriched in organic carbon and are often used for the cultivation of barley.

The vegetation is dominated by annual and perennial herbs. Local shrubs and grasses are associated with the 'irano-turanian' zone. The most important are trees of *Pistacia atlantica*, rarely seen nowadays, and bushes like *Artemisia herba-alba* and *Haloxyletum articulatum* and annual herbs like *Astragalus spp.* (Cocks *et al.* 1988, Wirth 1971). The natural vegetation is heavily degraded as a result of overgrazing under naturally unfavorable conditions. The disappearance of legumes, in particular, affects the productivity of pastures and illustrates extent of the degradation (Cocks *et al.* 1988). Severe soil degradation follows the degradation of the vegetative cover. The soil loses its stability and becomes vulnerable to water erosion caused by runoff after heavy rain storms.

Methodology

Scenes from the Landsat Thematic Mapper were selected for the evaluation of satellite data. As this sensor has channels in the near and mid-infrared, these data are helpful essentially in the assessment and evaluation of land vegetative cover and geological features. The resolution of 30 by 30 m on the ground is quite sufficient for this sparsely populated arid region where the spatial variability of the features is low. To assess water availability and identify locations with sufficient runoff, it is scenes obtained during rainy periods that should be evaluated. The disadvantage of such scenes is that cloud cover often impedes exact image processing. To avoid this, scenes from shortly after the rainy season, in April 1994 and 1995, were selected. To compare these data to the situation in the dry season, satellite scenes taken in July 1994 and October 1993 were also chosen. A schematic diagram illustrating the process used is shown in Figure 3.1.2.

A geo-information system database was established to ensure the exact fitting of the pixel grid of the image to a map projection system. The pixel grid of the satellite data is usually distorted due to instrument errors. However, radiometric and geometric distortions are caused by earth rotation effects (Lillesand and Kiefer 1994). Rectification was undertaken according to map references of features of known geographical position. In a project area with so few roads and landmarks, the identification of easily recognizable ground control points is difficult. To define the position in the field, the Global Positioning System was used where the coordinate system of the Universal Transverse Mercator projection was applied. The complete satellite scene was divided into 4 subsets for easier handling of the data. The results presented here refer to the south-eastern subset to the south of Palmyra.

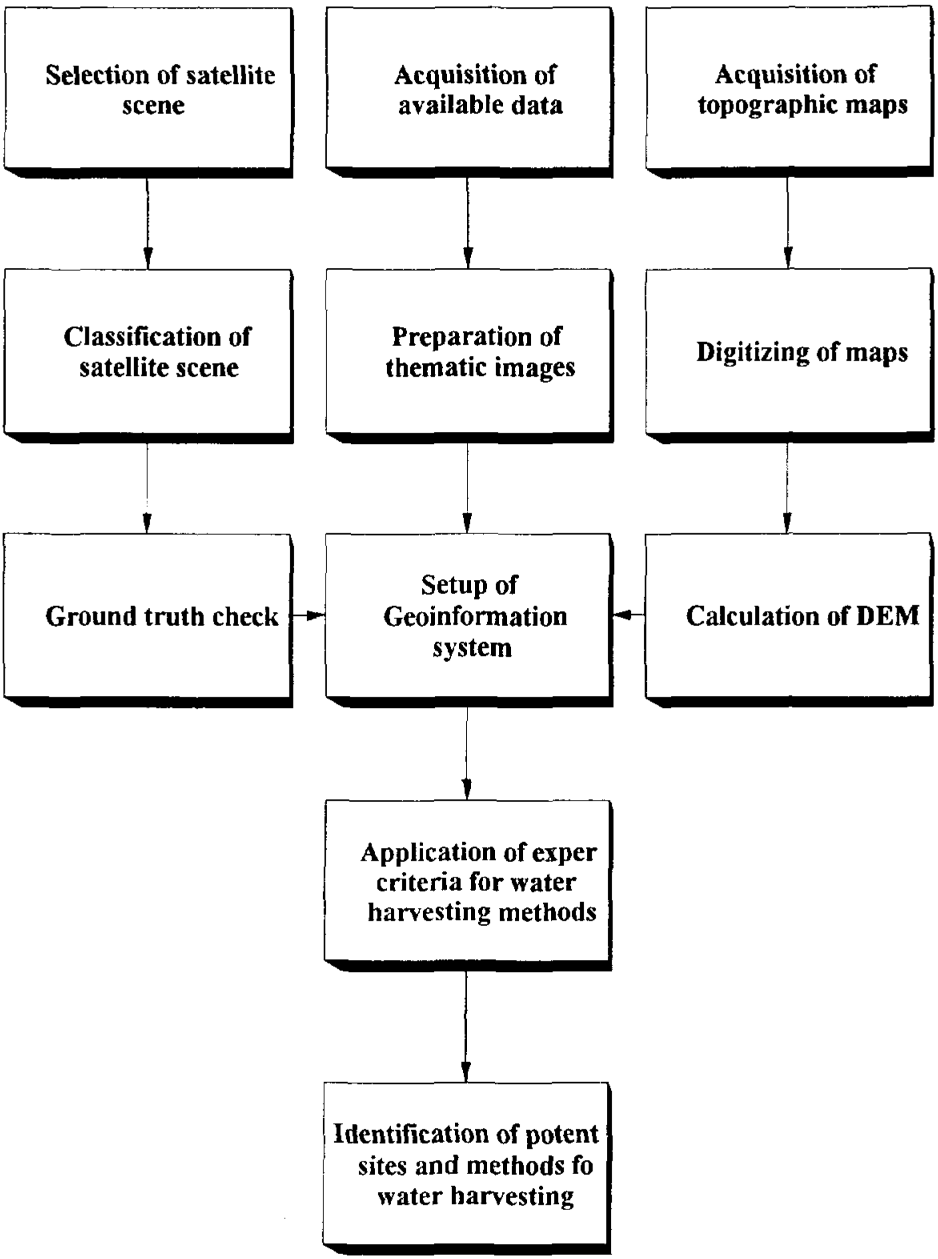

Figure 3.1.2 Planning scheme for the selection of potential sites and methods for water harvesting using remotely sensed data and GIS in central Syria (modified after Tauer and Humborg 1992)

The image was processed on a DEC Workstation using the software ERDAS IMAGINE. To enhance image visibility it was subjected to such optimization processes as filtering and principal component analysis. The resulting images allowed on-screen the digitization of the drainage system and the identification of different features. The false color images (channels 4,3,2) after filtering were the basis for the assignment of the different pixels to classes. The classification process utilized the maximum likelihood procedure. The classification obtained was then checked by field investigation where the typical characteristics of each class were investigated. The separability of the classes was checked by different statistical approaches.

The classified image has been incorporated in a Geo-Information System. Topographic maps available for the project site are of a scale of 1:100,000. They were digitized, and a Digital Terrain Model computed by the ILWIS system. The overlay of the digitized topography maps allowed the determination of slope, which is the basis for the different settings suitable for the various WH techniques.

Expert criteria were developed to match each of the water-harvesting methods and techniques to a set of ground, rainfall, crop and socio-economic conditions. These criteria are based on WH experience in the area and of successful ones from similar areas, and take into consideration the special tenure system and social relations that govern local agricultural activities. Several water harvesting methods and techniques can be considered for areas where topography, soil, rainfall, crops and socio-economic conditions allow. These may be divided into two major types: the micro-catchment and the macro-catchment types (Dutt *et al.* 1981).

Micro-catchments include semicircular bunds, nigarim, contour ridges and other small basins that collect and store rainwater directly in the root zone of trees, shrubs and field crops. The surface runoff from a catchment between 20 m^2 and 200 m^2 is directed to the lowest part of the catchment (infiltration basin) where the crop is planted. The applicability of such techniques is defined in terms of slope ranges, minimum rainfall, vegetative cover, and minimum soil depth for each crop.

Macro-catchments may vary in area from a few hundred square meters to several hundred square kilometers. Runoff water is directed to various water-storage media, and techniques include small earth dams, water spreading structures, hafeers and groundwater recharge systems. Of most importance is the division of land between catchment and cultivated areas and the ratio between the two. Soil characteristics such as depth, fertility, and slope determine the allocation of function, whereas crop water requirements, rainfall amount and runoff coefficient determine the ratio. The major requirements of each method and crop are included in the expert criteria applied to the geographical information base, so that sites and methods of water-harvesting and utilization can be matched appropriately to each other.

After the image processing and classifying the region according to the natural conditions, the classified image is linked to the digital data sets of topography, meteorology and soil. These different levels of information may then be superimposed to establish a Geo-Information System of the target area. Subsequent linkage to the established WH expert criteria leads to a classified image showing local suitability for different WH systems. The developed methodology is expected to be suitable for use in other arid regions with similar conditions.

Preliminary Results

Only preliminary output is presented here. Although the basic work is now complete for the whole scene, semi-final results have been produced only for a quarter sub-scene. Some layers of information are still under development for the area as a whole. These include the soil and climatic maps, the tenure system, the hydrology, and the classification in respect of individual WH techniques. The work on these levels of information and on the other sub-scenes is expected to be finished in 1997 when a complete package will be produced.

The processing and analysis of the satellite images, together with the application of the topography data and some criteria on macro and micro-catchment methods, resulted in the classification of the south-eastern sub-scene into areas favorable, suitable or unsuitable for micro and for macro catchments. Figure 3.1.3 shows the final classification of this area. Although the methodology is not yet complete, this output clearly shows the feasibility of the new approach for identifying high-potential locations and appropriate WH techniques in dry areas.

The analysis of the satellite image could be enhanced by more sophisticated land classification. Eight classes are currently differentiated; rock and scree slopes, bare ground, bare ground covered with flintstones, water bodies, ploughed ground, and three different levels of vegetation, very sparse (widely scattered bushes), sparse (grasses and green bushes) and dense vegetation (in flooded depressions or orchards near villages). This classified image is overlaid by the slope image, computed from the digital elevation model calculated with the digital data set of the topographic maps.

The final image shows that about 12% of the target land area is not suitable for any type of WH. However, about 68% is found generally suitable, out of which 24% is favorable for the application of a macro-catchment WH system. About

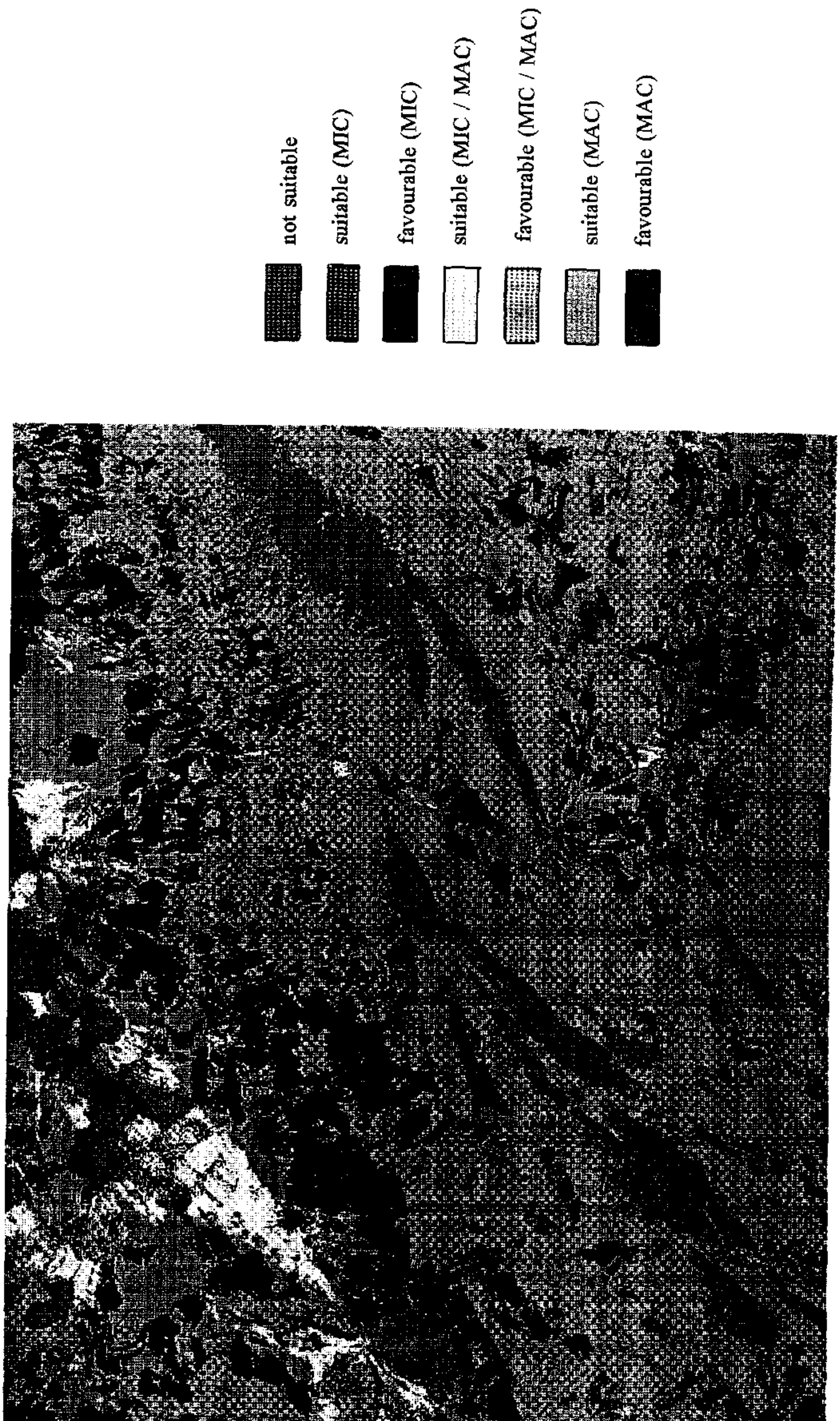

Figure 3.1.3 Land classification acording to suitability to micro - and macrocatchment water harvesting systems in Central Syria

4% of the area is suitable or favorable to micro-catchment WH systems, whereas 3% and 12% are suitable and favorable, respectively, for combined systems of WH methods. This classification supports the view that the main part of the region can be used for the application of one or more types of WH. The improved classification of the image by incorporation of more data that may be delivered by a multi-temporal approach will enhance the final results. Also the incorporation of further data levels will allow a more precise differentiation of the area according to the different topographic settings. Nevertheless, these first preliminary results demonstrate the applicability of the presented methodology. *[Theib Oweis, Annette Oberle (ICARDA) and Dieter Prinz, Karlsruhe University, Germany]*

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3.2 Irrigation water quality criteria for *wheat in semi-arid areas of Syria*

Introduction

There has recently been a very rapid increase in the supplemental irrigation of Syria's winter crops. During the last decade, more than 200,000 ha of new land has been brought under irrigation. Most of this expansion has been based on the exploitation of groundwater, which is of locally variable quality (Wakil 1994; 1995). The largest expansion took place in the Khabur and Aleppo basins, in northern Syria, where wheat is the main crop.

Conventional guidelines for the use of brackish groundwater give a wheat tolerance threshhold for irrigation water salinity of 4 dS/m (or soil salinity of 6 dS/m). This value was obtained from artificially salinized field plots, seeded under non-saline conditions and frequently irrigated (Ayers *et al.* 1952). However, more recent field reports from different parts of the world suggest that wheat does not exhibit the degree of salt tolerance implied by the guidelines (Abdel-Dayem *et al.* 1989; Fowler and Hamm 1980; Oosterbaan *et al.* 1991). The discrepancy between conventional and 'in-field' wheat salt tolerance is due to such factors as initial seedbed salinity, irrigation management including leaching fraction and irrigation timing, as well as climate, soil texture and soil chemistry.

The primary objective of the present research was to determine wheat yield response to irrigation water salinity under local field conditions in three locations in Syria where saline aquifers are used for irrigation: the low plains of the Khabur watershed, the Shedadeh plains (in the Khabur watershed plateau) and the southern plains of the Aleppo basin. All these places lie in the semi-arid zone of northern Syria and have soil textures ranging from clay to sandy loam.

Materials and methods

The climate is 'Mediterranean', characterized by winter rainfall that usually starts in October and ends in May. Mean annual amounts in the Khabur low plains, the Shedadeh area and the southern Aleppo plains are 275, 195 and 262 mm, resepectively, with mean annual potential evapotranspiration (US class A pan) 2230, 2450 and 2580 mm. Irrigated wheat is usually planted in these locations in October and harvested in late June. Local farmers apply four to six irrigations of approximately 50 to 75 mm each, usually coinciding with the planting season (one application), flowering (March) and grain filling (May).

Soil texture differs widely between locations (Table 3.2.1). In the **Khabur** low plains, it is predominantly loamy clay in the topsoil, with clay content increasing in depth, up to 60% at a depth of one metre. This limits the internal drainage of the soil and, in turn, restricts the degree of natural leaching by rainwater. In southern **Aleppo**, soils are clay loams (of subangular blocky structure) in the top 40 cm, grading to (prismatic) loam with depth; aggregates contain many fine pores allowing rapid water movement. At **Shedadeh**, soils are predominantly loamy, becoming sandy loam at depth, promoting good drainability. Soil physical characteristics are shown in Table 3.2.2.

Twenty-two farms in the Khabur basin, eleven in Shedadeh and thirty-two in the southern Aleppo plains were selected for collecting well-water samples and recording wheat yield over two seasons, 1993/94 and 1994/95. The farms selected were all applying the same cultural practices and growing the same wheat variety (Cham 3); and all had an irrigation history of more than three years, since soil salinity profiles may generally be expected to have reached an equilibrium condition after three years irrigation (Beecher 1991; Mehanni and Repsys 1986).

Table 3.2.1. *Typical soil texture values at the three target locations*

	Soil depth (cm)	Clay,%	Silt,%	Sand,%
Khabur low plains	0 - 20	42	44	14
	20 - 40	57	33	10
	40 - 60	61	32	7
	60 - 80	61	30	10
	80 -100	63	29	9
Shedadeh area	0 - 20	31	43	26
	20 - 40	28	45	27
	40 - 60	23	42	35
	60 - 80	21	40	38
	80 -100	17	38	45
S. Aleppo plains	0 - 20	30	44	26
	20 - 40	40	41	20
	40 - 60	45	41	14
	60 - 80	45	39	16
	80 -100	41	41	18

Table 3.2.2. Profile means of soil hydraulic characteristics (water content, cm^3/g) at three target locations

	Saturation	Field capacity	Wilting point
Khabur low plains	53.7	43.4	26.8
Shedadeh area	36.6	29.5	19.6
Southern Aleppo plains	44.8	35.3	20.8

Soil samples were collected from twelve farms in the Khabur and Aleppo locations at which the salinity of well-water varied from 0.43 to 14.1 dS/m, and from two Shedadeh farms with water of 5.3 and 7.4 dS/m (Table 3.2.3). The samples were taken, after harvest, at 20 cm intervals down to 120 cm and analysed for mechanical and physical properties and for electrical conductivity of the saturation extract (ECe), using the methods of the USDA Salinity Laboratory.

Table 3.2.3. Chemical composition of well-water samples at the three target locations

Farm named	EC S/m	Na meq/l	Ca + Mg meq/l	SAR
Khabur low plains				
Dabaghieh	2.95	3.7	37.7	0.85
Sylico PVB3	3.90	11.4	35.1	2.72
Abou Arzale	5.05	18.0	41.9	3.93
Smeihan Gharbie	7.16	42.1	55.5	7.99
Shedadeh area				
Oum Hajar (farm 1)	6.52	36.5	48.6	7.41
Oum Hajar (farm 2)	7.41	45.0	58.3	7.57
Southern Aleppo plains				
Tel Toukan	1.6	7.8	10.1	3.47
Tawahinieh	4.0	20.0	26.6	5.49
Oum-Hota	6.4	38.8	43.5	8.33
Kourbatieh (farm 2)	14.1	74.0	97.1	10.62

Farm yield values were obtained by total wheat production per farm area, and these were converted to 'relative yield' by dividing by analogous values from similar farms irrigated with non-saline water.

Results and Discussion

The relation between relative wheat yield and the salinity of the irrigation water shows considerable scatter, assumed to be caused by differences in inputs and irrigation management practices (Figure 3.2.1). The envelope curves in each case represent the maximum and minimum yield limits. The point, Y, at which the upper curve begins to fall away from the horizontal (relative yield = 1) defines the maximum threshhold water salinity value, ECiw, for each location: 1.2 dS/m for the Khabur low plains (clay soils), 3.5 dS/m for the southern Aleppo plains (clay loam to loam) and 6.5 dS/m for the Shadadeh area (loam to sandy loam).

The differences between locations in these threshhold values (or water salinity limits) is attributed to the local differences in soil texture and structure, which affect infiltration capacity, water retention and, hence, salt accumulation in the soil profile. The degree of lowering of these values, in two locations, below the 'standard' value of 4 dS/m, is of the same order as those reported by Abrol (1990) and Bhumbla (1976); but this result is contrary to the findings of van Horn (1991), Katerji *et al.* (1994) and Pasternak and de Malach (1995), all of whom worked under non-saline conditions at the sowing and early seedling stages.

Figure 3.2.2 shows the soil salinity profiles at the end of the irrigation season at one farm in each of the three locations having well-water of approximately similar salinity. The differences between them suggest that, due to good internal drainage and relatively low soil water retention, salt accumulation in the Shadadeh sandy loam was much less than that in the heavier Aleppo and Khabur soils. Further, the relation between the average salinity accumulated in the soil profile and the the salinity of the irrigation water (Figure 3.2.3) shows that, due to poorer internal drainage, salt accumulation in the clay soils of the Khabur low plains is greater than in the southern Aleppo plains soils. These observations are in agreement with the findings of Singh and Kanwar (1963) and Singh and Bhumbla (1968) that salt accumulation in the soil profile increases with soil clay content.

Moreover, since there is no rainfall in summer, the accumulated salt creates a saline soil medium and hence a saline seedbed for the following wheat crop. This adversely affects crop establishment and subsequent productivity. Reduced establishment results in part from the lower salt tolerance of seedlings relative

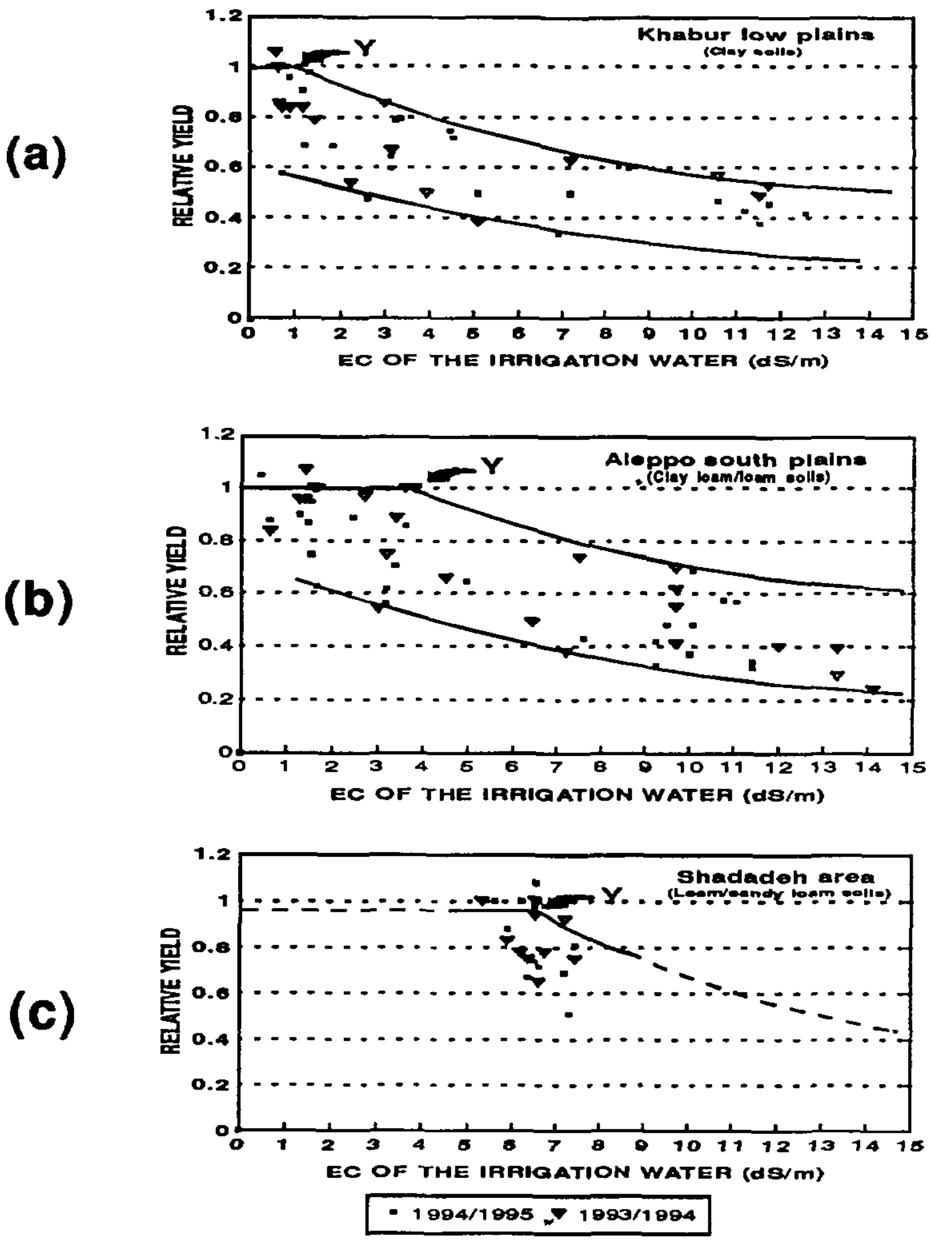

Figure 3.2.1 Relationship between irrigation water salinity and wheat relative yield, for two irrigation seasons in Khabur low plains (a), Aleppo south plains (b) and Shadadeh area (c). "Y" is the threshold water salinity point.

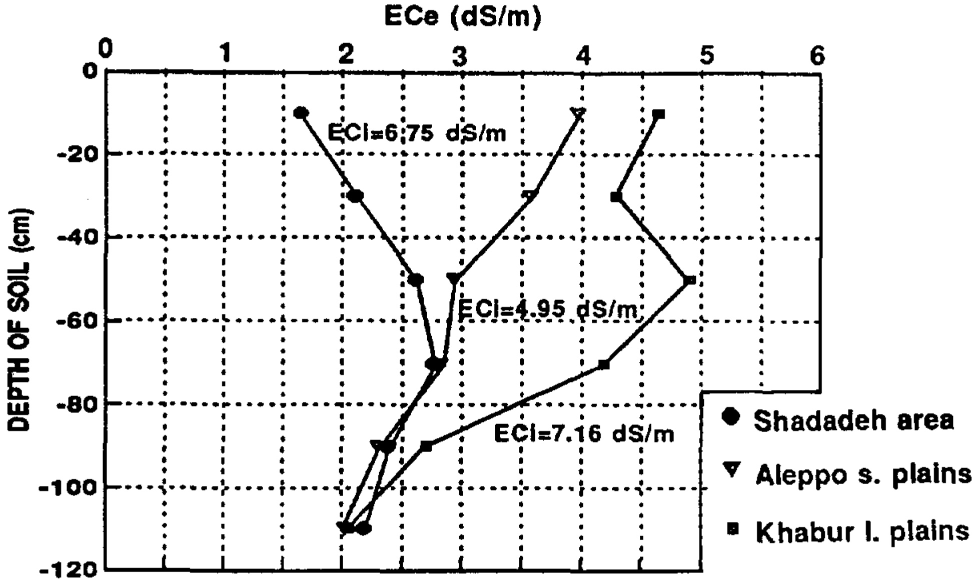

Figure 3.2.2 Soil salinity profiles at the end of the irrigation season in three farms at Khabur low plains (clay soil), Aleppo south plains (clay loam/loam soil) and Shadadeh area (loam/sandy loam soil).

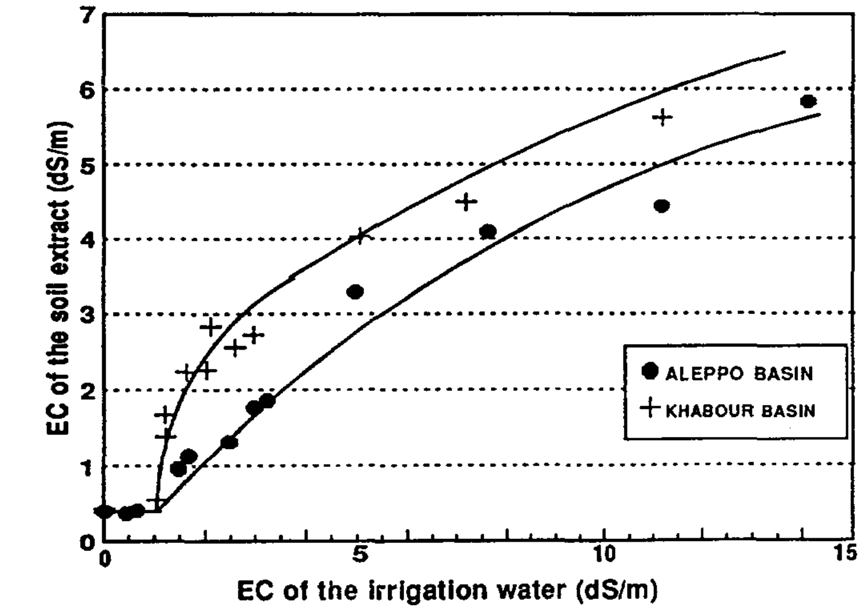

Figure 3.2.3 Relationship between average ECe of the soil upper layer (0-80 cm) with the ECiw of the irrigation water in Khabur low plains (clay) and Aleppo south plains (clay loam/loam)

to that of established plants. In particular, Maas and Poss (1989) and Maas and Grieve (1994) have shown that wheat is very sensitive to salt during germination and early seedling growth.

However, winter rainfall tends to reduce profile salinity, though to a degree depending on soil texture and related permeability. For example, at a farm on the southern Aleppo plains using water of salinity 14.1 dS/m, profile salinity was markedly reduced between the end of the irrigation season and the end of the winter rains (Figure 3.2.4). Similar results have been reported by Styliano and Orphanos (1970) in sandy loam soils with 150 mm annual rainfall. This reduction during rainy period may be expected to benefit plant development during vegetative growth, flowering and even grain filling, as salinity stress then leads to serious reductions in yield.

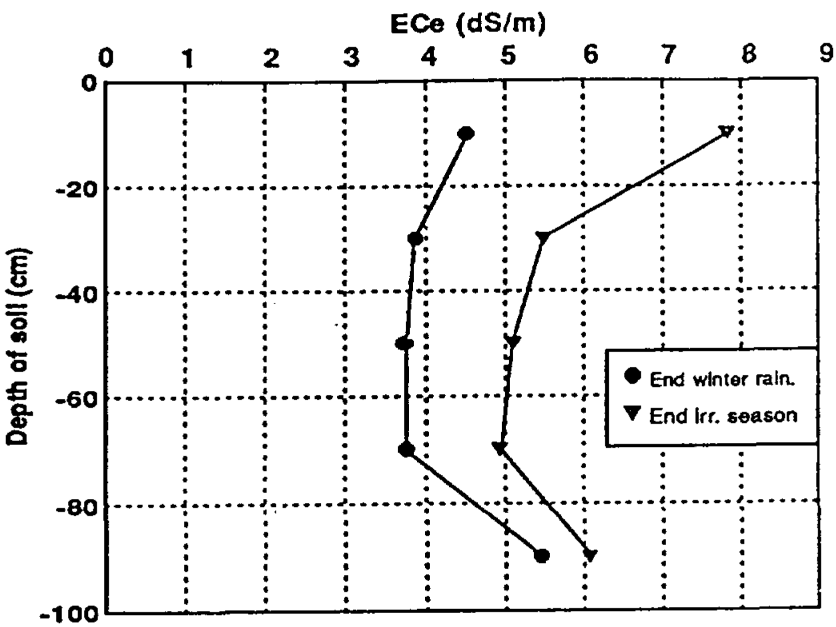

Figure 3.2.4 Soil salinity profiles at the end of irrigation season and after winter rainall in a farm using water salinity of 14.1 dS/m, Aleppo south plains (clay loam/loam soil)

Conclusion

This study has indicated very different levels of tolerance of wheat to the salinity of irrigation water, apparently dependent on soil texture. Such a result underlines the need to establish local quality criteria when planning the use of brackish and saline water in irrigation projects. The work confirms that under field conditions soil clay content affects both the degree of soil salinity accumulation and wheat tolerance to saline water. Wheat yields decline as clay content increases. ***[Michel Wakil, University of Aleppo, with the assistance of Pierre Hayek and Soil Lab technicians]***

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3.3 Building and sustaining the high production capacity of Egypt's irrigated lands: a long-term research program

Introduction

Egypt's highly productive irrigated agriculture is currently subject to unprecedented expansion in area and intensification, while competition with industrial and domestic sectors for the fixed supply of Nile water continues to increase. Salinization, heavy input use, nutrient export and pollution all threaten the health of soils that have been feeding Egypt for centuries. At the same time, the need to create an economically sustainable productive capacity on large areas of newly-reclaimed desert soils poses another major challenge.

To help Egypt meet these challenges, a new long-term resource management component has been developed within ICARDA's Nile Valley Regional Program. This activity aims to promote a sustainably high level of productivity, based upon the protection and maintenance of the resource base (soil and water) through good farm-level management.

Preparatory studies

The first stage of the work, during 1994 and 1995, comprised a series of Preparatory Studies, carried out by a multidisciplinary team representing the Agricultural Research Center (ARC), National Research Center (NRC), Desert Research Center (DRC), Water Research Center (WRC), and AinShams and Cairo Universities. The objectives were: (a) to define and characterize the basic farming systems in the main agroecological environments of Egypt; (b) to identify and prioritize the constraints to the optimum utilization of agricultural natural resources, the threats to their sustainable utilization, and the opportunities for their more productive utilization; and (c) to provide an outline for the strategy, design and implementation of appropriate long-term research activities.

The preparatory studies involved three modes of information collection:

Inventory studies, to identify existing information and gather details of ongoing research and development activities related to soil and water management, agronomy, cropping systems and associated socio-economic surveys.

Rapid appraisals to provide a qualitative sampling, in selected areas, of farmers' and extensionists' views concerning current limitations, constraints, dangers and opportunities in the utilization of soil, water and inputs.

Multidisciplinary surveys, employing short, focussed questionnaires, to fill major gaps in the information base with more quantitative data for the areas selected.

In general, information collected in the Preparatory Studies dealt with resource description, resource utilization and management, productivity, and threats to sustainability. Then through a series of planning meetings, this knowledge was used to select research locations and to identify high-priority researchable problems of resource management in those locations, in the context of realistic cropping sequences and farm-level economics.

Implementing the long-term research program

The new research program covers five locations, with two interrelated modes of activity at each location. The five locations were chosen to represent the old irrigated lands of the main Nile valley and delta, various types of newly reclaimed land (saline, sandy and calcareous soils), and the rainfed areas of the northern coast. The two modes of activity are:

- an intensively monitored, long-term rotation trial on one representitive (on-station) site in each of the five locations:
- an extensive program of regular monitoring of farmers' activities and farm resources in the area surrounding the site of each long-term trial.

The long-term trials were planned and initiated during 1995. Plans for the on-farm monitoring will be finalized, and field work started, during 1996.

Long-term trials

<u>Old irrigated lands</u>. These lands, in the Nile valley and delta, already supporting highly productive, intensive systems with close animal-crop integration, are now under pressure to become more intensive and more productive -- despite decreased water availability or poorer quality. The **Sids** location in Middle Egypt was chosen to represent such situations. Results of the Preparatory Studies had shown that the main threats to sustainability in these areas are:

- ongoing changes in the quantity and quality of the irrigation water;
- inadequate drainage systems, especially when coupled with overuse of water by farmers, leading to rising water-tables and salinity build-up;
- increasing use of low quality (field drain) water by farmers;
- overuse of fertilizer, and pollution from both fertilizers and pesticides;
- reduced integration of animals and crops.

The experimental treatments for the long-term trial were chosen, as far as possible, to represent these problems and possible solutions to them. Comparisons will be made in respect of

: irrigation water quality - fresh v. drainage
: irrigation water quantity - crop requirement v. overuse

: fertilizer rates - zero, low, medium and high
: manure - with v. without (with appropriate adjustments according to actual crop),

all within two contrasting three-year crop rotations:

- 'prevailing'(locally), ie, (yr 1) berseem-cotton; (yr 2) wheat-maize; (yr 3) faba bean-tomato;
- 'improved, high-input', ie, (yr 1) onion-cotton; (yr 2) wheat-soybean-sunflower; (yr 3) faba bean-tomato.

All three phases of each rotation are planted each year, and each phase comprises two (or three) crops, eg berseem in winter followed by cotton in summer.

Newly reclaimed lands. Three locations were chosen to represent three different types of newly reclaimed land:

Nubaria represents newly reclaimed calcareous soils, on which the specific management problems are

- soil crust formation;
- fertility imbalance and ineffective biological N fixation;
- lack of sustainable and profitable crop rotation;
- weeds and overuse of pesticides.

The long-term trial is conducted on the same basis as that at Sids; the experimental treatments chosen for it are

: irrigation water quantity - crop requirement v. overuse
: fertilizer rates - low, medium and high
: manure - with v. without,

which are compared within the two contrasting three-year rotations:

- 'prevailing', ie, berseem-maize; wheat-maize; wheat-tomato
- 'improved', ie, berseem-sunflower-tomato; sugar beet-maize; wheat-soybean-forage maize.

El-Bustan represents newly reclaimed sandy soils, which have such management problems as

- overuse of irrigation water, with high water-table and salinity build-up in some areas;
- nematode infestation in prevailing groundnut (summer crop) based rotations;
- foliar diseases, white-fly and aphids.

The long-term trial here has the following experimental treatments

: irrigation water quantity - crop requirement v. overuse (using at this site a sprinkler system)

: fertilizer rates - low, medium and high

: manure - with v. without,

which are compared within the two contrasting three-year rotations:

- 'prevailing', ie, wheat-groundnut; wheat-groundnut; berseem-groundnut
- 'improved', ie, wheat-groundnut; lentil-sesame; berseem- millet or potato.

El Serw represents newly reclaimed heavy-clay saline soils, for which the main problems identified were

- lack of fresh water and use of poor quality (drainage) water;
- ineffective biological N fixation;
- overuse of N fertilizer on legumes (and underuse on cereals).
- inadequate drainage system
- rising water table.

The experimental treatments chosen for the long-term trial here are

: irrigation water quality - fresh v. drainage

: fertilizer rates - zero, low, medium and high,

compared within three three-year rotations contrasting in respect of the water (or irrigation intensity) of the constituent crops :

- 'wet', ie, berseem-rice; berseem-rice; berseem-rice
- 'moderate', ie, berseem-rice; berseem-rice; wheat-maize
- 'dry' ie, faba bean-rice; sugar beet-sunflower; berseem-cotton.

<u>Rainfed lands</u> are characterised by a harsh production environment of low natural capacity and inherent physical fragility. North Sinai was selected as the location of study, centred on an experimental site at **El-Barth**. This site typifies flat, rainfed arable areas, where water harvesting does not provide an appreciable contribution to the water budget. The overall objectives of the long-term trial here are: sustainable fertility build-up and maintenance in arable land; crop diversification and rotation; water-use efficiency; and enhanced crop-animal synergism. Thus, the experimental treatments are

: fertilizer (P in cereal seedbed + N topdressed in 'high' rainfall years) - with v. without

: manure - with v. without

: legume inoculation.

The prevailing 'rotation' is barley (or wheat) monoculture, which will be compared with several different two-year rotations (one crop per year):

- barley - lentil
- barley - lathyrus
- barley - fallow,

each with two-phase entry (ie, both phases grown each year).

For each of the five experimental sites, a program of data collection has been devised (yields, soil, water and crop sampling, etc), within limits imposed by manpower resources, that will build up into a long-term data base for subsequent evaluation of rotational and treatment differences in productivity and trends in yields, soil and water condition, and pest and disease incidence.

Extensive monitoring

At each of the above five locations, it is planned to monitor farmers and farmers' fields in villages around the experimental site, to provide complementary information on what is happening over a wider area and under farmer management. Farmers will be chosen to represent different local situations of soil and water resource condition and socio-economic circumstances. Socio-economic and biophysical information will be collected in parallel, by a multidisciplinary team. Across all sites, this will include: in the socio-economic dimension, initial information on farm and farm family resources and characteristics and then subsequent regular recording of farmers' management decisions, activities and inputs; and, in the biophysical dimension, on the same farms, regular recording of the main parameters of crop growth and yield, soil fertility, soil salinity and water quality.

In addition, at the different locations, other parameters may be measured once or regularly according to local priorities. Thus in farmers' fields at **Sids,** special emphasis will be given to the quantity and quality of the water used and the long-term trends in soil salinity and herbicide and heavy metal content. In the newly reclaimed calcareous soils at **Nubaria**, monitoring will focus on irrigation methods, on farmers' control of weeds, diseases and pests, and on farmers' choices of crops and crop sequences. In the newly reclaimed sandy soils of **El-Bustan**, emphasis will be given to nematode infestation, fertilizer use in relation to legume nodulation, and farmers' perspectives on excessive irrigation; in the saline soils of the **El-Serw** area, on water quality and quantity, depth to water table and trends in soil fertility; and, in the rainfed areas around **El-Barth**, to farmers' choice of site and crop, to local utilization of water harvesting techniques, and to the occurence, severity and consequences of wind erosion.

Conclusion

Given their scarcity (on a per capita basis), the existing natural agricultural resources of land and water must be maintained intact, even enhanced, and further degradation avoided. The development of a new research methodology for long-term agricultural resource management in Egypt offers the opportunity to learn how to control the various processes of degradation before they seriously undermine the potential of the resource base. Further, the two interrelated components of the work --- long-term on-station trials and on-farm monitoring -- will provide a multidimensional view of each problem, not just a biophysical view of what happens under controlled conditions, but also how things happen, perhaps differently, under uncontrolled conditions, and why they do, and what changes the farmer can and will make to remedy the situation. This dual approach, we believe, will not only help Egyptian farmers to maintain high productivity without adverse effects on the environment but will also provide a model for future agricultural resource management research elsewhere. ***[Mohamed Abdel Monem and Hamdy Khalifa (Cairo Office) and Mike Jones, acknowledging important contributions from Mahmoud Solh, Ahmed Kamel and many others in Egypt and FRMP, Syria]***

4. PROJECT 13: AGRONOMIC MANAGEMENT OF FARMING SYSTEMS

INTRODUCTION

Over many years, agronomic research activities in the Farm Resource Management Program have related mainly to two general technical themes, linked and given intellectual coherence by a practical, applied 'farming systems' philosophy. Those themes comprise (a) a long-term approach, looking particularly at sequential and rotational effects of crops, cropping systems and management strategies, first, on production and, more recently, on the sustainability of production; and (b) the efficient use of inputs, especially nutrients and water. Each is driven by an increasingly strong perception that WANA agriculture, even rainfed agriculture, must become more intensive; and each is pursued, in both on-station and on-farm venues, in the context of actual farm-level circumstances and economic and policy realities.

This background is reflected in various ways in each of the six reports given in this chapter. The first activity (4.1) demonstrates our belief that research awareness of farm-level realities is just as important for NARS agronomists as it is for those at ICARDA, if possible more so; and, in Iran, we have been fortunate in achieving good working relations with the newly established Dryland Agricultural Research Institute (DARI). Practical training courses have been conducted in the field in northern Iran with the dual purpose of introducing DARI colleagues to the farming systems approach while at the same time, with them, surveying farmers and farm problems to guide the subsequent planning and design of relevant on-station and on-farm trials.

The next three reports summarize results coming out of our own on-station long-term studies. At Breda, different tillage and crop residue management treatments in long-term barley-barley and barley-vetch rotations have, over five years, had very little effect on the yield performance of either crop (4.2). Soil water data suggest that these treatments, chosen to represent water-conservation practices found effective elsewhere, have had only a highly marginal effect on rotational water-use efficiency in the harsh Breda environment.

Last year we reported a biometric procedure to quantify yield trends in long-term trials. Further application of these procedures to longer sequences of data, with adjustment for planting date, indicate that over a nine-year period grain and straw yields at Tel Hadya, but only straw yields at Breda, were maintained in continuously cropped barley by annual N and P fertilization (4.3). Further, comparison with barley-fallow rotations showed that the higher yields after fallow did not usually compensate for the lack of production in the alternate fallow year. Thus, as long as serious pest and disease build-up can be avoided, farmers' continuous cultivation of barley appears justified.

While seasonally-compensated yield trends provide an essential check on production sustainability, measurements of long-term changes and treatment differences in soil properties give other, more basic, indicators of crop and management effects on the resource base. After ten years cropping, appreciable and probably significant differences are evident, in topsoil organic matter and total nitrogen contents, among seven two-year wheat-based rotations (4.4). In general, values of these two parameters are higher where the alternate crop is a legume, and annual medic appears particularly effective in maintaining high soil organic matter and nitrogen contents. There are probable implications here both for soil physical properties, such as aggregation, and for the nitrogen fertilizer needs in the wheat phase of the rotation.

Nitrogen is the subject of the final two reports in this chapter. Deficient in many soils, fixed in varying degrees by different legume crops, but widely applied from the fertilizer bag, nitrogen is an elusive and volatile nutrient; and efforts to improve the efficiency of its utilization from all sources constitute an important but always complex research field. Both the present studies utilized ^{15}N. The first (4.5), a UK ODA-funded activity, conducted jointly with Reading University, sought to quantify major aspects of the nitrogen cycle in several crop rotations within the long-term wheat-based trial referred to above. Its provisional, rather pessimistic, findings are that: wheat recovery of fertilizer N may be very low, the result partly of apparently large losses of fertilizer N soon after application; and that neither chickpea nor lentil crops, though supplying much of their own nitrogen needs through fixation, make any positive net input of N into the system.

These results conflict in some respects with those of the second ^{15}N study, which followed the uptake of fertilizer N by wheat grown at four different rates of supplemental irrigation. Fertilizer recovery here was much higher, and considerable immobilization of applied nitrogen by the soil organic fraction was indicated. The reason for the discrepancy between findings has not yet been identified, but it well illustrates the hazards (and possibly situation-specific nature) of such research.

4.1 Crop Production Practices in the Farming Systems of Maragheh and Hashtrod provinces of Iran

Introduction

With financial support from the Iranian Government, ICARDA has a committment to assist the development of the recently established Dryland Agricultural Research Institute (DARI). One feature of that development has been the inclusion of a 'farming systems' dimension into DARI's research approach. This was initiated with a training course on 'Farm Survey Methodology' conducted at DARI headquarters at Maragheh in May 1994, to familiarize researchers of DARI with the utility and practice of farmer-orientated research approaches. To follow up on this, a second, practical training exercise was conducted in May 1995: (i) to enhance the skill of DARI researchers on conducting practical diagnostic farm surveys, with particular emphasis on questionnaire design, analysis and data interpretation, (ii) to provide a preliminary description and problem identification of major rainfed farming systems in Maragheh area; and (iii) to use the findings to guide the planning and design of on-station and on-farm trials.

A questionnaire was designed and farm survey conducted in the important agricultural areas of Maragheh (1300 m altitude) and Hashtrod (1600 m) provinces (Figure 4.1.1). A sample of 49 farmers was chosen randomly, using a multi-stage sampling method, and was interviewed by the trainees during the course. Analysis of the data collected provides an overview of the current farming system in the two provinces, identifying major constraints to crop improvement, and priorities for an adaptive research program.

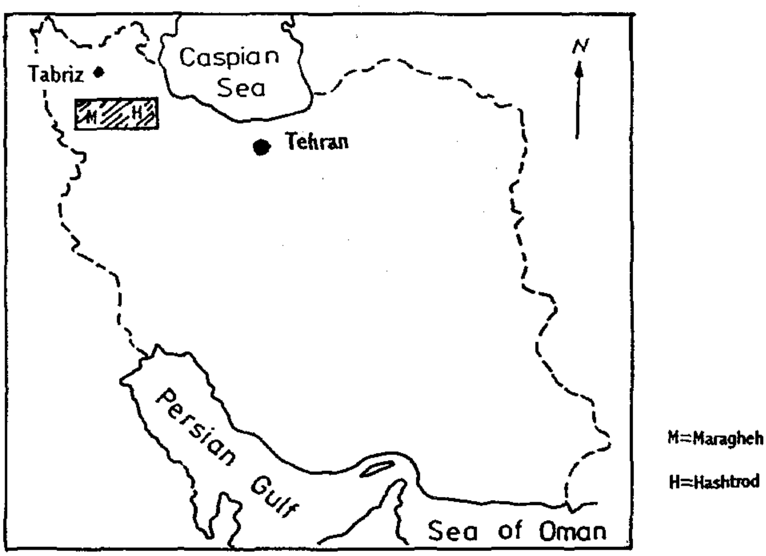

Figure 4.1.1 Iran map and area surveyed

Climatic characteristics

Mean climatic data of Maragheh (1983-1993) show that the dry period starts in mid June and lasts until the end of October (Figure 4.1.2a), which is similar to Central Anatolian Plateau of Turkey. Relative humidity falls from 65% in December-January to 35% in July- September. Mean temperature is below zero only in January (-1.2 C) and February (-0.8 C), but frost occurs frequently in the November-April period (Figure 4.1.2a). Total frost days have ranged from 69 in 1985 to 167 in 1993 (Figure 4.1.2b). Long-term mean annual rainfall is about 350 mm, analogous to Haymana (1150 m altitude) representing Central Anatolian Plateau (Guler *et al.* 1991) (Figure 4.1.2c) where similar physical and agricultural conditions prevail. Both regions have winter precipitation as snow.

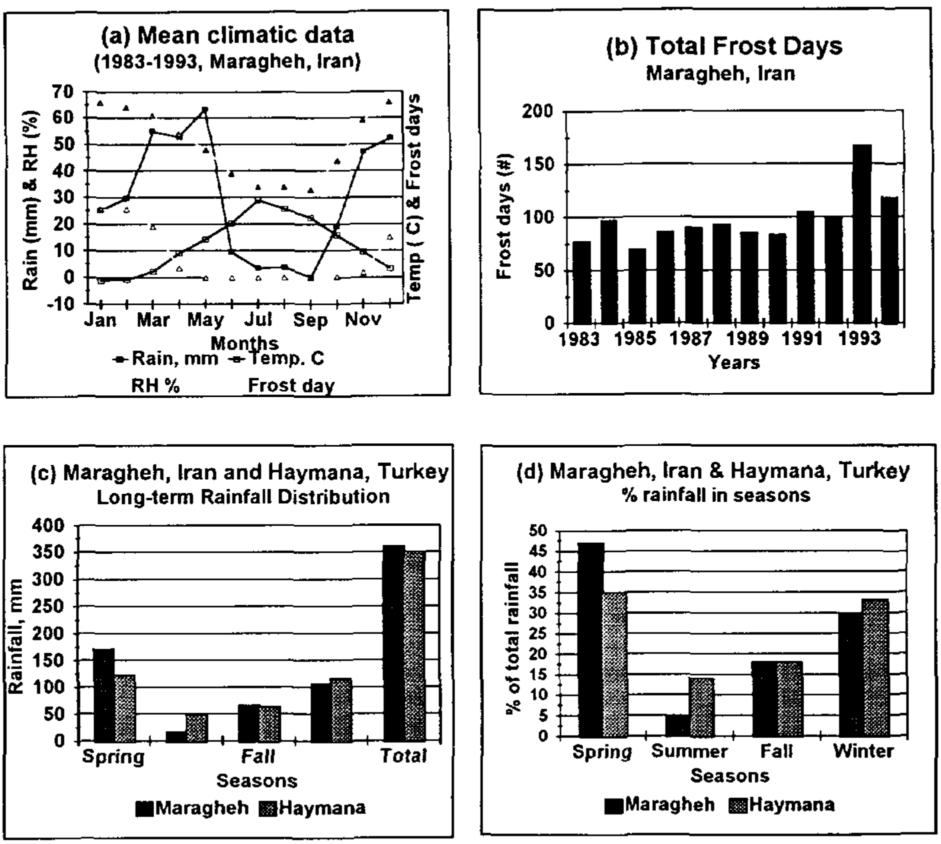

Figure 4.1.2 Summary of long-term climatic data in Maragheh, Iran compared with data from Haymana of Central Anatolian Plateau of Turkey

Spring rainfall, which is the most effective, is higher in Maragheh (175 mm) than in Haymana (125 mm); but summer rain, falling mainly in the first two weeks of June, is higher in Haymana, 50 mm compared with 20 mm (Figure 4.1.2d). These similarities between the two regions might allow the use of some research results from Haymana to develop appropriate technologies for Maragheh rapidly.

Soils of the region

The landscape of these provinces is undulating, with slopes ranging mainly from 2 to 8%, higher in Hashtrod than Maragheh, causing water erosion problems in some areas. Most soils are moderately deep to deep clay loams overlying a lime layer or a hard bed rock, with different levels of stoniness. Soil maps are available which, with long-term weather data which are also available, will be useful for agro-ecological characterization purposes and open up the possibility of utilizing crop models to extrapolate research findings.

Land use and farming system

The average landholding of the sampled farmers is 63.5 ha, of which 94% is rainfed and 6% irrigated (Figure 4.1.3). Cereal/livestock farming systems predominate, with 90% of farmers following a wheat-fallow rotation on **rainfed** plots. On **irrigated** plots the main rotation is forage-wheat or forage-forage. Wheat, assigned 44% of the total farm area and grown mostly in winter (96%), is the principal crop. Chickpea is also an important rainfed crop, grown every year by most farmers (92%). Barley is grown every year by 49% of farmers, spring-planted using local varieties, with very low seed rate and very low yields. Lentil has the smallest land allocation (1% only) but is grown every year by 27% of farmers. Forages are important irrigated crops, occupying 75% of the irrigated land. Some farmers grow rainfed forages but only on small plots.

The considerable proportion (40%) of land left fallow every year (Figure 4.1.3) indicates a good potential for increased crop production by fallow replacement. Oilseeds, lentil, cumin, and forages would be suitable fallow-replacement crops, as in Central Anatolia. Livestock is an integral part of the farming system, providing the second income source for crop farmers. Feed requirement therefore opens an horizon for the introduction of forage crops in fallow areas potentially good for legumes. However, the feasibility of growing rainfed forages, and the reasons why such crops are not already grown, should be investigated.

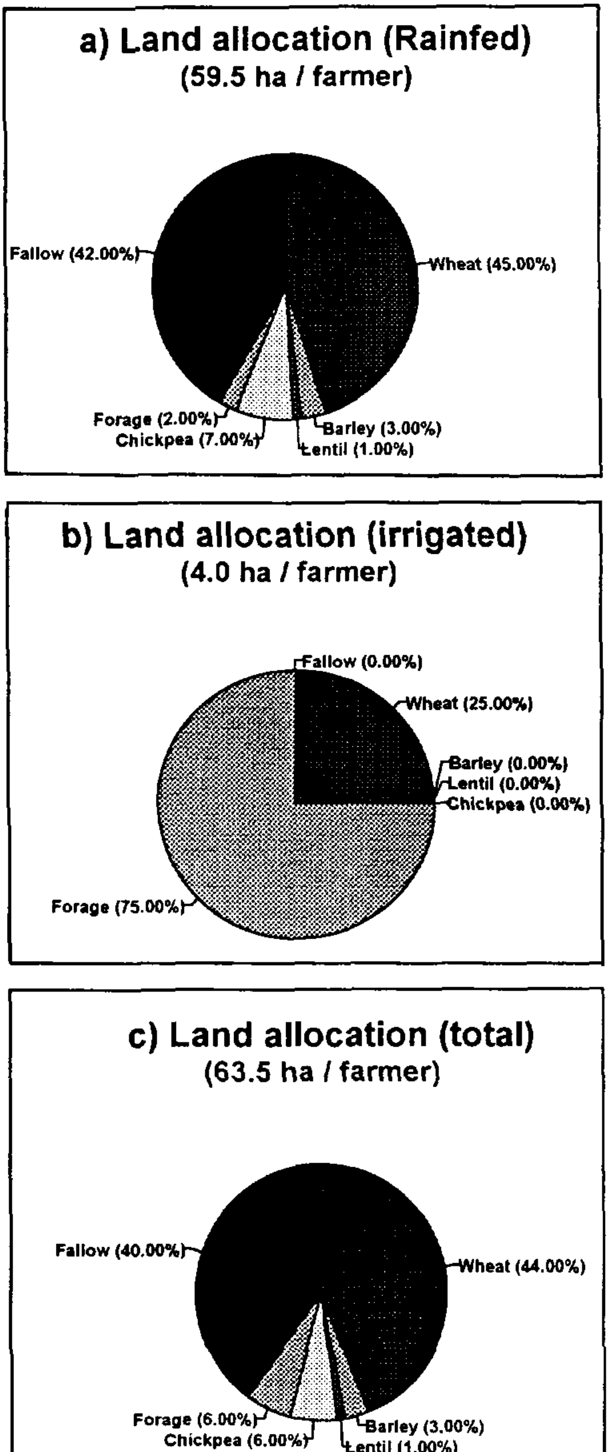

Figure 4.1.3 Land allocation in the surveyed area

Farmers' production practices

Tillage: Most farmers cultivate once before planting their wheat, some twice, and a few three times (Table 4.1.1). The first cultivation is late, mostly in late May or early June, and the second tillage is delayed by 62% of farmers almost until planting time (Table 4.1.2). This delayed tillage appears ill-advised, because it likely allows less rainwater to penetrate the soil and more moisture to be lost by evaporation and weed transpiration. For the first two tillages, respectively, 98 and 47% of farmers use a moldboard plow; and for the third, a sweep harrow (Table 4.1.3). On the basis of research findings under similar conditions in Central Anatolia, it would probably be better to replace the moldboard by the sweep for the second tillage. In Central Anatolia fallow efficiency in water conservation was increased by using moldboard for early spring tillage, and the sweep for secondary cultivation as soon as rainfall ceased (Yesilsoy 1974; Guler *et al.* 1979, 1991; Pala 1982). In those areas where the first moldboard tillage in spring is made difficult by snow melt and rainfall, it can be done the previous fall without affecting water storage.

Land planted to barley, lentil or chickpea receives fewer cultivations than that for wheat, to the extent that some farmers do not cultivate barley fields at all before planting. They just broadcast the seed and cover it (Table 4.1.1).

Planting: Most farmers plant wheat at what is probably the optimum time, between mid-September and mid-October (Table 4.1.4). However, most crops of barley, lentil and chickpea are planted in spring. This is necessitated by the lack of cold tolerance of the varieties used, which are mostly local. Varieties planted in the fall by 15% of barley producers are cold-tolerant improved ones. Almost certainly, the introduction of more cold tolerant barley, lentil and chickpea varieties to this area could appreciably increase production without any additional cost.

The commonest sowing method for wheat is hand broadcasting, followed by covering with a moldboard plow; and this inefficient practice is even more widely used for barley, lentil and chickpea (Table 4.1.5). The advantages of seed drills, though not yet locally available, need to be demonstrated. This might encourage farmers to buy their own machines or encourage the growth of custom-operated machine planting.

The surveyed farmers tend to use low seed rates for spring-sown crops, often less than 100 kg/ha for barley, lentil, and chickpea. In the case of wheat, most farmers sow 100-150 kg/ha of seed, which is quite an appropriate rate, but nearly 20% still use more than 200 kg/ha seed (Table 4.1.5). It would be instructive to study farmers' reasons for using higher seed rates for autumn-sown crops (mainly wheat and some barley) than for spring-sown crops.

Table 4.1.1. Distribution (%) of farmers according to the number of pre-planting tillages

Number of tillage operations	Wheat (n=49)	Operations Practised Barley (n=39)	Lentil (n=21)	Chickpea (n=48)
0	-	26	48	44
1	57	64	52	50
2	35	8	-	6
3	8	3	-	-

Table 4.1.2. Distribution (%) of farmers by time of tillage operations

Time	1st tillage	2nd tillage	3rd tillage
Previous fall	14	-	-
Before 15 May	6	-	-
15 May - 15 June	62	16	11
After 15 June	18	22	33
After 15 September	-	62	56

Table 4.1.3. Distribution (%) of farmers by tillage implements used

Implement	1st tillage	2nd tillage	3rd tillage
Moldboard	90	47	-
Chisel	6	-	-
Disc harrow	-	11	-
Sweep harrow	4	42	100

Table 4.1.4. Distribution (%) of farmers by crop sowing dates

Sowing date	Wheat	Barley	Lentil	Chickpea
15 Sept - 15 Oct	88	15	-	-
After 15 Oct (fall)	8	-	-	-
Spring	4	85	100	100

Table 4.1.5. Distribution (%) of farmers by sowing method, seed covering implement and seed rate

	Wheat	Barley	Lentil	Chickpea
Sowing method:				
Hand	84	92	95	92
Drill	16	8	5	8
Seed cover:				
Moldboard	48	68	75	89
Disc harrow	48	32	25	11
Sweep	4	-	-	-
Seed rate, kg/ha:				
< 100	12	64	73	46
100 - 150	49	23	18	30
151 - 200	21	3	9	13
> 200	18	10	-	11

Local varieties predominate in the survey area. Sardari, a local wheat, is planted by 90% of wheat farmers; other varieties reported were Sabalan, Azer, Spring and Sebtser. Akarpa, a local barley variety, is sown by 56% of barley growers and a small local lentil variety by 95% of lentil growers. Among chickpea growers, 58% use Desi types; other varieties grown are Pirooz and local cultivars designated Yellow and White. Great scope exists to test and subsequently disseminate improved varieties, as well as improved management practices, through on-farm verification and demonstration trials.

Fertilizer Use

All farmers apply nitrogen to wheat, and 80% also apply phosphate. Applications average 32 kg/ha of P_2O_5 and 46 kg/ha of nitrogen. Less fertilizer is used on barley -- 60% of growers apply nitrogen but only 23% phosphate -- and even less on lentil and chickpea crops (Table 4.1.6). Variability in fertilizer use is extremely high, with coefficients of variation of 78% for P_2O_5 and 56% for N on wheat, and over 100% for other crops. The importance of fertilizer is well known by farmers in these two provinces, and the majority of farmers (88%) consider the amount currently used on wheat as insufficient. However, fertilizer is not available in the quantities they require because of the current fertilizer allocation policy. This seems to be an institutional problem rather than a technical one.

Table 4.1.6. Distribution (%) of farmers by fertilizer application rates

Fertilizer	Wheat	Barley	Lentil	Chickpea
P_2O_5, kg/ha				
0	20	77	95	90
< 25	30	8	5	10
26 - 50	29	7	-	-
51 - 75	10	5	-	-
> 75	6	3	-	-
N, kg/ha				
0	-	41	81	67
< 25	20	31	19	23
26 - 50	41	8	-	6
51 - 75	27	10	-	4
> 75	12	8	-	-

Crop yields

Farmers were asked to state the yields of wheat, barley, lentil and chickpea that they would expect under good, normal, and bad agroclimatic conditions. Mean values show generally low yield expectancy (Figure 4.1.4).

Cereal estimates of Maragheh farmers were higher than those of Hashtrod, but the differences were not significant except for bad years. Even in good years, average yield estimates for wheat and barley were only 1.5 and 1.2 t/ha, respectively, with about 60% of wheat growers and 80% of barley growers harvesting less than these averages (Table 4.1.7).

Lentil yield is dramatically low in both provinces, less than 0.3 t/ha even in years of good climatic conditions. The main reason for this could be the spring sowing (to avoid cold damage), using very low seed rate, local cultivars, and other subotimal management practices. Average chickpea yield is about 0.8 t/ha in good years, and about 65% of producers obtain more than 1.0 t/ha, but in normal years the average yield is cut to less than 0.5 t/ha (Table 4.1.7 and Figure 4.1.4).

Table 4.1.7. Distribution (%) of farmers by crop yield levels, according to type of year

Yield, t/ha	Good	Normal	Bad	Good	Normal	Bad
		Wheat			**Barley**	
< 0.5	2	22	56	16	50	70
0.5 - 1.0	41	44	40	40	30	24
1.0 - 1.5	18	19	4	25	10	3
1.5 - 2.0	10	13	-	7	7	3
> 2.0	29	2	-	12	3	-
		Lentil			**Chickpea**	
< 0.5	37	90	100	5	15	54
0.5 - 1.0	58	10	-	30	58	39
1.0 - 1.5	5	-	-	23	20	5
1.5 - 2.0	-	-	-	28	5	2
> 2.0		-	-	-	14	2 -

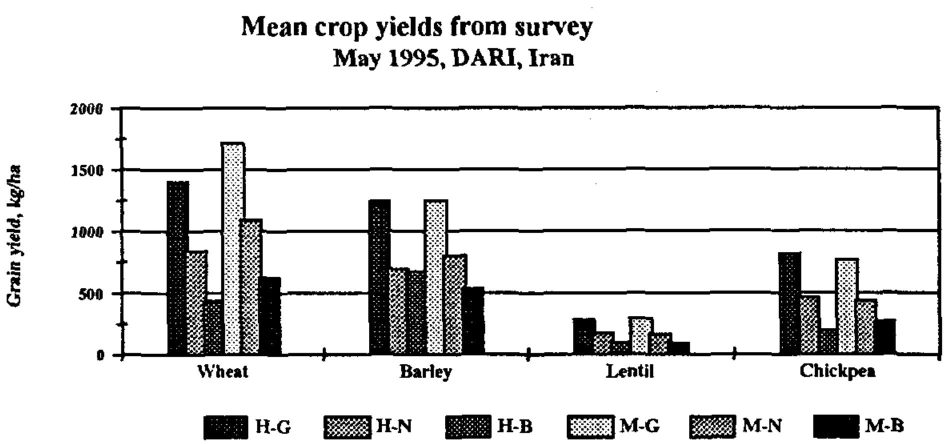

Figure 4.1.4 Mean grain yields of main crops under different conditions; (H=Hashtrod, M=Maragheh; G=good, N=normal, B=bad seasons)

Farmers rated restricted fertilizer use (88%) and lack of machinery (69%) as the most important factors limiting crop production, followed by time of tillage (30%). Other factors of lesser importance were credit, tillage implements, sowing method, labor shortage, harvesting method, weeds and seed rate. Although time of tillage was identified as the third most important factor limiting production, yet 70% of farmers rated it unimportant. Unless constrained by environmental and/or institutional factors over which farmers have no control, this may imply that farmers are unaware of some factors which may have significant adverse effects on crop production.

Crop yields, sowing date and seed rate relationship

As mentioned above, seed rates are rather low, and, although wheat is sown mainly in autumn, barley and legumes are sown in spring. It is interesting to try to relate yield data to these two important factors, seeding rate and date.

For wheat and barley, irrespective of seasonal conditions, the common trend in autumn sowings is for yields to increase significantly with seed rate, and this is what determines the mean seed-rate trend shown in Table 4.1.8; but, in fact, when cereals (mainly barley) are sown in spring, most farmers use a low seed rate and yield is not increased by rates over 150 kg/ha. Again irrespective of seasonal conditions, wheat and barley yields are much higher from autumn than from spring planting.

Table 4.1.8. Effect of sowing date and seed rate on crop yields (t/ha), according to the nature of the season (mean values of farmers' estimates)

Seed rate, kg/ha	Good	Normal	Bad	Good	Normal	Bad
		Wheat			**Barley**	
< 75	0.73	0.43	0.28 [4]	1.20	0.67	0.31 [19]
75 - 100	1.16	0.73	0.41 [14]	0.98	0.63	0.39 [8]
100 - 150	1.51	0.87	0.55 [12]	1.07	0.69	0.48 [2]
> 150	2.09	1.24	0.66 [18]	2.19	1.27	0.89 [5]
Winter sowing	1.62	1.02	0.57 [42]	2.38	1.58	1.18 [4]
Spring sowing	0.98	0.55	0.25 [2]	1.11	0.64	0.32 [30]
		Lentil			**Chickpea**	
< 50	0.24	0.14	0.08 [15]	0.73	0.44	0.22 [26]
50 - 100	0.45	0.30	0.23 [4]	0.95	0.48	0.25 [15]
> 100	-	-	-	0.73	0.46	0.26 [4]

Figures indicated in parenthesis are the number of observations.

Legumes are sown in spring with low seed rates -- most farmers are using less than 50 kg/ha. This results in lower yields. When seed rates are increased to 100 kg/ha, yields also increase. Nevertheless, farmers may opt to use lower seed rates in spring, because favorable soil and air temperatures for crop growth at that time allow most of the seeds to emerge. With autumn sowing, some of the seeds may not emerge, or emerged plants may be killed by frost. Under extreme conditions, emergence of autumn sowings may be delayed until early spring, in which case some of the seeds may die during the winter.

Conclusion: problems and proposed solutions

Probable factors limiting crop productivity tentatively identified by this diagnostic survey include:

1. Fallow management suboptimal in terms of frequency, timing and method of tillage.
2. Extensive use of local, or old improved, varieties, with very variable seed rates.
3. Seeding by hand, using the moldboard plow for covering.
4. Spring sowing of barley, chickpea and lentil.
5. Fertilizer allocation and pricing policies.
6. Lack of weed control. (Control applied by only about 25% of farmers).
7. Poor transfer of improved technologies due to an absence of research-extension-farmer interaction.

DARI researchers were encouraged to design new research to tackle some of these problems, ready for later discussion at the next Iran/ICARDA coordination meeting, with more emphasis given to on-farm research and demonstrations. A number of research activities at research stations are on-going or already completed; and some of the findings can be simplified and tested on farmers' fields as on-farm trials. Suggested research and demonstration activities are:

a) On-farm demonstrations of wheat varieties and seed rates (matching present on-station yield trials).
b) On-farm fertilizer trials to obtain data: (i) to persuade decision makers to allocate more fertilizers to farmers in these two provinces, and (ii) to calibrate the wheat response to different rates of nitrogen in relation to location and soil analysis.
c) On-farm trials to compare recommended and farmers' practices in respect of frequency and timing of tillage and sowing methods. (Findings of detailed on-station tillage work should be relevant to solving problems identified by the survey.)
d) Simple with/without herbicide trials superimposed on farmers' wheat fields. (On-station weed control research for legumes is already in progress.)

e) On-farm barley variety, sowing date, and seed-rate trials.
f) On-farm chickpea variety, sowing date, and seed-rate trials.
g) On-farm trials comparing chickpea varieties and seed-covering methods (spring planting).

Subsequently, farmers will be monitored for their perception and acceptance of the new technologies tested and demonstrated on their farms. These findings, along with the survey results, will help researchers to understand the factors behind farmers' acceptance or rejection of improved production practices.

Active participation of the extension authorities, together with researchers and farmers, in conducting and monitoring on-farm activities is strongly recommended for the success of this new exercise. Such participation will enhance the technical capacity of extension agents and their personal identification with improved farm practices, leading to more effective technology transfer. The appointment of socio-economist(s) to support the Dryland Agricultural Research team, at Maragheh, is strongly recommended. ***(M. Pala, A. Mazid, and A. B. Salkini from ICARDA and H. Maksood and A. Hagigati from DARI, Maragheh)***

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4.2 Tillage and Barley Residue Management Trial at Breda

Introduction

Systems utilizing zero-tillage, reduced-tillage and/or crop residue retention treatments have been variously credited with reducing soil erosion by wind or water, improving infiltration of rainwater, and reducing evaporation. Effects vary greatly according to local conditions: Bolton (1991) wrote that several US studies had shown that use of crop residues increased infiltration and reduced evaporation, resulting in increased water storage in the soil profile, but only in a few instances did this additional water increase yield or water-use efficiency; but at the same meeting, Papendick *et al.* (1991) felt able to say "conservation tillage has also been shown to benefit water conservation markedly and enhance crop yields in dry farming systems".

In WANA, drier and drier areas are being ploughed to grow barley. In many cases, after harvest the straw is removed and the stubble grazed by small ruminants, leaving the soil exposed to the strong summer winds. The retention even just of the stubble would greatly reduce the risk of erosion losses. It might also improve the moisture conditions before and after sowing, by increasing infiltration and reducing evaporation, to the benefit of crop yields.

To test this latter hypothesis, a "tillage and barley residue management" trial was set up on a 2.5 ha field at the Breda station in the 1989/90 season. The five main treatments examine the questions of: tillage (ducksfoot) v. no tillage; time of tillage; straw retention; and stubble retention, in the following combinations:

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

* Straw removal and stubble grazing (by sheep) soon after harvest, May/June. [The direct-drill (zero-till) planter, required by treatments 4 and 5, is used to plant the whole trial, to ensure uniform row-spacing and seed rate across all treatments.]

These treatments are applied, following barley harvest, to two rotations: barley-barley [B-B]; and barley-vetch (*Vicia sativa*) [B-V]. In the B-V rotation, following vetch harvest, vetch residues are removed, but tillage treatments are applied the same as after barley. Both phases of each rotation are represented each year, and the barley crop in the first phase receives phosphate fertilizer (60 kg P_2O_5/ha) in the seedbed. Further, each barley plot is divided into three subplots to carry three N-fertilizer rates, 0, 20 and 40 kgN/ha. These are applied in both phases of the B-B rotation but not to the vetch.

Barley yields are estimated by harvesting each plot in two ways: by hand cutting (at ground level) five 1-metre row samples, and by reaping a swathe from end to end of the plot with a Hege plot-harvester. Both methods give a value for grain yield, but straw (and harvest index and, hence, total biomass) estimates are made from the hand-cut material. In the case of vetch, biomass samples are taken at the hay stage, and then the whole plots are harvested by hand at maturity (and the residues removed).

This trial was previously reported by Jones and Harris (1992). It has now run for six years. Discounting the start-up year, there are now five years of data to evaluate. We report here results for: barley grain and total biomass (in B-B and B-V rotation, separately); vetch grain and total biomass, from the B-V rotation; and soil water-balance (in tillage/residue management treatments 1, 2 and 5). Crop data are statistically analysed on an annual basis. Analysis across years will not be attempted until data for three complete rotations are available (that is, until after the seventh season, 1995/6).

Yields of barley in B-B rotation

First, all three parameters of barley yield -- grain weight (from hand and Hege harvesting) and estimated biomass -- showed a response to fertilizer. Values were generally lower in the phase not receiving P-fertilizer in the current year and, in both phases, were increased by N-fertilizer, at least up to the 20 kg N/ha level. Five-year means are summarized in Table 4.2.1.

Table 4.2.1. Main treatment effects of biennial P-fertilization and annual N-fertilization on barley yields (t/ha) in B-B rotation: five-year means.

	Current season's P-fertilizer, kg P_2O_5/ha		N-fertilizer, kg N/ha		
	0	60	0	20	40
Grain (Hege)	0.75	0.82	0.60	0.86	0.90
Grain (hand)	0.81	0.96	0.71	0.96	0.99
Total biomass	2.12	2.48	1.80	2.44	2.66

However, the main focus of interest is on the effects of the five tillage/residue management treatments. In fact, differences were small and never reached statistical significance (at 5% level) for any of the three yield parameters in any of the five years. In only one respect was there any consistent yield trend: grain yields from Treatment 5 were in all years (Hege values) and in four years out of five (hand-harvest values) numerically higher than those from the other four treatments (Table 4.2.2). The mean advantage over five years for this treatment was around 10%. The same trend was not, however, seen in the total biomass values, which had a more erratic pattern from year to year. The mean value over five years for treatment 5 was identical with those for Treatments 1 and 3.

Yields of barley in B-V rotation

Yields of hand-harvested grain (Table 4.2.3) showed an appreciable 'rotation' effect, being at least 25% higher than those from the corresponding treatment (P-fertilized phase) of the B-B rotation; but response to N-fertilizer was numerically small and statistically non-significant. This may reflect greater soil availability of nitrogen following vetch.

Table 4.2.2. Effect of tillage/residue management treatments on annual barley yields (t/ha) in B-B rotation.

Treatment*	90/91	91/92	92/93	93/94	94/95	Mean**
Grain (hand harvest)						
	ns	ns	ns	ns	ns	
1	0.75	0.96	1.05	0.73	0.94	0.89 (0.81)
2	0.78	0.91	0.97	0.71	0.91	0.86 (0.76)
3	0.83	0.96	0.85	0.74	0.94	0.86 (0.75)
4	0.82	0.81	0.88	0.83	0.94	0.86 (0.74)
5	0.99	0.90	1.04	0.82	1.09	0.97 (0.85)
SE(+/-)	0.066	0.048	0.051	0.066	0.059	
Total biomass						
	ns	ns	ns	ns	ns	
1	2.34	2.55	2.88	1.63	2.36	2.35
2	2.49	2.47	2.64	1.55	2.15	2.26
3	2.71	2.61	2.36	1.67	2.41	2.35
4	2.04	2.25	2.37	1.89	2.33	2.18
5	2.15	2.50	2.67	1.83	2.62	2.35
SE(+/-)	0.144	0.081	0.144	0.096	0.150	
Total growth period rainfall, mm						
	225.3	260.2	267.8	298.6	214.8	253.3

All yield values are means over two phases and three N-fertilizer rates.
* For tillage/residue management treatment details, see text.
** Values in brackets are five-year means from Hege harvest.

Since barley followed vetch, preceding management treatments differed only in their tillage treatments; no vetch residues were retained on the soil surface. Highest yields tended to be from zero tillage (Nos 4 and 5), with differences statistically significant in one year, 1993/94 (Table 4.2.3).

Table 4.2.3. Effect of N-fertilizer and tillage/residue management treatments on annual barley grain yields (t/ha) in B-V rotation.

Treatment*	90/91	91/92	92/93	93/94	94/95	Mean
Fert-N rate (kg/ha)						
	ns	ns	ns	ns	ns	
0	0.92	1.14	1.79	1.04	1.18	1.21
20	0.77	1.28	1.86	1.14	1.32	1.27
40	0.88	1.29	1.87	1.09	1.27	1.28
SE(+/-)	0.041	0.054	0.071	0.063	0.086	
Treatment						
	ns	ns	ns	**	ns	
1	0.81	1.10	1.65	0.76	1.20	1.10
2	0.82	1.33	1.93	1.08	1.16	1.26
3	0.87	1.21	1.81	0.97	1.15	1.20
4	0.88	1.25	1.95	1.30	1.34	1.34
5	0.91	1.29	1.85	1.33	1.44	1.36
SE(+/-)	0.067	0.064	0.170	0.035	0.071	

All values from hand-harvested crops.
** indicates statistical significance at the 1% level.

Yields of vetch in B-V rotation

Vetch followed P-fertilized barley, received no direct fertilization, and showed no residual response to the different N-fertilizer rates previously applied to the barley (results not shown here). Tillage/residue (barley) treatment effects on the grain, straw and total biomass yields of mature-harvested vetch are summarized in Table 4.2.4.

As with barley yields, treatment differences tended to be small but were significant in two years. The main trend, though not fully consistent across all years, was for Treatments 2 and 3 to be relatively poor. Of the other three: Treatment 4 was the most consistently good; Treatments 1 and 5 were more erratic; and over 5 years, average values for Treatments 4 and 5 (both zero tillage) were similar to each other and around 5% superior to those of Treatment 1.

Table 4.2.4. Effect of tillage/residue (barley) management treatments on annual vetch yields (t/ha) in B-V rotation

Treatment*	90/91	91/92	92/93	93/94	94/95	Mean
Grain						
	ns	ns	ns	ns	*	
1	0.40	0.63	0.79	0.61	0.45	0.58
2	0.41	0.55	0.72	0.50	0.46	0.53
3	0.42	0.60	0.73	0.50	0.37	0.52
4	0.45	0.71	0.82	0.61	0.46	0.61
5	0.45	0.56	0.74	0.63	0.57	0.59
SE(+/-)	0.016	0.036	0.031	0.031	0.023	
Straw						
	**	ns	ns	ns	**	
1	0.93	1.79	1.31	1.68	0.83	1.31
2	0.93	1.67	1.26	1.29	0.96	1.22
3	0.93	1.70	1.27	1.33	0.84	1.21
4	1.07	1.91	1.40	1.56	1.05	1.40
5	1.06	1.76	1.23	1.63	1.39	1.41
SE(+/-)	0.016	0.071	0.031	0.089	0.033	
Total biomass						
	**	ns	ns	ns	**	
1	1.33	2.42	2.13	2.30	1.28	1.89
2	1.34	2.21	1.98	1.79	1.42	1.75
3	1.36	2.30	2.00	1.83	1.21	1.74
4	1.52	2.62	2.22	2.16	1.51	2.01
5	1.51	2.32	1.97	2.27	1.96	2.01
SE(+/-)	0.022	0.092	0.050	0.117	0.047	
Total growth period rainfall, mm						
	225.3	260.2	267.8	298.6	214.8	253.3

Yield values from hand-harvested samples.
* and ** indicate statistical significance at the 5% and 1% levels, respectively.

Crop water balance

Soil water content was monitored by neutron probe to a depth of 150 cm in both phases of both rotations (B-B and B-V) in treatments 1, 2 and 5 (N20 plots only). Measurements were made: at the beginning of the season, prior to rainfall; at approximately monthly intervals through the growing season; and, finally, after harvest. The data summarized here (Tables 4.2.5 and 4.2.6) are values of the apparent seasonal evapotranspiration (ET) based on the pre-season and post-harvest soil moisture contents and the total seasonal rainfall.

Rainfall averaged 253.3 mm, of which a mean (across rotations and crops) of 93% (range, between years: 89.1-95.4 %) could be accounted for as ET (Table 4.2.5). The remaining 9.8 - 32.6 mm (mean 17.8 mm) was apparently post-harvest subsoil storage, much of which is lost slowly to evaporation during the following summer. The soil is driest at the time of the pre-season measurements and shows a net gain in moisture content over the period of cropping.

Differences in ET between the three tillage/residue management treatments were very small and, in 3 years out of five, in favour of the tilled treatments (nos. 1 and 2). In other words, crops directly drilled into stubble and straw residues left on the soil surface tended subsequently to have lower ET than those drilled into tilled soil. Mean differences over 5 years were very small (around 1-3 mm per annum) and may reasonably be assumed to be negligible. There is no evidence here that the retention of crop residues conserved any soil moisture.

Table 4.2.5. Treatment effects on seasonal evapotranspiration (ET, mm): means across rotations

	90/91	91/92	92/93	93/94	94/95	Mean
Total growth period rainfall, mm	225.3	260.2	267.8	298.6	214.8	253.3
ET, mm						
Treatment 1	209.1	244.5	256.9	271.5	203.2	237.0
Treatment 2	208.7	241.3	255.2	269.0	204.5	235.7
Treatment 5	209.1	241.0	254.2	257.5	207.5	233.9
Mean	209.0	242.3	255.4	266.0	205.0	235.5
Mean as % rain	92.8	93.1	95.4	89.1	95.4	93.0
Unused rain, mm	16.3	17.9	12.4	32.6	9.8	17.8

The effect of rotation on seasonal ET values was similarly small (Table 4.2.6). In the B-B rotation, crop use of water was not appreciably affected by the timing of P-fertilizer. In the B-V rotation, on average, vetch used approximately 20 mm less water than the barley; but the barley used only about 3 mm more than the corresponding (P-fertilized) barley in B-B rotation. Thus most of the extra water left unused in the soil profile by the vetch crop (around 17 mm of the 20 mm) was lost during the subsequent summer period (May - September inclusive).

Table 4.2.6. Crop rotational effects on seasonal evapotranspiration (ET, mm): means over five years

Rotation:	B-B		B-V		
Crop:	Barley	Barley	Barley	Vetch	
P-fertilizer:	+	-	+	-	Mean
ET, mm					
Treatment 1	240.2	241.4	242.4	224.2	237.0
Treatment 2	240.1	238.5	241.8	222.5	235.7
Treatment 5	238.0	235.0	242.9	219.5	233.9
Mean	239.5	238.3	242.4	222.0	235.5

Five-year means of two replicates each with two access tubes in N20 subplots.

Discussion

Although annual differences were usually non-significant, a very small but fairly consistent yield trend can be seen in these results. Mean grain yields (barley and vetch across both phases of both rotations) show a mean advantage, of around 7%, for the two zero-tillage treatments (Nos 4 and 5) over the other three treatments. In particular, zero-tillage with straw retention (No 5) was the best in simple numerical terms. Pending more complete analysis of the full 6-year data set, we may provisionally conclude that the use of zero-till technology may confer a small advantage *vis-a-vis* sweep tillage under Breda conditions, irrespective of the timing of that tillage and, probably, also of the management of the stubble. However, the differences so far recorded are not such as to inspire farmers to change their current methods.

The initial hypothesis was that the retention of residues (with zero tillage) would improve the soil moisture regime, by increasing infiltration and reducing evaporation. Such improvement, on a small scale, may indeed be the cause of the marginal difference observed in the yields. Confirmation of this awaits more detailed analysis of the soil moisture data. Meantime, what the simple analysis of seasonal ET shows is that the water budgets of individual cropping seasons are essentially independent of those that precede and follow them. Irrespective of preceding crop (vetch or barley) and tillage and residue management choices, each crop depends solely on the current season's rainfall.

However, the small differences observed in the yields imply slightly higher water-use efficiency in the zero-till treatments. If real, this result suggests that zero tillage and/or surface residue retention have reduced evaporative losses from the soil, probably early in the growth period, thereby allowing a slightly higher proportion of the rainfall to be transpired by the crop. Evidence for this will be sought in the detailed soil moisture data. What can be said at this stage is the phenomenon we are dealing with here appears to be a very marginal one. ***[Mike Jones, with major technical inputs from Zuhair Arous]***

References

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4.3 Nine-year trends in continuous barley trials at Breda and Tel Hadya

Introduction

Last year, we reported a biometric procedure to quantify trends in yield data sequences from long-term rainfed barley trials, eliminating as far as possible the effect of annual rainfall variation (Singh & Jones 1995). Estimates of time trends in yields under different fertilizer treatments, and of the number of years of data required to detect significant trends, were made for a seven-year data set (1986/87 - 1992/93) from the 'continuous barley' trial at Breda.

This study has continued. The analysis now covers both Breda and Tel Hadya 'continuous barley' trials; data have been added for two more seasons (1993/94 and 1994/95); and a modification has been made to the procedure to take account of annual differences in planting date. Thus the model now used is:

$$Y = a + b_1R + b_2R^2 + cT + dD + e$$

where Y is yield, R is rainfall, T is time in years since the start of the trial, D is the planting date (days after October 31) and e is random error. The constant 'a' is the intercept, b_1, b_2 and d are the regression coefficients of R, R^2 and D, and c is the time-trend parameter. Such models have been derived, from grain and straw yield values, for each of nine annual fertilizer treatments (factorial combinations of 0, 45 and 90 kg P_2O_5/ha and 0, 60 and 120 kg N/ha).

As described last year, two approaches are used: in approach 1, models are fitted to the yields of each fertility treatment, and plot errors are assumed to be uncorrelated from one year to the next; in approach 2, models are fitted on individual plots values, assuming that plot errors are correlated from year to year and follow a first-order autocorrelated structure.

Results

<u>*Time trends.*</u> Time-trend parameters, or 'c-values', which estimate the mean annual decrease/increase in the yield trend are summarized in Table 4.3.1. We may note:

1. The patterns of the values (signs and relative magnitude) are very similar between the two approaches.
2. The Breda values are generally more pessimistic than those estimated previously from the 7-year data set: the grain-yield trend over time is generally downward (though, strangely, least strongly where N is

applied in the absence of P); the straw-yield trend is upward except where no N-fertilizer is applied.

3. Values from Tel Hadya data are generally more optimistic than those of Breda; all are positive except where N is applied in the absence of P.

Table 4.3.1. Estimates of the linear nine-year time-trends (c-values, kg/ha/yr) of barley yields, according to fertilizer treatment, under continuous barley cropping at Tel Hadya and Breda

		Grain			Straw		
	P_2O_5:	0	45	90	0	45	90
	N						
					Breda		
Approach 1	0	**-96**	**-82**	**-107**	-13	-25	-13
	60	-9	**-116**	-43	**78**	**94**	**129**
	120	-4	**-91**	**-94**	**106**	**105**	**112**
SE+/-(min-max)			(20.8 - 30.9)			(24.0 - 44.1)	
Approach 2	0	**-119**	**-81**	**-101**	-35	-14	-6
	60	-26	**-125**	**-65**	53	72	**107**
	120	-23	-95	**-102**	**89**	**83**	**92**
SE+/-			21.9			26.5	
					Tel Hadya		
Approach 1	0	10	19	75	**80**	41	**128**
	60	-95	**109**	**138**	**-111**	**135**	**136**
	120	-74	82	**162**	-54	**169**	98
SE+/-(min-max)			(38.9 - 54.3)			(35.5 - 79.1)	
Approach 2	0	29	33	**82**	92	50	**134**
	60	**-55**	**152**	**142**	-105	**149**	100
	120	**-80**	**108**	**184**	-71	**126**	97
SE+/-			27.9			62.5	

P_2O_5 and N indicate rates of phosphate and N fertilizer, kg/ha.
Bold indicates significance at 5% level.

The implications of these findings are that, for continuous barley, over a nine-year period, N and P fertilizers can maintain (and increase) grain and straw yields at Tel Hadya and straw yields only at Breda. At Tel Hadya, grain and straw yields appear to be maintained even without fertilizer, although a long time is required to establish the significance of this trend.

Estimates of the number of years needed to detect significant time trends, 'n-values' (Table 4.3.2), are a measure of the uncertainty of the 'c-values' given above. They show less agreement between approaches 1 and 2 and little obvious treatment pattern. The lowest time requirement (10-20 years) is for grain at Breda. Thus the most certain prediction that can be made from this analysis is that grain yields will decline at Breda irrespective of what fertilizer is used.

Table 4.3.2. Estimates of the number of years (n-values) to detect significant (5%) time trends in the yields of continuously cropped barley under different annual fertilizer treatments at Tel Hadya and Breda

		Grain			Straw		
	P_2O_5:	0	45	90	0	45	90
	N						
				Breda			
Approach 1	0	11	10	9	45	26	40
	60	51	10	20	13	13	11
	120	84	12	12	11	12	14
Approach 2	0	10	15	14	24	39	39
	60	18	12	15	35	36	46
	120	17	15	14	30	24	31
				Tel Hadya			
Approach 1	0	63	42	17	15	25	12
	60	17	16	13	16	18	15
	120	20	19	11	24	15	20
Approach 2	0	40	47	40	33	32	19
	60	50	19	39	21	14	28
	120	30	23	15	24	28	25

P_2O_5 and N indicate rates of phosphate and N fertilizer, kg/ha.

Also calculated were 'd-values', estimates of the daily increase/decrease in yield with lateness of planting (Table 4.3.3). The values obtained suggest delayed planting reduces yields, of grain and straw at Breda and of grain at Tel Hadya, but only where P-fertilizer is regularly applied. In the absence of P-fertilizer, delayed planting appears advantageous. However, it should be remembered that the range of planting dates was quite narrow, days 13 to 27 at Breda and days 11 to 51 at Tel Hadya (ie days after 31 October) and only a linear relation was permitted. Over a wider range of planting dates, almost certainly a curvilinear relationship would be more appropriate.

Table 4.3.3. Estimates of the daily increase/decrease in yield with lateness of planting (d-values, kg/day) in continuously cropped barley under different annual fertilizer treatments at Tel Hadya and Breda

		Grain			Straw		
	P_2O_5:	0	45	90	0	45	90
	N						
Breda	0	20	-32	-37	33	-33	-36
	60	39	-21	-4	54	-6	5
	120	33	-22	-19	46	13	4
SE+/-(min-max)				(11.6 - 17.2)		(13.4 - 24.6)	
Tel Hadya	0	-3	-5	-11	-2	-6	-12
	60	1	-21	-25	6	6	8
	120	1	-24	-32	8	6	3
SE+/-(min-max)			(7.2 - 10.0)			(6.6 - 14.6)	

Yield means. As another approach to examining the pattern of productivity across fertilizer treatments over time, we examined annual running means (values each year of mean yield to date in that plot) and the evolution of the relative treatment rankings as the experiment progressed. In fact, these rankings showed no further change after the first five years. They may be inferred from the 9-year mean values shown in Table 4.3.4.

It may be noted that, over nine years, the most productive treatments ($N:P_2O_5$) were 60:90 for grain and 120:90 for straw, at Tel Hadya and Breda. The annual fertilizer rates used were high (and almost certainly uneconomic), and yield responses to the second increment of each nutrient were small. However, an exception to this was straw N content, which responded strongly to the second increment of N at both sites and of P at Breda. Given the wide seasonal variation, in rainfall and therefore total biomass production, values of apparent fertilizer-N recovery were surprisingly good. For the $90P_2O_5$ treatment, these were (for N60 and N120 rates, respectively): 69.5% and 49.1% at Breda and 62.7% and 52.0% at Tel Hadya.

Table 4.3.4. Nine-year mean values of the yields of continuously cropped barley under different annual fertilizer treatments at Tel Hadya and Breda

		Breda			Tel Hadya		
	P_2O_5:	0	45	90	0	45	90
	N						
Grain (t/ha)	0	1.31	1.44	1.38	1.44	1.57	1.53
	60	1.21	1.80	1.96	1.96	2.41	2.56
	120	1.10	1.70	1.78	1.98	2.33	2.37
SE(+/-)			0.055			0.035	
Straw (t/ha)	0	1.63	1.71	1.82	1.59	1.78	1.78
	60	1.62	2.76	3.02	2.47	3.41	3.72
	120	1.60	2.68	3.27	2.65	3.71	4.04
SE(+/-)			0.056			0.073	
Grain N	0	18.0	16.8	16.3	21.9	22.9	23.1
(kg/ha)	60	20.9	33.5	40.4	34.4	42.8	46.2
	120	20.5	35.7	41.6	36.4	50.8	52.7
SE(+/-)			1.06			1.00	
Straw N,	0	8.9	6.8	7.4	8.1	7.7	7.9
(kg/ha)	60	13.8	24.3	24.6	18.2	20.9	22.5
	120	15.9	29.0	41.1	23.5	37.0	40.8
SE(+/-)			0.86			0.63	

P_2O_5 and N indicate rates of phosphate and N fertilizer, kg/ha.
Grain and straw N values are for the last seven of the nine years

Rotational comparison. Included in both trials, as controls, are four barley-fallow (B-F) treatments, two unfertilized and two receiving $N120{:}90P_2O_5$ in the barley year. Each year, under each treatment, one set of replicate plots is under fallow, another set under barley -- so that both phases of the rotation are represented each year.

Comparison of nine-year yield means with those from the corresponding continuous barley (B-B) treatments shows, as always expected, that values after fallow are generally higher (Table 4.3.5). However, except in respect of nitrogen in the unfertilized case at Tel Hadya, the ratio is much less than twofold, indicating that a higher yield after fallow does not compensate for the absence of production in the fallow year. In fact, these results, and particularly those from Breda, support the farmers' decision to eliminate fallowing. On the evidence of nine years (without serious pest or disease build-up), continuous barley cropping is more productive and, presumably, more profitable. ***[Murari Singh (CBSU) and Mike Jones, with major technical inputs from Nerses Chapanian]***

Table 4.3.5. Comparison between continuous barley (B-B) and barley-fallow (B-F) rotations in respect of nine-year mean yields from fertilized (N120:90P_2O_5) and unfertilized (N0:0P_2O_5) barley crops at Breda and Tel Hadya

	Breda		Tel Hadya	
	B-B	B-F	B-B	B-F
		0:0		
Grain, t/ha	1.31	1.69	1.44	2.49
Straw, t/ha	1.63	2.04	1.59	3.00
Grain N, kg/ha	18.0	28.8	21.9	43.9
Straw N, kg/ha	8.9	14.0	8.1	16.3
		120:90		
Grain, t/ha	1.78	2.35	2.37	3.43
Straw, t/ha	3.27	3.25	4.04	5.09
Grain N, kg/ha	41.6	50.1	52.7	73.2
Straw N, kg/ha	41.1	30.1	40.8	37.9

P_2O_5 and N indicate rates of phosphate and N fertilizer, kg/ha.
Grain and straw N values are for the last seven of the nine years

Reference

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4.4 Differences in soil organic matter and nitrogen after ten years in the wheat-based rotational cropping systems at Tel Hadya

Introduction

As noted in last year's Report (FRMP 1995), many of ICARDA's long-term trials have now been running for ten years or longer. In each case, the primary purpose was (and still is) to compare the productivity, biological and economic, of different rotational systems of crops and management treatments. We may call this 'system optimization', noting, however, that given the large annual variation in rainfall and therefore in crop yields, several cycles of cropping may be needed to distinguish significant differences.

A secondary but closely related purpose of many of the trials is to monitor differences in various soil, soil-water and pest variables. Such information may serve to explain yield differences between production systems and point to ways in which crop sequences and management operations may be chosen to increase efficiencies in water nutrient utilization and to control weed and pest populations. The long-term trials may thus act as 'laboratories', in which particular problems or mechanisms may be studied in an ongoing field environment, for which the cropping and input/output history is well known.

These activities are directed essentially at the improvement of production practices. They will only incidentally throw up information on issues determining long-term sustainability. For that, it is necessary to examine trends over time, either in the yields of the crops or in the quality of the resource base. For soil trends, the parameter most commonly used is organic matter content. This report summarizes the effects over ten years of different rotational cropping and fertilizer treatments on current soil organic carbon and total nitrogen status in a long-term trial at Tel Hadya.

Materials and methods

A two-course rotation trial with seven crop sequences was established in 1983-85 in Tel Hadya on land that had been cropped in cereal-based rotations since 1978. The 23 ha-site is gently sloping, and the depth of the soil, a Calcixerollic Xerochrept, ranges between 1 to 2 m with a few shallower patches. The cropping sequences are durum wheat following: fallow (W-F), summer crop, watermelon (W-SC), lentil (W-L), chickpea (W-C), vetch (W-V), medic (W-M), and wheat (W-W). Each of these is replicated three times, and both phases of the rotations are included each year. Individual plot size is 0.54 ha, and each rotation therefore covers 3.24 ha. Other management details and production information have been given previously by Harris (1990) and Harris *et al.* (1993). This trial is also the basis of the work of Wood and Pilbeam (1996).

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

Tillage and Planting. Since 1987-88, primary tillage for the wheat phase has been carried out with a tined cultivator after the first rain of the season, followed by a pass with a spike-toothed harrow for seedbed preparation. Since 1987, seed has been drilled -- wheat with a locally built seed drill at 17.5 cm row spacing following seedbed preparation as above, and other crops (vetch, lentil, chickpea, and wheat in the alternate phase) with a zero-till planter directly into wheat stubble at 30 cm row spacing. Medic seed was broadcast in 1983 and 1984, and now pastures are allowed to regenerate every second year annually. Watermelon is established as single plants on a 3x3 m grid according to local practice. Wheat and legumes are normally planted in the second half of November and early December, respectively, following the initial rains. Watermelon is sown in mid-April, providing the soil is wet to a depth of 1 m, on land that has been bare-fallowed through the winter.

Cultivars. The improved durum wheat, Cham 1, has been used throughout the trial. ILC 482, a cold-tolerant chickpea cultivar, with tolerance for *Aschochyta* blight, released in Syria as Ghab 1, was selected for the early sowing strategy used in the trial. It was replaced in 1991-92 by Ghab 2. Syrian local small lentil, used for the first two years, was replaced by a newly released cultivar, Idleb, in 1987-88. The vetch and watermelon are both locally used strains. Thirty kg/ha of 48 ecotypes of 12 species of medic was originally sown, with the objective of studying the species population dynamics under grazing. The pastures are now dominated by local ecotypes of *Medicago polymorpha* L., *M. noeana* (L.) All., and *M. rigidula* Boiss., but most of the species have survived and are represented in the swards.

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

Crop Protection. Weeds are controlled with appropriate pre- or post-emergence herbicides, while fallows are maintained weed-free by a combination of cultivation and herbicides. Grazing normally provides adequate weed control in the vetch and the medic pastures. Diseases, insects and rodents are controlled by routine seed dressing, and tactical use of chemicals when necessary.

Grazing management. Medic pastures are grazed in winter to control weeds and volunteers and, later, in spring and summer for as long as they will support 8 to 10 ewes (and lambs) per ha without prejudice to the maintenance of the seed bank. Vetch is used as a high quality feed source for weaner lambs in the spring and is grazed at 25-30 head/ha. Wheat stubble is grazed by temporarily fencing sub-plots and introducing a large flock (400-600/ha) for one or two days.

Yield Determination. Approximately 20% of the area of each wheat and chickpea plot is harvested with a plot combine to determine grain yield, usually in the first half of June. The harvest index is estimated from 5 x 1-m row samples per sub-sub-plot, and total dry matter and residue yields are estimated from the grain yield and the harvest index. The same proportion of lentil plots is hand-harvested (late April/early May), dried and threshed, and seed and residue yields are measured. The 'yield' of the vetch and of medic pastures is estimated as grazing days per year (number of days x stocking rate) and as animal products, lamb liveweight gain and milk yield.

Soil Analysis. The soil has been sampled on an almost yearly basis since 1989. That year, five surface samples (0-20 cm) were taken from each sub-sub-plot, bulked and analyzed for mineral N, and total N. In addition, those plots routinely monitored for soil moisture content, ie, the heavily grazed plots with 0 and 90 kg N/ha applied in the wheat phase in the W/F, W/C, and W/M rotations, were sampled in 20 cm increments to 1 m. Those samples were analysed for organic matter content.

Results and Discussion

Crop production. A brief overview of crop yield trends is pertinent prior to discussion of the soil data. A dominant feature has been the inter-annual variation due to varying rainfall; for example, mean wheat grain yield ranged from 0.83 t/ha in a dry year (1988/89, 235 mm) to 3.62 t/ha (and up to 5.0 t/ha with adequate N fertilization) in a wet year (1987/88, 486 mm). However, rotation has had a strong and consistent effect on wheat total biomass and grain yields. The ranking, according to the alternate crop, is wheat $\leq$ medic $\approx$ chickpea $<$ vetch $\approx$ lentil $<$ melon $\approx$ fallow, which largely reflects residual soil moisture after the preceding crop. There is little evidence to show that legumes contribute significant amounts of N to the cereal phase, except that wheat after medic shows no N deficiency at tillering, whereas deficiency symptoms are usually visible in all other sequences at zero and low N levels. There is in most years a significant yield response to at least 30 kg/ha of N fertilizer, with a response to 90 kg N/ha in the wet year, 1987-88, and to 60 kg/ha in the rotations with fallow, both related to a greater availability of soil moisture, but no response in dry years. Another exception is that after the third cycle of medic pasture the wheat grain yield without N fertilizer has equalled that from 30 kg N/ha.

Soil Nitrogen. Previous reports of the soil and crop N status of this trial have been limited to preliminary observations on data obtained in 1989 (Matar and Harris 1991). Since then we have had a limited sampling in 1990 and a complete sampling after the 1990/91. This included determination of mineral N (NO_3 + NH_4), and of total (Kjeldahl) N.

In the wheat phase, soil mineral N concentration was consistently greatest in the W-M rotation, while W-W and W-L tended to have lowest values. The same trend was again evident when measurements were made after harvest, of either wheat or alternate crop (Table 4.4.1). The residual effect of N fertilization was evident after the wheat phase but less obvious after the unfertilized alternate phase. Any mineral-N remaining after the wheat crop is likely to be used by the alternate crops, immobilized into soil organic forms, or lost through denitrification (see Wood and Pilbeam 1996).

Total soil N is effectively a measure of organic N, the predominant soil N fraction. Again, the medic rotation soil (W/M) was significantly enriched in total N relative to that under continuous wheat or wheat with fallow or summer crop -- none of which added to the soil N (Table 4.4.2). Total soil N values for other wheat-legume rotations exceeded those with no legumes, but whether this represents N enrichment or N saving is not clear. When the rotation effect was separated into phases, soil N values were consistently higher after the alternate crops and also after nitrogen fertilization at the 60 and 90 but not the 30 kg N/ha rate.

Organic Matter. In theory, any changes effected by different management treatments on soil organic matter are likely to be slow. However, there was some evidence that small differences had arisen in the 10 years since the trial began (Table 4.4.3). Notwithstanding the limited data for 1990, there was a general consistency across years. Lowest organic matter contents were found in soils under non-legume rotations, W-W, W-F and W-SC. Among rotations that include legumes, that with medics had the highest values, followed by rotations with vetch, chickpea, and lentil which were similar. Reasons for this pattern are not simple. More mineralization of OM might be expected in the fallow and watermelon rotations, due to greater availability of water. Accumulation under medic pasture could arise from inefficient use of dry matter due to trampling and soilage during grazing, deposition of some 400 kg dung/ha/yr, and an extensive root system characteristic of medic.

Table 4.4.1. Rotation effects on topsoil (0-20 cm) mineral nitrogen concentration (ppm)[1]

Year	Crop rotation[2]						
	W-F	W-W	W-L	W-C	W-S	W-V	W-M
1989	10.2	9.9	9.7	9.8	11.1	11.9	15.8
1990	9.5	-	-	10.3	-	-	11.0
1991	14.2	7.9	8.3	10.4	11.2	10.3	14.9
1992	16.2	13.6	-	11.7	-	-	21.0
1993	19.8	14.7	17.7	17.8	17.2	18.7	20.8
1994	21.5	21.9	17.8	17.1	17.0	19.5	22.1
1995	9.7	8.2	10.4	10.1	11.5	14.8	18.3

1. Sampled in autumn each year, mean of both cereal and alternate phases.
2. W Wheat; F Fallow; L Lentil; C Chickpea; S Watermelon; V Vetch; M Medic.

Table 4.4.2. Effect of rotation and time on topsoil (0-20 cm) total nitrogen concentration (ppm)[1]

Year	Crop rotation[2]						
	W-F	W-W	W-L	W-C	W-S	W-V	W-M
1989	686	698	737	716	668	739	806
1990	697	-	-	737	-	-	812
1991	688	678	718	696	651	738	792
1992	771	752	-	785	-	-	914
1993	745	752	787	802	715	823	905
1994	728	768	765	790	710	813	930
1995	737	796	786	831	732	873	970

1. Sampled in autumn each year, mean of both cereal and alternate phases.
2. See notation in Table 4.4.1

Table 4.4.3. Effect of rotation and time on the organic matter content (%) in the top 20 cm of soil[1]

Year	Crop rotation[2]						
	W-F	W-W	W-L	W-C	W-S	W-V	W-M
1989	1.03	1.05	1.12	1.09	1.02	1.13	1.26
1990	1.00	-	-	1.11	-	-	1.22
1991	1.03	1.05	1.09	1.07	1.02	1.14	1.21
1992	1.22	1.20	-	1.25	-	-	1.44
1993	0.98	1.01	1.05	1.12	0.97	1.12	1.23
1994	1.12	1.14	1.08	1.20	1.08	1.19	1.39
1995	1.14	1.17	1.13	1.23	1.11	1.32	1.46

1. Sampled in autumn each year, mean of both cereal and alternate phases.
2. See notation in Table 4.4.1

Nonetheless, it seems unlikely that these processes entirely explain the difference between the medic rotation and rotations with other legumes. The input during vetch grazing was probably similar to that during medic grazing, as total grazing days were similar. Vetch does, however, have a sparser root system. Chickpea, on the other hand, has an extensive root system, and all crop residues are returned to the soil after harvest. Lentil resembles vetch in having a small root system and all above-ground biomass is removed at harvest. In the other phase, wheat following lentil and vetch produces more above-ground biomass and, presumably, more root material than wheat following medic or chickpea.

Full elucidation of the dynamics of soil organic matter changes under different crop rotations requires more basic studies of carbon and N cycling. One further point is seen in the apparent effect of N-fertilizer rate on organic matter content (Table 4.4.4). This is probably attributable to a stimulation of root growth by the applied N. This hypothesis is supported by data on water use, which show greater drying of the soil profile by fertilized crops.

Table 4.4.4. Effect of nitrogen fertilization on the organic matter content (%) in the top 20 cm of soil [1]

Year	Fertilizer N applied (kg/ha)[2]			
	0	30	60	90
1989	1.06	1.07	1.12	1.14
1990	1.06	-	-	1.16
1991	1.05	1.08	1.11	1.11
1992	1.21	1.25	1.30	1.35
1993	1.03	1.04	1.10	1.11
1994	1.13	1.15	1.21	1.21
1995	1.20	1.18	1.26	1.26

1. Sampled in autumn each year, mean of both cereal and alternate phases.
2. In alternate years to wheat phase.

Conclusions

As yet, only the most tentative of generalizations can be made regarding the effect of crop rotation on soil N and organic matter. Notwithstanding the dominant effect of soil moisture and the positive influence of fallow and short-season crops on subsequent cereal yield, some effects were already evident after the first sampling. Organic matter content appeared to be higher in the medic-cereal rotation, and similar differences were found at the second sampling. Where there was no legume in the rotation, organic matter contents were always lower. With time it will become apparent what equilibrium content can be maintained by such rotations in this environment, and it is interesting to speculate how this will affect soil condition. Preliminary work suggests that evolving differences in organic matter content may be influencing such physical properties as aggregation and water-holding capacity. At the same time, higher soil N in the medic rotation should benefit the alternate wheat crop when moisture is not too limiting. Further, the greater grain and straw N content after medic provide a further bonus, in terms of improved food and feed nutritional quality, the value of which it is not easy quantify. ***[John Ryan, Samir Masri, and Sonia Garabet, with acknowledgements to Hazel Harris and Mustafa Pala for trial management details and crop yield information]***

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4.5 Nitrogen cycling in wheat-based rotational cropping systems at Tel Hadya

Introduction

It is often assumed that the use of a legume within the crop rotation will lead to an input of N to the system from biological nitrogen fixation. Data from Tel Hadya for the 1981/82 season indicated not only an increase in wheat yield in response to N fertilizer (up to 60 kg N/ha) but also a benefit to wheat following faba bean or lentil compared with wheat following wheat or fallow (Saxena 1988). Such a benefit is attributed to the ability of the legume to fix atmospheric nitrogen, some of which remains residually available to the following crop. The inclusion of grain legumes in cropping systems may therefore provide an alternative or complement to N fertilizer, thereby reducing the risks associated with using a high-cost input in areas of uncertain rainfall.

However, there is a need for more accurate information on N budgets within cropping systems, with gains and losses within different crops well quantified. To this end, ^{15}N experiments have been carried out within the long-term two-course wheat rotation trial at Tel Hadya, to quantify biological N-fixation, to determine the fate of applied fertilizer N, to estimate N losses and to determine the rate of N turnover in the soil-plant system.

Methods

Details of the rotation trial, initiated in the 1983/84 season, have been given previously (Harris 1990; Harris *et al.* 1993; Ryan *et al.* 1996). For the present work, four of the seven crop sequences were used: wheat following fallow (W-F); wheat following chickpea (W-Ch); wheat following lentil (W-L); and wheat following wheat (W-W). Both phases of the rotation were included.

In the 1991/92 season, in all wheat plots 4m^2 microplots were treated with ^{15}N-enriched urea (10.424 atom%) at the same rate of N application as the main plot (0, 30 and 60 kg N/ha), in order to measure fertilizer use efficiency. In legume plots, 1m^2 microplots were treated with ^{15}N-enriched ammonium sulphate (10.189 atom%) at a rate equivalent to 30 kg N/ha in order to estimate the rate of nitrogen fixation. In the two subsequent years ^{15}N-enriched ammonium sulphate (10.289 atom%) rather than urea was applied to both wheat and legume phases of the rotation.

At final harvest, dry matter, total N and ^{15}N enrichment of plant samples and soil samples (as mineral N) were determined. The proportion of N in the plant or soil derived from fertilizer was calculated from the ratio of the enrichment of the plant or soil to the enrichment of the fertilizer, and the proportion of N in the legume derived from fixation was estimated from the ratio of the enrichment of the legume to the enrichment of the wheat (Wood and McNeill 1993).

Results and discussion

Response of wheat to N fertilizer. Yield data from the earlier years of the trial have demonstrated a generally positive response of wheat to N fertilizer. They have also shown the dry-matter production and grain yield of the W-W rotation to be consistently the lowest, and there has been no yield benefit from the presence of chickpeas or lentil in the rotation relative to that of fallow (Harris 1990).

In the present work, if the legume component was providing an input of N to the soil, then a difference would be expected in the ^{15}N enrichment values of the wheat in the different rotation treatments. Specifically, the enrichment of wheat in W-L and W-C treatments should be lower than that in the W-W and W-F treatments, due to isotope dilution. However, there is no evidence of this in data from 1991/92 to 1993/4 (Table 4.5.1).

Table 4.5.1. ^{15}N enrichment of wheat (atom%) in different rotations and receiving 30 kg N/ha in the seedbed, Tel Hadya, 1991-1994

	Previous crop			
Season	Wheat	Fallow	Chickpea	Lentil
1991/92	1.275	1.434	1.674	1.432
1992/93	1.068	0.876	0.946	0.866
1993/94	1.098	1.044	1.455	1.264

[N supplied as urea in 1991/92 and ammonium sulphate in 1992/93 and 1993/94].

Recovery of N fertilizer. Detailed ^{15}N studies indicated that the recovery of N fertilizer in the above-ground parts of the wheat was very low, ranging from 8.7% to 26.4% (Table 4.5.2). This could be due either to immobilization of fertilizer N in the soil or to loss by leaching, denitrification or volatilization.

Table 4.5.2. Percentage recovery of fertilizer N in mature wheat in different rotations and receiving 30 kg N/ha in the seedbed at Tel Hadya, 1991-1994

	Previous crop			
Season	Wheat	Fallow	Chickpea	Lentil
1991/92	19.6	22.2	26.4	22.9
1992/93	12.6	11.5	15.7	10.5
1993/94	8.7	11.3	11.8	15.6

[N supplied as urea in 1991/92 and ammonium sulphate in 1992/93 and 1993/94].

Even when soil N is taken into account, only 38 and 49%, respectively, of the 30 kg N/ha applied in the seedbed in the 1991/92 and 1992/3 seasons could be accounted for at harvest time (Table 4.5.3). Values for another 30 kg N/ha applied at tillering time were higher (72 and 47%) but showed a large difference between seasons.

Table 4.5.3. Percentage recovery at harvest time of fertilizer N in wheat (whole crop) and soil layers (0-20cm and 20-40 cm) at Tel Hadya, 1991/92 and 1992/93

	Time of nitrogen application			
	1991/92		1992/93	
	Sowing	*Tillering*	*Sowing*	*Tillering*
Wheat plant	23.6	12.3	11.5	9.8
Soil, 0-20 cm	20.4	55.1	22.7	33.1
Soil, 20-40 cm	5.3	4.8	3.9	4.2
Total recovery	**49.3**	**71.9**	**38.1**	**47.1**

[Wheat in wheat-fallow rotation. N fertilizer (60 kg N/ha) was applied as a split dressing at sowing and tillering, 30 kg N/ha on each occasion but labelled with ^{15}N at either sowing or tillering].

Detailed studies in the 1994/5 season showed that up to 50% of 30 kg N/ha applied in the seedbed could not be accounted for, even after only 12 days (Table 4.5.4). Losses from urea were greater than from ammonium sulphate. Recovery of ^{15}N in the soil ammonium pool was lower following urea than ammonium sulphate, suggesting that volatilization may have occurred from the urea following hydrolysis. However, losses from ^{15}N-labelled nitrate were greater than those from ^{15}N-labelled ammonium. Nor could the labelled fertilizer be more than partly accounted for in the organic fraction of the soil, showing that immobilization is unlikely to be responsible for all the loss.

Table 4.5.4. Percentage recovery of different forms of fertilizer N in the soil (0-10 cm) 12 days after application at sowing at Tel Hadya in 1994

Soil	Form of nitrogen application		
N fraction	^{15}N-urea	^{15}N-ammonium	^{15}N-nitrate
Ammonium	11	36	0
Nitrate	18	22	42
Organic	15	18	15
Urea	6	nd*	nd
Total	50	76	57

[^{15}N-labelled fertilizer was applied at rate of 30 kg N/ha as urea or ammonium nitrate labelled either on the ammonium-N or the nitrate-N].
*nd - not determined

Denitrification therefore remains the only possible significant cause of N loss from the soil; only 42% of the applied nitrate fertilizer was recovered as nitrate even 12 days after application (Table 4.5.4). This requires further study to demonstrate by direct measurement the extent of denitrification in these soils. Data on split fertilizer application (Table 4.5.3) show greater recovery of fertilizer N after spring application, when conditions should be less suitable for denitrification.

N inputs and outputs. Studies with ^{15}N have made it possible to quantify the different sources of N to crops and to create N budgets for the different rotation treatments in the Tel Hadya trial. Annual values of grain N for wheat receiving 30 kg/ha fertilizer N varied widely between years and rotations, from 10 to 100 kg N/ha, with a mean of 45 kg N/ha. If only the wheat grain is removed from the land, then the average annual input of N required to sustain this level of production is 45 kg N/ha; but in most rotation treatments in most years the offtake of N in the grain is greater than the fertilizer input, implying that soil N is being mined.

However, this calculation assumes that all of the fertilizer N applied remains available for uptake by the wheat. Yet the data in Table 4.5.5 indicate that the fertilizer N recovered by the crop in the season of application accounts for only about 10% of the offtake in the grain; and residual fertilizer N could provide no more than 40% of grain N offtake in subsequent wheat crops. A continuous wheat cropping system fertilized with 30 kg N/ha/annum is therefore sustainable neither in the short term (during a single season) nor in the medium term (over, say, ten seasons).

Table 4.5.5. Source and amount of N (kg N/ha) in different parts of the soil-plant system at wheat harvest in the wheat-fallow rotation, Tel Hadya, 1991-1994

Season	Grain N	Fert-N in crop	Fert-N in soil
1991/92	41.5	6.7	10.4
1992/93	49.1	3.5	18.3
1993/94	35.6	3.4	13.2

[Wheat was fertilized with 30 kg N/ha, supplied as urea in 1991/92 and ammonium sulphate in 1992/93 and 1993/94].

Data presented above (Table 4.5.1) showed no consistent residual N benefit from the legume to wheat grown in rotation with chickpea or lentil. The net input to soil N from these legumes must take account of the N removed from the land in their grain. Over the three years of measurement, the chickpea grain contained 22 to 71 kg N/ha, less in two years out of three than the amount of N gained by the whole plant through N fixation (Table 4.5.6). The chickpea crop therefore is not providing a net input of N into the system.

Table 4.5.6. Source and amount of N (kg N/ha) in different parts of the soil-plant system at the harvest of chickpea and lentil in rotation with wheat, Tel Hadya, 1991-1994

Season	Grain N	Straw N	N fixed
		Chickpea	
1991/92	70.7	12.2	21.3
1992/93	31.7	25.0	47.7
1993/94	21.5	2.1	18.5
		Lentil	
1991/92	65.5	15.3	39.3
1992/93	27.7*		19.0
1993/94	75.9	29.6	96.5

[* figure is for grain + straw]

A similar result is obtained for lentil, particularly if the lentil straw, a valuable animal feed, is removed from the land together with the grain. Altogether, it appears that the inclusion of these grain legumes in rotation with wheat may deplete soil N less rapidly than continuous wheat cropping, but it is unlikely to yield a positive N balance. These particular grain legume-wheat rotation systems therefore do not offer the immediate prospect of sustainable cropping.

Conclusions

The data presented here quantify the balance between inputs and outputs of N in four different wheat-based cropping systems and highlight the net depletion of N which is likely to occur in all such systems. Of especial concern are:

1. The large losses of fertilizer N which apparently may occur soon after application, and the consequently very low recoveries of that N by the wheat crop.
2. The lack of a positive net input of N to the system by chickpea and lentil crops.

[Based on a paper by Martin Wood & Colin Pilbeam (Univ of Reading) and Hazel Harris, and acknowledging the support of John Ryan, Sonia Garabet and many other members of FRMP technical support staff]

Postscript

It is useful to place here results from the 1994/95 season's work, which was not included in the above paper but which supplements its findings.

Effect of fertilizer form on fertilizer recovery by wheat. Urea fertilizer was used in the first season (1991/92), ammonium sulphate subsequently (1992/93, 1993/94). In 1994/95, both fertilizers were applied at 30 kg N/ha to 1 m^2 microplots in the wheat in each replicate of the W-F and W-W rotations. Percentage recovery in the crop was greater in wheat following fallow, but there was no difference between fertilizers (Table 4.5.7). Percentage recovery in the soil was the same, irrespective of rotation and fertilizer form. Losses were large but unaffected by fertilizer form.

Table 4.5.7. Percentage recovery of ^{15}N, applied as urea or ammonium sulphate, in the crop and 0-40 cm soil layer, Tel Hadya, 1994/95

Fertilizer form	Previous crop	Crop	Soil	Unaccounted for
Urea	Wheat	6.6	21.8	71.6
	Fallow	17.9	20.3	61.8
Ammonium sulphate	Wheat	8.7	23.9	67.4
	Fallow	19.6	19.5	61.0

[Fertilizer was applied at planting time at an application rate of 30 kg N/ha].

Recovery of a previous application of fertilizer. Labelled ammonium sulphate was applied in 1992/93 at a range of N rates to wheat in W-F rotation. In the year of application, recovery by the crop ranged from 6.1 to 12.7% or between 2.9 and 7.6 kg/ha of ^{15}N-labelled fertilizer nitrogen (Table 4.5.8). Between 7.9 and 39.1 kg/ha remained in the soil. In the third year of the sequence (ie. the second wheat crop), the percentage recovery of this residual N was small (1.6-3.8%) but was greater if the original fertilizer had been applied in the spring than if it had been applied in the autumn only. The amount of labelled N remaining in the soil was much larger (15.0-23.3%) but followed a similar pattern to that recovered by the crop. ***[Colin Pilbeam, Univ of Reading]***

Table 4.5.8. Percentage recovery, in crop and soil at harvest time in 1993 and 1995, of labelled N, applied as ammonium sulphate to wheat in W-F rotation at Tel Hadya in the 1992/93 season. (Actual amounts of recovered N, kg/ha, shown in brackets).

Fertilizer rate	Time of label application	1992/93		1994/95	
		Crop	Soil	Crop	Soil
30	Autumn	11.5	61.1	1.6	16.2
		(3.4)	(18.3)	(0.5)	(4.9)
60	Spring	9.8	37.3	3.8	21.4
		(2.9)	(11.2)	(1.1)	(6.4)
60	Autumn	11.5	26.6	2.3	15.3
		(3.5)	(8.0)	(0.7)	(4.6)
60	Both	12.7	30.7	3.8	23.3
		(7.6)	(18.4)	(2.3)	(14.0)
90	Both	6.1	43.4	3.7	15.0
		(5.5)	(39.1)	(3.4)	(13.5)

30 kg N/ha was applied at planting time (autumn), and the remainder in the spring. The fertilizer was labelled at either or both of these times.

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4.6 Field Estimations of Nitrogen-Use Efficiency by Irrigated and Rainfed Wheat in a Mediterranean-type Climate

Introduction

Fertilizers are costly inputs for crop production and need to be used as efficiently as possible. Efforts to improve N fertilizer-use efficiency require a thorough understanding of the N dynamics of the soil-plant system in diverse situations. Crop response to fertilizer N and therefore efficiency of use is closely related to rainfall (or irrigation). Specific information on the fate of fertilizer N after application is necessary to determine its economic benefit and its contribution, if any, to environmental pollution, particularly under irrigated conditions.

Nitrogen-fertilizer use efficiency (NFUE) of crops may be calculated from the *difference* in N uptake between crops in fertilized and unfertilized plots. It is based on the assumption that addition of fertilizer N does not affect the availability or uptake of the native soil N, and that crops use the same amount of soil N in fertilized and control plots (Powlson and Barraclough 1993). Isotopic tracer methods may be used to determine NFUE directly. With ^{15}N-labelled fertilizer, it is possible to distinguish between N derived from the fertilizer and from the soil. This *direct* method, based on ^{15}N, assumes that neither plants nor soil microbial populations discriminate between ^{15}N and ^{14}N and use both in proportion to the amounts present (Barraclough 1991).

Estimates of NFUE based on ^{15}N uptake are usually lower than those calculated by the *difference* method (Harmsen and Moraghan 1988). While the magnitude of such differences varies with the crop and conditions, Westerman and Kurtz (1974) showed the overestimation to be 23 to 35% for sorghum, and Ayoub (1986) reported 27% for wheat. The most plausible explanation for such discrepancies is that fertilizer N may increase native N availability in fertilized soils, ie, the "*priming effect*" or stimulation of soil organic matter decomposition (Westerman and Kurtz 1973). Another hypothesis is that added ^{15}N is immobilized (and organic N mineralized) by soil microbial activity, causing pool substitution between fertilizer and soil organic N, ie, mineralization immobilization turnover (MIT) (Jenkinson *et al.* 1985). This process could explain the different values given by the two methods, and it implies that comparison of the two methods might shed light on the N dynamics of the particular soil-crop system.

Under dryland conditions, NFUE at harvest ranges from 20 to 80% depending on fertilizer type, time and method of fertilizer application, soil type and climatic conditions (Abdel Monem 1986; Wood and Pilbeam 1996). Most studies using ^{15}N in WANA have presented their results as balance sheets at crop maturity or harvest (Abdel Monem 1986; Ayoub 1986; Soltanpour *et al.* 1987), but efficiency of N uptake by plants during the growing season is not well described. Thus, the aim of the ^{15}N labelled experiment described here was to measure yield and N uptake by rainfed and irrigated wheat throughout the season. Soil mineral-N and organic N were also measured on several occasions, to allow the different soil/fertilizer N-dynamics and transformation pathways to be followed.

Materials and methods

The study was conducted at Tel Hadya over a 2-yr period. Wheat was planted after lentils in Yr 1, and after wheat in Yr 2. In the first year, seasonal rainfall (323 mm) was close to the long-term average; early season rain was relatively high, with little or no rain in March and April. In the second year, rainfall (275 mm) was about 10% below average, and crops suffered from moisture stress during the long dry spell from mid March to early May, when late rains brought relief just in time to save the harvest.

The 16 treatments comprised combinations of four irrigation rates and four N application rates, in a randomized complete block design with four replicates. During both years, supplemental irrigation was given in April (heading) at four rates: W3 was the amount (100%) of the water required to bring the profile back to field capacity; W1 and W2 were equivalent to 33 and 66% of W3 rate; and W0 received no irrigation water and represented rainfed conditions. In the first year, the respective irrigations were given on April 11 (28.5, 56.9, 85.4 mm) and May 6 (26.4, 52.8, 79.2 mm), giving total amounts of water applied of 54.9 (W1), 109.7 (W2) and 164.6 mm (W3). In the second year, three irrigations were given, on April 12 (27.3, 54.6, 82 mm), on April 26 (25.3, 50.6, 76 mm), and on May 12 (15, 30, 45 mm), giving totals of 67.6 (W1), 135.2 (W2), and 203 mm (W3).

Nitrogen was applied as $(NH_4)_2SO_4$ at 50, 100 and 150 kg N/ha. Micro-plots (2 x 1 m) were marked in the fertilized plots where $(^{15}NH_4)_2SO_4$ was evenly distributed as solution from a washbottle. Phosphorus was applied each season as a basal dressing of triple superphosphate at 40 kg P/ha. A local cultivar of wheat (Cham 4) was sown at 120 kg seed/ha in 20-cm rows in 4 x 5 m plots (20 Nov in year 1; 8 Dec in year 2). The crop was harvested in the first week of June each year. All plant samples were dried 48 h in an oven at 68°C, ground, and then analyzed for total N and N isotope ratio.

Crop and soil monitoring. In all four replicates of selected treatments (W0 and W3, zero N and 100 kg N/ha), soil moisture was measured with a Wallingford neutron probe at 0-180 cm soil depth, to monitor profile water depletion and calculate the water needed for each irrigation. Plant samples were taken at 15-day intervals from 3 x 70-cm rows during the two seasons. At harvest, 3 x 3-m row sample was cut to root level, and grain and straw were separated by hand with yields of both recorded and analyzed as above. Soil samples were taken four times each season to monitor N dynamics in selected treatments.

Analyses. In duplicate soil and plant samples, total N was determined by Kjeldahl digestion (Buresh *et al.* 1982). The ammonia was trapped in 0.01 *N* H_2SO_4 and the solution evaporated to dryness in glass vials. The $^{15}N/^{14}N$ ratio analysis and total N (expressed on an oven-dry basis at 105°C) were determined by a CN-Roboprep mass spectrometer.

Interpretation of total N and ^{15}N data. The proportion of N derived from fertilizer (%Ndff) was calculated as follows: atom %^{15}N in sample/atom %^{15}N in fertilizer, multiplied by 100. The resulting percentage was multiplied by the total N quantity found in the N pool (soil or plant) to get a value for NDFF (kg/ha). Percent N fertilizer-use efficiency was calculated as follows: *difference* method [N uptake (kg/ha) in fertilized plots - N uptake (kg/ha) in control plots]/[applied N (kg/ha)] x 100, and *direct* method [atom % excess ^{15}N in crop x total N uptake in fertilized plots (kg/ha)]/[atom % excess ^{15}N in fertilizer x applied N (kg/ha)] x 100.

Results

Dry matter production and grain yield. Treatment effects on dry matter and grain yield values are summarized in Figure 4.6.1. Both parameters were increased by N fertilization and by supplemental irrigation. Response to N was greater in the first (wet) year, while response to supplemental irrigation was greater in the second (dry) year. Harvest index (grain yield as a proportion of total dry matter) was influenced by rates of both N and water. In particular, values were high at low irrigation rates in the second year, and low at high N rates under rainfed conditions.

Growth-period estimates of NFUE. Estimated values of nitrogen fertilizer-use efficiency differed according to the method used, *direct or difference*, and evolved as the season progressed (Figure 4.6.2). However, differences due to irrigation were evident only in the drier year. Irrespective of the year, values from the *difference* method exceeded those of the *direct* method by about 30%. In both years, N uptake was low during the early growth period (February and

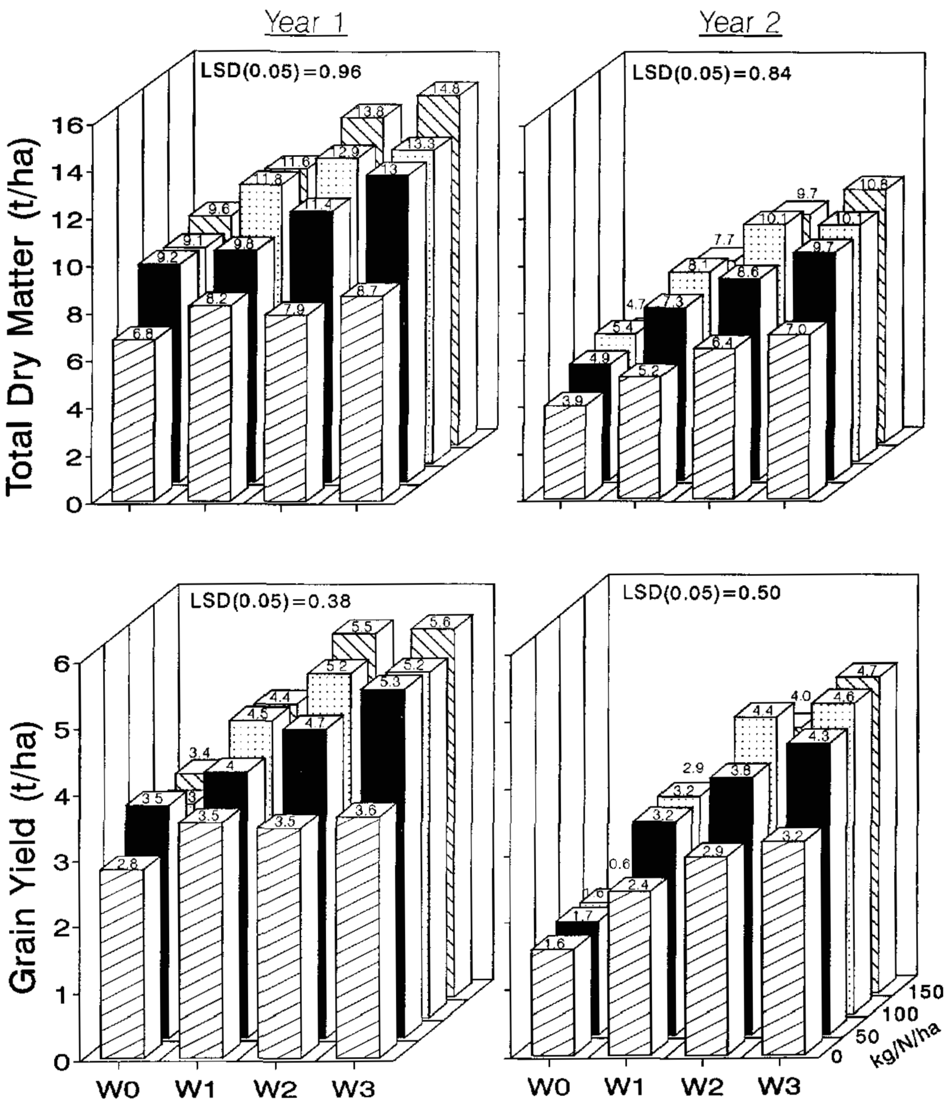

Figure 4.6.1 Total dry matter and grain yield in the two years

early March) because of the low crop N demand. Values reached a maximum in late April after a period of rapid growth in March-early April, that is long before harvest in both years. Then followed an apparent decrease in NFUE values, in both rainfed and irrigated treatments in the first year but only in rainfed treatments in the second year.

NFUE at final harvest. Efficiency values obtained at harvest (Figure 4.6.3) support the growth-period estimates (Figure 4.6.2). They show broad trends in the effects of rates of irrigation water and N on apparent fertilizer-use efficiency. Such trends are most clearly seen in the values obtained by the *direct* method, while those in the values from the *difference* method are less consistent. This inconsistency can be probably be attributed to variation in the control values, which introduce an additional source of variation into *difference* method values. It may be noted that the CVs of NFUE values were higher for the *difference* method: 24 and 30% (years 1 and 2, respectively) compared with 11 and 17% for the *direct* method (Figure 4.6.3).

However, both methods show a clear pattern in the effects of irrigation: efficiency of fertilizer use fairly generally increased with increasing water application, at least up to the W2 rate. With heavier irrigation, up to the W3 rate, there was a tendency for values to level off -- or to decline, an effect that was remarkably consistent for the 100 kg N/ha treatment across both years and methods.

On the other hand, NFUE methods show apparently contrasting patterns for the effect of N rate. In both years, the *difference* method showed a small mean decline in fertilizer-use efficiency with increasing rate of application. Given the considerable variability in the data noted above, this may or may not be meaningful. However, it is in sharp contrast to the trend shown by the values obtained by the *direct* method: mean values across W rates are 34, 50 and 52% (in year 1) and 31, 36 and 51% (in year 2), for the 50, 100 and 150 kg N/ha treatments, respectively. It seems unlikely that this contrast can be explained entirely by the variability of the *difference* method values but rather represents a real discrepancy between methods.

Soil N recovery. Fertilizer recovered in fertilized soil (100 kg/ha) after harvest as total ^{15}N was 56 and 43% for rainfed and irrigated treatments, respectively, in year 1, and 73 and 53% in year 2 (Figure 4.6.4). Over 80% of the recovered fertilizer was found in the top 20 cm soil layer.

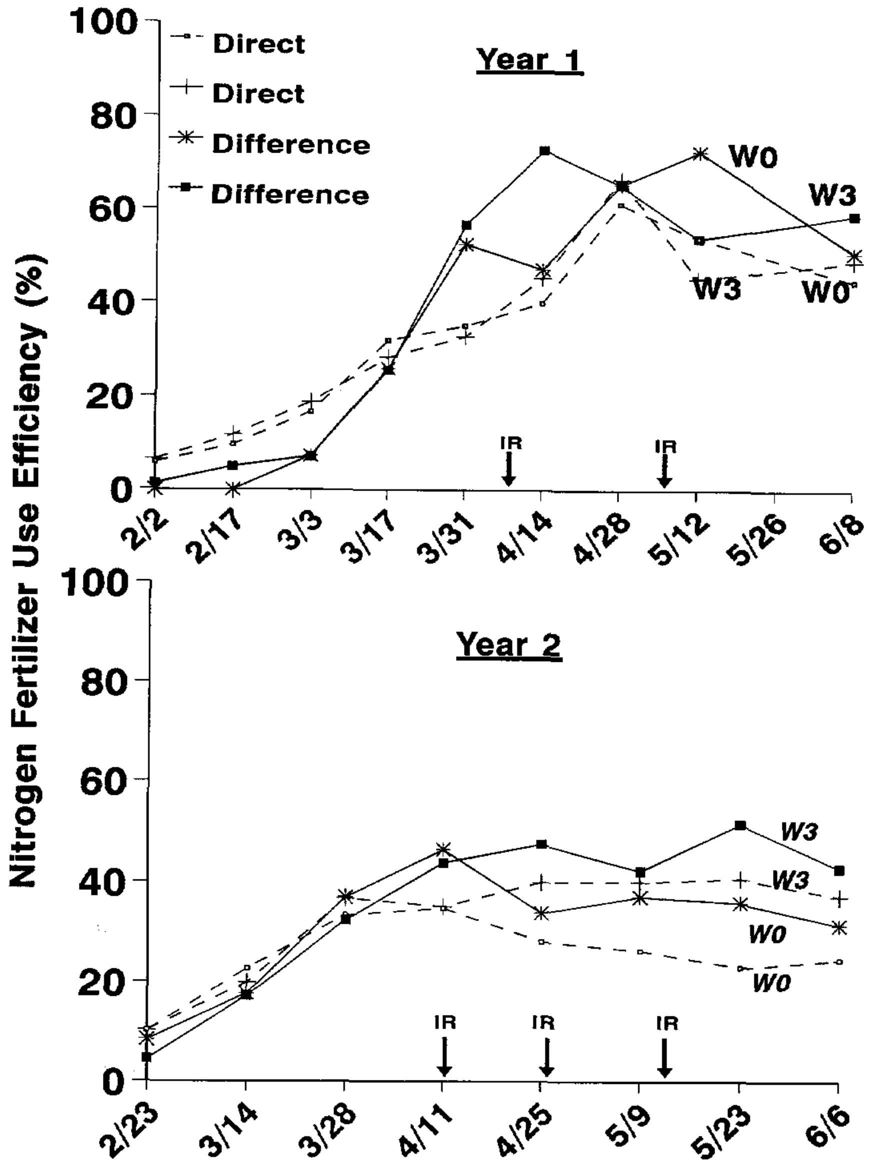

Figure 4.6.2 Nitrogen fertilizer-use efficiency (100 kg/ha rate) by the Direct and Difference method at different plant sampling dates for two seasons

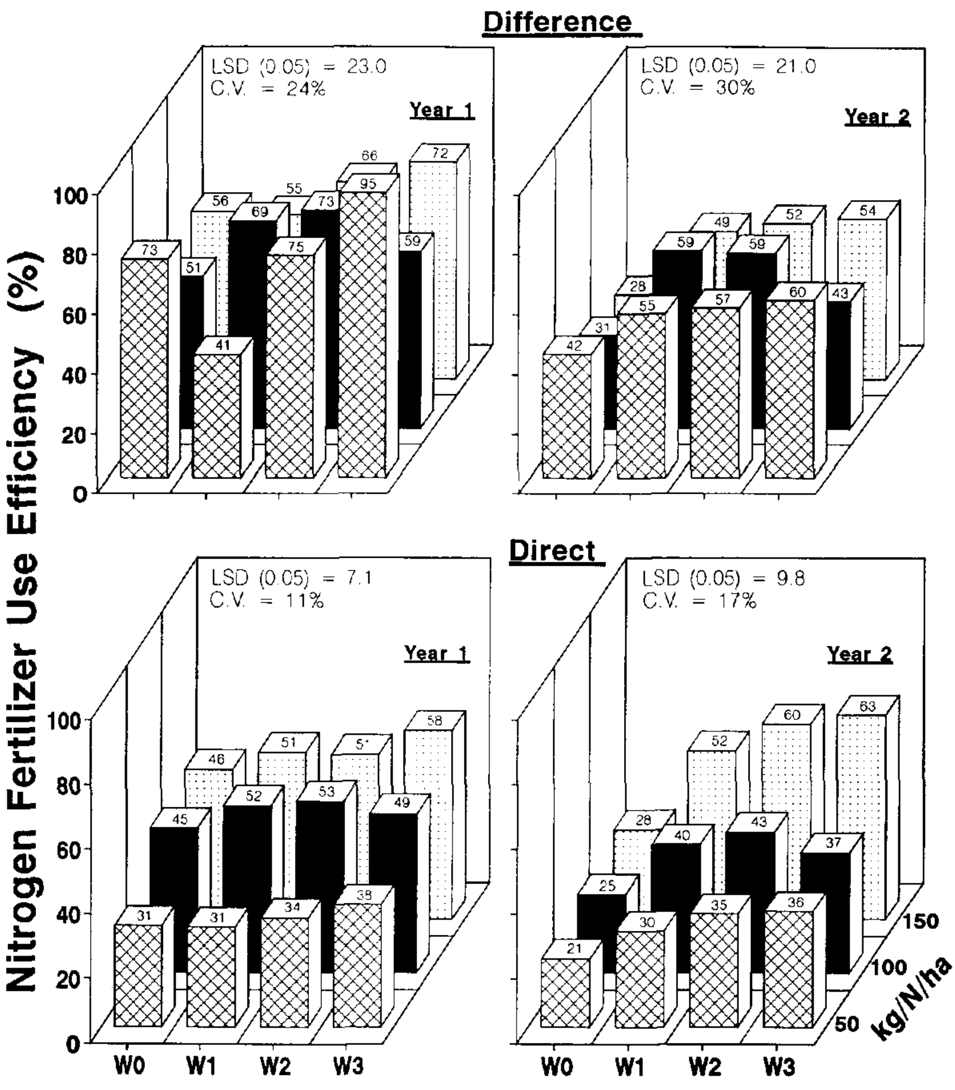

Figure 4.6.3 Nitrogen fertilizer-use efficiency by the Difference and Direct methods for two seasons

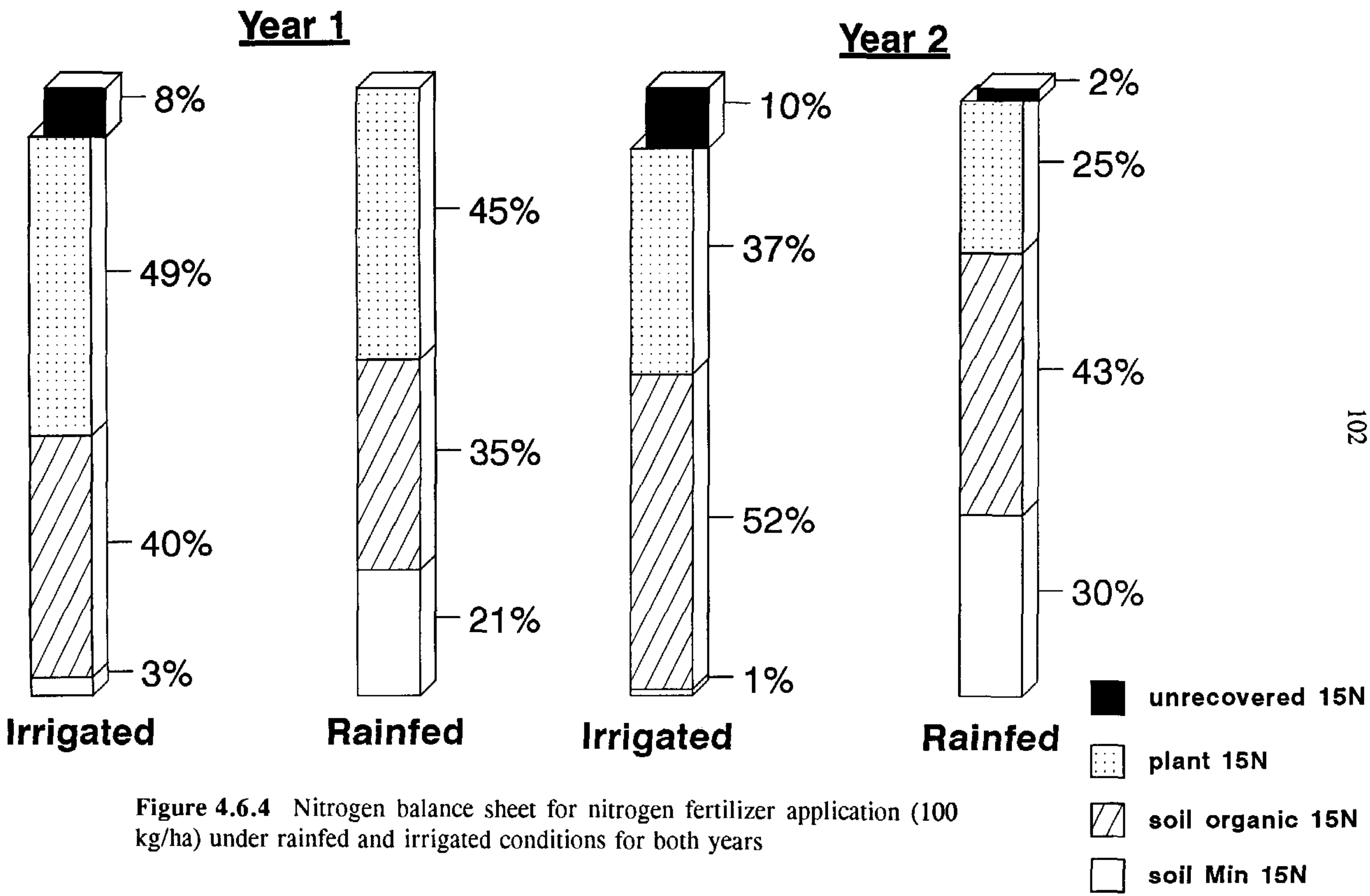

Figure 4.6.4 Nitrogen balance sheet for nitrogen fertilizer application (100 kg/ha) under rainfed and irrigated conditions for both years

Discussion

Nitrogen fertilizer-use efficiency measurements showed that, generally, the values measured at harvest underestimate the potential of fertilizer N uptake efficiency, since this value was higher before heading time than at harvest. This indicates that appreciable amounts of N can be lost after heading either as dead leaves or gaseous losses from live tissue (Mary *et al.* 1987). Thus, N fertilizer-use efficiency values recorded are highly dependent on the time or the growth stage selected for evaluation. However, supplemental irrigation, particularly in a dry year, may reduce the decline in measured NFUE from its peak value, by extending the life of the green leaves and preventing foliage decay.

Values from the *difference* method are generally higher than those from the *direct* method (Harmsen and Moraghan 1988). However, this situation is reversed during early growth, because, at that stage, in treated micro-plots, the quantities of labelled NH_4^+-N in the upper soil layer (where most roots are) are relatively large. Since the crop does not discriminate between ^{15}N and ^{14}N, the *direct* method is liable to give artificially high NFUE values under these conditions. This is the stage when crop uptake is still slow, and available soil N is probably sufficient (or almost sufficient) to meet the requirement, so that it is likely the lower values estimated by the *difference* method more closely represent reality.

In later stages, however, when temperatures are higher and plant growth much more rapid, labelled N may become involved in biological mineralization-immobilization processes, leading to an underestimation of NFUE values by the *direct* method relative to the *difference* method. When a rigorous N balance was done for both years, it was concluded that mineralization-immobilization-turnover (MIT), and not "added N interaction", was the mechanism responsible for the discrepancy between the two methods, with the immobilization process being dominant over mineralization.

In this study, considerable amounts (>50%) of residual fertilizer were left in the soil at harvest. Part of this was probably present in the crop root system, but this would probably not exceed 5-10% of that in the above-ground biomass. Fixation of NH_4^+-N by certain clay minerals (eg. montmorillonite) could occur but seems unlikely to explain the difference observed between the two methods. Small amounts of fixed-^{15}N were found in the same site and for the same type of fertilizer N (<10%).

The considerable degree of apparent $^{15}(NH_4)$ immobilization indicated in both years could be attributed to a large population of heterotrophic organisms and the presence of readily-soluble C source for microbial activity. The Tel Hadya soil is generally low in organic carbon (with a C:N ratio around 10 in this trial). With increased crop biomass production and increased root development, the amount of decomposable organic C in soils, particularly in the rhizosphere, is likely to increase. Therefore, the total amount of N immobilized in the growing season is likely to increase with increased N application -- not primarily because of increased N availability, but rather as a result of increased availability of organic carbon in the system. The higher values of immobilized N, and lower values of net N mineralization, calculated for the fertilized plots confirmed this.

The data in this study thus support the hypothesis that a significant portion of residual fertilizer N is immobilized in the soil organic fraction. However, the crop rotation can have a significant influence: for example, net N mineralization was greater under the lentil crop than under the wheat.

Conclusion

The method by which N fertilizer use efficiency is estimated can have considerable effect on the result. This is because the microbiological processes of nitrogen mineralization and immobilization interfere differently in the two different methods. In the *difference* method, there is what is called an "added N interaction" between the soil and fertilizer N (tending to stimulate mineralization); in the *direct* method, there is biological exchange between soil and fertilizer N due to mineralization-immobilization-turnover. However, in this study, under the prevailing conditions, mineralization-immobilization turnover was apparently the dominant process controlling the N dynamics in the soil-plant system. In this context, studies using ^{15}N-labelled fertilizer can exactly define the amount of fertilizer N in the plant and the soil, and particularly, what is lost from the system. Management practices, like supplemental irrigation, that ensure maximum N fertilizer uptake are important for improved N fertilizer use efficiency. ***[Sonia Garabet, Martin Wood (Univ of Reading), and John Ryan]***

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5. PROJECT 19: SOCIO-ECONOMICS OF NATURAL RESOURCE MANAGEMENT

INTRODUCTION

The strategic objective of this project is an informed, equitable decision making and resource allocation, at personal, community and national level, that ensures that current and future agricultural utilization of soil, water and indigenous flora will maintain (and enhance) their essential fabric and future productive capacity. In the first contribution, resource management is discussed in the context of economic and agricultural development for several Mediterranean countries. The conflict between food security and improvements in natural resource management is highlighted. Suggestions on how to solve this conflict involve not only technical research but economic, social and institutional aspects.

The project focuses on land and water resources but also, on a limited basis, conducts some work relating to natural vegetation. The second contribution demonstrates how the philosophy of the project links with real resource management situations identified by the NARS. The approach followed is that of problem-solving, multidisciplinary and participatory research to field problems of natural resource management and depends heavily on the capability and the adaptability of the NARS staff to implement such research. It is the diversity of situations that provides a wealth of information, problems and food for thought to consolidate a project with generalizable results.

5.1 Food Security and Natural Resource Management in Developing Mediterranean Countries

Introduction

The countries that now comprise the developing Mediterranean countries (DMCs[2]) were the breadbasket of western civilization two thousand years ago (Lowdermilk 1975). These countries are now overpopulated in relation to their resources and have become net food importers; meanwhile, poverty and frustration in local populations induce emigration. In 1992, the DMCs had a population of almost 200 million people, with an average annual growth rate of 2.1%, and with an average per-capita income of $1320. Because of their proximity to the major oil exporters with small populations in the Middle East, they are commonly perceived from outside the region to be rich countries. In fact, Algeria and Turkey, with the largest per-capita Gross National Product (GNP) among the DMCs ($1900)[3], are well below the average of large oil exporters ($8300). The DMC economies are largely agricultural; therefore, variable weather, particularly variability in limited rainfall, plays a major role in their overall economic performance (World Bank 1994b). Securing consumption of essential foods at an acceptable level, ie, food security, is still a major concern. Twenty per cent of the world's cereal food aid during 1991 was for the DMCs (UNDP 1994). Turkey is the only net food exporter among them.

Rapid population growth and urbanization have pushed demand for water to the point where withdrawals are exceeding replenishments. Because of agricultural, industrial and domestic demands for water, there is a need for appropriate demand-management policies, together with technological innovations and modern on-farm technologies. Cultivation in marginal lands has increased soil erosion, while inappropriate water management practices have caused soil salinization. The degradation of natural resources poses serious questions for sustainable economic growth. The Mediterranean countries are moving toward economic, social and political integration in the General Agreement on Tariffs and Trade (GATT) era. The DMCs intend to work towards realignment of their economies in a competitive world. The agricultural sector is part of this alignment process. This paper identifies the need for reconciliation of food security goals with those of improved natural-resource management for sustainable economic growth. It discusses the role of agriculture in fostering sustainability of the natural-resource base, not only for individual nations but for the Mediterranean region as a whole.

The developing Mediterranean countries

The estimated population of the DMCs in 1992 was 197 million. Projections put it at 316 million by the year 2020. The populations of the Maghreb countries (Morocco, Algeria and Tunisia), with 30% of the population in the DMCs, are growing at between 1.9 and 2.4% annually (World Bank 1994c). Middle Eastern countries present a more diverse picture. Egypt and Turkey, comprising 57% of the total DMC population, are growing at 1.9% per year. Small countries such as Jordan and Syria are growing at 3.3% annually. Palestine has the fastest growing population at 5.1% per year; by the year 2020, their population will be three-quarters that of Lebanon.

Almost half of the population in the DMCs lives in rural areas (Figure 5.1.1a). The rural population in the Maghreb ranges from 43% in Tunisia to 53% in Morocco. Middle Eastern countries, again, present a heterogeneous pattern. While Palestine has 70% of rural population, Lebanon has only 14%. The Egyptian population is distinctly more rural than that of Turkey. Per-capita gross national product (GNP) in the DMCs averaged $1320 in 1992 (Figure 5.1.1b; data not available for Lebanon and Palestine), which is within the range of lower-middle income countries (World Bank 1994b). Egypt has the lowest per-capita output ($640) and falls within the low-income bracket. Turkey, Algeria and Tunisia are the most productive countries, averaging $1850 per person. Morocco, Jordan and Syria constitute an intermediate group, averaging $1100 per person.

Trade and external debt: On average, the value of DMC exports represents 41% of what they import. Algeria is the only country that has a positive trade balance, because of large oil and gas exports. Syria is in equilibrium. Lebanon has the largest deficit in trade; its exports represent 13% of the value of its imports (Figure 5.1.2a; figures for Lebanon were estimated using 1991 GDP, data not available for Palestine). Economic links with developed Mediterranean countries are significant. The Maghreb countries are major trade partners of Western Europe, from which they obtain 56% of their total imports of goods and services, and to which 62% of their exports go. Corresponding figures for Egypt, Syria and Turkey are 39% and 33% (EIU 1992).

Food imports to the DMCs average 17% of the value of total imports. Algeria and Egypt have the largest food-import bills, while Tunisia and Turkey spend the least. These figures, however, do not reveal how agricultural exports balance with agricultural imports (Figure 5.1.2a).[4] The ratios of the value of agricultural exports to imports of the DMCs indicate an increasing agricultural deficit during the period 1970 to 1991. In Algeria, dependence on agricultural imports has grown dramatically since the early 1980s; an oil-for-food policy has

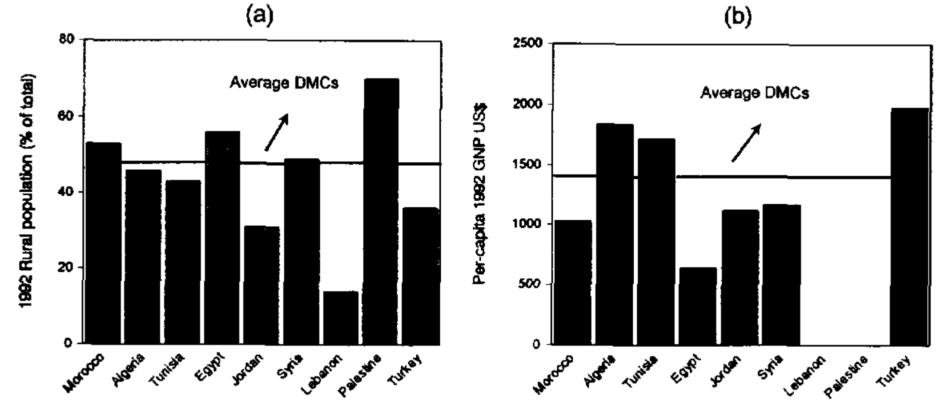

Figure 5.1.1 Rural population (a) and per-capita GNP in DMCs. Source: World Bank (1994b; 1994c; 1994e) and UNDP (1994)

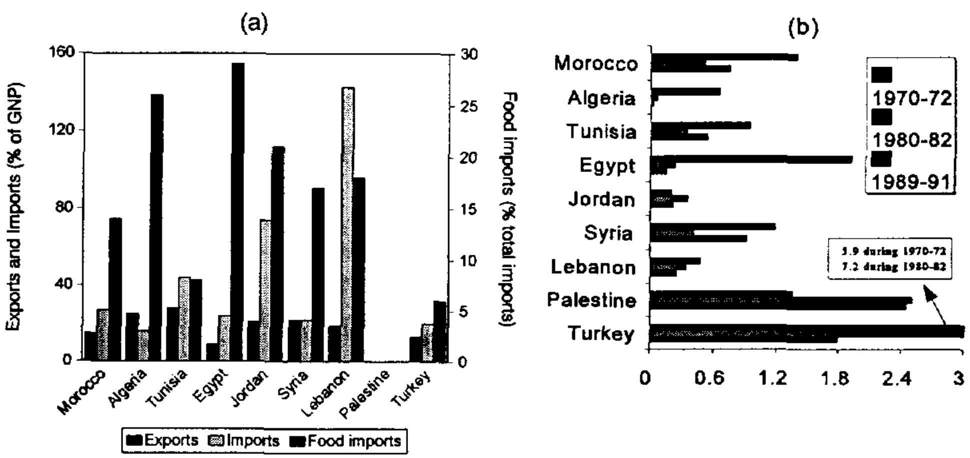

Figure 5.1.2 Trade and food imports (a), and ratios of the value of agricultural exprts to agricultural imports (b) in DMCs. Source: World Bank (1994e), Agrostat-PC 2.0 (1994) and FAO Trade Year Book computer tape (1993)

discouraged further development of its agricultural base. In the early 1970s, Morocco, Egypt, Syria, Palestine and Turkey were importing less than they were exporting. The rest of the countries were importing more than they were exporting. In the early 1980s, Morocco, Egypt and Syria became net importers of agricultural products. Gaza Strip and Turkey were the only net agricultural exporters (Figure 5.1.2b). However, there was an estimated negative food balance in both West Bank and Gaza Strip for 1990, except for citrus (ARCOTECH 1994). In the 1990s, the trend towards more imports than exports continued, with the notable exceptions of Morocco, Tunisia and Syria [see ESPC (1995a) for a detailed analysis of food trade and aid].

Trade deficits contribute to the external debt and the debt itself limits the availability of new funds to finance development. The net present value of the total external debt of the DMCs averages 190% of the annual exports (World Bank 1994e). Algeria, with a positive trade balance, and Syria, with a trade balance in equilibrium, are heavily in debt. Morocco, Egypt and Jordan are severely in debt, while Tunisia and Turkey are moderately in debt. Debt strategy continues to shift from repeated rescheduling to the maintenance of a positive cash flow as a means of speeding recovery of external viability (World Bank 1994b). This is particularly evident with low-income, heavily-indebted countries, such as Egypt.

Relevance of Agriculture: Total GDP of the DMCs amounts to $240,000 million (Figure 5.1.3a), which is about that of Switzerland alone. The share of agriculture in the GDP is about 17%. Agriculture has the largest share in Syria (30%), while in Jordan it is the smallest (7%). In the rest of the DMCs, agriculture contributes 13 to 19% to the GDP (Figure 5.1.3b). However, forward and backward linkages between agriculture and manufacturing are often overlooked (Janssen 1993). Agro-industries in Morocco, Tunisia and Turkey make major contributions to the domestic and international markets. Turkey, for example, exports close to $1000 million in processed agricultural products, which is about 45% of the value of various non-processed agricultural exports (EIU 1992). In Syria, food processing and fertilizer and small-vehicle production are a result of expanding agriculture.

As the economies of the DMCs have developed, the share of the agricultural sector in the GDP has declined; but it is still an important employer. On average, 40% of the labor force is involved in agriculture (Figure 5.1.3b). But while Morocco and Turkey have almost half of their labor force engaged in agriculture, followed closely by Egypt, only 10% of Jordanians work in agriculture. In Morocco, Egypt and Turkey, the large labor force employed in agriculture contributes only 16% of the GDP; in contrast, in Syria 23% of the labor force generates 30% of the GDP. Agriculture's share in the total labor force varies with the diversification and mechanization of agriculture.

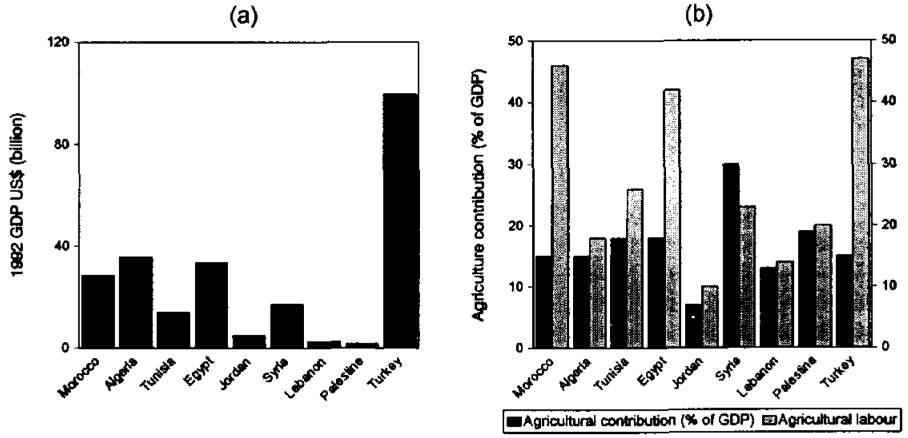

Figure 5.1.3 Gross domestic product (a), agricultural share in GDP and agricultural labour (b) in DMCs. Source: World Bank (1994e) and UNDP (1994)

Poverty: In 1960, the average DMC citizen could buy only one-fifth of the goods and services bought by a northern citizen.[5] In 1990, s/he was able to buy one quarter of what a northerner could buy. In the last three decades, Egypt has reduced the poverty gap by 15% and Morocco by 9%. In contrast, in Algeria and Jordan the gap has grown, by 7% and 2% respectively (UNDP 1994). Increased rural infrastructure has not been matched by job opportunities; under-utilized, it has surrendered potential employment to urban areas. Further, extreme poverty is more a rural phenomenon than an urban one. About 25% of the rural population in the DMCs fall below the poverty line (that income level below which a minimum nutritionally-adequate diet plus essential non-food requirements are not affordable; UNDP 1994) compared with 20% in the urban areas. Hence, poverty alleviation is largely a rural-development issue.

Migration: With employment creation lagging behind growth in the labor force, unemployment has become a serious problem in most countries. Rates of 15% or more are not uncommon in North Africa (ILO 1993). In a number of labor-surplus countries in the region, emigration has traditionally eased the pressure on labor markets. Laborers moving from the Middle East to the Gulf states, and from North Africa to southern Europe, constitute the major international migration patterns in the DMCs. In the 1980s, Arab workers constituted almost half of the non-national labor force in the Gulf countries -- which was 3.0, 4.4

and 3.6 million in 1980, 1985 and 1990, respectively. Recorded remittances of Egyptian, Jordanian and Syrian laborers were from $4000 million in 1986 and $5600 million in 1991 (ESCWA 1993a).

In 1992, there were almost 370 million people living in the European Economic Area. Of these, 0.8%, or 3.0 million, were from Morocco, Algeria and Tunisia. Turkish immigrants constituted 0.6%, or 2.3 million. While French-speaking migrants from the Maghreb have mainly gone to France and Spain, migrants from Turkey have tended to concentrate in Germany; there has been a long-term interaction between Turkish and German labor markets (EUROSTAT 1994; Zimmerman 1995). In the short term, the economic and demographic disparity between the Mediterranean's southern and northern shores will continue to encourage migration (Fraga 1994). A strategy to govern it cannot rely merely on legislation. This type of regulation must be accompanied by a structural strategy aimed at reducing the imbalances generating migration -- or by significantly modifying development where it is lagging in the migrants' areas of origin. Immigration policies cannot, therefore, be conceived in isolation from development co-operation policies (Brunetta and Turatto 1994).

Natural resource endowment and stewardship

Food production requires the use of natural resources. Farmers modify these to meet their needs within the bounds created by the availability of resources, institutions, regulating, and agricultural policies. Resource stewardship determines their sustainability.

Land: The total land area of the DMCs is about 5 million square kilometres, of which 12% is arable, 14% is permanent pasture, and the rest is rangeland, desert and urban areas (World Resource Institute 1992). Wheat and barley are the predominant rain-fed crops, occupying 87% of the rain-fed arable land. Irrigation in the DMCs makes possible not only the cultivation of cash crops but also higher productivity of staple crops.

Land reforms have been implemented in the last three decades. In many cases, the lands appropriated by governments were redistributed to landless or small-scale farmers. In Algeria and Egypt, the governments retained large tracts of land for agricultural production as state farms. In Syria, the maximum size of landholding was established in 1958 and further reduced in 1980. Tenurial arrangements have been revised in Egypt, Syria and Tunisia (ESCWA 1994a; El-Ghonemy 1993). The cropping pattern in Egypt is no longer fixed and there is no specific area allocated to wheat (Mahmoud Solh 1995, Nile Valley and Red Sea Regional Program, ICARDA Cairo, pers. comm.). Land concentration remains high. In Egypt, only 14% of all agricultural households benefitted from the reform which redistributed about 12% of the total cultivated area (ESCWA 1994a).

In some areas, however, inheritance laws and the regulatory framework governing ownership have resulted in land fragmentation. In Tunisia, about 50% of the landholdings consist of 6-10 plots with an average plot size of 1.8 ha. In Syria, the total number of landholdings in 1970 was about 400,000, comprising 1.8 million plots of land (ESCWA 1994b). The average variable cost of producing one kilogram of wheat in the region increases as the average field size decreases (Jabarin and Epplin 1994). Multiple, sparse and small plots, which decrease efficiency, are found in most of the DMCs. Fertilizer use is a variable that, among others, represents the degree of agricultural intensification. In the Maghreb, fertilizer use is relatively low, ranging from 13 kg/ha in Algeria to 36 kg/ha in Morocco (ERS-NASS 1994). Fertilizer use in Turkey, Jordan and Syria ranges from 51 to 64 kg/ha. The most intensive use of fertilizer occurs in Egypt, where 344 kg/ha are used, mostly in irrigated agriculture located in the Nile Valley and Delta. Returns from increased inputs are reasonable on well-endowed farms -- that is, large farms, or those with abundant water. They have proved less satisfactory in the less-favoured drier areas and highlands (Tutwiler and Bailey, in press). This has exacerbated rural-urban migration problems.

The greater part of the land mass of the DMCs receives less than 400 mm annual rainfall. Mediterranean rangelands receiving between 100 and 400 mm annual rainfall cover 707,000 square kilometres, or 14% of the land of the DMCs (Le Houérou and Boulos 1991). Rangeland vegetation in the DMCs made up 27% of the diet of 105 million small ruminants during 1988-92 (Rodríguez 1995). Land reforms have broken up large holdings, distributing them to former tenants and sharecroppers; and tribal control of rangelands has been virtually revoked in many countries. The unintended result of the latter was to shift the rangelands from community management to open access, leading to uncontrolled use and severe degradation (Nordblom and Shomo 1995). The ecological systems in the arid and semi-arid parts of the DMCs are extremely fragile. Once the land has been ploughed for cultivation or overgrazed, the natural vegetation cannot recover its original abundance. Subsequently, if the land is abandoned, erosion by water and wind may take its toll. Increasing rates of desertification have been documented for North Africa and the Middle East (World Bank 1994d). Intensification of agriculture and expansion into previously uncultivated areas is threatening the habitats of the wild progenitors of many of today's agriculturally-important species, reducing the genetic diversity.

Water: Fresh water is the most limited resource in the DMCs. Renewable fresh water generated from in-country precipitation averages 1000 m^3 per person, but there are differences of up to 3500 m^3 between countries (Figure 5.1.4a; Egypt, with 30 and 1200 m^3 per-capita internal renewable and annual withdrawal, respectively, was not included in the figure). Egypt has the least internally-generated water (it relies on external water flows from the Nile river) and Turkey is the best endowed. Per-capita annual withdrawal averages 400 m^3; Egypt, with the highest per-capita annual withdrawal, uses seven times as much as Algeria, which has the lowest. On average, 78% of the water withdrawal is used for agriculture (ranging from 91% in Morocco to 57% in Turkey), 15% for domestic purposes and the remainder for industry (Figure 5.1.4b; data for water use in Palestine is not available). Jordan also has a higher withdrawal than its internal renewable potential; it has to mine its groundwater resources. Domestic water use is relatively high in Algeria, Jordan and Turkey (22-29%) and relatively low in Morocco, Egypt and Syria (6-7%).

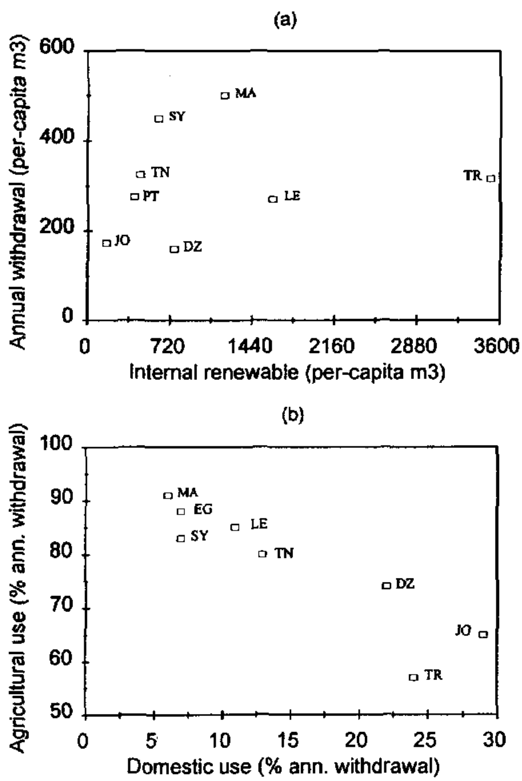

Figure 5.1.4 Water resources (a) adn its agricultural-domestic use (b) in DMCs. Source: World Resource Institute (1992) and ESCWA (1994a)

Despite scarcity, almost all the DMCs waste water. The overall efficiency of water use (network and on-farm) in Jordan, a high water-deficit country, is 53%, the highest in the region and much higher than other developing countries (30%). A large part of this is due to the proliferation of high technology, high-efficiency drip-irrigation systems, especially in the Jordan Valley (ESCWA 1994a). Water prices in agriculture do not reflect the scarcity of water or the real costs of investment in irrigation structures. Water pricing may be particularly difficult when, once a farmer has been able to drill a well, the water is virtually a `free access' resource. In contrast to land, most of the water in the DMCs has not been managed by traditional agreements or common property rights. The water has been brought to farmers through government schemes, which impose managerial procedures -- as opposed to users' participation in their development. As ESCWA (1994a, p. 10) puts it: "In the Arab region, water policies are inextricably linked to land policies and issues of food security. In the past, water policies focused on the supply-side management of water resources. Water policy was synonymous with irrigation policy, the objective being to expand irrigated areas through investment in irrigation and drainage systems. Water development projects included the construction of dams, reservoirs, well fields, and canal or pipe networks." In many countries, large-scale irrigation investment was undertaken without adequate control of drainage, resulting in waterlogging and salinity (ESCWA 1994a).

Lack of demand-management practices in the past has contributed to waste. In addition, improvements in the availability of water by the introduction of high technology have diverted attention from demand management and reduced emphasis on low-cost alternatives such as improving efficiency, conservation and reduction of waste through maintenance. "Subsidies on water are provided to offset low farm incomes brought about by controlled producer prices and, often, an overvalued currency. As such, pricing policies in agriculture, especially of water, are self-defeating; they conflict with the stated objectives of enhancing food security and maximizing agricultural exports" (ESCWA 1994a, pp. 11-12). If DMCs are to use pricing policies to lower demand, they must strengthen institutions that regulate the use of water and ensure accountability. The trade-off between alternative uses of water (agricultural, industrial and domestic) needs to be demonstrated to, and discussed with, the parties involved.

Agricultural development policies

Food security remains a high priority for the DMCs. The instability of food-aid shipments (cereals) poses a considerable threat to the food security of recipient countries (Taylor and Byerlee 1991). This is especially relevant for Egypt and, to a lesser degree, Morocco and Tunisia (World Bank 1994e). The balance between food self-sufficiency and food self-reliance policies depends on the perceived political stability of the region, the burden of the external debt exacerbated by food imports, and the comparative advantage of producing specific agricultural products. All the DMCs state that they aim at optimum allocation and use of agricultural resources, better exploitation of the country's comparative advantage to promote exports and contribute to overall food security, and creation of new employment opportunities. With variations from country to country, emphasis is put on price liberalization and trade. This includes: (1) removing government intervention through farm output prices, area and procurement quotas, and farm-input subsidies, (2) removing restrictions on the import and export of agricultural commodities by the private sector, and (3) reducing the gap between farm-gate prices and international prices of heavily-protected crops (eg cotton and sugarcane).

Highlights of natural-resource policies, marketing, and investment (or lack of it) in agro-industries are presented in Table 5.1.1. All the countries involved with irrigation are trying to improve water-use efficiency. Development of water-harvesting and supplementary irrigation are high on the agenda. However, approaches to this vary. In order to tackle water demand (management), Egypt has recently been conducting joint studies with the International Irrigation Management Institute (IIMI) on water charges; however, charges have been strongly opposed (Mahmoud Solh 1995, Nile Valley and Red Sea Regional Program, ICARDA, Cairo, pers. comm.). In contrast, pumping in the Khabur river basin (Syria) is restricted to two or three days a week to regulate water use; however, the role of subsidized diesel and electricity used for pumping is not clear. For example, Syria, uses expensive irrigation aiming at self-sufficiency in wheat, thus forgoing opportunities to grow more profitable crops. While Tunisia wishes to stop desert encroachment, Algeria seems to promote cultivation on marginal lands. Jordan is now emphasizing orchards under water-harvesting and barley/livestock systems in low-rainfall areas. It is also trying to develop improved range-management practices. However, overall in the DMCs, the conflict of interests between the public sector (governments) and the private sector (individuals or groups of individuals) is not emphasized enough. Lack of understanding of how resource-users perceive the abundance of resources and the role of regulatory institutions may lead to unsustainable resource use.

Morocco, Tunisia, Egypt and Turkey are aware that domestic and international policies need to be adaptable to market needs. Cotton in Egypt remains regulated by the government (ARCOTECH 1994), but in general there is liberalization; and the markets in Algeria and Syria are opening up to the private sector. Improvement in marketing conditions are expected in Palestine as a result of the peace process. However, transportation, post-harvest storage, grading, packing and supply constraints still hinder DMC products in international markets. Tunisia is the first country that has signed a free-trade agreement with the European Union. It is worth looking at agriculture in terms not only of non-processed products, but also its contribution to the economy in terms of value-added products and employment in manufacturing. Morocco,

Table 5.1.1. Agricultural policy issues regarded as important by DMCs

Country	Natural resource	Marketing	Agro-industry
Morocco	Encouraging fertilizer use in rainfed agriculture.	Needs to improve terms of trade with EU: fruit and vegetable competitiveness.	Major area of investment with good track record of employment creation.
Algeria	Development of steppe and desert farming in highland plateau and Saharan region.	Is increasing retail outside of state network.	Wheat flour, semolina and pasta are dependent on the extremely variable wheat production.
Tunisia	Investment in irrigation. Improved water-use efficiency. Protection against encroachment by the desert.	Has signed a free-trade agreement with EU.	Major area of investment with good track record of employment creation.
Egypt	Introduction of water charges is under consideration. Expansion of rain-fed agriculture, introducing drought-tolerant cereals with fodder crops and small ruminants. Use of supplementary irrigation to reduce risk and increase profitability.	Implementation of adaptable domestic and international policies according to market needs.	The government is privatizing agro-industries.
Jordan	Improvement of water-use efficiency. No more emphasis on wheat in the drylands. Instead, fruit trees under water-harvesting and barley/ livestock systems in low-rainfall areas. Improvement of range management and strengthening grazing rights.	Retail prices not freely determined. Lack of produce grading limits exports. Still has market protection.	There is a need for increased investment.
Lebanon	Land reclamation. Expansion of irrigation and improved water-use efficiency.	Needs to increase competitiveness in export of fruit and vegetables.	There is a need for increased investment.
Syria	Large investment in irrigation. Improvement of water-use efficiency. Pumping quotas rather than water pricing to tackle "free access" to water.	Needs less government involved in marketing cereals and increased freedom to sell at competitive prices.	Is expanding processing of fruits and vegetables, poultry and dairy products.
Palestine	Improvement of water-use efficiency. Use of improved varieties and techniques suitable for rain-fed agriculture.	Market regulated by occupation authorities. Poor support and extreme security restrictions for transport.	No processing or storage capacity.
Turkey	Improvement of natural-resource management in the highlands.	Adaptive policies according to market needs.	Continued support to its sophisticated agro-industrial sector.

Source: ARCOTECH 1994; Aw-Hassan *et al.* 1995; Dammak 1995; EIU 1992; ESCWA 1993b, 1994a, 1994b; World Bank 1994a.

Tunisia and Turkey have the most developed agro-industries; they have, therefore, already become exposed to international markets. Egypt and Syria need to ensure competitiveness in their agro-industries if they are to be exposed in this way. If trade barriers are lifted as a result of the peace process, there could be more opportunities for investment in agro-industries in the Near East. But it is the overall balance between natural resources and socio-economic policies that will determine the ability of the DMCs to achieve sustainable growth.

Trade and the anxiety for food security

The Uruguay Round of the General Agreement of Trade and Tariffs (GATT), affecting 117 signatory countries, started in January 1995. GATT includes measures aimed at trade liberalization and increasing world trade flows. The agricultural sector will be directly affected in terms of improvement of access to markets, reduction of domestic agricultural support and reductions of direct export subsidies of agricultural products (GATT 1993). Algeria, Morocco, Tunisia, Egypt and Turkey have signed the GATT. The World Trade Organization (WTO) will act as arbitrator of world trade, dealing with possible disputes arising from GATT. Lebanon, Jordan and Syria have applied for WTO membership (ESPC 1995b).

In the short term, the effect of GATT on DMCs is likely to be negative (ESPC 1995a, 1995b). Because of reduced production support and export subsidies, world food prices are expected to rise, causing an increase in the cost of imports. DMCs are highly dependent on food imports. GATT will therefore widen the food-gap in the region, increasing financial difficulties for food-importing countries. Reduction of tariff rates may also affect public revenues and lead to an increase in budget deficits (although this would be partly offset by the reduction in subsidies). Reduction of production support may be expected to lead to a rise in prices of local agricultural products. Exports of some DMCs, now heavily subsidized, will be affected as their competitiveness in world markets is weakened.

It is estimated that liberalization in trading agricultural products will benefit the developing world by $20,000 million annually (World Bank 1994b). However, this represents less than 60% of the Egyptian GDP, and will be spread over about 100 developing countries, who will be competing for it. The benefit of GATT is really more in terms of adaptation of economies to become competitive. This potential benefit -- invigoration of the economies -- may be larger than the immediate one of a more liberalized international market. The European Union and North American Free Trade Agreements are prominent examples of the recent trend to create regional trade arrangements. Tunisia is the first DMC that has signed a free-trade agreement with the European Union (Dammak 1995). Regional arrangements make sense -- either as a means for a developing country to ensure access to a particular industrialized country market, or as a sign of overall trade liberalization, starting with regional liberalization. However, previous regional trade agreements in the Middle East and North Africa have not been very successful (World Bank 1994a).

During the GATT implementation period, least-developed and net food-importing developing countries may experience difficulties in their food supply. This is recognized, and food aid in full-grant form and aid for agricultural development may be provided. This might take the form of assistance from the International Monetary Fund and the World Bank, including short-term financing of commercial food imports (GATT 1993). But the idea of being food-dependent in any way is difficult to accept when regional conflicts may turn food-dependence into a bargaining chip. It is unrealistic to expect DMCs to be food self-sufficient (Janssen 1993), but it is reasonable to expect food self-reliance. That is, the agricultural sector does not necessarily have to produce cereals if fruit and vegetables, oilseeds or fibres give higher returns in the international markets and offset food imports. However, this means dependence on international markets, and these vary with the weather and consumer preferences. Effective market intelligence and highly adaptable agriculture are necessary, but more than that is needed if a country is to succeed in competitive world agricultural trade.[6] The DMCs must also be encouraged to make their own opportunities rather than be led by more aggressive economies. It has yet to be seen whether developing countries can evolve towards food self-reliance while simultaneously improving resource stewardship.

Challenges for the agricultural sector

In the GATT era, the DMCs face two major challenges: (1) to reconcile the need for improved natural-resource management with the need for increased food security, and (2) to support regional natural-resource management and rural development efforts to promote trust and security in the Mediterranean Basin -- creating a suitable atmosphere for food self-reliance.

The increasing degradation of land, water and vegetation resources in the DMCs threatens more than the sustainability of the agricultural sector. It can damage national economies, regional economic growth prospects and human well-being, especially among the poor. This degradation contributes to climatic change, desertification and loss of biodiversity (World Bank 1994d). Resource degradation is, ultimately, the cumulative effect of decisions made by individual resource-users over time. Resource-users would not deliberately damage their resource base unless it were in their own best short-term interests, given the physical, economic, social, infrastructural and institutional constraints which govern their decisions (Tutwiler and Bailey, in press). Degradation cannot be dealt with in the agricultural sector alone, but through broader national strategies for reducing poverty and managing natural resources. Such strategies need a multi-sectoral approach; they must have the full backing of public institutions, governments and local communities.

The peace process follow-up represents a major example of possible agricultural development. There is a need for international financial support to gear resources to regional co-operation; it is necessary to counterbalance the tendencies of the national governments to focus on their own problems. If regional co-operation succeeds, this will encourage governments to look at food self-reliance rather than food self-sufficiency since governments will perceive that food is not a bargaining chip in a region of conflict.

Complementary dimensions of opportunities

This paper has defined the *status quo* of the agricultural sector in the DMCs and identified the major challenges. The next step is the formulation of actions aimed at sustainable rural development. Development needs are identified in three complementary dimensions of the agricultural sector: generation of appropriate technology, strengthening of institutions, and regional co-operation.

<u>Appropriate technology</u>: Rainfed agriculture has been overshadowed by irrigated agriculture. Typically, rainfed crops have low and highly variable yields. However, there is potential for increasing productivity if appropriate technology is generated for marginal environments. For example, barley is a dual-purpose crop grown at the dry frontier of the arable land (150-300 mm annual rainfall). Both grain and straw are used for supplementing the diet of small ruminants. By focusing on developing cultivars specifically adapted to these harsh conditions, rather than widely-adapted cultivars (traditional approach; Ceccarelli 1994), barley improvement programmes can increase average grain yields by 24% and minimum yields by 16%. These yields are attractive to risk-averse farmers in marginal areas, and the innovative approach can be further enhanced by taking advantage of indigenous knowledge and farmers' participation in selection and breeding (Ceccarelli *et al.* 1995).

Adaptive research for wheat production in Upper Egypt has proved to be highly efficient. The essence of adaptive research is to develop packages of new technologies by increasing farmers' involvement in technology generation so that they help define what is relevant and useful; this also involves enhancing researcher-farmer-extension interaction through on-farm trials and field demonstrations. Such an approach has led to increased adoption of new technology in Upper Egypt and has resulted in an increase of average real gross income per hectare of 50% -- most of which is due to impressive yield increases (Aw-Hassan *et al.* 1995). *Adaptive research* should continue to be seen as the desirable *modus operandi* of agricultural research. At the same time, a system-oriented approach -- focusing on the sustainability of the agricultural system as a whole -- should be emphasized in preference to strictly commodity-oriented research.

Harvesting rainfall (that may otherwise be lost through run-off) and supplementary irrigation are alternatives which can help increase and stabilize yields of crops grown in rain-fed areas. Water-harvesting may use natural catchment areas, or may require modification of the landscape or an artificial catchment basin (Jones and Oweis 1995). Supplementary irrigation involves timely application of additional water according to the seasonal needs of rainfed crops (Perrier and Salkini 1991). These techniques can help reduce rates of water use where the withdrawal exceeds natural recharge, a feature of large areas of the DMCs. However, water demand-management -- through users' awareness, water metering and pricing -- remains a big concern which requires strengthening of institutions involved in natural-resource management.

Strengthening institutions: Improvements in the structure of incentives, the regulatory framework, and protection of property rights are needed if the private sector is to invest in job-creation. If the land market is well developed, there may be opportunities for individual farmers to increase average field size by acquiring the rights to farm contiguous units. However, very liquid markets for land may exacerbate unequal distribution. The problems of open access to water and rangelands, and opposition to water charges must be worked out with the resource-users. Policies developed without consultation, and without understanding of users' perceptions of resources, are likely to fail.

Agricultural research and market intelligence units need to be reinforced to tackle complex inter-sectoral issues related to agricultural development. These units would monitor policies, supply and demand of import and export commodities, trends in income growth and population, consumers' preferences and international trade. Economic and market overviews are desperately needed to determine comparative advantages, both domestic and international. To some extent comparative advantages are inherent (depending on national endowments); however, in rapidly-changing economies, comparative advantages may develop in a few years. These intelligence units would identify opportunities and estimate the risks associated with them. There is a need for interaction between technology development and the opportunities it brings. Development strategies could be decided in partnership between the public agricultural research entities and the private sector. This could ensure private investment in an open-market system. There must be mechanisms for the monitoring and evaluation of national strategies for reducing poverty and managing natural resources.

Regional co-operation projects: Resource management, and agricultural research and development, can cross national boundaries. Inter-sectoral and multinational participation should be encouraged. Co-operation could be enhanced in the development and exchange of information relevant to: (1) natural-resource use and degradation or improvement; (2) agricultural development projects and impact analysis; (3) climatic variables used for early-warning systems in agriculture, and definition of agro-ecologies suitable for different crops; and (4) marketing opportunities. Some infrastructure projects involving regional co-operation (World Bank 1994d) are likely to have an impact on the agricultural sector. Regional road improvement and development in the Middle East will enhance the potential for agricultural trade. Electricity interconnection among these countries could have an impact on water use -- although more, and more reliable, sources of power may affect the rate of extraction if not accompanied by appropriate regulations. There is regional co-operation experience in the exchange of genetic resources, control of regional pests and diseases, and systems-oriented research in the Nile Valley and more recently in the Mashreq and Maghreb.

Conclusions

In the last 20 years the DMCs have become increasingly dependent on food imports. The GATT will have far-reaching consequences on the economies of the DMCs, whether or not they sign it. Initially, food prices are expected to rise, increasing import costs. The major challenges faced by the agricultural sector in the DMCs in the GATT era are: (1) to reconcile the need for improved natural-resource (environmental) management with the need for increased food security, and (2) to support regional natural-resource management and, consequently, international rural development efforts to promote trust and security in the Mediterranean Basin. To face these challenges, the DMCs need to encourage the creation of appropriate technology, strengthen institutions involved in natural-resource management and agricultural policies, and enhance regional co-operation.

Appropriate technologies demand a good understanding of the needs of end-users. The dry environments require specifically-adapted crop varieties and low-input technologies acceptable to risk-averse farmers. Farmer participation in research ensures that appropriate technology is developed. Farmers' indigenous knowledge can supplement researchers' scientific expertise. Adaptive research -- which relies on researcher-farmer-extension interaction, through testing technology on-farm and through field demonstrations -- has proved effective, and can be used to promote improved technology packages. A whole-farm (systems) view mimics that of the farmer in balancing crop and livestock needs, with the added facet of the environment.

The area of agricultural policy is complex; what is appropriate for one country (or subregion) may not be so for another. A few areas where policy decisions are urgently needed are given here.

- Policies to curb migration must consider domestic employment needs in order to counter the urge to emigrate. Within countries, improvements conducive to full use of infrastructure would create jobs, and thus curb the rural urban migration seen today.

- Marginal and range lands need rehabilitation. There is also a need for policy to limit, or regulate, grazing of marginal land. A review of the status of land ownership is required; open-access land is being misused and degraded, and some or all of the responsibility for management needs to rest with the resource-users.

- Water conservation and water-harvesting techniques are essential for increased food production. Bilateral and multilateral agreements are often needed to share the resources of rivers and aquifers which cross political boundaries. Strengthening of the water-regulatory bodies is required so that use efficiency can be improved and waste reduced. Pricing should be considered carefully to curb demand; alternatively, quotas could be set to conserve supplies.

- The balance between food self-sufficiency and self-reliance needs to be reviewed, so that the institutions governing future directions in agricultural policy can be strengthened. Multi-sectoral aspects of the economy need to be examined, and policies pursued, which exploit each country's comparative advantage. National market intelligence units could actively monitor global demand and supply to see where and when their country will have an advantage; then the country will be ready to exploit its advantages to the full. Private investment in agriculture should be encouraged.

Regional co-operation encompasses: sharing information; regional trade agreements; monitoring and evaluating policies and projects with regional emphasis; and international treaties on water use and natural-resource management. Regional co-operation will always be given lower priority by governments than will domestic issues. So, such activities require external encouragement and funding. Sharing information on research findings and environmental indicators fosters mutual trust and aids political and social stability.

Reconciliation of food security and natural-resource management can be achieved if action is taken now to address the issues raised in this paper. Delay in tackling these issues increases the cost of rectifying the problems. ***(Abelardo Rodríguez)***

Footnotes

1 *Help from Bassam Bayaa and Jerome Gintzburger in abstract translation, Hala Khawam in graphics preparation and Guy Manners in editorial review is appreciated.*

2 *Morocco (MO), Algeria (DZ), Tunisia (TN), Egypt (EG), Jordan (JO), Palestine (PT) comprising West Bank and Gaza Strip, Lebanon (LE), Syria (SY), and Turkey (TU). Libya was excluded because of its much-reduced agricultural base. Both Jordan and Palestine were included because of their strategic importance in the Near East.*

3 *Algeria is a major oil exporter with a large population and a relatively large agricultural economy.*

4 *Agricultural exports and imports here include processed and non-processed food, feed and fibre, but exclude fisheries and forestry.*

5 *Using average per-capita real GNP (adjusted by purchasing power parity) for all developed countries as a baseline (UNDP 1994).*

6 *Products with greater scope for intra-regional trade are meat, vegetables, fruits and pulses where all or a large part of the regions's requirements could be met from its extra-regional exports. For cereals, sugar and vegetable oils, however, the chances for intra-regional trade are very limited and the region would remain dependent on the outside world (ESPC 1995a).*

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5.2 Resource Management and the NARS: the Dryland Resource Management Project

Resource management and development

There is great concern among researchers, development agencies and policy makers about the degradation of natural resources (soil, water and natural vegetation) and its potential impact on the sustainability of agricultural development in dry areas. Increased food demand, deriving from rapidly growing populations and rising income levels, requires high rates of resource use which could lead to irreversible degradation. Conflicts arise between alternative land uses (fruit trees, grazing, rainfed cropping). As pressure mounts on limited land resources, farmers adopt more intensive production systems with little regard to future consequences. Cereal production encroaches on the marginal areas traditionally reserved for extensive grazing. Furthermore, to meet the increasing demand for livestock products, livestock numbers continue to increase and degrade rangelands.

Traditional mechanisms of resource management, in which communities and community institutions played a vital role, are disappearing. Traditional conservation practices are deteriorating, leading to accelerated soil erosion and siltation of dams. The mountain terraces of Yemen and jesours of Tunisia are examples of ancient and indigenous systems now under threat. Cultivation in steppe land, as in Syria, increases wind erosion. Conflicts in the management of small community dams hinder efficient water allocation and proper maintenance. Not least, land degradation results also in the loss of the natural biodiversity, reducing future options for crop improvement.

Social, economic, institutional and policy factors determine resource management decisions and influence resource users' behavior. There is a direct linkage between resource degradation and poverty. Due to low productivity, farmers in marginal areas are trapped by poverty. Poverty, in turn, causes farmers to overlook the long-term effects of resource degradation while struggling to meet their immediate or short-term needs. Thus, improved resource management, in addition to sustaining the long-term productivity for future generations, should also enhance resource productivity in the short-term in order to improve the well-being of current users.

Policy makers are increasingly concerned about the degradation of natural resources, its implications for poverty, and the social and political repercussions. The urban-rural population migration, which is a result of increasing rural poverty, imposes substantial social and environmental penalties, such as congestion, unemployment, pressure on social services, and health risks.

To try to counter this, more efficient use of available natural resources has become an important goal of rural development strategies in many developing countries of the Mediterranean region. Public land development and reclamation projects are undertaken, and private investment in land reclamation and improvement is encouraged. These policies are imperatives in reducing rural poverty through efficient and sustainable use of natural resources.

Although public awareness is increasing, the knowledge base upon which to formulate appropriate solutions to degradation problems is inadequate -- for various reasons. First, natural resource management is low on the list of research priorities in most national research systems, so that few national programs have sufficient capacity to conduct the necessary multi-disciplinary research. Secondly, the local people who are directly affected by resource degradation and who ultimately make the management decisions, are not fully consulted, which discourages their cooperation; and the wealth of their indigenous knowledge is not incorporated into the research process. As a result, the complexities of the socio-economic environment that shape peoples' perceptions, attitudes and behavior, and which, therefore, determine the potential adoption of any solution, are not well understood. Furthermore, poorly coordinated policies and programs often send conflicting signals to resource users that undermine opportunities for improved resource management.

Dryland Resource Management Project (DRMP)

This project was initiated to increase awareness and to stimulate and strengthen national multidisciplinary capability to conduct research on problems of natural resource management in the agricultural context. A major aim was always to compensate in some degree for the imbalance found in so many national systems, by which priority and a large part of the available capacity is perennially devoted to productivity enhancement research. Our message remains that if enhanced productivity is to have any long-term future, considerably more effort must be put into maintaining the land and water that support production and into helping the users of those resources to manage them sustainably and avoid degradation. To this end, since its beginning in 1990, DRMP has sought to assist national research systems to initiate studies of agricultural production systems and resource management in dry areas to assess their impact on the natural resource base, with a view to identifying viable and sustainable improvements.

The project's second phase, which started (after some delays) in 1995, involves case studies in six countries: Iraq, Jordan, Lebanon, Syria, Tunisia and Yemen. Field visits, discussions with end users and researchers, and interactions among national scientists at a workshop (held at Tel Hadya) has made possible the identification of common methodologies and common research themes.

Common research approaches

It can be argued that many (most?) resource management problems are location-specific, require locally specific solutions, and so can be effectively tackled only by specific national research efforts. That is probably true. Nevertheless, the fundamental principles (technical, social, economic, and policy) governing resource management, combining efficient utilization with conservation, are common. Moreover, in what is largely a new field, there is still much for everyone to learn on how best to conduct effective research that produces applicable, user-acceptable results. There is thus much to be gained by working together, pooling experiences and seeking to develop common approaches and methodologies that will come to form an international public good.

Researchers, planners and policy makers concerned with natural resource management in numerous, however different, situations are faced with similar questions. For example: what is the optimal management in the long term? how does one reconcile conflicting individual, community and societal interests in resource use? how does one balance national against global views? Research principles have to be clarified and methods developed and tested to address these, and many other, basic common problems. During the DRMP workshop discussions, two methodological approaches were identified and accepted for the DRMP case studies, multidisciplinary and participatory.

1. **The multi-disciplinary approach.** Multidisciplinarity is necessary in order to understand problems from different perspectives, and it will be a common approach for all case studies in DRMP. However, it is noted that this approach is 'easier said than done'. It requires intensive interaction among researchers from different disciplines, and mutual appreciation of everyone's roles and potential contribution. Once this is achieved, and a common problem definition agreed upon, finding appropriate solutions is made very much easier.

2. **Participatory research.** The second common methodology identified is the participatory research model where farmers and resource users are active research participants, not passive recipients of information. It was agreed that an effective use of the participatory approach will be a common thread linking all national case studies. There is no simple formula for applying this approach to resource management. Achieving an effective participatory approach requires a great deal of creativity and sympathetic researcher attitude towards resource users. In simple terms, it requires researchers to communicate interactively with users in a way that encourages their spontaneous and open discussion of the problems. In this context, it has to be said that conventional farmer-

survey methods, though useful tools, will not guarantee effective user participation in the research process. It is important that researchers systematically record participatory methods used (farmer meetings, meetings with community leaders, focus group discussions, users' networks, etc), and their results and contributions to the research findings. This will facilitate a comparative analysis of the effectiveness of the different methods used in the case studies.

Problem solving approach. It was recognized that both interdisciplinary interaction and user participation would be more effective if a problem-solving approach were used to direct research purposes. The approach comprises: problem definition, identification of potential solutions, evaluation of these solutions (along with users' feedback) for further refinement and wider adaptation. Different case studies are currently at different stages in that cycle.

Collaborating with partners. It was acknowledged that RM research is complex and requires researchers to identify and collaborate with appropriate partners. Resource users are not the only partners. Other important partners whose cooperation is essential in the problem-solving cycle include local communities, NGOs, farmer cooperatives, development projects, and extension workers. There are also a number of important local decision makers, whom the research team should be aware of. In Tunisia and Jordan, development projects are involved in the study sites, while in Yemen the extension service is part of the research group; and, in Lebanon, researchers are collaborating with NGOs. This interaction should be mutually beneficial to all the institutions involved.

Common research themes

The common research themes to be addressed by the national research teams are:

Physical assessment. This includes the description, characterization, qualitative and quantitative assessment of the state of the resources, problems faced, and the practices and management systems that are responsible for these problems, and the identification of possible solutions. This should be done through a participatory approach. It was suggested that all case studies should gather local indigenous typologies used to describe different states of the resources and local arrangements for their use. The boundaries of the study area have to be well defined. Watershed (or catchment) is commonly used as a unit for soil and water management research and could be used where applicable. Earlier studies and literature should be reviewed.

User perceptions, attitudes and choices. This theme includes the identification of factors influencing users' perceptions and their attitudes toward resource conservation and management. These attitudes affect management choices. Both rapid appraisal and formal survey methods can be used to gather that information, but it is strongly advised not to formulate a questionnaire before fully comprehending farmers' views through informal participatory approaches.

Sustainability. This theme involves determining the impact of users' management choices and decisions on the resource base and its sustainable use.

Collective management. In this theme the potential and incentives for collective resource management will be examined and ways to enhance them will be identified. Early communities recognized the need to pool their energies to build and maintain terraces, dams, cisterns, and other structures. Social systems in which such collective action evolved are changing rapidly as a result of population pressure and commercialization. Yet governments have insufficient resources to provide incentives to large numbers of users to promote better management. Research into the enhancement of sustainable community action for resource management is therefore essential.

Benefit-cost analysis of resource conservation. This theme promotes the analysis of the benefits and costs of different resource management choices, and of the private and social benefits and costs of resource conservation. There can sometimes be negative spill-overs or externalities, whereby individual user's actions affect others. The incentive for that user to adopt a "good" management system is less than the total loss to the community. Therefore, the social cost of degradation will be valued.

Policy impact. In this theme the impact of government programs and policies on resource management will be analyzed.

These six themes cut across the case studies, even though other technical and socio-economic details may differ greatly. Many analytical methods may be used to address these themes, depending on the study objective, the particular resource management problem, data availability, and researcher experience; but the lessons learned in one situation will be valuable to others.

Case studies

Iraq: The study site is in the Jebel Sinjar area, known for its rich biodiversity. Some areas there face degradation while others appear to be in good condition. The case study will undertake a diagnostic analysis of the status of the natural resources (mainly rangelands and biodiversity) in the area. It will determine the social and economic factors affecting rangeland management and will propose ways in which collective management could be used to enhance the sustainable use of these resources. **[Contributors: IPA Agricultural Research Center; Mosul University; and Ministry of Agriculture]**

Jordan: The study area is in the Zarqa valley, where the Jordan government recently undertook a substantial land development project. That work included building terraces and cisterns, providing fruit-tree seedlings at subsidized prices, and the construction of rural roads. The aim was to improve the living conditions of the rural communities, through improved agricultural productivity and, at the same time, reduce the sedimentation of King Talal dam by arresting soil erosion on upper slopes. The study will examine farmers' attitudes toward these land improvements and determine factors influencing the local community's willingness to adopt and sustain these improvements. The study will also analyze the impacts of these land improvements on farm income. **[Contributors: National Center for Agricultural Research & Technology Transfer (NCARTT); University of Jordan; and Zarqa Valley Development Project]**

Syria: The Syrian case study is in Jebel Al-Zawiya area of the Idleb governorate, south west of Aleppo, where mounting pressure in recent years on the limited land resources has resulted in a decline in the size of land holdings and, related to this, extensive private reclamation of marginal lands and expansion of orchard cultivation at the expense of cereals. Land degradation threatens. Cultivation up and down the slope and insufficient vegetative cover in the rainy season encourages rainfall runoff and accelerated soil erosion. Research, a diagnostic study, will analyze these changes in land use and determine their causes and implications for soil erosion. The study will also examine the economics of land reclamation (its impact on land values and farm income) and assess its long-term sustainability. **[Contributors: Aleppo University]**

Tunisia: The Tunisian case study is in a typically dry area of southern Tunisia, close to where the Institut de Regions Arides (IRA)is located. In this region, water availability is considered a major development constraint and a major limiting factor on agricultural growth. However, the techniques currently used to control floods in the rainy season and store water for the dry season have been found inappropriate. Researchers at IRA have improved the traditional jesour systems and found, at least at experimental sites, that the improved technique is superior to the widely-used systems in water retention and soil erosion control. The case study will test these techniques under farmer conditions and examine the technical and socio-economic factors that affect farmers' acceptance. The team will also develop an optimization model for water-use analysis. The team works closely with government development projects and NGOs concerned with water use in southern Tunisia. **[Contributors: Institut des Regions Arides (IRA) and Ministry of Agriculture]**

Lebanon and Yemen: Both Lebanon and Yemen have bilaterally-funded projects following from the first phase of DRMP, and therefore have wider research activities than the single case studies in other countries. However, part of their research will be linked to the other case studies through the identified research methodologies and themes. **[Contributors: Lebanon American University of Beirut (AUB). Yemen Agricultural Research and Extension Authority (AREA); Sana'a University and Aden University]**

[Aden Aw-Hassan]

6. PROJECT 20: PRODUCTION SYSTEMS, ADOPTION AND IMPACT

INTRODUCTION

Enhanced adoption and impact of new agricultural technologies is influenced by social and economic factors operating at the farm, village and national levels, including the performance and technical requirements of the technologies themselves; farmers' objectives, preferences and capacities; the nature and circumstances of the farming household; access to inputs, credits and markets; and attitude and behaviour to risk and uncertainty. Understanding these factors is essential to the proper identification of research objectives, as well as to the improved targeting of transfer efforts once the technology has been developed. Successful analysis of problems and the identification of appropriate technical solutions, in the farming systems context, greatly enhance the cost-effectiveness of research.

That is the mission of this Project, and each of the following four activity reports illustrates different facets of it. It may be noted that the first three activities were undertaken in close partnership with the relevant national institution.

In a rapidly changing economic world, agriculture must also be dynamic. Although there are naturally large local differences even within a single country like Syria, the general trend is away from subsistence-orientated farming towards increasingly market-driven systems. The effects of this are obvious in the landscape even to the casual eye, and nowhere more so than in Syria's Zone 2. Described less than twenty years ago simply as supporting rainfed barley-livestock systems, this stability zone now carries large areas of irrigated crops and fruit and olive orchards. The present report, of a rapid appraisal, describes what is now on the ground (6.1). Clearly, development has taken a different course in different parts of Syria. These differences will be followed up in subsequent surveys. The overall purpose is twofold: first, to readjust our perceptions of our research targets -- this is important equally for the Syrian NARS and for ICARDA -- and, secondly, moving beyond description, to try to understand the processes taking place and their possible future directions.

There have been great changes also in Lebanon, where the need for agricultural renewal parallels that of rebuilding the country's infrastructure after wartime destruction; and our next two reports summarize the findings of two activities conducted jointly with the national Agricultural Research Institute, ICARDA's Lebanon-based staff and, in the second case, the American University of Beirut.

The first (6.2) concerns the on-farm demonstration of new and promising varieties of cereals and legumes and subsequent interviews of the farmers concerned. Apart from the purely technical information gained, which should guide later demonstration and transfer activities, a major point to emerge is the wide variety of farm environments and farm-level objectives that exist even within a small country like Lebanon and which must be taken into account in planning research and extension. The message from the second piece of work is very similar (6.3). A diagnostic survey of legume production in Lebanon again revealed great diversity -- of crops, cropping systems and, not least, in farm sophistication and yield levels. It is pointed out that Lebanese farmers are generally good adopters of improved technology, if it is feasible and accessible. All they need is well-targeted support from agricultural institutions.

The final report brings us back to Syria. Over many years, ICARDA has carried out a great deal of research on barley, on its genetic improvement for yield and feed value and on the agronomy of the dry-area farming systems in which it is grown. As background to this research, it is well known that, while farmers use the barley mainly to feed sheep, there is nevertheless a great deal of buying and selling of both grain and straw, and that prices vary considerably both within and between seasons. Now we have a study that reveals the complexity of that purchasing/marketing system (6.4); and this is valuable particularly in respect of the light it throws on farmers' behaviour and the incentives and constraints they are responding to in their choices of variety and management of barley. It is also salutary, to technical and even many socioeconomic researchers, in revealing part of the economic environment of agriculture we too often choose to ignore.

6.1 Agricultural Production System and Resource Management Studies in Zone 2 in Syria

Introduction

The need for this study arose from some clear indications that agricultural activities in zone 2 have been changing rapid. This zone, defined as having an annual rainfall of 250-350 mm in not less than two-thirds of years, covers about 2.47 million ha, which is 13.4% of the total area of Syria and about 40% of its cultivable land. Twenty years ago, this zone was described as "a dry area suitable for cereal growing and animal husbandry", or "cereal production and animal raising areas". Now the situation is very different: trees, especially olives, grapes, and pistachio, have been widely planted, and the increase of irrigation, based on the development of wells and pumps, has led to the diversification of crops and production systems.

This study is important for both research partners: for the Directorate of Agricultural and Scientific Research (DASR), because it updates information on zone 2, which helps the identification of solutions to existing problems, highlights new problems arising from new production practices, and feeds information back to national decision makers; and for ICARDA, because it provides an easily-accessible example (for research) of farming system dynamics under social, economic and technical pressures. Perhaps more important, it provides a reality check to some of our institutional research assumptions. ICARDA has based much of its research thinking until now on system stereotypes -- the barley-based (or barley-livestock) system in drier areas, and the wheat-based system in wetter areas -- following classifications made nearly 20 years ago. It is time to check whether these concepts are still meaningful and useful. Most of zone 2 was previously described as supporting barley-livestock farming systems; to what extent is this still true?

Objectives

The immediate objectives of this study are:

1. To describe the present land and water use systems applied in zone 2, including the cropping systems and the animal husbandry practices.
2. To describe the recent historical evolution of the farming systems and the factors associated with it, and including the prediction of possible changes in the short or medium term future.
3. To discover farmers' priorities regarding the use of their land and water resources, including crop preferences at different levels of resource use.

4. To discover farmers' perceptions of their natural resource base and its limitations, renewability, and depletion.
5. To look into specific questions *viz.*: wheat and barley production trade-offs; groundwater use and allocation decisions; incentives and constraints to tree crop production; and perceived constraints to productivity within different farming systems.

Research is being conducted in two stages:

A. Rapid appraisal (informal survey) by visits to different locations in zone 2 to obtain insights into the farming system, identifying major constraints, and guiding the planning, design, and implementation of the subsequent farm survey.

B. Farmer interviews (formal survey) to complement the first stage and obtain more quantitative information.

Analysis of some secondary data

Re-examination of information collected in adoption and impact surveys of wheat farmers conducted over the past three years revealed several relevant issues concerning zone 2 farming systems:

- competition between wheat and barley under completely rainfed conditions;
- high adoption rates of improved wheat varieties compared with low adoption rates of improved barley varieties;
- land-use contrasts between farmers of the North East (Jezirah), the North West (Aleppo, Idleb, Hama, and Homs), and the South (Hauran), which may indicate three different farming systems; and different types of change in resource management (land and water) and other factors between these areas.

Summary of findings of rapid appraisal

During the 1994/1995 season, a multidisciplinary team from DASR and ICARDA, including economists, an anthropologist, an agronomist, and a livestock scientist, conducted four field tours, visiting Hama, Homs, Aleppo, Dara', Sweida, Hasakeh and Raqqa provinces. They met many officials in the agricultural and agricultural extension services, interviewed many farmers (according to a pre-prepared checklist), and made local field observations. The following points summarize the findings in each region:

Hama and Homs region. The four locations visited have all experienced big changes, but the changes have differed in character. In the first location (Maar Shehour), there has been competition between tree planting and sheep keeping. In the second (Sheikh Ali Kasoun), a wheat-based farming system predominates, and the majority of farmers practise a wheat-lentil-summer crop rotation. In the third location (Kseir), farmers tend to grow irrigated crops, while in the fourth location (Zeidal) they prefer fruit trees especially grapes.

A farmer's strategy in all this depends, first, on whether or not surface or groundwater is available at his farm, and its quantity and persistence; and decisions, such as whether to plant trees or keep the land under arable cropping, depend upon a range of (interacting) factors:

- quality of natural resources on the farm (eg soil depth);
- availability of funds for investment;
- suitability of crops (or trees) to this land; and
- constraints imposed by need/availability/cost of inputs, labor, prices, output value and government policies.

Across the four locations, soils may be grouped broadly into three types (or situations):

1. Shallow or stony soils, which could be left as rangelands or seeded with barley. When change occurs on these lands, they are usually planted with fruit trees (grapes, olives, pistachio, or almonds).

2. Good (deep) soils with no water source for irrigation, where farmers follow a three-course rotation (cereals-legumes-summer crop or fallow). Wheat is the most important cereal crop in this rotation, and lentil the most important legume. Barley and vetch are also grown but in smaller quantities.

3. Good soils with an irrigation source, where farmers prefer to grow improved varieties of wheat (under supplemental irrigation) and summer crops like potatoes, sugar beet, and cotton (under full irrigation).

Aleppo province. The introduction of irrigation has intensified land use. What used to be a barley/livestock farming system has changed in many parts of Zone 2 into various vegetable-wheat-fruit production systems; and, in some places, cotton is also found. Livestock production had been a complementary activity, at least to satisfy household needs for meat and milk products, but it has now been pushed towards the drier areas, to make space for more intensive, water-based production systems. Many unlicenced wells are in operation. Farmers appear to be conscious that groundwater levels are falling as more farmers use more water; but they appear to perceive water scarcity as a solvable problem and trust that technical improvements will provide solutions to enable them to maintain increased land productivity.

Availability of irrigation water has increased the use of fertilizer. Farmers, on average, use 200 kg/ha of superphosphate and 250 kg/ha of urea annually. The cereal seed rate is very high, even up to 400 kg/ha. Sometimes such high planting densities are intended to control weeds. This exemplifies the fact that, in many cases, farmers have an economically rational explanation for their high input use.

Part-time farming has increased near urban areas, and better roads allow day-to-day communication. Development of poultry farms has also increased as a result of urban expansion; and land markets and land speculation seem to be developing in some of the areas surveyed.

Remittances from household members working abroad or in urban centers has improved the cash-flow situation of some farms; and capital availability has permitted investment in the farm and the improved use of inputs.

Some villagers mentioned that labor scarcity is a problem in the management of olive orchards. When asked whether the necessary labor and inputs to establish and maintain orchards had been planned for, the farmers admitted that they had not thought in advance about these needs and outlays. Extension personnel are not always available or even not fully aware of the different technical options in different provinces.

Hauran region. Wheat is the most extensively grown crop here; and until few years ago, local durum varieties, especially Haurani, were the predominant ones because of an agricultural policy which prevented the introduction of improved wheat varieties into the Hauran region. This policy has recently changed, and farmers have begun to adopt improved wheat varieties, thereby increasing average yields by about 50%.

Land reform has allowed some shallow soils and hilly lands to be planted to trees. The barley area is tending to decline over time, being replaced since about 1985 with olive trees. Local Arabic Abiad is the only variety grown, since no farmer knows about improved barley varieties. The predominant rotation is wheat-chickpea-(or lentil or vetch)-summer crop(or fallow).

Digging tube wells started in Hauran ten years ago. Some farmers believe that the water level does not decline, because that area is surrounded by two mountains, Jebel El-Sheikh and Jebel El-Arab mountain, which gather water into the Hauran plain. Water availability has encouraged the planting of irrigated vegetables; but farmers feel that growing vegetables is costly and the returns unstable, because they depend on a free market. Wheat is seen as safer, with less economic risk, because of the government subsidy policy; but good prices are increasing the area under legumes, especially chickpeas. Thus it may be, in the Hauran, that farmers are more influenced by economic consideration than by technical problems.

Labor, however, is not perceived as a problem. In general, the number of household members is usually sufficient to support the farm. If more labor is needed, it is possible to hire people from nearby villages. There are gender specializations in farm work: men usually do the irrigation, women the harvesting. Average holdings range in size from 10 to 15 ha, but with a decline from one generation to the next due to distribution among the children. However, small holdings, no longer economically viable, may be sold.

In Sweida province, trees are beginning to replace field crops, though there has been no economic study yet to assess the profitability of this change. All crops in Zone 2 are rainfed, and agricultural policy forbids farmers to dig any new well, to control the amount of groundwater used. There are some dams to collect rainwater, but this water is used essentially for drinking.

Livestock include sheep, goats and cattle. In fact, sheep numbers are declining as more pasture land is given over to fruit trees, although the number of cows has recently started to increase. The general decrease in livestock and shift way from sheep to cattle husbandry is becoming an important issue in Hauran. Again links are limited between farmers and extension units and research stations, which is an important factor restricting farmers' progress.

Al-Jazirah region. Changes started in the Jazirah zone 2 in the early 1980s, with the uncontrolled digging of wells to support private irrigation enterprises. Since agricultural policy prohibits the planting of fruit trees in the plains, the focus has been on field crops, particularly wheat. Nowadays, 90% of the zone is planted to wheat, which has largely replaced barley. Sheep numbers have greatly decreased; each household has kept just a limited number of sheep to satisfy domestic needs.

The introduction of irrigation also brought new crops such as cotton. Some farmers believe that water requirements for cotton are very high, and that the predominant rotation wheat-cotton is not successful because it excludes legumes. Such crops as soybeans could be grown instead, with mechanization, although there are some marketing problems.

The available labor force is sufficient, although some laborers are brought from outside the province during peak periods, for lentil harvesting and cotton picking. Mechanical harvesting of lentils is practised by some big farmers, using conventional combines with appropriate modification. Small farmers prefer manual harvesting (and retain old local varieties), because the value of the hay covers the expense of harvesting.

Public irrigation schemes have brought significant benefit. Under rainfed conditions, there were some dry years when farmers could not harvest their barley. After irrigation was provided, household income increased nearly fivefold, and there is potential for raising it further. Nevertheless, farmers still face problems: the water supply may be short, especially at critical periods; and seed (of the best wheat varieties) and fertilizers and seeds are not always available at the right time.

Where irrigation depends on tube wells, problems of water quality and quantity are beginning to arise. Most wells were drilled to depths of 200 meters or more; some produce calcareous water, others sulfurous water. Flood irrigation is widely used, which tends to be inefficient and wasteful of water. At most of the places visited, groundwater levels are falling.

Durum covers about 75% of the total wheat area, with Cham 3 the most common variety; Cham 6 is the most common bread wheat on the other 25%. However, continuous wheat cropping has given rise to nematode problems in some places.

There is no direct relationship or communication among agricultural departments and extension units in different parts of the province. Thus, it seems there has been no direct exchange of information between the agricultural department in Abu Rasein which has a long experience of irrigated cropping, and the extension unit in Sayyed Ali where irrigation started two years ago.

Thus most changes that have occurred to zone 2 farming system in the Jezirah, particularly increased cereal production, have been driven by the introduction of full or supplemental irrigation. Livestock production has been adversely affected. The need to employ available family manpower in irrigated crop production does not encourage the farmer to keep a large number of animals, which also need full-time labor input. Further, irrigation has eliminated fallowing and decreased the area of marginal land, leading to a significant decline in seasonal feed supply and therefore in sheep numbers. At the same time, the substantial boost to crop production from irrigation has greatly increased the volume of crop residues; but there are now insufficient livestock to graze these residues quickly when needed. For these reasons, the farmer prefers to burn his crop residues to speed up the preparation of his land for the next season. This practice is liable to contribute to land deterioration. The farming systems evolving in these newly irrigated areas need guidance to help them to integrate cropping and livestock enterprises in a sustainable way. ***[Ahmed Mazid, Richard Tutwiler, and Hasan El-Ahmad (DASR, Douma)]***

6.2 Farmers' perspectives of promising varieties of cereals and legumes in Lebanon, 1994/5

Objectives

On-farm demonstrations (OFDs) of promising varieties (PVs) of cereals (wheat, barley) and legumes (lentil, chickpea, faba bean) were conducted in the 1994/95 season by the ICARDA/ARI-Lebanon joint research project: (i) to test variety performance when grown by farmers in different biophysical and socio-economic environments; (ii) to familiarize farmers with these PVs at an early stage in the technology transfer process; (iii) to feed back to research farmers' evaluation of the potential acceptability of the PVs; and (iv) additionally, in the case of cereals, to multiply limited seed stocks of these varieties for further testing and diffusion.

Methodology

To meet these objectives, PV seeds were given to farmers near the research stations at Tel Amara and Terbol (Bekaa), Sour (South), and Kfar Shakhna (North), to grow according to their own farming practices. At the end of July 1995, after crop harvest, a team of ICARDA/ARI staff interviewed 15 farmers who had grown PVs in OFDs. A simple checklist was used to standardize the discussion with farmers on agronomic practices applied, growth characteristics of PVs, incidence of weeds and other pests, variety performance in terms of yield (grain and straw), quality (seed size and color), marketability, and PV potential for adoption. This report summarizes the findings of those farmer interviews.

The promising varieties tested were:

<u>Cereals</u>:
- Waha and Lahn (durum wheats)
- Nisr (bread wheat)
- Rihan (6-row barley)
- Litani (2-row barley)

<u>Legumes</u>:
- Lentil FLIP 86-2L (a large white-seeded variety)
- Chickpea FLIP 85-5 (a winter-sown, large white-seed variety)
- Faba bean FLIP 85-98

Interviewed farmers with OFDs were located as follows:

Bekaa Province

Zahle district, 550-600 mm rainfall; villages: Terbol, Ryak, Kebb Elias

Baalbak district; villages: Houch Sneed, 400-500 mm rainfall, and Saaida, 300-350 mm.

Bekaa Gharbi district: Aana village, 550-600 mm.

North Province

Zgharta, Sabaa village (altitude 750 m), over 700 mm rainfall (but 1075 mm in 1994/95)

South Province

Sour: Villages: Sour, 650 mm rainfall, Deir Kanoun, 500-600 mm.

Findings from farmers interviews

WAHA, durum wheat. Six farmers growing Waha were interviewed, 3 from Bekaa, 2 from the South, and 1 from the North.

In Bekaa, farming is on a large scale (80-400 ha farm area), on good, deep clay soils. Waha was grown rainfed, mechanically broadcast (by a spinner) between mid-November and early January at a rate of 150-170 kg seed/ha. In Zahle, because Waha was planted after "intensively managed" potatoes, only 2 cultivations (including seed covering) were performed and there was no application of phosphate; but 140 and 170 kg N/ha were given in one and two applications by the two farmers. In Baalbak, 3 cultivations, phosphate at the rate of 63 kg P_2O_5/ha, and 120 kg N/ha in 2 applications were applied. Two supplemental irrigations were given: both in February in Baalbak; April-May and May-June in Zahle. No problems of weed (protective herbicides are commonly used in Bekaa), insects, diseases, or other pests were reported. Crop maturity and harvest were achieved in mid-July.

Remarkably high yields were obtained by the two Zahle farmers from Terbol and Ryak (7.5-8.0 t/ha grain and 7.5 t/ha straw); but yield at the Baalbak site was much lower (2.5 t/ha grain and 3.75 t/ha straw) due, according to the farmer, to a hot wind at flowering time). This might be true, but it could also be that the crop was not well managed; two supplemental irrigations were given in February.

The three Bekaa farmers were impressed by the grain and straw yield of Waha, its seed color and size, and its lodging resistance, although Baalbak farmers considered the variety Bekaai (or Baalbak) more marketable. The Ryak farmer believed Waha to be better in every respect than the variety Stork; but the Terbol farmer was hesitant: although Waha outyielded Stork, this could be due, he thought, to the residual effect of preceding crop management (potatoes vs. sugar beet).

We may tentatively conclude that Waha has good potential for acceptance and adoption in the Bekaa.

In the North, Waha was grown by one small-scale farmer (2.0 ha) at Sabaa. This is not a cereal but rather a fruit production region. Waha was grown rainfed, hand broadcast in early December at a rate of 160 kg seed/ha on 0.2 ha of red clay soil. There were three cultivations (including seed covering). No phosphate was applied, but 170 kg N/ha was given at tillering (early March). No problems of weeds, insects, diseases, or other pests occurred. Maturity and harvest in June gave a grain yield of 1400 kg/ha (straw was not estimated).

Compared with the variety Baalbak usually grown by the farmer, Waha proved better in terms of grain yield (but not straw), seed size, and lodging resistance (as it is shorter than Baalbak). Lodging is a major concern in this high rainfall region. In conclusion, it seems that Waha has good potential for the small wheat area of this district, but it is recommended that future demonstrations of wheat PVs be conducted in other parts of the North (eg Aakkor plain) where the crop is relatively more important.

In the South, Waha was grown under rainfed conditions by two small-scale farmers (1.5 and 4.0 ha) at Sour. They hand broadcast a seed rate of 250 kg/ha (too high) on a small area (0.10-0.15 ha) of light yellowish soils in December. Three cultivations (including seed covering) were performed; no phosphate but 70-85 kg/ha of N was applied. There were no reports of insects, disease or other pests, but weeds (*Avena sterilis*) and (*Sinapis arvensis*) were a problem, reducing yields by about 35%. Maturity occurred in late May-early June, earlier than Tolyani (Senator Capelli, the usual preferred variety). Yield could not be estimated by one farmer (processed for freekeh making), but the other plot yielded 1200 kg/ha grain and 1000 kg/ha straw.

Waha was rejected by both demonstration farmers and other local farmers present at the interview. The consensus was that Tolyani is better than Waha in terms of grain and straw yield and quality. Waha is thus unacceptable in the South, where farmers prefer tall varieties over dwarf or semi-dwarf ones.

LAHN, durum wheat. This variety was grown by one large-scale farmer at Kebb Elias (Bekaa), where rainfall and altitude are similar to Terbol. Seed was mechanically broadcast (by spinner) at the rate of 180 kg/ha in early December. Three cultivations (including seed covering), then rolling, were performed; 90 kg/ha of P_2O_5 was applied at sowing, and 170 kg/ha of N in mid-February. Two supplemental irrigations were given in May. No weed or pest problems were reported (following protective treatments against weeds and rodents).

Maturity occurred in late July, and the crop had not been harvested at the time of the survey visit.

The farmer's yield estimate was 5500-6000 kg/ha for both grain and straw. He, and other farmers who visited the field, were impressed by crop yield (grain and straw), seed size and color, and lodging resistance. They expected high acceptability and adoption rate. However, the farmer expressed concern about frost susceptibility, as part of the plot was frost-damaged. Thus, while there appears to be good potential for Lahn in the Bekaa, more tests are needed to assess its susceptibility to frost.

NISR, bread wheat. This variety was grown by one large-scale farmer (400 ha) in the Bekaa, and by one small-scale farmer (1.5 ha) in the South.

In the Bekaa, Nisr was mechanically seeded on 6.0 ha of good soil at a seed rate of 160 kg/ha. Since the preceding crop was "well-managed" potatoes, only two cultivations (including seed covering) were carried out and no phosphate applied; but 167 kg N/ha was given at tillering (late February), two supplemental irrigations, in late April and mid-May and protective treatment against weed and rodents. Maturity and harvest were reached in early July, giving a yield of 6000 kg/ha grain and 5000 kg/ha straw.

According to the farmers, Nisr is a good bread wheat variety in terms of yield, quality, tillering, and lodging resistance. It outperforms Seri 82 both in yield and grain size and outyields Frensawi, although the latter is probably more popular in the market. We may tentatively conclude that good potential exists for the adoption of Nisr by Bekaa farmers if marketing can be guaranteed.

In the South, Nisr was grown rainfed (550-600 mm), hand broadcast on 0.10 ha at a very high seed rate of 250 kg/ha. There were 2 cultivations including seed covering, only 85 kg N/ha applied at tillering (mid-February), and no weed or pest control. Maturity and harvest was in June (15 days earlier than Tolyani or Senator Capelli), and the yield was 1500 kg/ha each of grain (10% higher than Tolyani) and straw (lower than Tolyani). However, there appears little chance for Nisr in this area, as the demand is only for good quality durum wheat.

RIHAN, 6-row barley. There were three Rihan OFDs, two on large-scale farms in the Bekaa, the other on a small farm in the South.

In the South, Rihan was grown rainfed on 0.20 ha by the same farmer as grew Nisr wheat and using the same agronomic practices. The yield was 1500 kg/ha of grain, 10% higher than Baladi (most likely Beecher). Straw yield was not estimated. Grain and straw quality is similar to Baladi. The farmer, and visitors, were impressed of Rihan's performance, and a good potential for adoption exists.

In the Bekaa, in Baalbak, Rihan was grown on 12 ha of good soil in Housh Snaid village, with 3 cultivations and rolling, a 150 kg/ha seed rate, 63 kg/ha of P_2O_5 at sowing and 100 kg/ha N at tillering. There were no problems of weeds or other pests. The crop matured in June and was harvested in July, to give a yield of 2700 kg/ha grain and 2500 kg/ha straw. Under these conditions, Rihan yields more than Baladi. It is initially accepted, but the farmer needs further trials to assess potential adoption locally. If he has to buy seed next season, he would allocate 50% of the barley area to Rihan.

In Zahle, Rihan was grown rainfed on 4.5 ha of good soil, mechanically broadcast at a rate of 130 kg/ha, with two cultivations (including seed covering), no phosphate but 100 kg N/ha at tillering, and protective herbicides and rodent control. It was harvested on 10th July and gave a yield of 4000 kg/ha grain and 7000 kg/ha straw. Rihan outyielded Baladi but not Shams, most likely because part of the plot was badly affected by waterlogging. We may conclude that more time and trials are needed to assess potential acceptance and adoption.

LITANI, 2-row barley. Litani was handbroadcast (20th January) on 9 ha of one large-scale (60 ha) farm at Saaida (Baalbak), at a seed rate of 150 kg/ha, following tobacco. There were just two cultivations including seed covering, and 170 kg N/ha was put on as a split application (March, April). One supplemental irrigation was given in early May. There was no weed problem as herbicide was applied; but, despite control measures, rodents (mainly rats) caused crop damage estimated at 25%. The crop matured in mid-June and was harvested at the end of June, to give a yield of 3000 kg grain/ha. This was considered low by the farmer, as a result of the rat damage and late sowing, but straw yield was high though not estimated.

It seems that Litani is a 2-row barley of good potential for relatively low rainfall areas where supplemental irrigation is not available. With higher rainfall, or with supplemental irrigation, Rihan and other 6-row barley varieties are more acceptable to farmers, as they give higher yield than the 2-row varieties.

LENTIL, FLIP-86-2L. One small-scale farmer at Deir Kanoun village (Sour) hand broadcast FLIP 86-2L (end of December) on 2.2 ha of good yellowish rainfed soil at a seed rate of 125 kg/ha. There were two cultivations including seed covering, no fertilizer, and no control of weed or other pests. The crop matured and was harvested in May, giving a yield of over 2000 kg grain/ha. Farmers were very impressed by the crop yield, seed size and color, and resistance to lodging -- much better than Baladi. This variety therefore appears to have good potential for acceptance and adoption in the South and other areas where large white-seeded lentil is preferred.

FABA BEAN, FLIP 85-98. One small-scale farmer in Deir Kanoun (Sour) sowed 0.15 ha to this variety (mid-December). There were 3 cultivations including seed covering, no fertilizer and no problems of weeds or other pests. The yield could not be estimated by the farmer as much of the crop was harvested green by neighbours. However, all were very impressed by the variety's yield, seed size, color, and taste, so that a good potential for adoption appears likely in the South.

CHICKPEA, FLIP 85-5. This promising variety was grown in three OFDs, on two large-scale farms in the Bekaa and one small farm in the South.

In Baalbak (Bekaa), FLIP 85-5 was winter-sown (November) on 0.4 ha of good soil at a seed rate of 125 kg/ha There were 2 cultivations including seed covering, followed by rolling, no fertilization, and no problems of weeds or other pests. Two supplemental irrigations were given in April. The crop matured in early May and was harvested mid-May, giving a yield of 1250 kg/ha of grain (low due to rat damage).

At Bekaa Gharbi, 0.8 ha was spring sown (early April) at a seed rate of 120 kg/ha. Four cultivations were performed, and 100 kg/ha of NPK fertilizer applied (because the plot was initially prepared for sugar beet). No supplemental irrigation was given. There were no problems of weeds or other pests. The crop matured and was harvested in early July, to give an estimated yield of 2000-2500 kg/ha; and the farmer believes that a higher yield could have been obtained had the crop been sown in winter.

In the South, FLIP 85-5 was winter-sown (December) on 0.15 ha of good yellowish soil at a seed rate of 150 kg/ha. There were two cultivations including seed covering. No fertilizer was applied. There were no weed or other pest problems. The crop matured and was harvested in May. Although much of it was harvested green, what remained gave 800 kg/ha of grain.

All the farmers who grew FLIP 85-5, and their neighbours, were very impressed with its yield (grain and straw), seed size, color, and marketability. This variety therefore has a good potential for acceptance and adoption as a winter-sown chickpea in this area.

Comments and Conclusion

1. All the demonstrated cereal and legume varieties performed well technically and biophysically. However, this exercise has shown that yield superiority is not the sole determinant of acceptance and adoption. Other criteria (seed and straw quality, price, demand and marketability, and suitability for domestic requirements) may be equally, if not more, important. Defining the major characteristics of a farming system helps to identify critical criteria for the adoption of new varieties (and any other new technology). In Lebanon, these characteristics are:

   Bekaa: Large scale, market-oriented farming systems. Field crops (cereals and legumes) have equal economic importance to that of vegetables and fruit production but are more important in terms of area. Water for supplemental irrigation is available. Critical criteria for a new variety are yield, price and marketability of grain (straw is less important), and response to supplemental irrigation.

   South: Fruit and vegetables are much more important than field crops both economically and in terms of area, and for cereal and legume production small-scale, rainfed, domestically-oriented production systems prevail. Critical factors for a new variety are its suitability for domestic needs, quality and yield of grain and straw (quality is more important than quantity, and straw is equally important to grain).

   North: Farming systems here are similar to those in the South. In particular, cereals and legumes are very minor crops in the mountainous regions of the North (Zgharta).

2. No definitive conclusions can be drawn from a one-year investigation, but results so far have indicated that:

   * Durum wheat varieties **Waha** (particularly) and **Lahn**, and the bread wheat **Nisr**, have good potential for adoption in Bekaa and the North but not in the South.

   * Only those varieties that make good quality bourghol and freekeh have a chance for adoption in the South. Otherwise, farmers prefer to grow local durum wheat.

   * Rihan (6-row barley) has good adoption potential in barley-growing areas of high rainfall or where supplemental irrigation is available in low rainfall areas. The 2-row **Litani** variety is adoptable only

in rainfed areas of relatively low rainfall (north-eastern parts of the country).

* The winter chickpea **FLIP 85-5** has high adoption potential everywhere the crop is grown in Lebanon.

* The lentil variety **FLIP 86-2L** also is highly adoptable in the South and other areas where large-white-seed lentil is preferred.

* The faba bean **FLIP 85-98** has a good adoption potential where tested (in the South). Demonstrations are needed elsewhere to assess its wider suitability.

3. Feedback provided by large-scale demonstrations is very important for the development and transfer of new varieties. Therefore, it is recommended to continue this activity, with a wider geographical coverage, next season (1995/96), with the following points to be considered:

   * Demonstrate only those varieties that meet the locally critical criteria for acceptance and adoption, as elaborated above.

   * Include the Aakkar plain (North) in the exercise, since cereals and legumes are important components of the farming systems in that area.

   * Take more care in the selection of demonstration farmers in the North and South -- farmers whose principal occupation is farming and who have a real interest in growing the crops being demonstrated.

   * Systematic technical follow up and evaluation is crucial for meeting the objectives of OFDs. It is therefore suggested that a team of the ARI and Terbol staff concerned should visit all OFDs at least twice a season, making observations, collecting basic biotechnical data, and talking to farmers.

   * It would be useful to conduct some field days at selected OFD sites, to familiarize neighbouring farmers with new varieties and solicit their evaluation.

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Dedication: This report is dedicated to the late Mr Husein Dallol, our co-author, who passed away from a heart attack after completing this report.

6.3 Legume Production Systems in Lebanon: A Diagnostic Farm Survey

Background

Legumes are allocated about 7% of the total crop production area in Lebanon; but, though relatively small in absolute terms, legumes are of considerable importance in certain Lebanese farming systems. In fact, legume area increased by around 12%, from 12700 to 14000 ha, in the 25 years up to 1990 (LSA 1973; FAO 1990), and further increase in area has occurred since then. Legumes are a basic component of many crop rotations and contribute to the sustainability of agricultural production. Moreover, the well-established role of legumes in the Lebanese diet (and the deficit of 52% in the production/consumption balance of these products), the total eradication of illicit crop cultivation, and reductions in vegetable and fruit production (due to export difficulties) all justify giving special priority to improving legume production. This report summarizes the findings of diagnostic research conducted by ICARDA/Lebanon Collaboration Program, as part of a series of activities to enhance and give direction to legume research and technology transfer.

Objectives and methodology

What is the importance of legume crops in the farming systems of Lebanon? What kinds of legumes are grown, where, and how do farmers grow these crops? What are current yield levels obtained by farmers, and is there any potential for yield improvement? What are the major biophysical, socio-economic, and institutional constraints to improved legume production? Most importantly, is it worthwhile -- for ICARDA and the national research institutes -- to invest more in the research and technology transfer of these crops, and what priority should they receive?

To answer these, and other, questions, a diagnostic farm survey was conducted in Lebanon's major crop production areas. A sample of 136 legumes producers was selected from 124 villages of 17 districts located in the four provinces of Bekaa, Jebel Lebnan, the North, and the South. The sample covered the wide variability in agroclimatic and socio-economic conditions existing in Lebanon. Selected farmers were interviewed by an ICARDA/ARI/AUB team, a structured questionnaire was used, and data were analyzed using SPSS.

Socio-economic characteristics of legume producers

* Land ownership averages around 10.5 ha (CV 214%), but about one third of the sample farmers have only 2.0 ha or less, and 15% are landless. However, the availability of land leasing and/or sharecropping makes the average total land holding 19.6 ha (CV 157%), of which 54% is owned, 34% leased, and 12% sharecropped. Water for irrigation is available in 55% of the landholdings (30% surface water, 17% groundwater, and 8% both sources). Land holdings are largest in Bekaa, averaging 34.5 ha, and smallest in Jebel Lebnan (4.1 ha), with the South (16.0 ha) and North (10.0 ha) intermediate. The variability is very high, with CVs over 100% in each province.

* Agriculture is the main occupation and income source for most households in the sample (53% have no other source), and the contribution of agriculture to total family income averages 71% (CV 50%). Bekaa farmers are the least dependent on non-agricultural income sources (19% of total family income), while Jebel Lebnan farmers gain 45% of their income from non-agricultural activities.

* Livestock production is not common. Only 17% of farmers have sheep, mostly 10-30, but a few have some hundreds. Goats are raised by 13% of farmers, mostly 3-10. However, 41% of farmers have cows, mostly 2-5. Ignoring a few mass-production enterprises, poultry production is practiced by 27% of the sample, mainly for home consumption.

* Machinery (owned, or hired) for farming operations is available to almost all farmers. Tractors are owned by 36% of farmers, trucks by 30%, spinners by 12%, and 4% have their own drills and threshers.

* Living conditions (in terms of housing, electricity, clean water for home use, health and education) are generally good, better in Bekaa and Jebel Lebnan than in the North and the South.

* Most farmers are middle-aged or old, with 60% older than the average of 55 years. The majority are educated (illiteracy is 29%), with an average of six years of schooling, and many have completed secondary schooling, and a few are university graduates. Large families are common, so that the average family size is 9 persons (but with a reported range from 2 to 20+). On average, 4 family members are either fully, or partially, employed on-farm, 2 members have off-farm occupations, and 3 members are either very young or unemployed.

Importance of Legumes

* Legumes are very important in specific areas where wheat/vegetable-based farming systems prevail. Thus, about 25% of the total land holding of the sample farmers is allocated to legumes, 36% to cereals, 8% to fruit trees, 15% to other crops and vegetables, with 16% fallow and/or uncultivable. The fallow and uncultivable land class is greatest in Jebel Lebnan (53%) and least in the North (6.0%).

* 25% of the total land holding under legumes generates 21% (CV 86%) of the agricultural income; but these figures may not reflect very accurately the economic importance of legumes. A considerable proportion of legume products is consumed at home, and it is likely that neither this nor the income from leguminous vegetables was included in farmers' assessments. When farmers were asked to rank crop groups according to profitability, 49% considered legumes as the most profitable crops, followed by non-legume vegetables (22%), cereals (17%), and fruit (12%).

* Of the total legume area, chickpea covers 35% and lentil 21%. Other legumes are mainly faba bean, bean, pea, and cowpea. Chickpea is grown by 93% of sample farmers and every year by 72% of them.

* After chickpea, faba bean is the next most frequently grown legume. It is grown every year by 51% of farmers (88% of Jebel Lebnan's but 23% of Bekaa' farmers), but it is not grown at all by 30% of the sample (48% in Bekaa, 10% in the North and Jebel Lebnan).

* Lentil is an important crop in the South and Bekaa, grown by nearly all the sample farmers, but among those in Jebel Lebnan and the North only 6 and 20% grow lentils.

* Forage legumes are less important than food legumes in terms of area, growing frequency, and economics. They are not grown at all by about 52% of the sample farmers (42% in the South, 47% in Bekaa, 50% in the North, but 80% in Jebel Lebnan).

* Other legumes (bean, pea, and cowpea) are important components of some cropping systems. They are assigned one third of the total legume area in Jebel Lebnan but only 9% in the North. Cowpea is grown every year by 38% of the sample, bean by 26%, and pea by 21%. However, cowpea is grown every year by 88% of Jebel Lebnan farmers and was reported to be the most profitable crop. In the North 53% of farmers grow cowpea every year, 23% in Bekaa and the South.

Bean is more frequently grown in Jebel Lebnan as 41% of farmers grow it every year, compared to the North (30%), and Bekaa and the South (21% each).

Pea is grown every year by 34% of the South farmers, Jebel Lebnan and the North (30% each), but by only 8% of Bekaa farmers.

Legume cultivation practices

Crop rotation. Sample farmers grow legumes in rotation with other crops, mainly wheat, sesame, tobacco, potatoes and other vegetables. Fallowing is a component of crop rotation for about 23% of farmers. The following two-or three course rotations were identified:

Legumes/cereals, reported by 56% of farmers;
Legumes/cereals/fallow, reported by 21% of farmers;
Legumes/cereals/potatoes (or other crop), reported by 21% of farmers;
Legumes/fallow, reported by 2% of farmers.

The two-course rotation, legumes/cereals, is more widely practised by farmers in the North (77%) and Bekaa (67%). Fallowing is more common in the South (52%) and in Jebel Lebnan (41% of the sample farmers).

Tillage and sowing. Lentil and faba bean are sown in winter, mostly in November-December, although some farmers may delay to January-February. Chickpea is commonly sown in spring (March-April), but some 17% of producers sow the crop in winter.

The majority of farmers precede legumes with 2-3 tillages (including the seed covering one). When there are 3 or more tillages, the first is usually a deep mouldbord plowing, followed by harrowing, sowing calibration (Ayar), and seed covering (Rdad). All cultivations are done in the month before sowing. A few farmers may use the traditional animal-drawn plow. Some rainfed farmers, especially those with shallow soils, may omit the preplanting tillage, and till only to cover the seed. On irrigated deep soils, some farmers may give 4 or 5 tillages including the rotavator and tabban.

Legume seeding is done mostly by hand, either by broadcasting or hand-drilling. A few large farmers (in Bekaa) use mechanical spinners.

Seed variety, source and rate. Only 9% of lentil producers grow improved varieties, compared with 36% for chickpea and 66% for faba bean. Six of the seven growers of the improved lentil variety, Talya 2, were from Bekaa, and all located near to Terbol or to ARI's research stations. The very low adoption rate of improved lentils, compared with that for improved chickpea and faba bean, is most likely due to the unavailability of improved seed in the market. Improved varieties of chickpea reported by farmers were Genta 2 and FLIP 85/98 (promoted by ARI/ICARDA), Turki, Karouni, and Fouai. (These last two varieties may be local names for the Turki variety). Improved faba bean varieties grown include Frensawi (French), Kubrusi (Cypriot), Masri (Egyptian), Maghrabi (Moroccan), and Shami (of Damascus). Geographical differences in the adoption of improved varieties are shown in Table 6.3.1.

Table 6.3.1. Adoption of new varieties (% of crop growers) by province

Crop	Whole sample	Bekaa	South	North	J. Lebnan
Lentil	9	12	4	0	NG*
Chickpea	36	26	58	58	0
Faba bean	66	46	67	74	87

* NG, not grown

Farmers fail to grow new varieties either because they are not aware of their existence, or seeds are unavailable, or local cultivars are preferred (Table 6.3.2). It is likely, however, that many of those who prefer local cultivars have not been exposed to the new varieties.

Table 6.3.2. Reasons for not growing improved varieties (% of crop growers)

Reason	Lentil	Chickpea	Faba bean
Unaware, or seed of new varieties unavailable	71	51	19
Prefer local varieties	20	13	15
New vars. already grown	9	36	

The main source of lentil and chickpea seed is farmers' own stocks, but for faba bean it is the market. The very few farmers who used seed of improved varieties from ARI or ICARDA research stations (Table 6.3.3) reported significant yield increase (50-100%).

Mean seed rates are 180 kg/ha (CV 26%) for lentil, 120 kg/ha (CV 35%) for chickpea, and 155 kg/ha (CV 40%) for faba bean.

Table 6.3.3. Seed source (% of crop growers)

Seed source	Lentil	Chickpea	Faba bean
Farmers' own stock	66	48	27
Market	24	43	70
ARI or ICARDA	6	7	1
Other sources	4	2	2

Fertilizer application. Fertilizer are not commonly applied to legumes in Lebanon. Less than 30% of growers use N, and even fewer apply phosphate. An NPK compound was applied to lentil by three farmers, to chickpea by 13, and to faba bean by 16 farmers. Faba bean is more likely to be fertilized (and at higher rates) than the other two crops. Across all growers, the rate of N application averaged 50 kg/ha of the trade material for lentil and chickpea, and 80 kg/ha for faba bean. Rates of P_2O_5 and NPK are even lower, except for NPK on faba bean.

Supplemental irrigation. Most legumes are grown rainfed, but they may be given a few supplemental irrigations where water supplies are available. Priority is given to faba bean (2-4 irrigations), then chickpea (1-2), and last to lentil, which may be given one irrigation in dry years only. (A few farmers reported surprisingly large numbers of irrigations, 9 for lentil and chickpea, and over 20 irrigations for faba bean.)

Weed and pest control. Weeds were considered a problem by over 80% of the sampled growers of chickpeas, lentils and faba bean. Most farmers use hand weeding to control weeds; very few apply herbicides. Insects, especially pod borers and leaf miners, were a problem for 32% of lentil producers, 45% of chickpea producers, but for 80% of faba bean growers. Other insects reported are aphids, grasshoppers, thrips, and gryllotalba. Diseases are more serious on faba bean than on chickpea and lentil; problems were reported, respectively, by 30%, 26%, and 14% of producers. Very few farmers apply pesticides to lentil (9%) or chickpea (16%), but more than 44% of faba bean producers use pesticides for insect and disease control.

Harvest. Harvesting of legumes starts in March/April (for green products of faba bean and chickpea) and may continue until August/September (for delayed planting and harvesting of dry faba bean). Lentil is harvested in May-June, and dry chickpea in June-July. Harvesting is mostly done by hand. One lentil and two chickpea producers have tried mechanical harvesting recently. They used an autopropelled cereal cutter (swather), and the trial was satisfactory. Hand harvesting of legumes, especially lentil, is viewed as a major production constraint, for large producers in Bekaa particularly.

Crop yields. Yields are usually low and highly variable (though some farmers achieve remarkably high yields). In years of normal harvest, average yield is about 1.0 t/ha for lentil, 1.1 t/ha for chickpea and 1.3 t/ha for faba bean. Variability is greatest for faba bean, followed by lentil, then chickpea, with CVs for the yield means in Table 6.3.4 of 88%, 81% and 59%, respectively. In years of good harvest, yields can be higher by about 0.5 t/ha for lentil and chickpea, and by 0.7 t/ha for faba bean. However, even in good years, yields as low as 0.30-0.35 t/ha were reported by some farmers -- although, at the same time, yields of 4.0-6.0 t/ha were also reported. These exceptionally high yields are achieved by farmers growing improved varieties, applying timely supplemental irrigation, appropriate rates of phosphate, and using pest control. Yields are generally highest in Bekaa (Table 6.3.4). In contrast to the situation in some other countries, legume straw has little economic importance. Its price is usually less than 20% that of the grain.

Table 6.3.4. Normal grain yield means (kg/ha) by province

Crop	Sample	Bekaa	South	North	J. Lebnan
Lentil	1010	930	800	540	1090
Chickpea	1080	950	1100	930	1190
Faba bean	1310	600	ND	1365	1730
Green Chickpea	4710	4310	2570	6530	ND*
Green Faba bean	4430	2570	4640	5890	6500

* ND, no data

Purpose of legume growing. Most food legumes are grown as cash crops. Growing mainly for home consumption was reported by only 7% of chickpea producers, by 10% of lentil producers, and 20% of producers of faba bean and other food legumes. In general, production aims are determined by landholding size and crop area, and thus farmers in Bekaa tend to be more market-oriented than those in other provinces.

Forage legumes are grown mainly for on-farm feeding (64% of forage producers), with 21% grown for marketing and 15% for both purposes. Market-oriented forage production is relatively more common in the North (40% of producers); in Jebel Lebnan all forages are utilized on-farm.

Marketing. Legume producers sell their products to wholesale or retail traders. A few, large-scale farmers (mainly in Bekaa) make contracts with a cannery, by which the company may provide cash or credit repayable at the end of season and farm-gate prices are determined in advance. This arrangement is practised by 4% of chickpea and pea producers, and 2% of faba bean and cowpea producers.

With the exception of lentil, all food legume crops may be marketed and consumed either green or dry. Cowpea and faba bean are mostly sold green (by 85% and 61% of producers, respectively), whereas chickpea and beans are mostly sold dry (68% of producers). Problems of marketing legumes are mainly economic. Almost all farmers complained of 'untimely' imports dumped in the market causing surplus supply and reduced prices.

Winter chickpea. As in other WANA countries, most chickpea in Lebanon is sown in spring (March-April). However, successful demonstrations of winter sowing conducted by the ICARDA/Lebanon collaborative research program showed yield increases of 50-100%, and farmers have recently started to adopt this practice. Some 17% of chickpea producers sampled in the present survey sowed the crop in winter (November-December); 10% used local or Turkish improved varieties, and 7% grew the Genta varieties released by ICARDA/ARI. Some success was reported for the Turkish varieties, especially in the coastal region (with mild winter). More success was reported for Genta: only two of the 10 adopting farmers will discontinue cultivation, and not because of poor performance but due to marketing difficulties. These farmers grew Genta 1, which has unfavourable seed colour and size characteristics. Introducing the new varieties Genta 2 and FLIP 85/98 (lighter seed color and larger size than Genta 1) will most likely enhance the adoption of winter chickpea.

Conclusions

* Legume crops are basic components of cropping systems in many parts of Lebanon. In some cases, such as the wheat/vegetables-based farming system, legumes may cover 25% of the total area under crop production and contribute significantly to the earnings of rural families.

* Legumes grown in Lebanon are mainly chickpea, lentil, and faba bean. Other legumes are bean, pea, cowpea, and forages. With the exception of lentil, food legumes are produced, marketed, and consumed either green or dry. Green legumes are highly valuable cash crops.

* Yields are generally low and highly variable. However, a great potential for doubling, or even trebling, current yields has been demonstrated by some progressive farmers, and by research findings of the ICARDA/Lebanon collaborative research program.

* Major constraints to crop improvement identified are

  i) biotechnical, relating to: seed variety and quality; crop management; fertilizer use; weed and pest control; supplemental irrigation; manual harvesting; and, in some areas, soil quality (stoniness);
  ii) socio-economic, such as high input costs and low market prices for outputs (due to competition from imported products); and
  iii) institutional: mainly the absence of a well-established mechanism for improved seed multiplication and distribution to farmers, and the absence (or weakness) of extension and other technology transfer institutions.

  Alleviating these constraints is a crucial requirement if any substantial crop improvement is to be realized.

* Lebanese farmers are generally good adopters of new improved technologies, if feasible and accessible. Support is therefore needed for ARI and other Lebanese institutions involved in agricultural technology generation and transfer, including the enhancement of the on-going ICARDA/Lebanon research and demonstration collaboration program.

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Dedication. This report is dedicated to the late Mr. Hussein Dallol, our co-author, who passed away before it was completed.

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6.4 Barley markets of northern Syria

Introduction

While previous research has characterized the barley producers of Syria (Somel *et al.* 1984) and evaluated the economics of barley cropping under rainfall risk (Mazid and Bailey 1992), little is known about barley markets, marketing channels, consumer preferences for grain and straw, or the preferences of farmers who grow barley. The objective of the work summarized here was to present a descriptive analysis of the existing private marketing channels for barley in Syria and the factors that contribute to the price of grain and straw.

A market survey was conducted from September to November 1995, through informal interviews with 20 market participants in Aleppo and Hama, using the Structure Conduct and Performance approach. In order to capture all essential information a question guideline was developed. Each interview was then structured in two parts: first, appropriate questions were selected from the guideline; then, additional information was collected by asking questions arising from the previous conversation. Market places and participants were initially selected at random, but once the market structure had been understood, selection was done systematically.

Structure of barley markets

Market places. Rural and urban markets show the same basic structure: market places for barley can be distinguished as Bazar, Khan and Broker's office.

Bazars exist in all sizeable towns, meeting usually on an open place at the side of a major traffic road on the edge of the town center. Depending on their importance, bazars in rural towns meet daily or weekly. Larger towns might have two daily and an additional weekly bazar. Each bazar specializes in different products. Barley traders usually congregate next to sheep bazars. The most important daily bazars for barley grain, Aleppo and Hama, are adjacent to large-scale sheep fattening operations, while certain important weekly bazars are situated at the edge of the steppe, for example Abo Duhur, Salamiye. Daily and weekly bazars draw most of their clientele from the immediate area; but, in the case of barley, the bazars' zone of influence is generally wider. Barley grain is traded in bags on a per-lorry basis. The grain is not displayed to the public, but samples are given to every prospective buyer.

Khans, a combination of store and office or shop, are found in most towns. Depending on trade volume and range, they are situated either near the city center or next to an easily accessible main road. Khans specialized in the same products are usually all together in one part of the town. Those trading in barley also sell other feedstuffs, wheat and coarse grains. The trade range of a khan is determined largely by the owners' capital base and his communication network.

Brokers Offices coordinate product transactions. Unlike in bazars and khans, the traded product is not present during transaction. Brokers offices trading in barley are either located in areas of production surplus, like Hasakeh and Qamishly, or of high demand, like Damascus and Homs.

Institutions, taxes and market facilities. Institutions supporting private marketing of barley, market organization, information and transport are totally missing. Although this may be due partly to the fact that private barley trading was forbidden until 1990, the situation is not much different for products which have been traditionally traded by the private sector, such as livestock and livestock products.

No official permission is necessary to trade in barley inside Syria. Traders can apply for a commercial registration number, which gives them the right to participate in governmental auctions. Officially, no market tax has to be paid. However, the bazar in Aleppo is dominated by one family, and people wishing to trade there have to supply barley free of charge to this family. Traders in khans have to pay as tax 7.5% of their income, determined by estimating khan size and annual turnover. Market facilities in bazars are very basic. As there are no public stores and shelters, market activity is highly susceptible to weather conditions. Public telephones and large-scale transport facilities are not provided. In Aleppo and Hama, platform scales are available, owned and operated by private individuals. Khans, due to their location near town centres, tend to have slightly better facilities. At least in major towns, telephones and vehicles are more readily accessible. Public offices for large-scale transport are located in major cities but not necessarily close to the khans. In rural areas, scarce availability of transport facilities can be a constraint for market activities. All barley grain is handled in bags, in khans as well as bazars, with consequent disadvantages in high labor cost and storage losses.

Market participants. The relationship between producer and consumer affects the transaction of a product and thus market performance. To assess the private marketing sector for barley in Syria market participants other than producer and consumer needed to be identified and characterized. This could be done in terms simply of their function in the transaction process: retailer, wholesaler, assembler, transporter. However, most of the barley market participants in Syria perform more than one task. Therefore, the following criteria were found to be most effective for characterizing intermediaries:

Title to the product: trading can be done by anyone having title to a product for sale or mediating the transaction of a product.

Storage time: a trader may purchase and resell on the same market day or he may purchase in order to store and resell after some time.

Trading range: traders' zone of influence can cover several regions (interregional), one entire region (regional), several markets within one region or one single market.

Working arrangements: an intermediary may be engaged by one trader, may cooperate with several traders, or may work independently.

Using these criteria the following categories of intermediaries can be distinguished (see also Table 6.4.1):

Table 6.4.1. Market places, participants and their trade ranges in private barley marketing in Syria

	Market place			
Participants	Bazar	Wholesalers' Khan Brokers' Office	Wholesaler-Retailers' Khan	Retailers' Khan
Supply	Farmer Assembler Dallal	Farmer Assembler A'mil Middleman Agents	Farmer Assembler Traders	Traders
Demand	Consumer Trader	Consumer Trader	Consumer Trader	Consumer Trader
Trade range	inter-regional	intra-regional	inter-regional subregional	within markets

Assemblers are always owners of vehicles ranging in capacity from 2 to 20 t. Assemblers purchase and resell in one market day. Their trading range depends on the size of the vehicle owned. Thus, an assembler owning a vehicle with a capacity of 7 t or more may purchase barley from farmers or khans in areas of surplus (eg Ain Arab, Menbij, Hasakeh) and sell it in markets where he expects to get the highest price, whereas the owner of a smaller vehicle will assemble barley in the area around his village and sell to the nearest market. Assemblers either cooperate with traders or work independently They may trade in barley exclusively during the post-harvest season, but most of them are farmers or have other activities (like working in building construction).

An **a'mil** is engaged by a trader to purchase grain, from his village and from surrounding villages. Unlike the assembler, he does not travel from village to village but is known by farmers in the area. If farmers want to sell they approach the a'mil who then acts as a mediator between them and the trader. The trader provides capital as well as transportation and pays a commission to the a'mil.

Agents are employed by traders. Their operational base is the trader's office, and they represent the traders in different business transactions.

Middlemen mediate transactions and often cooperate with brokers. They work on their own behalf within a region or across regions. Their task is, for example, to negotiate the price according to the seller's interests or to inform a broker where he can purchase barley. Commission for the middleman is charged to the person who required his services.

Brokers coordinate transactions across regions. In contrast to middlemen, they have an operational base, located in major towns in areas of surplus (Hasakeh, Qamishly) or in areas of high demand (Damascus, Homs).

Dallals operate in bazars. Unlike other intermediaries, they deal exclusively in barley. Depending on the size of the local barley market, up to four dallals may work in one bazar and perform the following functions:

* dallals are the only accepted holders and distributors of price information;
* they distribute grain samples to prospective buyers and give information on quality and the origin of a lot;
* they arrange and mediate negotiations and comment on the price bids;
* they give a guarantee, if a customer wants to purchase on credit.

During price negotiations, the dallal supports the bargaining position of the seller, who then pays him a commission. However, in bazars close to large sheep fattening operations, the dallal also acts as a middleman for barley consumers.

Traders are characterized by two points: they have a khan at their disposal, and they work on their own behalf. According to their volume of trade, traders can be described as wholesalers, wholesaler-retailers or retailers. **Wholesalers** have a large capital base and trade exclusively on a lorry basis. They are located either in urban market centers or in the major town of an area of surplus. They may own several khans and always have good telephone access. The trade range of wholesalers is countrywide, and some of them import barley from Turkey or Rumania. Transport utilizes owned or rented trucks. Wholesalers employ large staffs: book-keepers, loaders, drivers, and a'mils. Except during the post-harvest season, barley is most often purchased and resold on the same day. It is also possible that the trader is performing the task of a middleman. This working practice allows wholesalers to reduce capital, transport and loading costs as well as storage losses. Wholesalers are often members of powerful families running several khans, who may dominate the market in a given area of the city. **Wholesale-Retailers** purchase on a lorry basis between regions and sell on a bag basis within one region. To a quite large extent they purchase and resell on credit. They do not necessarily own a vehicle or a telephone. **Retailers** operate in urban centers and are located in the Souk. They purchase on bag basis and sell barley by the kilogram, along with coarse grains, wheat, spices and herbs.

Marketing channels

Private sector. Possible ways of transferring barley from producer to consumer are illustrated in Figure 6.4.1. Most farmers who sell barley to the private sector sell it at village level to intermediaries. Farmers explained their marketing behavior in the following way. Especially in remote areas, transport is scarce and therefore expensive. Because farmers usually are in urgent need of cash, most of them sell their produce directly after harvest, when prices are low, and it is not then profitable for the farmer to transport barley to the market himself. However, even farmers living next to a market place prefer to sell at village level: if they sell directly in a bazar, they have to pay commission; and if they sell to a khan their bargaining power is handicapped by insufficient information on prices. Moreover, the farmer would need at least one working day to accomplish this transaction.

As shown in Figure 6.4.1, middlemen, agents and a'mils transact barley to wholesalers, most of them coming from other regions. Mobile traders sell 90% of their barley in bazars, but if the bazar price is too low, they sell on credit to khans to fetch a higher price. On average, 75% of the barley reaching bazars is then transacted via dallals directly, or by middlemen, to consumers; and 15% is bought by wholesale-retailers coming from within the region. Consumers purchasing barley from bazars are large-scale sheep fatteners (especially in Aleppo and Hama), bedouin and farmers. Wholesalers market about 70% of the purchased barley to large-scale fattening operations and 30% to wholesale-retailers, most of them coming from other regions. Wholesale-retailers transact about 90% of their traded barley to small-scale sheep fatteners and farmers, the other 10% being sold to retailers. A considerable number of those transactions seem to be on credit. Retailers sell barley to urban consumers owning some sheep for meat or milk production or owning a donkey or horse for transportation.

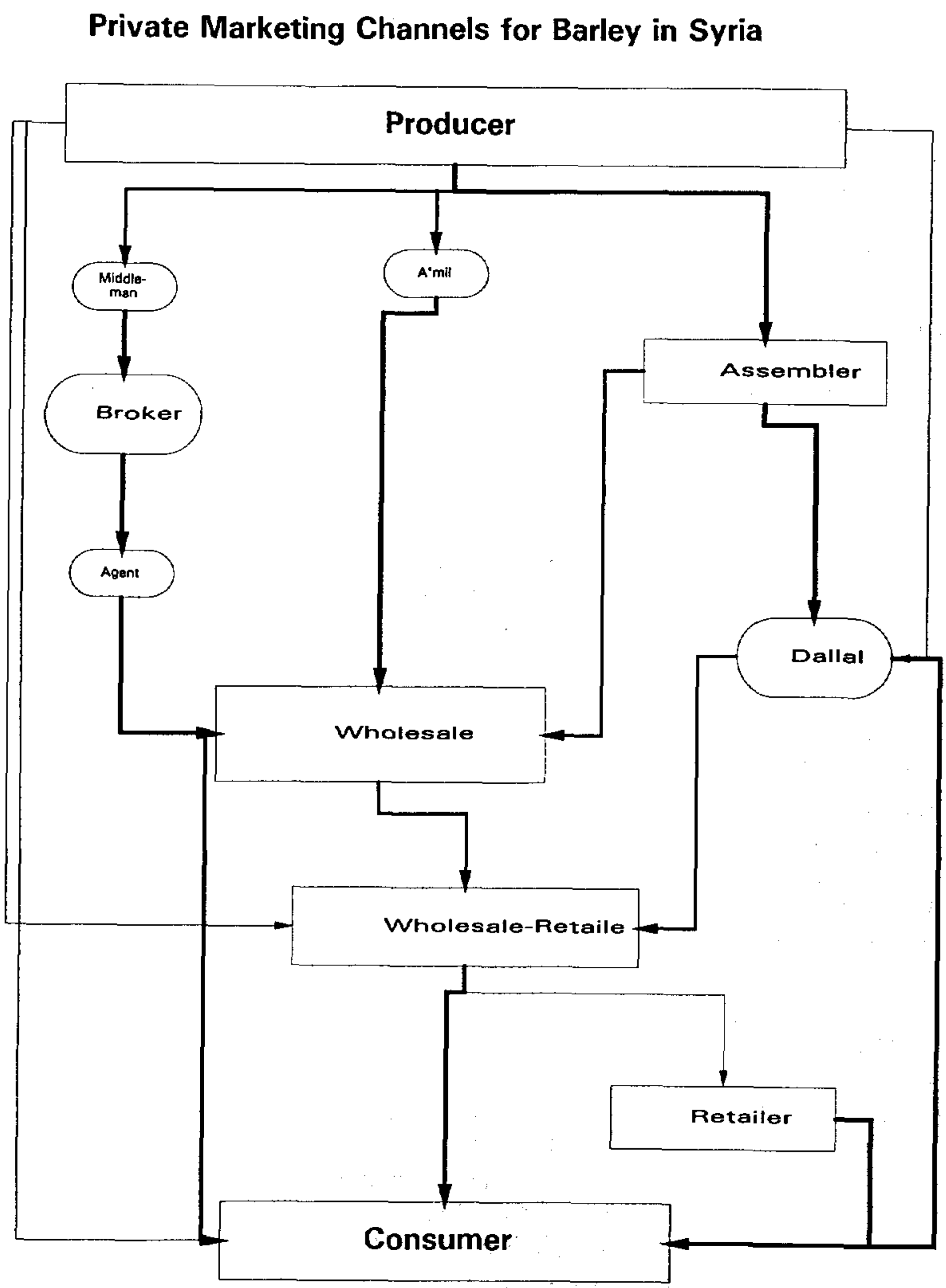

Figure 6.4.1 Private marketing channels for barley in Syria. Codes: resctangular boxes represent title to the product, round boxes represent no title to the product; the thickness of the arrows represents the importance of marketing channel

Linkages to the public sector. In the immediate post-harvest season, the General Organization for Trading and Processing of Grain (GOTPG) buys barley at a fixed price, 10-15% higher than private market prices. Traders take advantage of this situation by purchasing barley from farmers and selling it to GOTPG. We can assume that a large portion of barley sold post-harvest to markets is subsequently resold to the government. During the winter season, traders have another opportunity to profit from government intervention: barley is sold to cooperatives by the General Organization for Feedstuff. The sale price is fixed and, unless there is an excess of feed stuff available in the private sector, can be considerably lower than market prices. Thus, cooperatives are encouraged to sell barley instead of using it on the farm.

Market conduct

Accessibility of market information. No institutions, like a general marketing board for agricultural products or market announcements in newspapers and radio, exist to provide general market information. Each participant must visit the market personally or rely on information from others. This complicates transactions, especially for those living far from the markets. The farm survey revealed that traders buying barley pay up to 20% below the actual market price in villages with difficult market access but pay the full price in villages with easy market access.

Consumers and producers often face the additional constraint of having very few business connections to the markets. To collect price information they must either ask in every khan or visit the bazar. Here, prices are not announced or discussed in public, making it very difficult to get any overview of the market situation. In contrast, traders can easily telephone and collect market information from all over the country, so that they respond directly to price movements over time as well as to differences from place to place. The common practice is to call several traders in each market and to ask the prices of several products, including the one they wish to deal in. Traders can also be easily contacted by prospective buyers, allowing them to optimize buying and selling activities and to minimize loading, storage and transportation costs.

Price formation. In contrast to other countries, where public auctions are a common way of price negotiation, price formation in Syria is the product of private bilateral negotiations. Sellers and buyers receive price information through the dallal. The announcement of the price the seller wants is also mediated by the dallal. Negotiations are carried out between the prospective buyer and the dallal. If several buyers are interested in one lot, price negotiations take place individually. The seller is present during bargaining but not actively involved. He is not, however, obliged to accept the negotiated price. Although the dallal's task is to support the bargaining position of the seller, there is no price agreement. On the contrary, buyers' interests have also to be taken into consideration. Commission is paid only on completion of a transaction. Further, dallals have usually to compete for customers with their colleagues and have to take care of their reputation.

Factors determining price formation. These include transportation costs, mode of payment as well as grain quality and origin. Transportation costs are a matter of negotiation. If it is agreed that the seller will pay, then the barley price is increased by the expected costs. Likewise, if the transaction is to be paid on credit, the price is increased. It could not be ascertained whether the price increase covers or exceeds the capital costs in this case.

Importance of quality. In the market, barley is classified according to landrace: aswad (black barley), abiad (white barley) and abrash (intermediate between black and white). Traders associate specific, visible traits of barley grain with its value for animal feed; the colour of a lot seems to be the most important trait for judging quality. Traders link the following attributes with black grain: 1) softness, and easy detachment of the awns; 2) short time for chewing; 3) white colour of the endosperm; 4) high content of "salts" and high nutritional value; 5) good digestibility; and 6) fast liveweight gain by sheep. In contrast, the following characteristics are associated with the white grain: 1) low nutritional value; 2) hard grain texture; 3) good grain; 4) greater suitability for crushing and mixing with supplements than black grain; and 5) high water requirement after seeding.

In Aleppo, black-seeded landraces fetch higher prices than white-seeded ones. The degree of blackness may increase grain price by 5-10%. However, in Hama, aswad was found to be less expensive than abiad or abrash. One reason could be that consumers in the Hama area give importance to traits other than those determining feed quality.

Assessment of quality. In the bazar, each prospective buyer can take a grain sample from any lot on sale. He takes the sample into the palm of his hand and checks its colour, softness, moisture content and weight. Softness is examined by testing if the grain is "prickly", which is caused by sticking awns or pointed ends of the seeds. To test the weight, the sample is thrown lightly into the air and the movement of the dropping grains watched. Sample origin is also considered important, as traders and consumers seem to associate certain quality characteristics with particular locations. Traders transacting by telephone may even ask only about the origin of the grain, which implies an expected quality. The price will be decreased later, if the delivered lot does not meet quality expectations.

Quantity measurement. In bazars and khans, the availability of scales means that quantity is usually determined by weighing. However, especially when small quantities are sold, the bag weight is estimated from grain size. When barley is sold at the village level, farmers are usually not present during the weighing. There is no institution controlling the accuracy of scales.

Price seasonality. Prices follow supply and demand, which is reflected in price fluctuations within as well as between market days. However, governmental buying and selling activities at a fixed price may influence price fluctuations. Figure 6.4.2 shows barley prices over two complete years, 1994 and 1995, collected in the Aleppo bazar, Nekarein. The price variation recorded probably reflects the varying balance between market arrivals and demand for barley at different seasons. Prices are low during the post-harvest season, from May to July but subsequently tend to rise. In 1994, the barley price peaked in November/December, at a level 31% higher than the lowest price (in July), which represents an increase of about 5% per month over 6 months.

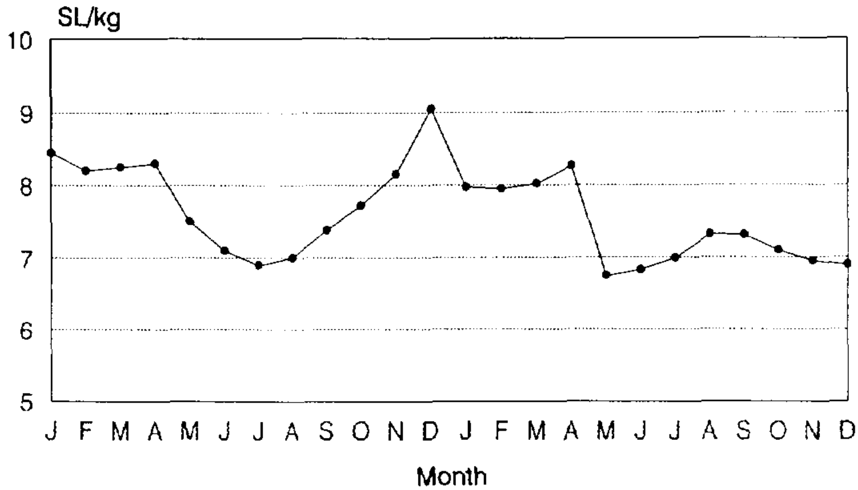

Figure 6.4.2 Monthly prices of barley grain in Aleppo Nekarein market, Januiary 1994 to December 1995

This rise reflects an increased demand for barley for two purposes: barley seed for planting, from September onwards, and increased demand for feed at the beginning of winter. Traders reported that barley for feed is bought mainly between the end of cotton harvest (end of September) and the beginning of rapid spring growth (mid-March). However, in 1995, prices failed to follow this pattern. No price peak was observed in November/December; rather, the price even dropped slightly after August, and the difference between lowest and highest price in Aleppo Nekarein market was only 8%. According to traders, the situation in the Raqqa market was similar. In both years, prices remained relatively stable during spring and then dropped about 17% during the harvest period. Traders reported that price changes in the spring depend on rainfall conditions.

Finally, it should be said that the account given here is based largely on information from Aleppo. More detailed price information collected in different markets and for different feed commodities, including barley straw, is needed to generalize the story. Further, secondary data on the feedstuff transactions of government organizations would be useful to show the impact of the public sector on private-sector barley markets.
[Susanne Pecher (University of Hohenheim) and Abelardo Rodriguez]

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7. TRAINING AND AGROTECHNOLOGY TRANSFER

FRMP's training activities are directed towards the improvement of the national programs research capabilities to conduct independent and collaborative research in specific areas of farming systems and resource management. FRMP tends to utilize its on-going research as a working demonstration to increase the trainees' practical knowledge and skills in identifying constraints that limit agricultural production. By involving trainees in actual farm surveys, FRMP aims at enhancing their comprehension of the "technology transfer" process and the complexity of farmers' decisions in adopting new technologies.

FRMP's training activities conducted during 1995 may be summarized as follows:

7.1 Headquarters Training Courses

Individual non-degree training

Participant	Country	Subject	Duration
Yaghoob Mirsoleimani	Iran	Soil Fertility	2 mths
Saleh El-Hammali	Libya	Economic Analysis of Survey & Experimental Data	2 wks
Taher Faraj Gala	Libya	Economic Analysis of Survey & Experimental Data	2 wks
Rita Hasbany (Ms)	Lebanon	Nitrogen Analysis in Soil	2 mths
A. Maher Tawil	Syria	Data Entry and Analysis for Wind Erosion Studies	1 wk
Maisoun Abdel Karim (Ms)	Syria	Data Entry and Analysis for Wind Erosion Studies	2 wks
Nawal al-Kharban (Ms)	Syria	Data Entry and Analysis for Wind Erosion Studies	1 wk
Lotfi Khiari	Tunisia	Soil Fertility	3 wks

Individual degree training

Name	Country	Degree	University	Topic
M. Mahmoud Khalaf	Jordan	MSc	Jordan	Soil Fertility
Sharif M. Obeid	Jordan	MSc	Jordan	Wind Erosion
Noureddin Al-Khokhen	Jordan	MSc	Jordan	Wind Erosion
Zouhair Masri	Syria	PhD	VV Dokuchaev/ Russia	Soil Phys. Status of Rotations
Annette Oberle (Ms)	Germany	PhD	Karlsruhe	Water Harvesting Potential
Suzanna Pecher (Ms)	Germany	PhD	Hohenheim	Barley Marketing
Sonia Garabet (Ms)	Syria	PhD	Reading	N Dynamics
Ahmed Mazid	Syria	PhD	Nottingham	Technlgy Adoption
Leith Mahdi	Iraq	PhD	La Trobe	Factors for Wheat Emergence
Malika Abdelali (Ms)	Algeria	PhD	Reading	Women Labor in Agriculture

7.2 Non-Headquarters Training Courses

Supplemental Irrigation Technology Transfer: This in-country training course was conducted in cooperation with the Directorate of Agricultural Extension in Syria. It was held in Damascus, Syria, during the period 14-19 January 1995, and attended by 21 participants.

Winter Chickpea Technology Transfer: This was a sub-regional training course conducted jointly by GP and FRMP in cooperation with Iraq National Program. It was held in Mosul, Iraq during the period 2-4 May 1995, and attended by 28 participants from Iraq and Jordan.

Implementation, Analysis and Interpretation of Farm Surveys: In response to a request from Iran National Program, FRMP conducted this in-country training course in Maraghe, Iran, during the period 20-31 May 1995. Twenty two participants attended this course.

Farm Survey Methodologies: This regional training course was conducted in collaboration with the Mashreq and Maghreb Project. It was held in Amman, Jordan, during the period 13-23 November 1995, and attended by 11 participants from Iraq, Jordan, Lebanon, Libya, Syria and Tunisia.

7.3 Workshops

During the period 19-23 November 1995, ICARDA hosted a Soil Fertility Workshop which was attended by 35 soil scientists/agronomists from 13 countries in the WANA region as well as by international agencies, ie, FAO, International Potash Institute, International Atomic Energy Agency, and IMPHOS which co-sponsored the meeting. The purpose of the meeting was to assess the state of soil fertility research in WANA and to establish guidelines for future action. This was achieved by two days of formal presentations followed by two days of discussion and ensuing recommendations.

7.4 Miscellaneous Activities

As in previous years, FRMP staff contributed to other programs' training courses through lectures and practicals, mainly on farming system approach and resource management studies. A number of researchers visited the program for varying periods of time to work on collaborative research projects or to get acquainted with the program's activities.

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Maher Hamoudeh*	Research Technician
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