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FARM RESOURCE MANAGEMENT PROGRAM

Annual Report for 1987

ICARDA

Farm Resource Management Program

Annual Report for 1987

International Center for Agricultural Research in the Dry Areas

P.O. Box 5466, Aleppo, Syria

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THE FARM RESOURCE MANAGEMENT PROGRAM. ITS GOALS, STRUCTURE, RESEARCH PRIORITIES AND OPERATIONAL STRATEGY

(i) Background

Since its foundation, ICARDA has emphasized the concept of thinking in terms of "the farming system" when determining its research strategy, its priorities and the development of new technologies which are relevant and easily adopted by farmers. During the period 1977-1987 the Farm Resource Management Program of ICARDA has evolved as it matured and gained experience in the crucial issues affecting the farmers of West Asia and North Africa and their crop and livestock production enterprises. During this period, two major reviews also played a role in guiding this evolution.

In 1983, ICARDA hosted the first External Program Review (EPR). The review of the Farm Resource Management Program (then called Farming Systems) was supportive of the research foci and strategy we had developed, and encouraged their further development with several specific recommendations. A summary of the panel's comments and recommendations is presented in Appendix A.

In May of 1986, the CGIAR completed and published major reviews on research priorities and strategies. All programs of ICARDA gave considerable thought to the content of these publications. Members of the Program felt that many issues raised in these reviews had important implications for our future research foci and strategy. We concluded that the evolution of thought within FRMP had in almost all respects proceeded along very similar lines to that of the CGIAR. We noted some differences of emphasis of methods, stemming from the realities of agriculture in a difficult environment, but none that conflicted with CGIAR recommendations. A summary of major issues raised which were of direct relevance to the program and our reaction to them is presented in Appendix B.

In 1987, in the light of these CGIAR recommendations, a sharpening focus and 10 years of practical experience, we re-examined our program structure. This led us to the conclusion that, although the major foci of our research were correct and remained relevant, we should re-structure our research to provide greater emphasis to the management and conservation of physical, biological and human resources in our drought prone and environmentally variable region.

We also decided that a change of name to reflect the nature of the restructuring and to give a clear indication of our research direction would be appropriate. After much deliberation, we decided that "Farm Resource Management Program" reflected both the major emphasis of our research and the strong systems perspective and farm orientation which we have retained. The details of our new structure, goals and objectives, are described in the subsequent sections of this introduction.

(ii) The Regional Context of Resource Management

In West Asia and North Africa, rainfed agriculture has evolved over many centuries to cope with the problems of farming in an environment characterized by a very variable and fragile resource base.

Whilst the climate, soils, crops and livestock which form the essential physical and biological components of the farming systems have probably changed little in recent years, both the social and economic environments of farmers have undergone radical changes. National policies emphasizing industrialization, pricing policies favouring urban populations, and neglect of both basic services and farming in rural areas have led to stagnation of agriculture and emigration of the farming community.

In most countries food production per capita has also declined and it has been estimated that by 1990 the countries within the Mediterranean basin will face an annual 30-34 million MT food deficit. More recent estimates indicate that by the year 2000, cereal deficits alone will rise to nearly 60 million MT. It is clear that, in order to alleviate this potentially disasterous situation, economic and stable gains in food and feed production must be achieved through more efficient use and conservation of the basic resources upon which agricultural production depends.

Short and long term performance of major regional agricultural commodities, which form the central focus of three of the four research programs at ICARDA will be largely dependent upon the prevailing climate, the soil and adequate crop nutrients. Production increases must come through more efficient management of these edaphic components by farmers and their families. It is these agricultural resources, and their integrated management, that form the principal focus of the Farm Resource Management Program.

The unique characteristics of the climate, soils and the farming systems of the region have been reviewed elsewhere (Cooper *et al.* 1987). They have also been described in some detail in ICARDA's Strategic Plan, where their implications for ICARDA as a whole are discussed. The following points are of particular importance:

- Except in Sudan, and to some extent Ethiopia, land suitable for rainfed agriculture is currently all used for some form of production. Increased and sustained crop and livestock production can be achieved only through more efficient use and conservation of existing resources.

- The majority of farms are small, family operated, multi-enterprise and have limited financial resources. A multidisciplinary farming systems research perspective is essential to ensure that new technology is relevant and can be profitably adopted.

- Limited time, financial and human research resources dictate that the generation of new technology will suffer from an element of time and location specificity, and yet the environment in which we work exhibits substantial temporal and spatial variability. It is essential that methods be developed to characterize this variability in order that the relevance, performance, transfer and adoption of new technology can be carried out in a cost effective manner.

- Efficient resource management and commodity improvement are essential and complementary in alleviating food shortages; in the long run neither can be expected to succeed on its own. Complete and optimum solutions to agricultural problems can only be achieved through full cooperation between all disciplines of research.

- Given the urgency of the food shortage problem facing West Asia and North Africa, both ICARDA and National Programs must continually reassess the relevance and success of their research priorities to ensure that limited research and financial resources are being used and targetted effectively. It is necessary to develop methods to predict, monitor and improve the adoption and impact of new technology.

(iii) Program Goal, Organization and Operational Strategy

The long term goal of FRMP is to collaborate with National Programs in improving and stabilizing crop production through the development of sustainable cropping systems which both conserve and enhance the use of farm resources and result in greater social and economic welfare of farming communities in West Asia and North Africa.

To accomplish this goal, the program has developed a framework of research and training which is described by a two dimensional matrix of three principal research projects and four broadly defined agricultural systems. The major physical, biological and sociological features of these systems are described in ICARDA's Strategic Plan (see Appendix C in this report) and provide a logical framework within which research can be prioritized and developed.

The long term goals and objectives of our three projects are presented in the introduction to Sections 2, 3 and 4 of this report where we provide an overview of our major on-going research. In the first project, *Management of Soil, Water and Crop Nutrients*, research aims to identify technologies which optimize the efficiency of use and the conservation of these physical resources. Such research is undertaken with a systems perspective to ensure that it remains relevant to the needs of the region we serve.

The second project, Agro-ecological Characterization for Resource Management, focuses on the development and application of methods to examine the effect of both temporal and spatial environmental variability on innovative resource management technologies to determine the relevance, performance and transferability of technology.

The third project focuses on the Adoption and Impact of New Technologies: the final test of the relevance and performance of technologies developed by ICARDA and National Programs. Adoption will depend, not only on farmers' means and attitudes, but in many instances will be influenced by governments' priorities for agricultural development. Once adopted, new technology should improve food production and the economic security of farmers and Nations. Nevertheless, less desirable *side effects can occur and this possibility must not be ignored.* Research will concentrate on the development of methods to predict, monitor and improve the adoption and impact of new technology.

To enable the Program to fulfil its long term goal, and in cooperation with all ICARDA programs, FRMP is actively seeking to extend its research activities through the development of linkages with the National Programs, Universities and research institutions of the region. In establishing such links, we bring together scientists who share common research objectives, either through their focus on one of the four broadly defined agricultural systems, or through a more discipline oriented focus on a specific component of resource management.

Equally, when and as appropriate we aim to develop links and collaborative programs with advanced institutions in developed countries, and with other International Agencies. This is of particular relevance to project two, in which the goals are shared by other Centers in the CGIAR system and by several International Organizations. Data, and methods for using them are of relevance to all, and we are active in promoting collaboration with, and among, these institutions.

As an integral part of our collaborative activities with National scientists the program will continue to assist in the development of National Research capabilities through its sustained effort on training, both at ICARDA and in-country. The emphasis will remain on training in applied research methods associated with farming systems research, and will include courses on specific aspects of resource management. As ICARDA's regional network of collaborating scientists expands, the efficiency of this training will improve further. We are increasingly able to target training towards institutions, projects and scientists with whom ICARDA has developed permanent links. The relevance, focus and follow-up of the training is thus greatly enhanced.

(iv) Resource Allocation and Priorities

The current allocation of our core budget between our three major areas of research and training are given in Table (a). The relative emphasis placed on each of the four agricultural systems is indicated for each project.

Research on the Management of Soil, Water and Nutrients is currently our principal research activity and uses 50% of our budget. Major areas of research are discussed in Section 2 of this report. Within this activity, we continue to place our highest priority on research aimed towards the dry barley-livestock systems of the region. These areas contain some of the poorest farmers, depend upon a fragile resource base and face some of the harshest conditions in the region. To date they have been largely ignored by National Planners and Researchers and yet they have potential for improvement. In such dry areas (200-300 mm of annual rainfall), improved efficiency of use of rainfall is essential to achieve stable increases in production. Our current research, much of it in collaboration with the Cereal Improvement Program (CP), the Pasture, Forage and Livestock Program (PFLP) and national institutions, is aimed towards generating technology for sustained improvement in livestock feed supply through increased barley production and fallow replacement with forage and pasture legumes. However, in parts of the region,

TABLE (a) Allocation of resources and relative priorities of FRMP

	% Allocation[1] of Core Budget 1988	Native Pasture & Steppeland	Barley-Livestock Systems	Wheat-Based Systems	Irrigated Agric. Systems
Management of Soil Water & Nutrients	50	x	xxxxx	xxx	-
Agro-ecological Characterization for Resource Management	19	xx	xxxx	xxxx	-
Adoption and[2] Impact of New Technologies	13	x	xxx	xxxx	x

1) 18% of FRMP core resources are currently allocated for support of two specially funded projects in Syria and Tunisia (11%) and to the Program Leader's Office (7%).

2) This project is currently receiving substantial additional special funding from Ford Foundation which is scheduled to end towards the end of 1988.

barley and livestock are produced in areas where rainfall is so low and erratic, that sustainable and economically viable crop production can only be achieved through water harvesting. Part of our research addresses this.

The wheat based systems form the second priority in the first project. National Programs have allocated most of their resources to these higher potential areas, and much progress has already been made in improving wheat and food legume production. Given this progess, our research focuses on <u>technology refinement</u> rather than technology generation and seeks to find ways to improve the conservation and efficiency of use of resources. Improved efficiency of fertilizer use, better weed control, more efficient tillage, stubble management and supplemental irrigation of wheat are all major research activities. Much of this work is done in cooperation with ICARDA's commodity programs and increasingly with national institutions.

In all our work on the Management of Soil, Water and Nutrients, we place emphasis on the development of research methodologies and analytical techniques which will improve the efficiency of research in the region as a whole. Our research in Project 1 is thus directly linked with that in Project 2, Agro-ecological Characterization for Efficient Resource Management. This is a principal area of upstream research at ICARDA, and currently receives 19% of our budget. This research has developed and expanded steadily during the last few years, and, in creating the research structure of FRMP, we developed a clear set of goals and an operational strategy which are discussed in Section 3 of this report. This work is unique in the region and again we emphasize the development of methods which we expect to be of value to national programs. It will have an equally important impact on research priority setting and the transfer and adoption of technology in both the wheat-based and the barley-livestock systems. We give equal emphasis to both. Native pastures are an integral and important part of these two systems. Their productivity is also dependent on soil and climatic conditions, and thus our research is not limited only to arable crops.

Adoption and Impact of New Technology is an important new area of research for ICARDA to which we allocate 13% of our budget. These resources are currently supplemented by substantial special funding. At the moment we give greater emphasis to the wheat-based systems for which technology development and farmer adoption are more advanced. However, given the Center's overall high priority for the development of improved technologies for the drier Barley-Livestock Systems, these form a strong second priority. We recognize that secondary impacts of technology, and the policies designed to encourage adoption, are likely to extend beyond the boundaries of the immediate target area, and that these effects must also be considered.

(v) Future Trends

Our allocation of resources between the three major projects, and the priority we place on the four broadly defined agricultural systems will not change radically in the short term. However, it is possible to predict shifts in emphasis over the longer term resulting from the successful outcome of research activities.

As regional research in the Management of Soil, Water and Nutrients progresses, and as we further develop and extend our capabilities and sphere of influence in Agroecological Characterization *for Resource Management*, we plan a gradual shift in resource allocation from the first to the second project. Concurrently, as on-going research in the region reaches maturity and the number and diversity of new technology options for farmers increase, we would also envisage a need to allocate greater resources to project three, The Adoption and Impact of New Technologies. However, given the current low level of resource allocation to this project and our heavy reliance upon special funding, we recommend that a more immediate boost is given to this important area of research through the creation of additional core funded senior staff positions in the field of social science.

Our priority for research in the Barley-Livestock Systems will remain. Indeed, as we continue to generate regional research interest and activities in these systems, we anticipate a need to allocate greater resources to support such work. As a result of the close association between these systems and the steppeland and native pastures in the annual livestock feeding cycle, we also expect to expand our cooperative research with PFLP in marginal land improvement.

Given the comparatively advanced state of technology development for the wetter wheat based systems, the existence of agriculture policies to support their adoption, and the ability of financially more secure farmers to continue to adopt improved production practices we expect, in the long run to reduce our resource allocation to these systems.

FARM RESOURCE MANAGEMENT PROGRAM

ANNUAL REPORT 1987

1. INTRODUCTION

1.1 The Scope of this Report

Special circumstances surround the preparation of our annual report for the 1986/87 season. This is the first report we have produced within the context of our new name, our new operational structure and our re-defined goals and objectives. In addition, it is written at a time when ICARDA as a whole is carefully assessing its long term strategy and priorities.

Because of these circumstances, we have produced a report which reflects our priorities and strategies and which indicates how current research findings point toward future directions of emphasis. To achieve this, we present a series of articles which address major areas of research in the program and which pull together and discuss results from several years research, both at ICARDA and elsewhere.

What we have not tried to do is present, in detail, all the research results we obtained in 1987. As is so often emphasized, each year and each trial location constitute a unique set of conditions in all fields of agricultural research, and thus more often than not, a single seasons results must be viewed in this context, and conclusions viewed with caution. Many of the articles in this report consider the problem of identifying improved crop production practices for farmers in an environment which is as variable in space as well as time as the Mediterranean region. This is the challenge which faces ICARDA and the scientists of the National Programs, and which forms a central theme to much of our research. Indeed our Project 2, "Agro-ecological Characterization for Resource Management" is specifically focused on this issue (see Section 3).

Every year, the number of scientists in the region with whom we collaborate is increasing. This is a trend which we welcome and we acknowledge, with pleasure, their contribution to the collaborative research reported in this document.

1.2 Staff Changes During 1987

During the year, the program welcomed several new staff members. Dr. Mahmoud Al Ashram, a senior economist from Aleppo University joined us in November for one year as a senior visiting scientist. He is working on the production of a model for National Fertilizer Allocation. Dr. Ammar Wahbi, a former Syrian PhD student associated with the program, re-joined us as a Postdoctoral Research Fellow. Ammar is giving leadership to our cooperative fertilizer research with the Syrian Soils Directorate. Drs. Sobhi Naggar (an agronomist) and Mohamed E. Shykhoun (an economist), both from Egypt, have also joined us as Postdoctoral Research Fellows. They are working in our collaborative project for the Barley/Livestock farming systems of the NW Coast of Egypt. Dr. Hamid Faki from Sudan also joined us as a Postdoctoral Research Fellow and is responsible for the production of two training manuals which address the problems of how to conduct crop on-farm trials and farm surveys.

Several Postgraduate Students have also become associated with our program, and we wish all of them success in their studies. Mr. A. Ben Achour from Tunisia, and Mr. Talal Razzouk from Syria are both working for their PhD. Mr. Ben Achour is looking at labor as a factor associated with the adoption of technology in Tunisia, and Mr. Razzouk is studying the factors affecting the adoption of new technology by wheat growers in Syria. Mr. J. Sting from Germany spent part of the year with us to undertake a survey associated with the introduction of the medic ley farming system as part of his MSc thesis, and we have been recently joined by Miss Fatmah El Jassem from Syria who will carry out her MSc research on food legume responses to phosphate fertilizer.

Dr. Kutlu Somel re-joined the program towards the end of the year following a sabbatical leave at FAO, Rome. Kutlu spent his time as part of a team involved in the study Agriculture: Toward 2000. Some important features of this study are presented in Section 4.2 of this report.

In November, Mr. Omar Ben Shuaib from S. Yemen was awarded his MSc at Aleppo University, with outstanding marks, for his research on fertilizer and herbicide use on wheat. Our congratulations and best wishes to him as he returns to his country.

Mr. Lars Sorensen, studying for his BSc at the University of East Anglia, UK, spent several months with us during the summer and using a rainfall simulator conducted research on the effects of rainfall intensity and crop tillage on infiltration, run-off and soil erosion losses. Our thanks to him. Mr. Ali Hussein and Miss Widad Shehadeh from the Syrian Soils Directorate have also joined us for one year as part of our collaborative research program on fertilizer use on wheat and barley.

Several regional staff, namely Maria Hallajian, Zuka Hamwieh, Rim Harmoush, Clara Garabet, Anna Maria Roumieh and Maher Khodeir have left the Program for personal reasons. We thank them all for their contributions whilst they were with us, and wish them success in the future. Bana Rifaii, Zuka Instanbully and Sabeeh Duhni have joined us and Mr. Mohamed Salem and Ghazi Yassin, responsible for Tel Hadya meteorological station, have been tranferred to our Program. They are all welcomed, and we once again take this opportunity of expressing our sincere thanks and appreciation to all regional staff who continue to form the solid core of our Program. A full list of program staff for the year 1987 is given at the end of this report.

1.3 The Weather during the Season 1986/87

Wolfgang Goebel and Mira Abdelnour

Weather during 1986/87 exhibited a number of peculiarities, which made it a better than average season at the wetter sites (Jindiress, Tel Hadya) and resulted in poor yields or even total crop failures at the drier sites (Ghrerife, Boueidar). This remarkable difference between sites cannot be attributed to a single cause, rather it was the result of the combined interaction of moisture and temperature related factors with crop growth.

TABLE 1.1 *Monthly precipitation (mm) for the 1986/87 season*

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN*	Total
Jindiress											
1986/87 Season	0.0	30.0	70.6	115.0	161.9	83.0	118.6	18.8	2.8	0	600.7
Long term average	1.5	25.3	51.3	98.5	92.3	76.3	60.6	44.9	19.1	2.7	472.5
% of long term average	0	119	138	117	175	109	196	42	15	0	127
Tel Hadya											
1986/87 Season	0.0	31.5	33.4	47.0	88.9	63.2	63.5	12.6	2.6	15.0	357.9
Long term average	0.4	21.3	44.8	53.8	66.1	51.6	42.0	31.9	15.6	4.0	331.5
% of long term average	0	148	75	87	134	122	151	39	17	375	108
Breda											
1986/87 Season	0.0	23.0	25.4	33.2	66.8	31.6	47.2	17.4	0.0	0.0	244.6
Long term average	1.5	13.9	31.5	57.4	49.4	38.5	35.1	34.3	15.8	1.4	278.8
% of long term average	0	165	81	58	135	82	134	51	0	0	88
Ghrerife											
1986/87 Season	0.0	18.4	7.0	29.2	51.8	26.8	37.2	13.4	0.6	0.0	184.4
Boueidar											
1986/87 Season	0.0	10.8	23.8	27.2	48.3	24.4	27.8	11.7	2.2	0.0	176.2

* No rainfall during July and August

One factor contributing to the difference was a steeper than normal geographical gradient of rainfall which persisted throughout most the season (Table 1.1). Whereas Jindiress received 127% of the long-term average seasonal rainfall total, this dropped to 108% for Tel Hadya, 88% for Breda and to an estimated 80% for Boueidar for which unfortunately no historic data are available. The 300 mm annual isohyet appeared to mark the boundary between areas with higher than average and lower than average rainfall. This was exacerbated by a parallel gradient of temperatures, which is reflected in the number of frost days observed at the various stations. This rose from 20 at Jindiress (the wettest location -- which is only 2/3 of the long-term average), to 39 at Tel Hadya (average 37), 47 at Breda (average 43), and 52 at Boueidar, (the driest station). With the exception of February the cropping season on the whole was somewhat cooler than average with minimum temperatures being rather milder in the wetter area than at the drier sites.

The season started very early, with germinating rains falling during the first week of November at all sites with the exception of Ghrerife. However, then followed a prolonged spell of dry and cold weather which lasted until December 18. Such a combination of a dry spell of 38 days following heavy rains early in November is without parallel in the over 50 years of weather records from Aleppo. The drought and cold virtually stopped crop growth soon after emergence. Rainfall resumed just in time to save the crops, and milder, rainy weather prevailed until the third week of February, broken only by another spell of dry and cold weather during the second decile of January. The period from the last week of January until mid-February was especially mild except in the drier areas where minimum temperatures dropped close to zero or below zero too frequently to permit vigorous crop growth. In these areas barley crops failed to reach full ground-cover, especially at Boueidar. March brought back cold, though moist weather, with temperatures dropping below $-5^{o}C$ at Boueidar as late as March 21 and 22. Rainfall effectively stopped at all sites during the second week of April. This is somewhat earlier than usual, but due to prevailing cool weather and an adequate supply of soil moisture, crop yields were not adversely affected at the wetter sites. This is in contrast to the drier locations. At Ghrerife the available moisture was inadequate and yields suffered, and at Boueidar the effects were even worse. Much of the already low soil moisture evaporated directly from the soil surface because the crop had failed to cover the ground, and almost complete crop failure was recorded at this site. Another factor which may have contributed was a severe pest ("Ground pearl", Porphyrophora tritici) infestation of the already weakened crop.

Although of no consequence to winter sown crops, another weather extreme of 1987 deserves recording. On August 7 the screen temperature at Tel Hadya reached an all-time high of $47.6^{o}C$. The other sites recorded similar, though slightly lower temperatures. How exceptional such temperatures are is illustrated by the fact that according to our knowledge $44^{o}C$ has never been recorded since weather stations were first established in the region in the first half of this century.

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

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

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

2.1 Long Term Goal and Objectives

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

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

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

3. To provide data for the development and/or refinement of methods for the extrapolation of research findings in space and time. [Linked to Project 2.]

4. To provide socio-economic evaluation of problems of farming systems and of the adaptability of research results to strategies for resource management at the farm level. [Linked to Project 3.]

2.2 A Strategy for Fertilizer Research in Variable Rainfed Environments: Cereal in Syria, A Case Study

Michael Jones, Abdallah Matar, Mustafa Pala

2.2.1 Introduction

Fertilizer is a costly input, to governments (which often subsidize it) and to farmers. The allocation of fertilizer to different crops must therefore be based rationally on the demand for each crop, its value and its expected biological and economic response to the fertilizer. Such considerations apply, on a small scale, to individual farmers but equally, at a national level, to government planners. At either level, the situation is dynamic, varying according to fluctuations in needs, costs and values of particular commodities (local, national and international factors may be involved here) and to changing patterns of soil fertility status resulting from previous fertilizer use and land management. It is the thesis of this paper that any research on soil fertility and fertilizer use, be it chemical, agronomic and economic, should be viewed within a broad framework that inter-relates natural environment (soils and climate), farming system (agronomic and socio-economic factors) and national policies. We seek here to summarize recent FRMP work on fertilizer use on cereal crops; to explore the relationships between the various chemical, agronomic and economic aspects; and to develop guidelines for new research within that framework.

Depending on viewpoint, efficiency of fertilizer use may be judged in either biological (agronomic) or economic terms. Of course, the two are closely related. For any crop, economic response to fertilizer depends on:

- biological response
- current costs and prices

And, in turn, the biological response to fertilizer depends on:

- soil fertility and soil chemical factors
- weather, especially rainfall
- crop rotation
- soil and crop management
- crop variety

and on numerous synergistic mechanisms and interactions between these factors. For example, the improved crop nutrition resulting from fertilizer use improves water-use efficiency, increasing yield response to rainfall (Cooper et al. 1987); crop rotations influence fertility, notably the availability of nitrogen; and continued fertilizer use over time results in changes in soil fertility.

Here we look first at the factors determining biological response to applied fertilizer; and then in two final sections attempt a synthesis within a broader, socio-economic context.

2.2.2 Current levels of soil fertility (NP) in wheat and barley areas of Syria

The natural availability of soil nitrogen and phosphate for crop uptake is usually a function of more fundamental soil properties such as organic matter content and mineral composition; and on old land surfaces like Syria's these properties are, in turn, mainly a function of climate. The semi-arid climate of Syria's cereal-growing areas, with its long, hot dry summers, keeps soil organic matter content low but encourages the accumulation of calcium carbonate and the fixation of phosphate as insoluble calcium compounds. Thus the mean organic matter content of 86 surface soils used in a productivity study of rainfed wheat across central Syria was only 1.58%, and 85% of those soils contained free calcium carbonate (Matar 1984); and in over 150 topsoils from barley fields across northern Syria, organic matter contents ranged from 0.3 to 1.3% and pH values from 7.9 to 8.5 (Harmsen 1984).

It is therefore not surprising that soil deficiencies of nitrogen and phosphate and crop responses to nitrogen and phosphate fertilizers are often reported. Crop-available nitrogen derives from the mineralization of soil organic matter, so that, in a general way, the less organic matter the less nitrogen likely to be made available. Most soil phosphate is held in mineral form. In calcareous soils, these minerals are highly insoluble materials that maintain only very low concentrations of phosphate ions in the soil solution and release phosphate only slowly as that solution is depleted by crop uptake.

The consequences of these inimical chemical conditions are evident in the measurements that have been made of nutrient availability. A survey in the 1960's by the Syrian Soils Directorate showed that 70% of rainfed wheat and barley soils contained less than 6ppm available-P (by Olsen method, see below)

(Matar 1969, Fig. 2.1a). Similar results have been obtained more recently for barley fields across northern Syria (Harmsen 1984) and in four provinces of northern and western Syria (SD/FSP 1985, 1986, SD/FRMP 1987), with 68 and 62 % of soils, respectively, having less than 6ppm Olsen-P (Fig. 2.1b and 2.1c). However, a recent survey of wheat soils showed there had been a marked change since 1969. Now only 25% of wheat-growing soils in north-western Syria have Olsen-P values of less than 6ppm (Fig. 2.1d), the consequence presumably of fertilizer use by wheat farmers over the last twenty years.

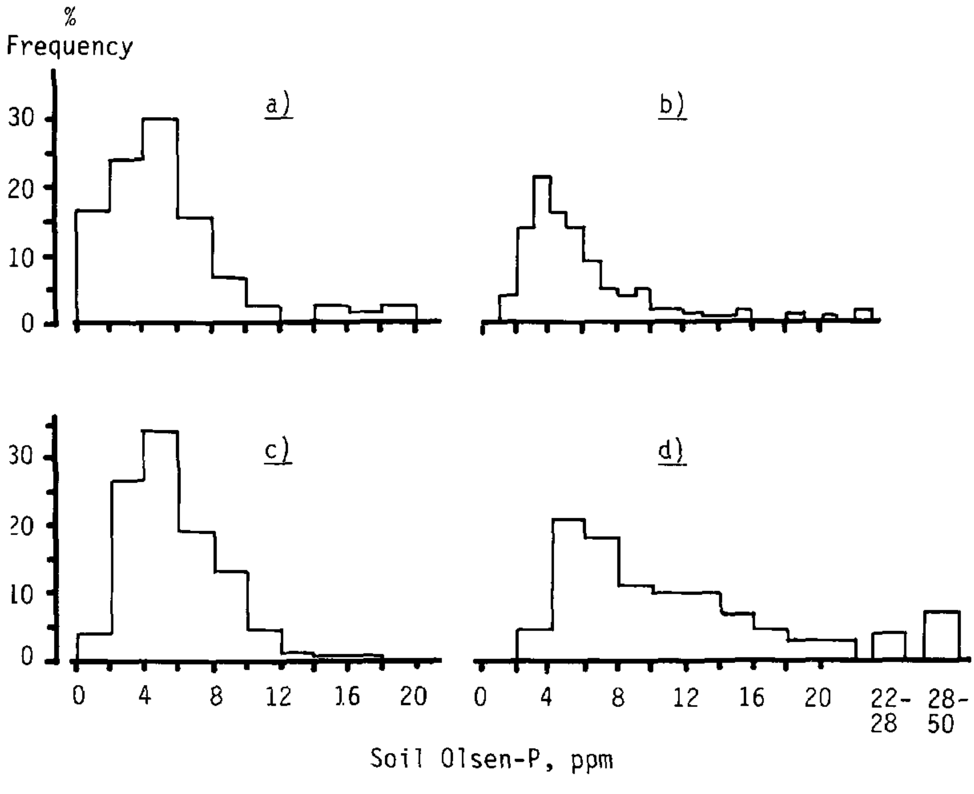


FIGURE 2.1 Distribution of topsoil Olsen-P values: a) barley and wheat fields, 1969; b) barley fields, 1982; c) barley fields, 1987; d) wheat fields, 1987

This finding shows that the unfavourable chemistry of the soil does not preclude the build-up and maintenance, through fertilizer use, of an adequate soil phosphate status; but the presence of some very high Olsen-P values among the data suggests that some farmers have been using wastefully high rates of fertilizer. This emphasizes the need to gain a real understanding of the relationships between fertilizer input, soil P-status, and P-adsorption properties in these soils.

The nitrogen picture is less clear. Soil organic N content is closely related to organic matter content but has little direct value as an indicator of availability at any particular site. Plant-available nitrogen is mineral-N, nitrate and ammonium. However, these ions are directly involved in the microbial dynamics of the soil organic fraction, and in any moist soil, processes involving their release (mineralization) and recombination into unavailable forms (immobilization) are proceeding simultaneously. Amounts present are therefore liable to fluctuate with ambient conditions. Moreover, the highly soluble nitrate moves with the soil solution, which probably accounts for the high subsoil contents of nitrate that are sometimes found. Harmsen (1984) presented soil nitrate data from five ICARDA experimental sites at planting time in 1982: values were less than 10ppm at all depths at four of the sites, but at Khanasser, the driest site, soil nitrate content increased steadily with depth to almost 100ppm at 150 cm.

More data have been obtained from the sampling of on-farm wheat-trial sites over the last two years. Mean mineral-N (nitrate + ammonium) in the top 20 cm over 28 sites was 15.5 $\pm$ 9.8ppm (Pala and Matar 1987). In general, most of the sites had a decreasing mineral-N content with depth. And in three years' barley trials, if one excludes just two sites with anomalously high values (>200ppm), the mean content of mineral-N in the top

20cm over more than fifty sites was only 14ppm $\pm$ 6.8ppm (SD/FSP 1985, 1986, SD/FRMP 1987). However, in addition to the two anomalous sites, a number of others had, like Khanasser, an increasing nitrate content with depth; and some of the shallowest soils showed a tendency towards high mineral-N contents in the topsoil. Such phenomena are as yet unexplained. Indeed, notwithstanding some detailed work at Tel Hadya (Harmsen, 1986), the nitrogen dynamics of these soils, like the phosphate dynamics, still require a lot more study.

2.2.3 Crop Responses to NP Fertilizers

It has long been known that cereal crops in Syria, wheat especially, respond to N and P fertilizers; and many years of trials by the Syrian Soils Directorate lie behind the current fertilizer recommendations for wheat and the yield increases that have resulted from them. Current work by FRMP at ICARDA, much of it in collaboration with the Soils Directorate, is concerned with the development of fertilizer recommendations for the relatively neglected barley and, for both crops, the consideration of ways to improve efficiency of fertilizer use.

The barley work has been extensively reported in recent Annual Reports (ICARDA 1986, 1987) and in other publications (SD/FSP 1985, 1986, SD/FRMP 1987); and it is sufficient here to outline only the broad pattern of results and current proposals for their analysis. So far, in 55 successfully completed trials conducted over three years and distributed over a wide range of sites and soil types across four provinces of northern Syria, grain yield has shown a significant response to phosphate fertilizer 37 times and to nitrogen fertilizer 20 times; and straw yield responses have been slightly more numerous.

However, for maximum usefulness, such results need to be carefully analysed and interpreted. The current debate is how best to do this. Three aims may be distinguished. The most immediate is to assist the Syrian Soils Directorate to produce optimum fertilizer recommendations for barley farmers in dry areas, taking account of both agricultural and economic factors. The second is to use the very large and comprehensive data set to explore the interactions between barley, its growth environment and its nutrition and fertilization, to improve understanding and identify areas requiring further agronomic research. And the third aim is to apply the experience gained in this multi-site, multi-season research program towards the definition of the most efficient experimental system for the development of fertilizer recommendations. A number of different analytical approaches are currently being tested. They include developments of the multiple regression procedure described previously (Somel 1984, SD/FSP 1985); different site pooling strategies (Jones 1987); the application of modifications of the Mitscherlich equation (Matar et al. 1987); and the use of models pioneered by Colwell in Australia (Colwell & Morton 1984).

Early work on the fertilization of wheat in Syria indicated good yield increases from both nitrogen and phosphate (Matar and Samman 1969; 1975); but, with time, responses to phosphate in farmers' fields appear to have become smaller and less reliable. In the large number of on-farm wheat trials conducted by ICARDA over the last two years, increases from nitrogen were stronger and more frequent than those from phosphate. This was probably due, at least in part, to improvements in soil phosphate status accumulating from the use of fertilizer by wheat growers over the last twenty years (see Section 2.2.2). However, that use has been uneven, resulting in what is now a very wide range of phosphate-status values (Fig. 2.1d); and in 1985/86, a rather dry year, total dry matter production in 18 wheat trials could be significantly related to the soil content of available-P at planting time (Matar et al. 1986; Fig. 2.2).

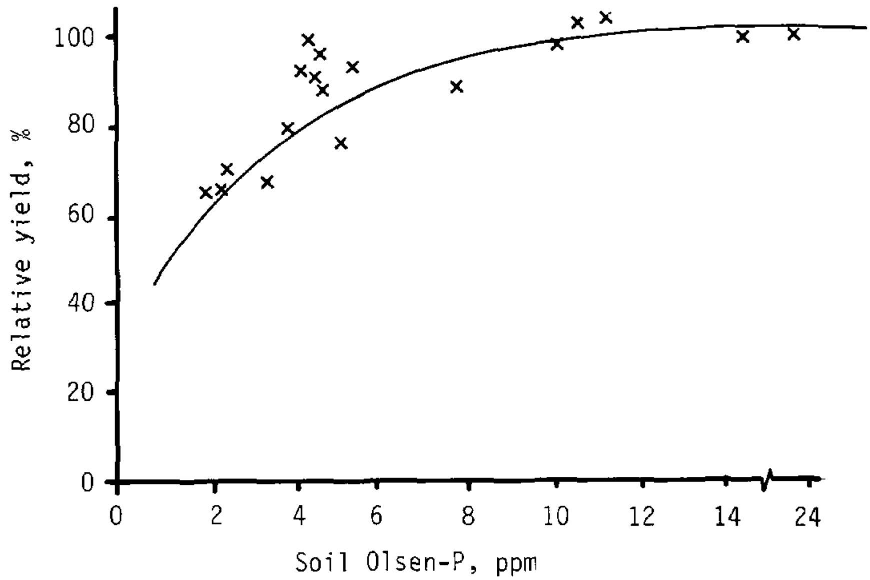


FIGURE 2.2 *Total dry matter production of wheat, as percentage of estimated maximum, as related to Olsen-P content of 0-20 cm soil at planting time*

In the same year, responses to nitrogen fertilizer were limited to sites with low soil-nitrate availability at planting time (<7ppm NO_3-N in 0-60 cm) -- although over all sites combined, yields showed a significant interaction between applied nitrogen and weed control (grain response to fertilizer being increased by herbicide use) (FSP, 1987). However, in 1986/87, a wetter year, nitrogen significantly increased grain yield at 10 sites and straw yields at 13 sites (out of 14), irrespective of the initial soil content of nitrate-N (Pala and Matar 1987).

Another finding in these trials is of relevance to efficiency of fertilizer use. Additional to any increase of yield, nitrogen fertilizer had a substantial effect on the protein content of the wheat grain. Mean grain protein contents for the four fertilizer rates, 0, 60, 120 and 180 kg N/ha were 9.2, 10.3, 12.4 and 13.8%, respectively, in 1985/86 (Pala et al. 1987), and 9.9, 11.2, 12.8 and 14.1% in 1986/87.

2.2.4 Soil Testing

Soil testing involves the application of simple, routine methods of analysis to samples taken from farmers' fields for the purpose of making fertilizer recommendations on an individual field basis. However, given the diversity of soils, climates, and crops and the complexity of the relationships between them, the establishment of those simple, routine methods requires much careful work. No simple chemical test measures the actual plant-availability of a nutrient; at best, it gives values that can be correlated with that availability. For that reason, wherever soil testing is newly introduced, it is necessary first to identify analytical methods appropriate to local soil conditions and then calibrate them against crop performance in the field. One may then be able to specify levels of nutrient availability below which the probability of a large crop response to fertilizer is high and go on subsequently to recommend specific rates of fertilizer for specific values of the soil test, taking account of economic factors and, where possible, local site and field conditions.

For phosphate, it is widely agreed that the bicarbonate extraction procedure of Olsen et al. (1954) is the best available method for calcareous soils. However, for nitrogen, with its complex dynamics, the issue is not yet settled and perhaps never can be finally settled to suit all views and all situations. Mineral-N values are undoubtedly superior to total-N values, but uncertainties inevitably exist over whether to measure nitrate-N, ammonium-N or both, and over what depth range. Work is continuing at ICARDA to try to resolve such questions.

Current studies of soil testing in the Region have been reported at ICARDA/MIAC workshops in Aleppo (1986) and Ankara (1987). (See also Section 5.3 of this report.) Most progress has been made in Turkey. Yurtsever (1986) showed how Mitscherlich equations, relating relative yield to soil-test values for available-P, can be coupled with current prices of fertilizer and crop to indicate rates of fertilizer for wheat in central Anatolia. He made the point that while one can calculate rates to produce the economic optimum yield, it may be more relevant to calculate the smaller amounts of fertilizer that will give the farmer the highest cash return on his limited available capital.

Soil-test work on wheat has recently been started in Morocco (Soltanpour et al. 1986). Findings so far point to the importance of previous crop for responses to nitrogen fertilizer and to possible differences between soil types (rendols, calcixerols and vertisols) in the critical level of available-P, below which fertilizer responses may be expected. These critical levels may depend on the soil content of calcium carbonate. From Pakistan, Rice et al. (1986) reported that soil tests for mineral-N correlated well with wheat response to nitrogen fertilizer and appear to offer improvement over total-N and organic matter measurements that are still widely used as bases for recommendations.

In Syria, soil-test calibration work is fully integrated into the FRMP/SD fertilizer trials on wheat and barley referred to above. Phosphate results from the first two years of the barley study were reported last year (FSP 1987). Those from the third year have confirmed the trends previously identified. Critical levels of topsoil Olsen-P, i.e. giving at least 80% of maximum yield, appear to be around 5-6ppm. This figure matches the 5ppm that Soltanpour (1987) has found for wheat in Morocco and the findings to date in FRMP/SD work with wheat.

As already noted, many Syrian wheat soils already have fairly high contents of available-P resulting from previous fertilization, and significant yield responses to fertilizer are fewer than in the barley trials; but there are enough data to show that the relative yield/available-P relationship is similar (Fig. 2.2). A comparable approach has identified 40 kg NO_3-N/ha in the 0-60 soil layer as representing approximately the critical level of available-N for the achievement of 80% of maximum barley yields (Fig. 2.3).

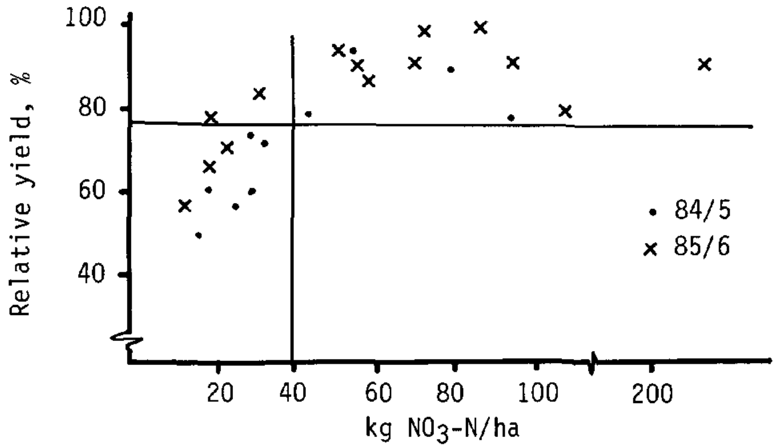


FIGURE 2.3 Total dry matter production of barley, as percentage of estimated maximum, as related to nitrate content of 0-60 cm soil at planting time.

2.2.5 Banding and Broadcasting of Fertilizer

Even when the need for fertilizer has been identified, there is still the question of how best to apply it. Indeed, the optimum rate of fertilization may often be influenced by the time and technique of application. Fertilizer can be applied to soil and crop in a number of different ways: broadcast over the soil and cultivated in before planting; banded with (or alongside) the seed by the seed-drill; or top-dressed to the soil surface during crop growth. For phosphate, which is almost immobile in the soil and which is most effective during the early stages of growth, incorporation into the soil at or before sowing time is essential. However, to what extent fertilization efficiency depends upon whether such incorporation is achieved by banding or broadcasting remains an important question. We summarize here our results so far.

Wheat experiments at three phosphate-deficient sites in north-western Syria (Breda, Tel Hadya and Jindiress) over the last three seasons have compared banded and broadcast phosphate at two (or three) rates, 40, 80 (and 120) kg P_2O_5/ha. Differences appeared early. At tillering, plants in banded-P plots always showed a clear superiority over those that had received the same amount of phosphate, broadcast; and total crop dry matter and phosphate content at that stage were often higher for 40 kg/ha P_2O_5 banded than for 120 kg/ha P_2O_5 broadcast.

Although such differences diminished as growth proceeded (Fig. 2.4), subsequent grain yields showed a significant response

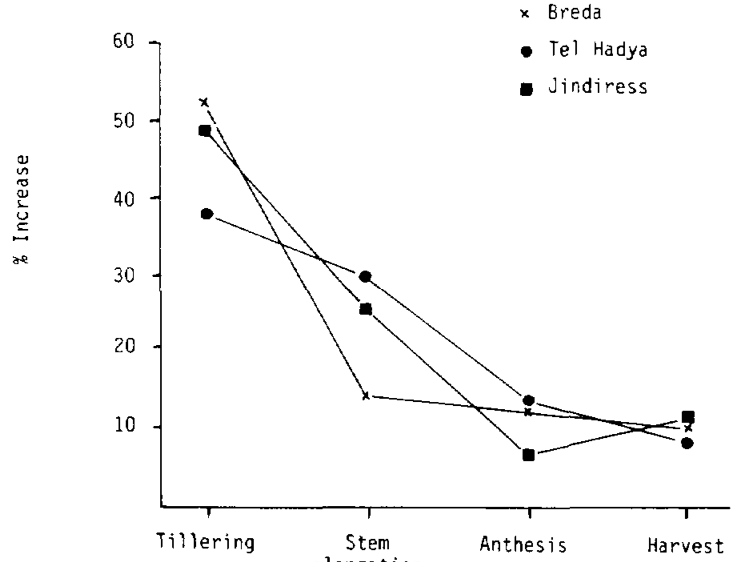


FIGURE 2.4 Increase of total dry matter of wheat receiving banded phosphate over that of wheat receiving broadcast phosphate, at various stages of growth

to phosphate in six out of nine trials, and the advantage of banding over broadcasting was clearly evident in all nine (Table 2.1). In fact, there were appreciable differences between sites and seasons in the optimum rate of phosphate; and also between sites, seasons and rates of phosphate in the relative advantage of banding. However, over all rates in all trials, banding increased the mean grain-yield response to phosphate from the 17% achieved with broadcasting to 29%. And in no case did broadcasting give higher yields than banding.

TABLE 2.1 Response of durum grain yield to broadcast and banded phosphate at three sites over three seasons

	Breda			Tel Hadya			Jindiress		
	84/5	85/6	86/7	84/5	85/6	86/7	84/5	85/6	86/7
Significant yield response to P:	+	+		+			+	+	+
Mean yields, t/ha:*									
Control	1.67	0.86	0.81	3.35	2.04	2.42	2.69	1.71	2.55
Broadcast P	1.97	0.99	0.78	3.67	2.09	2.41	3.52	2.33	3.35
Banded P	2.33	1.15	1.02	3.90	2.28	2.53	3.56	2.73	3.76
% Increase over control									
Broadcast P	18	16	-5	10	3	0	31	36	31
Banded P	40	34	25	16	12	4	32	60	47

* In fertilized treatments, means of 40, 80 and 120 kg P_2O_5/ha in 1984/85 and 1985/86; and of 40 and 80 kg P_2O_5/ha in 1986/87.

Previous work has demonstrated that the main mechanism by which applied phosphate improves cereal yields in Syria is the acceleration of growth and phenological development during the immediate post-emergence period. This increases early ground cover, reduces evaporative losses from the soil and channels a greater proportion of the available water through the crop. But it seems that the strength of this early boost is much diminished if the fertilizer is broadcast, presumably because contact between plant roots and fertilizer granules is delayed.

However, the magnitude of the eventual yield gain is, as this work has shown, season-dependent. The relative advantage of earlier maturity resulting from more rapid phenological development may be lost completely if there are late, damaging frosts; or it can be much reduced if late-season rains are good and temperatures are moderate during the grain-filling period. Conversely, at a dry site in a dry year (e.g. Breda, 1985/86), when lack of moisture during grain-filling is the major limitation on yield, the maximum achievable benefit may be obtained from low rates of banded phosphate. These may outyield higher rates of broadcast phosphate. It therefore seems quite likely that the surest advantage from the banding of phosphate will be realized in barley crops in dry areas. This, however, still needs to be tested.

2.2.6 Residual Effects of Fertilizer

Crop utilization of nutrients added by fertilizers is often surprisingly small (especially in the case of phosphate) even in situations in which the fertilizer promotes a large increase in yield. This apparent inefficiency prompts the question "what happens to unutilized nutrients?" Experiments on barley in Syria have shown a mean uptake of about 6% of the phosphate applied as fertilizer at rates of 30-90 kg P_2O_5/ha, with fluctuations depending upon site, rainfall and rate of application (Matar et al. 1987). Thus, 94% of the phosphate applied was left in the soil after harvest. This is not an unusual result, but its consequences for subsequent crops and the fertilizer needs of those crops are important to assess. Phosphate added to the soil is, we know, subject to chemical transformations into less available, perhaps almost completely unavailable, forms; but the rate of those transformations, the compounds formed and their "residual" effects on subsequent crops are likely to vary according to soil type. The development of rational fertilizer strategies require that these phenomena be understood.

The decrease in the availability of fertilizer phosphate in soil has been monitored at Tel Hadya and Breda. Olsen-P values of fertilized soil confined in metal cylinders inserted into the field were found to decline exponentially with time (ICARDA 1985). Following Larsen et al. (1965), it is possible from such observations to develop equations to predict current phosphate availability in terms of the amount of fertilizer phosphate previously applied and the time elapsed since application. These equations have the form:

$$P_t = P_{eq} + (P_{init} - P_{eq}) \exp^{(-kt)} - PU \qquad \ldots\ldots (1)$$

where P_t is current soil available-P, ppm; P_{eq} is the natural equilibrium value of available-P, ppm, in unamended soil; PU represents any uptake of P by crops since the fertilizer was applied; k is the loss constant determined experimentally in the field; and t is time.

The term P_{init} requires more explanation. When fertilizer phosphate is added to the soil, part of it is immediately adsorbed on mineral surfaces and rendered unavailable (the amount depending on the so-called buffer capacity of the soil). It is only the fraction unadsorbed at this time that is then subject to the exponential decline represented by the above equation. We have found that for the Syrian soils tested, values of P_{init} can be expressed in terms of an expression of general form:

$$P_{init} = P_{eq} + bF \qquad \ldots\ldots (2)$$

where P_{init} is in ppm, F is the rate of phosphate applied (in kg P/ha) and b, specific to the particular soil, represents the slope of a line describing buffer capacity. Laboratory work at ICARDA has found:

for Breda: $P_{init} = 2.66 + 0.683\ F$ ($r^2 = 0.99$)

for Tel Hadya: $P_{init} = 2.92 + 0.784\ F$ ($r^2 = 0.99$)

In a trial on Sham 1 wheat at Tel Hadya in 1984, phosphate fertilizer was applied pre-planting at rates of 0, 40, 80 and 120 kg P_2O_5/ha, and phosphorus uptake by the wheat was measured. One year later, actual P_t values in the soil were compared with values predicted by equation (1). The degree of correspondence was encouraging (Table 2.2). To use this method more generally, one needs to know for each soil in question: the rate constant, k; the buffer capacity b; and the equilibrium value of available-P in unamended soil, P_{eq}. The latter two, b and P_{eq}, may be fairly easily determined in the laboratory; but k needs to be determined over time in the field. This is a limitation. Moreover, before this method of estimating residual available-P can be confidently applied, it will be necessary to investigate how k values vary from year to year according to the differing soil moisture and temperature regimes.

TABLE 2.2 Comparison of actual and predicted values of available-P, ppm, in a Tel Hadya wheat trial one year after fertilizer application

Rate of P-fertilizer previously applied, kg P_2O_5/ha	Tel Hadya		Breda	
	Actual	Predicted	Actual	Predicted
0	3.4	3.4	4.8	4.8
40	6.6	7.4	8.0	7.4
80	11.2	12.8	10.0	12.0
120	15.3	17.8	15.7	16.9

2.2.7 Crop Sequence and Rotation Effects

Different crops have different effects on the soil in which they grow. These can arise both from the crops themselves (e.g through differences in depth and intensity of water and nutrient exploitation or through the quantity and quality of residues left behind) and from how the crops are managed (e.g. with or without irrigation). The consequences can be seen in the performance of the crops that follow after and in their response to fertilizer.

The wheat crops in the NP fertilizer trials referred to earlier followed either summer crops (rainfed or irrigated) or legumes (chickpeas or lentils); and these preceding crops had large and significant effects on both the general level of wheat yields and their response to fertilizer (Fig. 2.5). High yields following irrigated summer crops can be explained by the greater amounts of available N and P in the soil, together with the probability of residual moisture from the summer irrigation; but the superiority of wheat following rainfed summer crops over wheat following chickpea is not so easily accounted for. Soil nutrient status was not significantly different. However, other studies have shown that not all the water stored in the profile is used by summer crops such as melon, and what is left can be used by subsequent wheat crops (ICARDA 1984, 1986, Cooper et al. 1987). Significant response to phosphate in these trials was limited to crops following rainfed summer crops in 1986/87 only. Significant response to nitrogen followed only chickpeas in 1985/86 but all crops in 1986/87. To what extent these sequence differences represent real sequence effects is as yet uncertain. There has unavoidably been some confounding with site differences and rainfall amounts and distribution. More work is needed, in the form of continuous rotation trials, to sort this out.

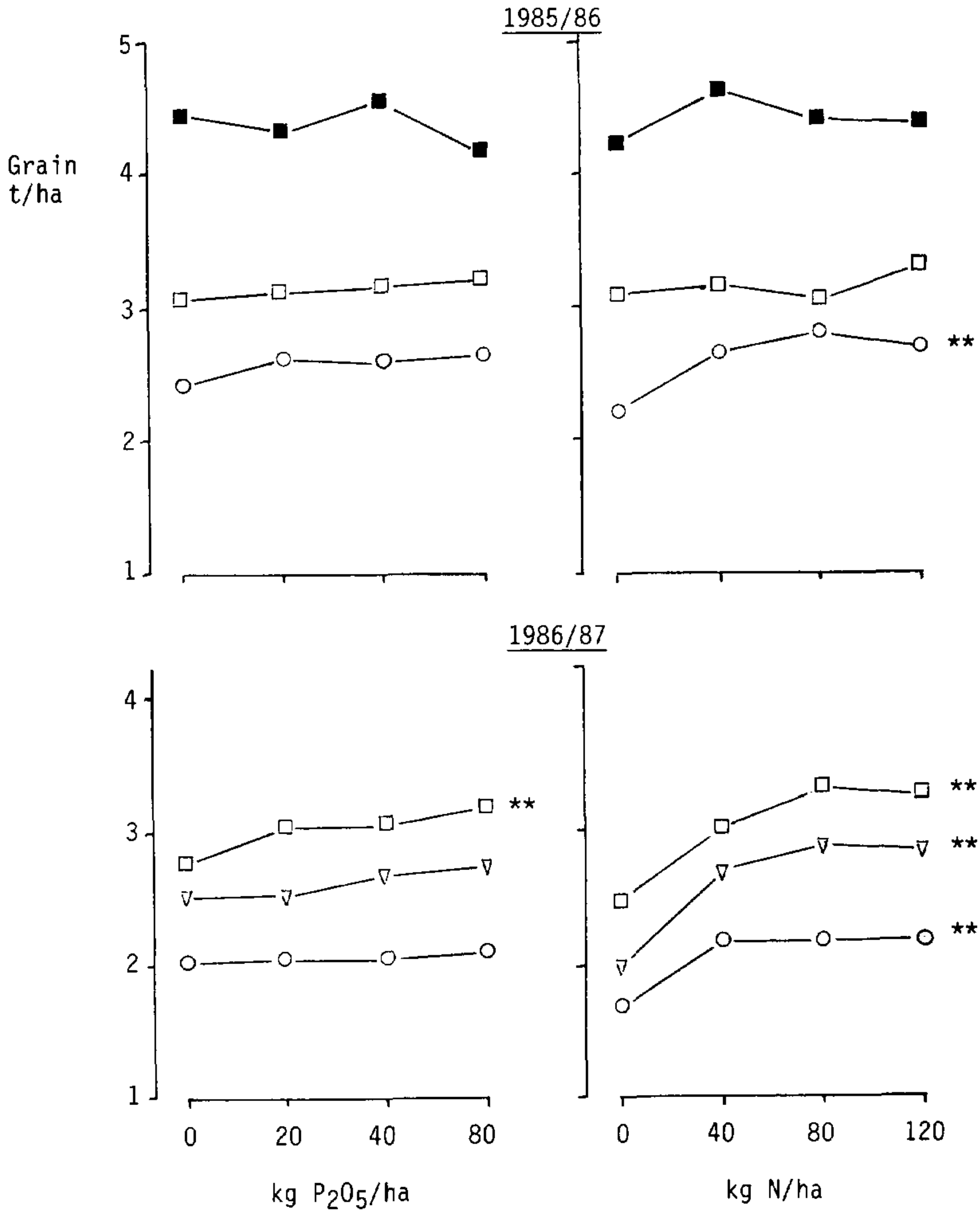
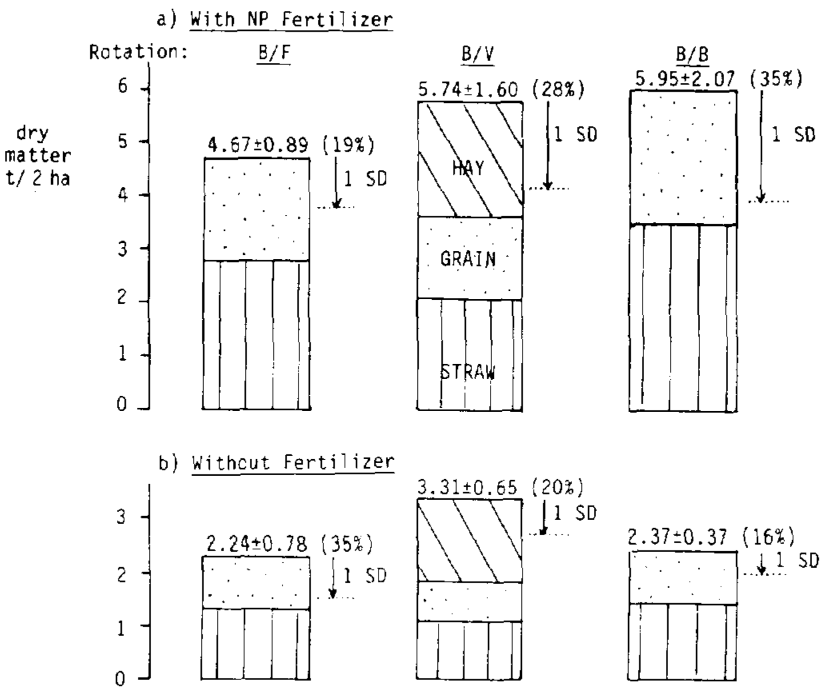


FIGURE 2.5 Grain yield responses to P and N fertilizers of wheat grown after irrigated summer crop (■), rainfed summer crop (□), lentils (∇), and chickpeas (○), (**$p<0.01$)

In areas where barley is the dominant crop, there are only two important crop sequences: fallow-barley (F/B) and barley-barley (B/B); but these sequences can have markedly different effects on barley production levels and response to fertilizer. As reported elsewhere (SD/FSP 1986), in comparisons at six sites, mean barley grain and straw yields were respectively 19 and 25% lower in the B/B sequence; but response to nitrogen fertilizer was much increased. All six B/B trials, but only one F/B trial, showed a significant yield response to nitrogen. Moreover, this difference was only partly explained by differences in amounts of mineral-N in the soil at planting time. The implication is that a preceding barley crop imposes a demand for nitrogen greater than any that might arise from an intrinsic site deficiency. Such a finding is not unusual for soil under continuous cereal production. The microbial processes of crop residue decomposition are probably responsible. But here again, more work is required to confirm these effects, identify their relationships to other site factors and study how sequence differences may be allowed for in practical fertilizer recommendations.

We have so far looked at cereal responses to fertilizer in single-year trials and in crop sequences. We have also reviewed the residual effects of fertilizer application. These different aspects must be considered together where crops are grown in continuous, regular rotations. Some data from a barley rotation trial at Breda that has now completed seven cropping seasons may be used to illustrate this.

The effect of fertilizer use on the mean production from barley-fallow (B/F), barley-vetch (B/V) and barley-barley (B/B) rotations over the last six seasons (i.e. omitting the first, "start-up" season) is summarized in Fig. 2.6. Calculated on a two-hectare basis, that production comprises barley grain and straw from one hectare in the B/F rotation but from two hectares in the B/B rotation; and in the B/V rotation, it is grain and straw from one hectare and vetch hay from the other. Fertilization comprised 20 kg N and 60 kg P_2O_5 per hectare in the barley seedbed only. Thus, B/F and B/V rotations received fertilizer in alternate years, the B/B rotation every year.



Mean increases from fertilizer use (t/2 ha):

Hay	-	0.65	-
Grain	0.97	0.78	1.56
Straw	1.47	1.00	2.04
Total	2.43	2.43	3.58
SD (±)	1.01	1.25	1.89

Mean available-P in topsoil after five years, ppm:

+F	8.8	8.2	16.0
0	3.1	3.0	2.8

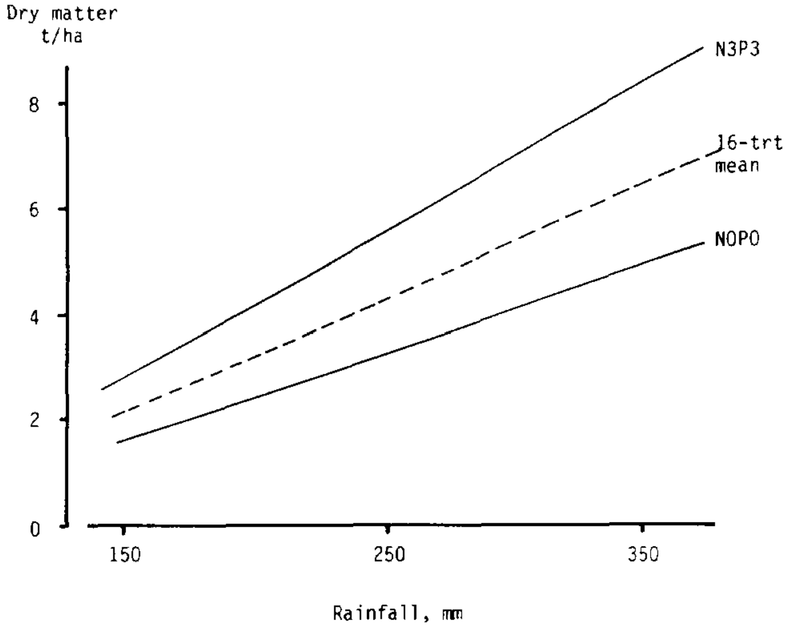
FIGURE 2.6 Effect of fertilizer on production from three rotations at Breda, barley-fallow, barley-vetch, and barley-barley; six-year means, 1981-87

The use of fertilizer increased production by 108, 73 and 151%, respectively, in B/F, B/V and B/B rotations. Remarkably, the absolute increase in total dry matter production was precisely the same in B/F and B/V rotations, though differently distributed among grain, straw and vetch hay. The B/B rotation showed the greatest production increase; but since twice as much fertilizer was applied, efficiency of fertilizer use was actually least in that rotation.

Farmers faced with new technology are usually as much concerned with its reliability from year to year as with the mean long-term increase in productivity that it promises. In this context, we may note that in this trial, while NP fertilizer reduced the coefficient of variation of production in the B/F rotation, it increased it in both B/V and B/B rotations. And at one standard deviation below the mean, production was much the same in all three fertilized rotations.

2.2.8 Rainfall Effects on Crop Response to Fertilizer

A major determinant of yield in all unirrigated cereal-growing areas is rainfall. At many sites the year to year fluctuation in yield level with rainfall is larger than any yield difference between fertilized and unfertilized fields. An important question is how do these two factors interact. A linear regression on total rainfall (range: 147-339 mm) accounted for 54% of the variability in mean dry matter production among 32 barley fertilizer trials in 1984/85 and 1985/86 (Jones and Harris 1987). Phosphate fertilizer was effective over the whole rainfall range, but response to it increased with increasing rainfall (Fig. 2.7). One may view this as meaning that fertilizer efficiency is increased by rainfall, or rainfall efficiency is increased by fertilizer.



For the regressions of each treatment:

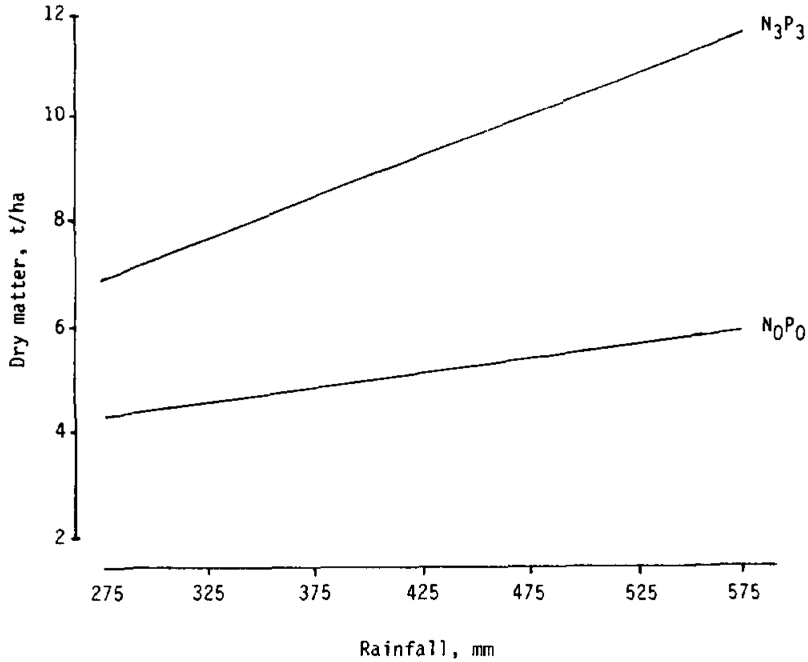
	r² values (%)				Slope coefficient			
	P0	P1	P2	P3	P0	P1	P2	P3
N0	39.3	38.9	35.5	29.2	16.6	17.2	17.2	18.0
N1	41.1	47.5	49.3	46.1	18.1	22.0	24.0	20.4
N2	48.6	50.2	51.8	64.2	20.7	22.5	21.5	26.1
N3	49.8	51.7	59.6	64.1	21.6	23.9	24.9	27.8

FIGURE 2.7 Regressions of barley dry matter response to seasonal rainfall under different fertilizer regimes, from thirty-two trials in northern Syria

Either way, in a variable rainfall environment, fertilizer use increases year to year variability. As the R^2 and slope coefficient values for each of the fertilizer treatments show (Fig. 2.7), fertilizer use increased the relative dependence of yield on rainfall. This is simply because fertilizer greatly reduced the influence of the next most important site factors, the available-N and available-P initially present in the soil. The fact is, the more successful one is at controlling the controllable factors (in this case, nutrient supply), the more dependent production becomes, albeit at a higher level, on the uncontrollable factors like rainfall. The implication of this for attempts to stabilize production have been discussed elsewhere (Jones and Harris 1987).

Rainfall data for on-farm wheat trials are available only for the 1986/87 season, but already they are showing similar relationships (Fig. 2.8). The inclusion of total rainfall values in a multiple regression equation relating the grain yield of every treatment at every site to rates of applied N and P increased the adjusted R^2-values from 13 to 43%. It did not, however, affect the fertilizer rates required for a 100% marginal rate of return, 77 kg N/ha and 55 kg P_2O_5/ha at current prices. The preliminary conclusion would be that, while the rainfall information can improve the explanatory power of a multiple regression relationship, rainfall itself has little influence on optimal rates of fertilizer inputs. In simple terms, this is because increasing rainfall increases average yields but does not substantially affect the shape of the response surface with respect to added nitrogen and phosphate (Fig. 2.9).

This finding may not be limited to the more reliable rainfall regimes found in wheat-growing areas. In the two-year data set from the barley trials, little difference was found in the profitability of fertilizer use between sites in Stability Zones 2 and 3 (mean rainfall across sites, 266 and 216 mm, respectively) (Jones 1987). In the absence of nitrogen fertilizer, phosphate was less profitable in zone 2 than in zone 3, but otherwise differences were negligible.



Slope Coefficients for the Regression of Each Treatment:

Treatment	P0	P20	P40	P80
N0	5.3	9.4	11.4	12.7
N40	10.9	11.9	12.4	9.7
N80	7.4	13.6	13.4	14.3
N120	14.1	13.1	12.1	15.7

a) Intercepts do not differ significantly from each other

b) All slope coefficients related to rainfall are significantly different from the slope coefficient of N0P0 treatment at $p<0.05$

c) All slope coefficients are significantly different from zero at $p<0.05$

FIGURE 2.8 Effect of fertilizer on wheat dry matter response to rainfall from fourteen trials in northwest Syria, 1986/87

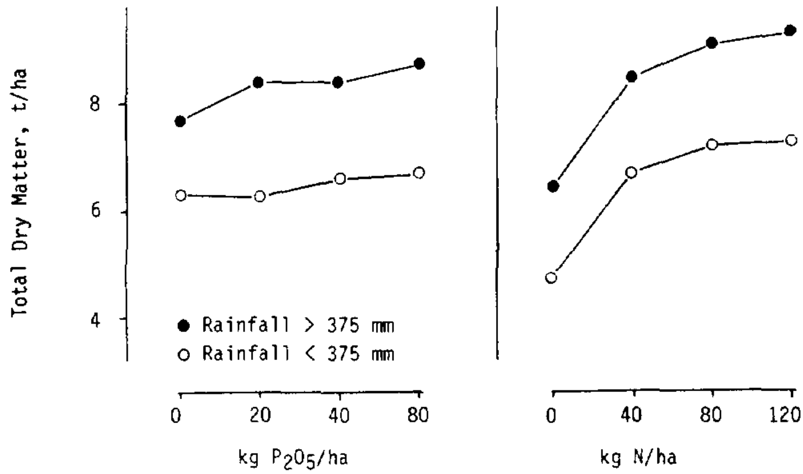


FIGURE 2.9 Effect of rainfall on pattern of wheat response to fertilizer, 1986/87 (means of sites grouped according to total rainfall)

2.2.9 Economic and Socio-Economic Considerations

All the experimental findings summarized here derive from crops grown by research scientists. Even the numerous on-farm trials referred to were managed largely or entirely by scientists. To a considerable degree, that is unavoidable. Few farmers have the training or the facilities to conduct the relatively complex trials required to explore the relationships between fertilizers, crops and the variable environment in which they are grown. But we need to be aware of the discrepancies this can introduce and make allowance for them.

One important discrepancy is that, at most sites, the yield the scientist gets, even in his zero-fertilizer control plot, is usually greater than that achieved in the same field by the farmer. (See Section 4.3 of this report.) The reasons vary from site to site but may derive from differences in seed rate, seed quality, time of seeding, quality of seedbed and degree of weed control. So, when we report crop yield responses to *fertilizer in an on-farm research trial, those responses are* increases above a basic unfertilized yield level specific to that trial and almost certainly different from the farmers' yield. What is not certain is whether the farmer, if he had used fertilizer, would have obtained similar increases. For example, if the best experimental treatment increased grain yield from 1000 kg/ha (control plot) to 2000 kg/ha, what effect would the same treatment have had in the farmer's crop, where the yield level otherwise was only 500 kg/ha? Would it have doubled the yield (to 1000 kg/ha) or increased it by the same absolute amount (to 1500 kg/ha), or given no increase at all? Unless we know the answer to this question, all the careful economic calculations we make from our experimental results are of very uncertain validity.

We can respond to this situation in several ways. For instance, we can make some informed guesses about how much smaller fertilizer responses would likely be under farmers' management -- say 50% of research response -- and calculate profitability on that basis. Alternatively, we can tie fertilizer recommendations to a package of other management recommendations, specifying seed rate, weed control measures, etc., and assume that the response of the farmers' crop will then be the same as that of the scientist. *Or we can try to find out, experimentally, what happens when the* farmer uses fertilizer and compare that with what happens, on the same field, when the scientist uses fertilizer. During the 1987/88 season, each of the SD/FRMP barley fertilizer trials managed by scientists will be paired with an adjacent farmer-managed trial, carrying a small number of the same fertilizer treatments applied by the farmer himself. We hope this will give us a measure of the difference in fertilizer response between scientist-managed and farmer-managed conditions and some clearer insight into the reasons for it.

The foregoing problem is one of micro-economics, determining the profitability of fertilizer use to individual farmers. No less important is the macro-economic problem concerned with the profitability of subsidized fertilizers nationally. At this level, it is not sufficient to demonstrate that phosphate significantly increases, say, barley production in dry areas and that such increases give good economic returns to individual farmers. It is also necessary to show that phosphate gives a better return, economically and in terms of national priorities, than the same fertilizer applied elsewhere to other crops.

Here we have a dynamic situation. For example, at the present time it might be the case that dry-zone barley is not the most profitable crop to which to apply subsidized phosphate fertilizer. But, even if true now, that condition is unlikely to be permanent. Circumstances change. For one thing, the value of barley relative to, say, wheat, may be expected to fluctuate according to changes both in world prices and, locally, in the demand for barley-based livestock products. At the same time, we may expect the availability of soil phosphate in land carrying high-value crops to increase with continued fertilizer addition, to the point of diminishing returns. We already know that important residual effects can build up even in Syria's predominantly calcareous, phosphate-fixing soils. Associated with this our on-farm trials have shown greater marginal rates of return from fertilizer use on dryland barley than on wheat.

Such a decline in response to further fertilization would gradually alter the balance of advantage between applying phosphate to higher-rainfall wheat and irrigated crops and applying it to less reliable, lower-yielding dry-zone crops like barley. We may anticipate a time when much of the wheat land will require only small maintenance dressings, and the best economic option nationally then will be to use more phosphate elsewhere.

An important research objective for the next few years, integrating expertise in soil chemical, agronomic and economic disciplines, is to study the parameters of this situation and from them to construct a model, "fertilizer allocation strategies", aimed at maximizing the efficiency of use of an important and expensive agricultural resource.

2.2.10 Discussion

The purpose of this section of our report has been to examine current FRMP research on fertilizer use on wheat and barley -- in the context of previous work, soil conditions, agro-economic priorities and an aim to improve the efficiency of fertilizer use. However, in reviewing research in this way, it can be seen that the need for efficiency applies no less to the organization of our own work. Because fertilizers impinge on agriculture at various levels and because the biological and economic effectiveness of fertilizers is influenced by many different factors, topic-specific research on fertilizers tends to proceed simultaneously at several different levels independently. While there may be real limitations to practical integration of different research thrusts, a more integrated framework of objectives is desirable. We need to see how our different efforts will all eventually fit together logically. To do this, it appears useful to distinguish four different technical levels or dimensions of fertilizer study:

1. Environmental. That is, relationships of crop fertilizer responses to weather and site and soil properties. Research topics include both the regression of crop responses on weather and soil data in static models and the development of nutrient sub-routines in dynamic crop models. Equally important, ways need to be found to lift studies of nutrient availability, phosphate fixation, mineral-N dynamics out of the site-specific mode and

obtain general predictive relationships. We need to ask, for instance, whether those properties that control nutrient availability and fertilizer need and effectiveness have any significant dependence on soil taxonomic group, clay content, calcium carbonate content, prevailing rainfall regimes, etc? In terms of what factors can the most useful generalizations be made?

2. Agronomic. The issues here include: i) crop sequence and rotation effects, particularly in the more complex, wheat-dominated systems; ii) the analysis and interpretation of multi-site, multi-season trials -- for the production of practical farmer recommendations, for elucidating critical management factors and site interactions, and for the design of an effective experimental tool for the conduct of similar work elsewhere; and iii) evaluating the effect of farmer management practices on fertilizer efficiency.

3. Micro-economic. The main point here follows directly from the third agronomic issue: how are the economics of fertilizer use affected by farmer practice; but, equally, how are farmer practices and the management and economy of the whole farm affected by fertilizer use?

4. Macro-economic. Here, too, the processes are two-way. On the one hand, we are concerned with how national policies on agricultural priorities, fertilizer prices and crop prices determine which crops and soils receive the limited amounts of fertilizer; on the other hand, how the resulting distribution of resources affects production. And taking the two together, which distribution would maximize output?

Added to these four, we have the dimension of time. At the level of the soil, as has been said already, phosphate availability may increase over time through the continued use of fertilizer to the point at which further use may, for a while, be uneconomic. It will then be better used on another soil and another crop. At the same time, continuous cropping of unfertilized soils may encourage degradation and the gradual depletion of a natural resource. Simultaneously, local, national and international pressures can bring changes in markets and prices. The web is intricate. It stretches from the complexities of phosphate sorption and desorption reactions on soil mineral surfaces, through the socio-economic realities of actual farming, to government policy-making. Our various research thrusts on fertilizer all have their place in that web; but we need to maintain a positive awareness of their interconnectedness as well as of their likely individual impacts on specific issues within the web.

2.2.11 References

Colwell, J.D., and Morton, R. 1984. Development and evaluation of general or transfer models of relationships between wheat yields and fertilizer rates in Southern Australia. **Australian Journal of Soil Research**. 22, 191-205.

Cooper, P.J.M., Gregory, P.J., Tully, D., and Harris, H.C. 1987. Improving water use efficiency of annual crops in the rainfed farming systems of West Asia and North Africa. **Experimental Agriculture**. 23, 113-158.

FSP, 1987. Annual Report for 1986, Farming Systems Program ICARDA.

Harmsen, K. 1984. Dryland barley production in northwest Syria. I. Soil conditions, II. The chemistry and fixation of phosphorus in calcareous soils. pp. 12-67 in Proceedings of the Soils Directorate/ICARDA Workshop on Fertilizer Use in the Dry areas, Aleppo, March 1984. MAAR, Syrian Arab Republic and ICARDA, Syria.

Harmsen, K. 1986. The role of soil testing in assessing the nitrogen fertilizer requirements of rainfed cereal crops in the Syrian Arab Republic. pp. 9-65 in Proceedings of First West Asia and North Africa Soil Test Calibration Workshop, Aleppo, June 1986. MIAC, Morocco and ICARDA, Syria.

ICARDA, 1984. Annual Report for 1983.

ICARDA, 1985. Annual Report for 1984.

ICARDA, 1986. Annual Report for 1985.

ICARDA, 1987. Annual Report for 1986.

ICARDA/MIAC, 1986. Proceedings of First West Asia and North Africa Soil Test Calibration Workshop, Aleppo, June 1986 (Ed. P.N. Soltanpour). MIAC, Morocco and ICARDA, Syria.

ICARDA/MIAC, 1987. Proceedings of Second West Asia and North Africa Soil Test Calibration Workshop, Ankara, September 1987 (in press).

Jones, M.J., and Harris, H.C. 1987. Climatic variability and agronomic management in Mediterranean barley-livestock farming systems. Paper presented at International Symposium on Climate and Food Security, New Delhi, India, February 1987.

Jones, M.J. 1987. Interpretation and utilization of data from on-farm fertilizer trials for situations in which soil test values are not available. Proceedings of Second West Asia and North Africa Soil Test Calibration Workshop, Ankara, September 1987 (in press).

Larsen, S., Gunary, D., and Sutton, C. 1965. The rate of immobilization of applied phosphate in relation to soil properties. **Journal of Soil Science**. 16, 141-148.

Matar, A. and Samman, M. 1969. Evaluation of potential fertility of major soil groups of Syria by means of pot tests and chemical analyses of soils. 10th Week of Sciences. Part 5: 131-183. High Council of Sciences. Damascus, Syria. (in Arabic)

Matar, A. and Samman, M. 1975. Correlation between $NaHCO_3$-extractable P and response to P fertilization in pot tests. **Agronomy Journal**. 67: 616-618.

Matar, A. 1984. Wheat productivity under rainfed agriculture as related to soil, precipitation and management variables in Syria. ACSAD, Damascus.

Matar, A., Abdel Karim, J., and El Hajj, K. 1986. Studies on response of cereals and food legumes to phosphate fertilization in Syria as related to available P in soils. First West Asia and North Africa Soil Test Calibration workshop Proc. P.N. Soltanpour (Ed.): 133-150. ICARDA.

Matar, A., Jabour, E., and El Hajj, K. 1987. Nitrogen and phosphorus soil test calibration with barley. Proceedings of Second West Asia and North Africa Soil Test Calibration Workshop, Ankara, September 1987 (in press)

Olsen, S.R., Cole, C.V., Watanabe, F.S., and Dean, L.A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S. Department of Agriculture, Circular No. 939.

Pala, M., and Matar, A. 1987. Soil test calibration with N and P for wheat under dryland conditions in Syria. Proceedings of

Second West Asia and North Africa Soil Test Calibration Workshop, Ankara, September 1987 (in press)

Pala, M., Tully, D., Rassam, A., Mazid, A., and Cooper, P.J.M. 1987. Fertilizer and herbicide effects on farmers' wheat production in northwest Syria. FSR Symposium, Fayetteville, Arkansas, USA, October 1987.

Rice, W.A., Tahir, M.B., Amin, R., and Winkelman, G.E. 1986. Soil test methods for determining the nitrogen fertilizer requirements of rainfed crops in Pakistan. pp. 67-83 in Proceedings of First West Asia and North Africa Soil Test Calibration Workshop, Aleppo, June 1986. MIAC, Morocco and ICARDA, Aleppo.

SD/FSP, 1985. Fertilizer use on barley, northern Syria, 1984-1985. Collaborative Research Project Report. Soils Directorate, MAAR, Syria and Farming Systems Program, ICARDA, Aleppo.

SD/FSP, 1986. Collaborative research project report on fertilizer use on barley in northern Syria, 1985/1986. Soils Directorate, MAAR, Syria and Farming Systems Program, ICARDA, Aleppo.

SD/FRMP, 1987. Collaborative research project report on fertilizer use on barley in northern Syria 1986/87. Soils Directorate, MAAR, Syria and Farm Resource Management Program, ICARDA, Aleppo. (In preparation.)

Soltanpour, P.N., El Ghrous, M., and Azzaoui, A. 1986. Nitrogen and phosphorus soil test calibration studies in Morocco. pp. 85-95 in Proceedings of First Soil Test Calibration Workshop, Aleppo, June 1986. MIAC, Morocco and ICARDA, Syria.

Soltanpour, P.N., El Ghrous, M., and Azzaoui, A., and Abdel Moneim, M. 1987. Nitrogen and phosphorus soil test calibration studies in the Chaouia region of Morocco. Second West Asian and North African Soil Test Calibration workshop Proc. Ankara 1-6 September 1987. ICARDA.

Somel, K. 1984. Environmental variability and multiple site-multiple season trials. Discussion Paper No. 12. Farming Systems Program, ICARDA.

Yurtsever, N. 1986. A study on calibration for the Olsen phosphorus test with wheat responses under Turkish soil conditions. pp. 97-113 in Proceedings of First Soil Test Calibration Workshop, Aleppo, June 1986. MIAC, Morocco and ICARDA, Aleppo.

2.3 Tillage and Stubble Management Effect on Soil Conservation, Crop Establishment and Yield, and Economics of Production

Hazel Harris and Mustafa Pala

2.3.1 Introduction

In rainfed agriculture in semi-arid regions tillage has two purposes -- to prepare a seedbed, and to promote the *infiltration and conservation of water within the soil profile.*

Within the region in which ICARDA works, tractors have been introduced widely and most primary, and much secondary tillage is mechanized. Equipment was originally imported from Europe and North America, but the disc and mouldboard ploughs, disc and spike toothed harrows, and chisel ploughs and sweeps which are the main implements used, are now largely locally made (Tully 1986, Cooper et al. 1987).

In much of the region it is regular practice to plough, with a disc or mouldboard, to a depth of 20 to 30 cm each year, and then to prepare a seedbed with either a harrow or tyned implement. Several reasons for deep ploughing are given by regional scientists and farmers: increased water and soil conservation through prevention of runoff; disruption of a plough layer in the soil; and weed control, through deep burial of weed seeds.

The landscape of much of the region contains relatively few streams, which suggests that only limited runoff occurs. However, in recent years an increase in population has led to an expansion of cultivation on to steeper marginal lands. At the opening of the rainfall season, when there is no protective vegetation following the arid summer, intense thunderstorms are not uncommon. In some places and years severe soil erosion, resulting from runoff from storms, can be seen on steeper hillsides. It is not clear that the type of tillage has much effect in these cases. The direction of cultivation, which for convenience is often with the slope, is probably the dominating factor.

Many of the soils used foı cropping in the region are self-mulching clays which are plastic when wet, and crack extensively when dry (Cooper et al. 1987). Compaction and plough layers can develop on such soils if they are worked with heavy equipment when they are too wet (Hodgson and Chan 1984, McGarry 1984). This is mainly a problem on irrigated land, and, with the relatively small equipment used in the ICARDA region, is probably unlikely to be a major problem in rainfed agriculture.

Weeds are a major problem of rainfed agriculture in the Near East, and especially in North Africa where the value placed on weedy fallows for the provision of grazing ensures continued supply of weed seed. A long term trial in Syria (Dozom 1986) compared deep tillage with zero till and showed an advantage of ploughing in weed control. The timing of the tillage was clearly important, but the trial was not designed to examine whether other forms of tillage may be equally effective for controlling weeds.

Deep tillage is costly of fuel and time. Moreover, by increasing the surface area of soil exposed to radiation and wind it increases the loss of water through evaporation. This is especially so when the soil is inverted, exposing moister layers from depth to the evaporating forces. There is a school of thought which suggests that the tillage practices used in the region have evolved through millenia, and therefore are the best suited for the environment. However, it seems more logical to suppose that they were imported from more humid areas, along with the tools of mechanization, and their continued use in the region deserves close scrutiny.

Research in semi-arid regions elsewhere in the world, has shown that shallow tillage is adequate for weed control, and can aid in the conservation of water stored in the soil profile by disrupting the micropores through which evaporation occurs (Papendick et al. 1973, Anon 1979, Fischer 1987). It can also promote infiltration of water in the short term. However, any tillage which leaves the soil bare and loose increases the risk of erosion by water and wind.

Within the region, and deep tillage in the spring of a fallow year is recommended for control of grass weeds in cereal crops on the Anatolian Plateau of Turkey (Guler et al. 1980). This has the additional advantage of having the surface rough to increase infiltration rate during rain late in the season. When followed by a shallow tillage at the end of the rains the practice leads to greater storage of soil water (Soane et al. 1973; Dogan et al. 1977; Unver et al. 1978; Guler et al. 1980; Ozkan et al. 1984).

In the long term, tillage can be expected to cause breakdown of the surface structure and increased crusting. In soils where the surface structure is inherently weak, cultivation rapidly leads to surface degradation, reduced infiltration, and failure of crops to emerge through the heavy crusts which form. There are many such soils in the region and widespread evidence of the ensuing problems can be seen, particularly towards the drier margins of the cropped area (Cooper et al. 1987). If these same soils are cultivated when they are dry, the lack of structure renders them very susceptible to wind erosion. Again, observations in the region suggest that this is a problem, but its severity is unquantified.

Concern for such factors has stimulated research on conservation farming in other parts of the world. In particular, stubble retention and direct drilling have been shown to reduce the rate of runoff and hence soil loss through water erosion, to reduce wind erosion, and to contribute to the development of more stable aggregates in the surface of fragile soils.

There is little, if any, evidence on the effect of stubble retention in the ICARDA region where stubbles are valued as summer grazing for sheep and goats. In recent years, however, an increase in the burning of stubble has been observed in several countries. The reason for the increase is not clear, but it does suggest that there is now excess stubble and the potential should exist to introduce concepts of stubble management if advantages for it can be demonstrated.

In the soil, water, and nutrients management project research is being undertaken on both the short- and long-term effects of tillage, and on the effects of stubble management practices. In this section of the report we report some aspects of the work in detail, and outline other work in progress.

2.3.2 Short-Term Tillage Trials

Seedbed preparation. Establishment is the most important step in crop production. Unless an adequate plant population for the environment is achieved at the outset, the yield potential will be decreased. Some tillage is normally used in the preparation of a seedbed. However, tillage operations are costly, and can form some 30 to 50% of the costs of planting, depending on the method used.

Other land preparation normally carried out by Syrian farmers is removal of cereal stubble to facilitate the seeding of legumes in rotations. The long-term effects of this can be expected to be detrimental (Hamblin 1987); short-term effects are unknown.

In 1986/87 we compared the effect of several commonly used tillage sequences on the yield of wheat and lentil. For lentil, plus and minus burning of the standing stubble of the preceding cereal crop was included, and in both crops the plots were split for plus and minus chemical weed control.

Primary tillage was carried out with either a disc plough or a chisel plough working to a depth of 30 cm, or with a duckfoot cultivator to 15 cm. The latter is locally manufactured and is used both for tillage and seeding. It has two sets of tynes, forward and rear, both of which are used for tillage.

For seeding, the front set is usually removed, leaving 5 tynes each 48 cm apart, this distance being determined by the wheel spacing of the tractor. A pass is made across the land leaving it ridged (Fig. 2.10), seed and fertilizer are hand broadcast, and in a second pass the ridges are split (point 's', Fig 2.10a) to turn the soil over the seeds (curved arrows, Fig. 2.10a). The seed and fertilizer are buried at variable depths, and the crop is established in broad bands rather than in a single row as when drilled (Fig. 2.10*b*). Occasionally the first pass is omitted; the seed is broadcast and the soil is ridged to cover it. This results in a less uniform crop stand.

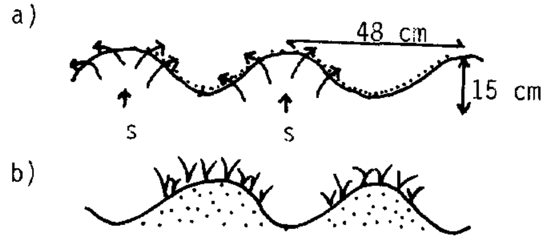


FIGURE 2.10 Schematic representation of traditional sowing method, northwest Syria

In the trials the tillage sequences used were those in Table 2.3. Unless otherwise stated, plots were sown after rain using the two-pass method described.

TABLE 2.3 Tillage sequences used for planting wheat and lentils at Tel Hadya, 1986

1. Disc plough before rain; plant before rain
2. Disc plough before rain
3. Chisel plough before rain
4. Duckfoot cultivation after rain
5. No primary tillage
6. No primary tillage; first pass of sowing sequence omitted

In wheat, ploughing and seeding before rain (Treatment 1) significantly increased yield in this season (Table 2.4). The treatment germinated and established on 20 mm of rain in early November. The other treatments were planted following the same rain but did not germinate until the next substantial rain in late December (see Section 1.3). The advantage in treatment 1 was thus one of earliness, rather than one due directly to tillage sequence. There was no difference in yield amongst the other treatments, suggesting that on a self-mulching clay soil primary tillage probably is not necessary with local planting practices.

Herbicide significantly increased wheat yield, but there was no interaction with tillage sequence. This supports our contention that deep discing is ineffective for weed control. Furthermore, it indicates that current planting methods themselves provide control of weeds which germinate after the first rain, and there is no cause for additional tillage for weed control.

The results for lentil were essentially the same: the tillage sequence in seedbed preparation did not lead to yield differences, but herbicide increased seed yield by approximately 200 kg/ha (Table 2.4).

TABLE 2.4 Seed yield of wheat and lentil (kg/ha) sown following different tillage sequences, Tel Hadya, 1986/87

Crop	Herbicide	Stubble Burning	Tillage sequences 1	2	3	4	5	6
Wheat	+	na	1700	1450	na	1235	1355	1260
	-	na	1225	1095	na	1060	1140	1075
		SE	156					
Lentil	+	+	na	1225	1215	1230	1140	na
	+	-	na	1215	1360	1500	1300	na
	-	+	na	1050	1075	1020	1010	na
	-	-	na	1170	1245	1110	1220	na
		SE	146					

na = treatment not applied

The burning of stubble almost consistently reduced yields, but the effect was not statistically significant. Nor was there any interaction between stubble burning and herbicide (Table 2.4). This is encouraging, as it had been feared that the presence of stubble might reduce the effectiveness of the pre-emergence herbicides used. These are the main chemicals available for use on legumes, and although they have not yet been adopted by farmers, their use has proved to be economically feasible over several seasons. (See also Section 2.4.)

The estimates of costs and net returns (Table 2.5) show some increases of 300 to 400 SYP/ha due to primary tillage (excluding Treatment 1, see above). This is coupled with a greater initial outlay of 100 to 250 SYP. Only a farmer could judge the relative merits of the systems on these figures.

TABLE 2.5 Costs and net revenue of primary tillage treatments (see Table 2.3) for production of wheat and lentil

		Tillage treatment					
		1	2	3	4	5	6
Wheat	Costs*	1299	1149	na	1031	857	783
	Net revenue**	7389	6036		5926	5610	5247
Lentil	Costs	na	2193	2248	2162	2018	na
	Net revenue	na	9562	10203	10020	9902	na

* Does not include common costs of seed and fertilizer. Custom hire charges used for estimating cost of tillages and planting. Harvest costs estimated as 10% and 15% of gross revenue for wheat and lentil, respectively.

** Includes returns for seed and straw

Single pass planter. Two years ago (ICARDA 1986) we reported the development of a single pass planter (SPP). Locally built seed and fertilizer boxes were mounted on a local duckfoot cultivator. In a single pass the planter tills the soil, forms ridges and places fertilizer, scatters seed over the ridges, and covers it by smoothing the ridges with a heavy bar. It thus carries out in one pass the three or four operations of planting illustrarted in Fig. 2.10. The resulting crop geometry is similar to hand broadcast crops, but the bands of crop tend to be narrower.

The planter was originally designed with the purpose of reducing costs for the resource-poor farmers of drier barley-growing areas, and for the placement of fertilizer in the extremely phosphate deficient soils of those areas. Early testing showed considerable promise of both yield and economic advantages (ICARDA 1986).

Testing of the planter has been continued in the past two seasons with a greater range of crops, and in different soil and climatic conditions. The outcome of the tests is summarized in Tables 2.6 and 2.7, and in Figs. 2.11 and 2.12.

The results of tests at Breda, a dry site and Tel Hadya, a wetter one (Table 2.6) show variability between crops and seasons. In general there is not a great deal to choose among the three planting methods and the differences were rarely statistically different. The SPP appears to be best suited to drier conditions, and to cereals rather than legumes. This is to be expected due to the greater crowding of plants in the band of crop noted earlier.

Some design problems remain with the SPP. In particular, the method of covering the seed is not adequate. When there are stones or large clods on the surface the rigid bar used to cover

TABLE 2.6 Grain and straw yields (kg/ha) of plots planted with an Oyjord plot planter (drill), the single pass planter (SPP), or broadcast over ridges (BOR) in three seasons at Breda and Tel Hadya

Crop			BREDA									TEL HADYA					
			1984/85			1985/86			1986/87			1985/86			1986/87		
			Drill	SPP	BOR	Drill	SPP	BOR	Drill	SPP	BOR	Drill	SPP	BOR	Drill	SPP	BOR
Barley	Grain	+P	1775	1390	1675	1405	1460	1425	1870	1480	1855	2835	2290	2495	2925	3206	3340
		-P	1035	800	1010												
	Straw	+P	1920	1375	1580	1185	1245	1215	2390	1905	2440	3065	2445	2995	3965	3920	3810
		-P	845	725	875												
Wheat	Grain					875	955	995	1175	990	1020	2360	2550	2330	2805	1565	2325
	Straw					1365	1530	1600	2465	1890	2030	3530	3750	3480	6445	3470	4575
Vetch	Seed					1095	920	845	1200	1060	1040	1235	1175	1370	1940	1740	1950
	Straw					1710	1395	1415	1840	1740	1830	2350	2260	2530	2810	2720	2490
Lentil	Seed					1345	975	1090	1220	1150	1230	1495	1165	1370	2670	1820	2040
	Straw					2010	1245	1545	1800	1650	1830	2075	1685	1820	3680	2560	3070

tends to ride on them, and the seed is not covered and establishment is not always satisfactory.

It was also noted that weed control was less satisfactory with the SPP than when planting was done by conventional methods (Table 2.7) although the effect on yield was not significant. Again, this could be associated with the use of the heavy bar for the covering of seed. This tends to compact the soil surface and could cause weeds to be transplanted when the soil is moist at sowing. The bar also leaves the soil smooth and fine which tends to promote surface crusting in the silty soils at Breda. This could result in reduced crop emergence and greater surface run off in certain seasons.

TABLE 2.7 Comparison of seed yield of wheat and lentil kg/ha from sowings made with the single pass planter and conventional methods

Crop	Herbicide	Stubble burning	Sowing Method SPP	BOR
Wheat	+	na	1280	1350
	-	na	1000	1140
Lentil	+	+	1050	1140
	+	-	1230	1295
	-	+	760	1005
	-	-	950	1220

These data are a subset of the experiment described above.
SPP=single pass planter; BOR=broadcast over ridges.

The planter showed a much more consistent advantage when used to plant chickpeas in wetter areas (Figs. 2.11 and 2.12), and this was so for both winter and spring sown crops.

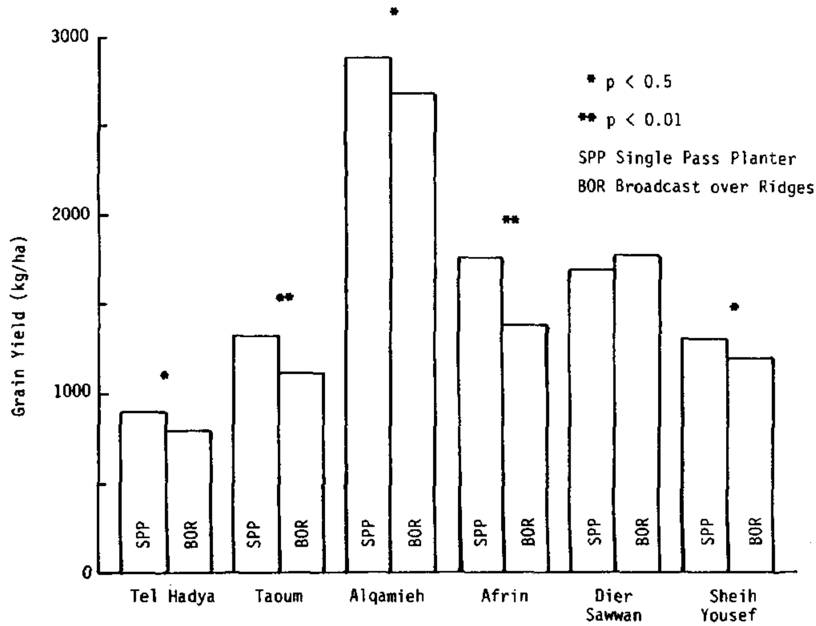


FIGURE 2.11 Seed yield of chickpeas sown with the single pass planter (SPP) or hand broadcast (BOR) in 6 on-farm trials in northwest Syria

Winter sowing of chickpeas has been made possible by the release of cultivars with resistance to Ascochyta Blight. By sowing early the crop duration is increased, and greater biomass production is accompanied by higher seed yields. However, one consequence of winter sowing is that weed problems are increased. Pre-emergence herbicides are available which can be used, but they do show some degree of phytotoxicity to chickpeas. When the crop is hand broadcast some of the seed remains very close to the soil surface and is affected by the herbicide. A slight modification to the SPP enabled seed to be placed deeper, with the expectation that herbicide damage would be reduced. However, rain washed the herbicide into the profile and similar damage (8%) occurred with both sowing methods. More uniform plant stands were achieved with

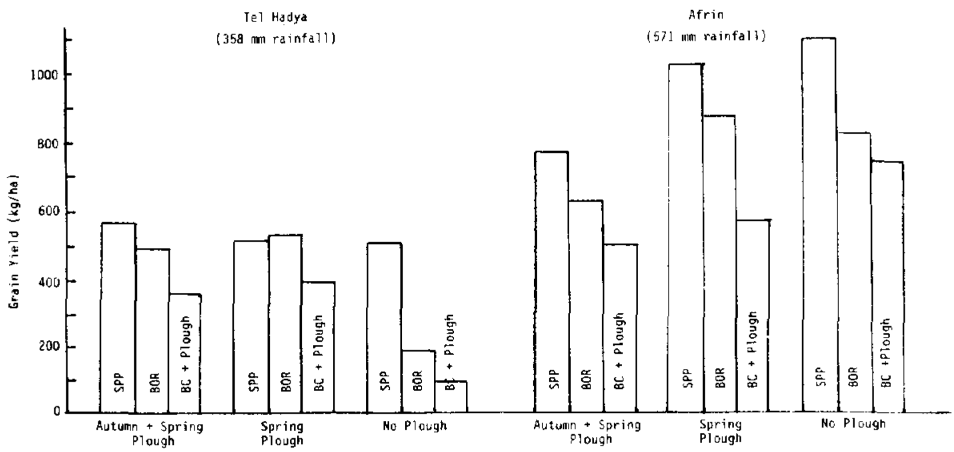


FIGURE 2.12 Seed yield of chickpea sown with single pass planter (SPP) and two traditional methods following three seedbed preparation sequences at two sites in northwest Syria. (BOR, broadcast over ridges; BC + plough, hand broadcast and cover with light mouldboard ploughing

the planter which caused the yield increase, and under other rainfall conditions this could be expected to be greater.

Most chickpeas in the region are still sown in spring when the disease risk is much lower. Commonly farmers carry out two deep discings for chickpeas, one in the autumn and a second in the spring. In trials at two sites with contrasting rainfall deep tillage appeared to confer a yield advantage at the drier site (Tel Hadya), but at the wetter site the reverse held (Fig. 2.12). However, at Tel Hadya the SPP had the same effect as the deep discing, and at Afrin plots sown with the planter gave the greatest yield irrespective of prior tillage (Fig. 2.12). The results also show no advantage of the second deep discing in spring.

The data of Table 2.8 show the reduced costs of the single pass planter. Net revenue (as calculated) overall did not differ greatly from the hand broadcasting method, being greater for some crops and less for others. Drilling conferred a revenue benefit.

TABLE 2.8 Costs and net revenue comparing the single pass planter with hand broadcast and drill seeding. Based on mean yields across sites, seasons, and, for chickpeas, prior tillage treatments and sowing times

	Planting method					
	Costs*			Net revenue*		
	Drill	SPP	BOR	Drill	SPP	BOR
Fertilized barley	763	672	834	5565	5000	5408
Wheat	875	777	867	6576	5940	5705
Vetch	1973	1784	1961	10312	9409	9709
Lentil	2667	2021	2382	14243	10749	12098
Chickpea		1063	966		5321	4075

* See notes of Table 2.5

2.3.3 Long-Term Tillage Trial

In 1978/79 a trial was laid down with the objectives of examining the effect of tillage practices, phosphate fertilizer, and method of weed control on weed flora, and on the yield and water balance of wheat and lentils grown in alternate years. The trial continue for 7 years and the results have been reported elsewhere (ICARDA 1984, Dozom 1986).

A review of the trial at the end of the 1984/85 season concluded that the weed control and fertilizer treatments should be discontinued, but, because of visible effects on soil condition, the tillage should continue. The design of the trial was modified to include both phases of the rotation, i.e. wheat and lentil in each year. The tillage treatments (main plots), previously split in one direction for fertilizer and weed control, were now split at right angles to the original division so that each new subplot includes all of the previous treatments. Phosphate fertilizer has been liberally applied to previously unfertilized subplots, and intensive chemical weed control to weedy plots to even out residual effects.

The tillage treatments are:

1. Deep discing, seedbed preparation and planting before rain. (Conventional Tillage Early: CTE)

2. Deep discing before rain; seedbed preparation and planting after rain. (Conventional Tillage Mid: CTM)

3. Deep discing, seedbed preparation and planting after rain. (Conventional Tillage Late: CTL)

4. Zero tillage, planting before rain. (Zero Tillage Early: ZTE)

5. Zero tillage, planting after rain. (Zero Tillage Mid: ZTM)

The objectives of the redesigned trial are to study the effects of the tillage treatments on soil physical parameters and the water balance of wheat-lentil rotations. The CTE and ZTE treatments are sown on the same day, as are the CTM and ZTM treatments and this report focuses on comparisons of these treatments. In 1985/86 the zero till lentil plots established poorly and results therefore are not presented.

Soil water status and crop water use is monitored at frequent intervals during the season by neutron scattering techniques. Neutron probe access tubes are permanently installed, and identical soil profiles are measured each year. In 1984/85 only lentil was sown, but in 1985/86 and 1986/87 both phases of the rotation were monitored.

Effect of tillage on crop water use. In 1984/85 CTE lentil used more water than ZTE. There was 15 mm more loss from CTE during seedbed preparation and planting than from the zero till plots, and the remainder of the difference was recorded in the last ten days of crop growth. In the succeeding years there were no differences between the treatments in the amount of water used by lentil (Table 2.9), but the pattern of use differed (Fig. 2.13). The season's water use was less than the rainfall (Fig. 2.13) in all years.

In sharp contrast, there were differences of 50 and 20 mm between the tillage treatments in total water use by early sown wheat in 1985/86 and 1986/87 respectively (Table 2.9). In 1985/86, emergence of early sown plots in mid-November was followed by six weeks with only intermittent light showers of rain. There was considerable plant death and more loss in the zero till plots than in the conventionally tilled ones, and zero till treatments were abandoned. The difference in plant stand between CTE and well established CTM plots, probably accounts for the greater cumulative use by CTM for the season. In the following year total water use by CT treatments was greater than ZT treatments, and early sown plots used water at the greater rate until the end of March. Later sown CT plots again used more water than the earlier sown ones, and in both years all crops used more water than was received as rain, due to stored water remaining after the previous lentil crop (Fig. 2.13, Table 2.9).

TABLE 2.9 Water use, maximum stored water, rainfall, yield and water use efficiency of wheat and lentil crops in response to four tillage treatments

		Lentil				Wheat			
	Year	CTE	CTM	ZTE	ZTM	CTE	CTM	ZTE	ZTM
Water use (mm)	84/85	318	-	276	-	-	-	-	-
	85/86	251	245	-	-	366	415	-	-
	86/87	300	295	301	290	342	363	332	330
Max. stored water (mm)	84/85	-	-	-	-	-	-	-	-
	85/86	124	127	-	-	132	120	-	-
	86/87	118	152	111	137	77	99	103	117
Rainfall (mm)*	84/85	342				313			
	85/86	284				317			
	86/87	313				317			
Seed/grain yield (kg/ha)	84/85	1220	-	795	-	-	-	-	-
	85/86	460	455	-	-	1540	1370	-	-
	86/87	1385	1600	1230	1615	1850	1800	1260	1360
WUE (kg/ha/mm)	84/85	3.84	-	2.88	-	-	-	-	-
	85/86	1.48	1.49	-	-	4.21	4.02	-	-
	86/87	4.62	5.42	4.09	5.57	5.41	4.96	3.80	4.10

* From start of season to harvest

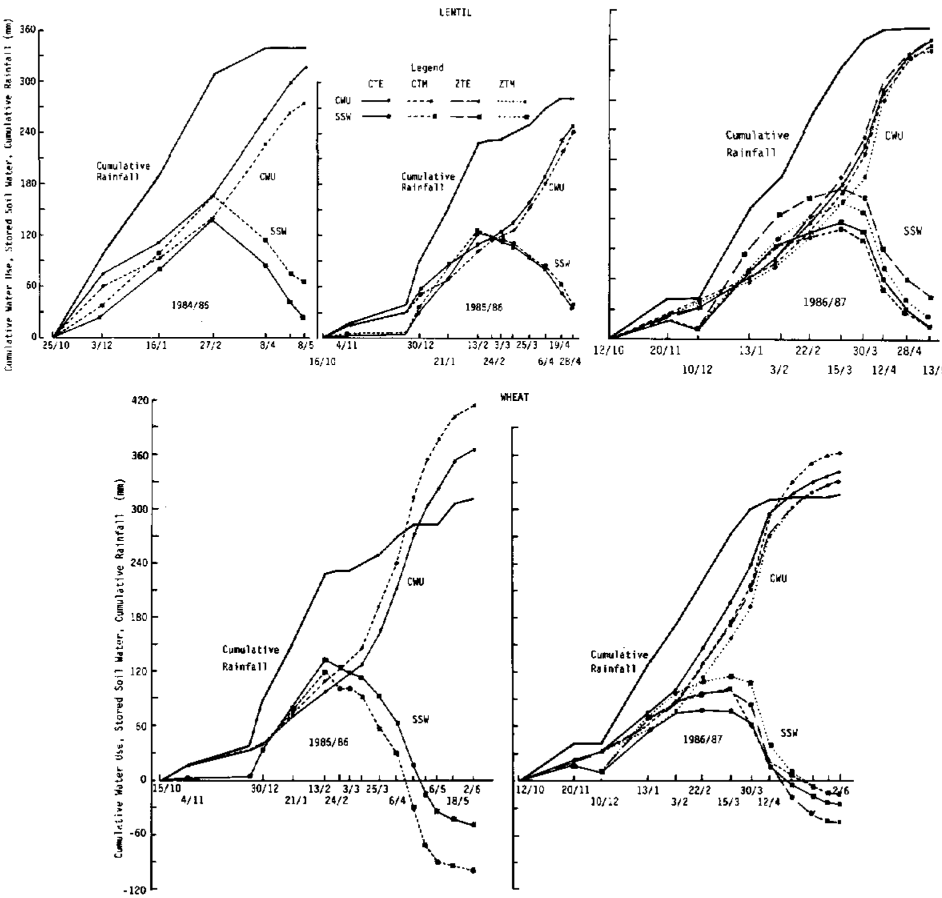


Figure 2.13 Cumulative water use (CWU), stored soil water (SSW), and cumulative rainfall under lentil in 3 seasons and wheat in 2 seasons in response to tillage treatments (see text).

Effect of tillage on stored soil water. Stored water, calculated as the difference between the total in the profile at any time and the amount present before rain in October, is also shown in Fig. 2.13. Maximum profile recharge occurred at the end of February in 1985, in mid-February in 1986, and in mid-March in 1987. There is no consistent effect of tillage treatment on the pattern of water storage. In 1984/85 more water accumulated in the lentil zero till profile than in conventionally tilled plots (CTE), but in the succeeding years the difference did not exceed 7 mm in early lentil crops. With late lentil, more water was stored, and more was stored by conventional than by zero till (Table 2.9). Under wheat, the maximum differences were approximately 20 mm in each year, but in 1985/86 maximum storage was under the CTE plots, whilst in 1986/87 it was greatest in ZT plots, at both times of sowing (Table 2.9). With the limited data available it is impossible to judge the significance of these differences.

It does appear significant, however, that in each year, as noted in the previous section, water apparently remained in the profile at harvest of the lentil crop, and in the next year the wheat was able to use that water. The effect occurred over the whole profile (Fig. 2.14), suggesting that durum wheat is able to extract water against greater potentials than lentil. Lentil thus seems to complement wheat, which probably accounts for the widespread use of this rotation in the 300 to 400 mm, rainfall zones.

Rate of water use. In 1986/87 the rate of water use was greater in wheat than in lentil early in growth, and greater in early than later sown crops until the beginning of March (Fig. 2.15). At the time of peak water use the rate was similar in all treatments except CTM for wheat and ZTM for lentil, in which the rate of crop water use exceeded pan evaporation for a short

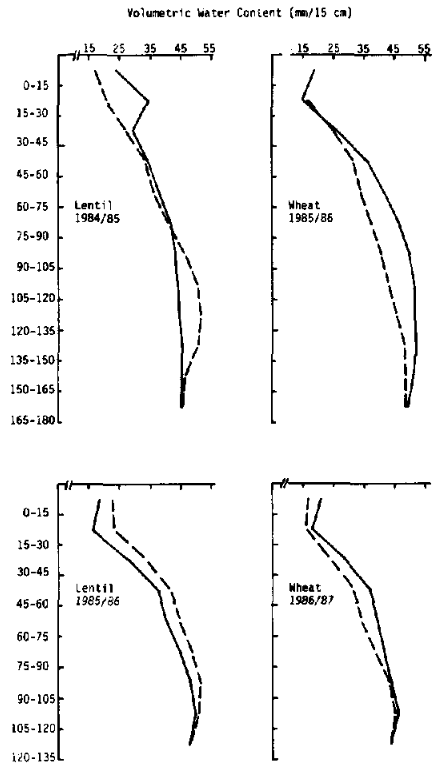


FIGURE 2.14 Soil water profiles at the start (solid lines) and end (dashed lines) of growth of lentil (left) and following wheat (right) crops.

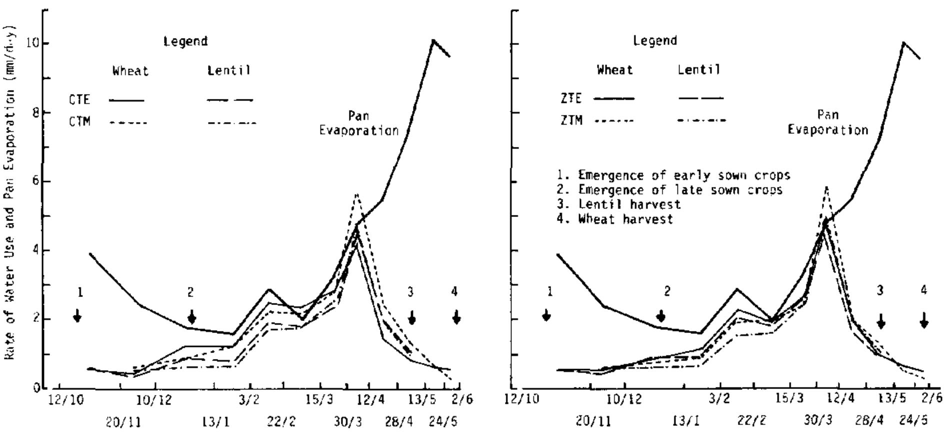


FIGURE 2.15 Rate of water use (mm/day) of wheat and lentil crops in response to 4 tillage treatments in 1986/87, and rate of pan evaporation.

period. The very rapid fall off in rate of use from the middle of April illustrates one of the major constraints to crop production in the environment, namely the regular occurrence of drought in the terminal stages of crop development.

Crop yield and water use efficiency. There was a striking difference in lentil yield between 1985/86 and 1986/87, two years with similar total rainfall (Table 2.9), but somewhat different distribution. Part of the difference arose from poorer establishment in 1985/86, but part was also due to a longer period of stress during late growth stages in the same year. Maximum soil water storage (120 mm) occurred in mid-February. After that time temperatures and evaporation rates were higher than normal and the crop matured by the end of April before late rains. In the following year, maximum soil water storage (150 mm) occurred four weeks later. Temperatures were mild and evaporation rates not excessive. The lentil crop duration was 15 days greater and yields increased by a factor of 3 to 4 (Table 2.9). Mean water use efficiency for seed yield was 1.5 kg/ha/mm in 1985/86, but 4.9 kg/ha/mm in 1986/87. There were no differences in yield in response to tillage treatment in either year, but later sown crops outyielded the early ones in the second season. Water use efficiencies therefore also showed no consistent trend with tillage treatment.

Again the results for wheat contrast with those for lentil. There was much less difference in wheat yield between the two years, presumably reflecting the different degree of stress tolerance of cereals and legumes. In addition, soil water not used by the 1984/85 lentil crop obviously provided considerable buffering against terminal drought for the 1985/86 wheat crop. In both seasons conventional tillage gave higher yields and greater water use efficiency than zero tillage (Table 2.9).

Soil physical parameters. The infiltration capacity of soil under the different tillage treatments was examined. A rainfall simulator (Asseline and Valentin 1977) was used to measure the time, at a range of constant rainfall intensities from 35 to 100 mm/h, for surface saturation of air dry soil to occur. The work was carried out on the part of the plots which had grown lentil in the 1986/87 season. The lentil was hand harvested in May, when all plant material was removed. A hail storm in June left the surface uniformly weakly crusted. This was broken up gently with fingertips and the simulated rainfall applied until free water was present at the surface, but no ponding had occurred.

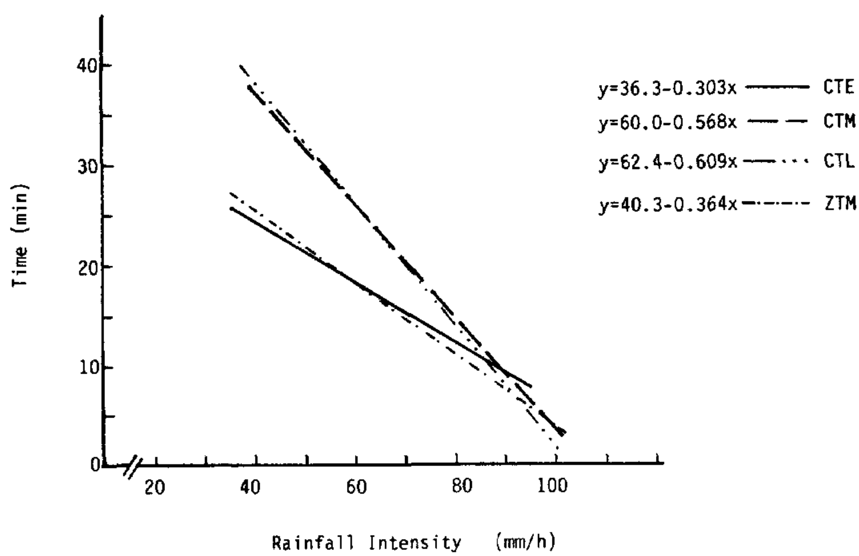


FIGURE 2.16 Time (minutes) for surface saturation of air dry soil under a range of rainfall intensities following 8 years of different tillage practices

The rate of infiltration in the CTE and ZTM plots was lower than in either of the other conventional tillage treatments (Fig. 2.16). This appears to support visual observations that the structural integrity of the CTE plots has been affected by the tillage methods applied. Certainly, there are fewer large clods in this treatment following deep discing. It might be supposed that working the soil in a dry state has caused greater disruption to the ped structure, but more conclusive evidence awaits laboratory analysis.

There is some suggestion in the pattern of soil water contents in the profiles that compaction is occurring in the 15-30 cm layer of soil (Fig. 2.17). Measurement of saturated bulk density is planned for the next rainfall season.

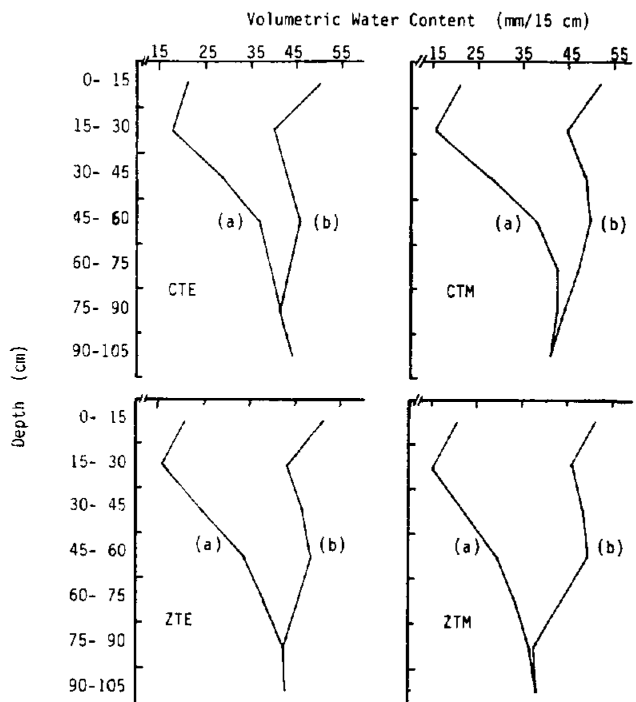


FIGURE 2.17 Soil water profiles at the end of summer (a) and at maximum recharge (b), in 1986/87, following 8 years of different tillage practice

2.3.4 Other Tillage and Stubble Work in Progress

Long-term tillage trial. A long-term tillage trial was established on Tel Hadya in 1985/86 to compare local practice with reduced tillage. The treatments are imposed within 2 three-course rotations — breadwheat/chickpeas/melons and durum wheat/lentil/melons. Primary tillage treatments are deep discing, deep chisel ploughing, duckfoot cultivation and zero till.

To date there have been no effects of tillage treatment on yield, except that it has proved to be difficult to establish melons under zero till conditions and fruit yield is significantly depressed. The major impact of the treatments is expected to be an economic one associated with reduced number and cost of operations. Careful records of all activities are kept to ensure that thorough economic analysis can be carried out.

Stubble management. The effect of stubble retention is being examined at Tel Hadya in two-course rotations of wheat with lentil, chickpeas, vetch, medic, fallow, and melons. Complete wheat stubble retention is being compared with heavy and moderate grazing by sheep. Four levels of nitrogen fertilizer application are superimposed during the wheat phase of the rotations. Factors being monitored include the annual water balance, and soil microbial activity.

This trial too is in the early stages, only one year's data on stubble effects being available. It is expected that several years will be required before we can draw any firm conclusions on the response to stubble management.

2.3.5 The Future

Soil is a fundamental resource of farming systems. It is also, for all practical purposes, non-renewable. If agricultural production is to be sustained, let alone increased to meet the demands of increasing populations, it is essential that conservative soil management practices be devised and applied. Current trends for the expansion of mechanized farming into ever more marginal areas (Tully 1986) increase the urgency of the problem.

Within ICARDA, long-term work on Tel Hadya will be continued with the objective of relating tillage practice and crop residues management to the maintenance and improvement of soil physical status and the efficient use of water in rainfed conditions. It is urgent that we do not confine the work to Tel Hadya, but seek means to undertake similar studies in a range of environments and on a range of soil types representative of soil diversity in the region.

Because of the deleterious effect of continuous cereal culture on crop yields in the environment (see e.g. PFLP 1988), sustainable production will necessitate the use of rotations in which non-cereal food are forage crops, probably principally of leguminous species, will form a vital component. Crop sequence can affect the response to fertilizer (FSP 1987; Section 2.2.7) and the water balance (FSP 1987; Section 2.3.3) as well as undoubtedly other factors such as the weed flora and soil physical conditions. The long-term studies therefore must be carried out within the common crop rotations of the region, and should maintain a farming systems perspective which includes the impact of livestock within the system.

It is important that this work be of a fundamental nature in order to establish principles which will allow the findings to be extrapolated to other parts of the region. We will draw, where ever possible, on experience in other parts of the world. At the same time we recognize that the combination of heavy soils and a climate with winter rainfall/summer drought is somewhat unique to the region and this may mean that that experience may not be directly transferrable to our purposes.

We should seek to quantify the size and nature of soil loss in the region. There are estimates which suggest that erosion by water causes substantial soil loss (e.g. Nahal 1984). Observations indicate that wind erosion also is important, but we know of no quantification of this. One way to derive estimates is through the use of simulation models. We will seek to collaborate with advanced institutions involved in the development, verification, and calibration of systems models, and in conjunction with work in project 2 of our program, will seek to apply this methodology.

Research on short-term effects of soil management probably should be concentrated on the effects of surface management on efficient storage and use of water. This of necessity would involve agronomic studies on the timing, depth, and direction of tillage. If carried out on-farm it would serve to introduce ideas on alternative management strategies to farmers. It needs must include considerations of weed control, and general crop agronomy.

The work reported above is in its early stages. Initial results indicate that modifications to current costly, and possibly exploitative, tillage practices are feasible. However, we would want to be cautious in drawing firm conclusions. 1986/87 was a favourable season in northwest Syria where the work was done. It may be that in another season the modified practices may be less appropriate.

2.3.6 References

Anon, 1979. Dryland agriculture in winter precipitation regions of the world. Dryland Agriculture Technical Committee, Oregon State University, Corvallis, USA. pp 218.

Asseline, Y. and Valentin, C. 1977. Construction et mise au point d'un infiltrometre a aspersion. **Series Hydrologie** 15, 321-344.

Cooper, P.J.M., Gregory, P.J., Tully, D., and Harris, H.C. 1987. Improving water use efficiency of annual crops in the rainfed farming systems of West Asia and North Africa. **Experimental Agriculture**. 23, 113-158.

Doğan, O., Cimilli, B. and Güçer, C. 1977. Orta Anadolu İklim Koşullarında Nadas-Buğday Tarım Yönteminin Uygulandığı Yörelerde En Uygun Sonbahar, İlkbahar ve Yaz Toprak İşleme Aletleriyle Bu Aletlerle Uyuşabilen Mibzer Çeşitlerinin Saptanması Üzerinde Bazı Araştırmalar. Merkez Topraksu Arş. Ens. Müd. Yayınlari. Genel Yayın No. 45.

Dozom, S. 1986. Effect of tillage systems, weed control, and fertilization on yield, moisture, and weed community. Thesis submitted to Aleppo University, Syria, for MSc degree.

Fischer, R.A. 1987. Responses of soil and crop water relations to tillage. pp 194-221. In, Tillage. New Directions in Australian Agriculture. (P.S. Cornish and J.E. Pratley eds). Australian Society of Agronomy and Inkata Press, Melbourne, Australia.

Güler, M., Durutan, N., Pala, M. and Karaca, M. 1980. A study on fallow systems. Ministry of Agriculture, Central Anatolian Regional Agricultural Research Institute. Publication No. 35/90-1. Turkish.

Hamblin, A. 1987. The effect of tillage on soil physical conditions. pp 128-170. In, Tillage. New Directions in Australian Agriculture. (P.S. Cornish and J.E. Pratley eds). Australian Society of Agronomy and Inkata Press, Melbourne, Australia.

Hodgson, A.S., and Chan, K.Y. 1984. Deep moisture extraction and crack formation by wheat and sunflower in a vertisol following irrigated cotton rotations. pp 299-304. In, The Properties and Utilization of Cracking Clay Soils. (J.W. McGarity, E.H. Hoult and H.B. So eds). Reviews in Rural Science 5. University of New England Press, Armidale, Australia.

ICARDA. 1984. Annual Report for 1983. pp 31-40.

ICARDA. 1986. Annual Report for 1985. pp 87-89.

McGarry, D. 1984. The effect of land management on the physical condition and yield potential of cracking clay soil in the Namoi Valley, New South Wales. pp 292-298. In The Properties and Utilization of Cracking Clay Soils. (J.W. McGarity, E.H. Hoult and H.B. So eds). Reviews in Rural Science 5. University of New England Press, Armidale, Australia.

Nahal, I. 1984. Water erosion in the Syrian Arab Republic and how to combat it for soil and water conservation. **Research Journal of the University of Aleppo**, No. 6, 79-110. Arabic. Eng. Summary.

Özkan, İ., Ünver, İ., Pala, M., Durutan, N., and Karaca, M. 1984. The effects of various tillage systems on the amounts of water stable aggregates in soil. University of Ankara, Faculty of Agriculture, Annual Report Vol. 33, Ankara 1983. Turkish.

Papendick, R.I., Lindstrom, M.J., and Cochran, J.L. 1973. Soil mulch effects on seedbed temperature and water during fallow in Eastern Washington. Soil Science Society of America Proceedings 37, 307.

Soane, B.D., Campbell, D.J and Herkes, S.M. 1973. Cultivations in relation to continuous barley growing. II. Soil physical conditions. Tillage Research Methods. Silsoe, September 7-11, 1970.

Tully, D. 1986. Rainfed farming systems of the Near East region. ICARDA.

Ünver, İ. 1978. Nadas Toprak İşlemesinde Zaman, Derinlik ve Yöntemlerinin, Toprağın Rutubet ve Sıcaklık Değişimine Etkileri. A.Ü.Z.F. Toprak İlmi Kürs. Doktora Tezi. Ankara.

USDA, 1974. Summer fallow in the Western United States. Conservation Research Report No. 17. Agricultural Research Service, United States Department of Agriculture, Washington D.C., USA, pp 160.

2.4 Improved Production Practices for Chickpea: On-Farm Assessments

M. Pala and T. Nordblom

2.4.1 Introduction

About 9.8 million hectares are sown to chickpea in the world as a whole (FAO 1984), which represents only 1.2% of the total cereal + pulses area. However, chickpea accounts for 15% of the total world area of pulses, and 18% of the total chickpea area is found in ICARDA region (Table 2.10).

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the crop are common in most regions due to low moisture level in the seedbed at the time of germination of spring sown crops. Yields are further reduced by increasing stress during flowering and pod filling.

The possibility that winter sown chickpeas would make better use of the available moisture and could be harvested earlier was first pointed out by Hawtin (1975). The climatic conditions of the "lowland" zone of the West Asia and North Africa region have been discussed in detail by Harris (1979), Kassam (1981) and Smith and Harris (1981); it was clear that during the period of vegetative and reproductive growth a winter planted crop would be exposed to relatively lower thermal stress and better moisture regimes than that of the spring-planted crop (Saxena 1981). Thus, winter planting would result in the development of plants with a larger vegetative frame capable of supporting a bigger reproductive structure, leading to increased productivity, and greater water use efficiency (Keatinge and Cooper 1984).

Saxena (1984) showed, at Tel Hadya research station, progressive advancement of the planting date from March 11th to February 13th, December 19th, and November 20th gave corresponding increases in yield of 69, 155, and 250%.

In spite of the many potential advantages of winter over spring sowing, a number of problems had to be resolved, namely development of cultivars with cold tolerance and Ascochyta Blight resistance, controling the greater infestation of weeds, and the identification of appropriate mineral nutritional requirements.

Cold and Ascochyta Blight tolerant cultivars were recently made available through the efforts of ICARDA's breeders. However the winter planted crop faces a more serious weed problem than the spring crop as most of the weeds that would have competed with the spring crop are killed by the preparatory tillage. In the winter sowing, weeds emerge with the crop and this creates serious competition for water, nutrients and light. Chickpea yield losses due to weeds have been estimated to range from 23 to 54% in West Asia (ICARDA 1981).

The traditional local methods of controlling weeds in the region involve hand hoeing during the early crop stage, hand pulling of weeds for fodder, or a combination of both (ICARDA 1978). All weeding systems have been shown to lead to greater yields, but rising labor costs impose increasing limitations on hand weeding in the West Asian region.

Mechanical weed control is a feasible alternative, but requires special and carefully set equipment as well as improved crop sowing geometry. Because of this, chemical control merits appropriate consideration. Several herbicides have been tested in different countries as well as at the ICARDA research station for weed control and crop tolerance. The combination of pre-emergence applications of cyanazine, or terbutryne with pronamide, has proved to be promising for broad-spectrum weed control.

Since the yield levels of a winter planted crop are much higher than those of the spring planted crop, it might be expected that the mineral nutrient requirement of the former would also be considerably higher. On the soils with a poor fertility status the limitation of the mineral nutrients might prove a significant constraint to the realization of the greater yield potential of a winter planted crop. An important dimension to the mineral nutrition of the crop is its capability to meet a major part of its nitrogen required by symbiotic nitrogen fixation, provided the suitable Cicer Rhizobium is present in the soil (either as a native organism or through inoculation) and no other mineral nutrient is limiting the functions of the symbiotic association.

If the potential demonstrated in research trials in Syria can be repeated throughout the region, and extended to its farmers, it might be expected that total production could be increased from its present level of just over 1 million tonnes to almost 2 million tonnes. Such a target might even be exceeded if areas which are currently considered too dry for chickpeas (down to the 250 mm isohyet) are brought into cultivation of the winter sown crop.

2.4.2 On-Farm Trials in Syria

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

2.4.3 Treatments Applied

Except for half of the plots in the second year, all soil was prepared and seeds sown according to the farmers' method: hand broadcasting seed over ridged land, and subsequent splitting of the ridges with a ducksfoot cultivator (see Fig. 2.10, Section 2.3.2). The treatments imposed in the two years are given in

Table (2.11).

TABLE 2.11 Treatments imposed in on-farm chickpea trials in 1985/6 1986/7

	1985/86	1986/87
Number of locations	8	6
Trial design	2^4 factorial	2^5 factorial
No. of replicates/ location	2	1
Cultivar	ILC 482	ILC 482
Treatment imposed		
a) Time of sowing	Winter.v.Spring	Early winter.v.Late winter
b) Rhizobium inoculation	+ .v. O	+ .v. O
c) Weed control	Chemical[1].v. O	Chemical[1].v.Hand weeding
d) P_2O_5 (kg/ha)	50 .v. O	50 .v. O
e) Sowing method[2]	na	Broadcast.v.Single pass planter (SPP)

1. Chemical weed control: Terbutryne + pronamide, 2.0 + 0.5 kg ai/ha.
2. 100 kg/ha seed rate used in both years.

2.4.4 Pooled Analyses for 1985/86 and 1986/87

The main effects, first order interactions and levels of significance for grain yield responses of chickpea are presented for each year in Table (2.12). Unlike the case of lentils, chickpea straw has little economic value as animal feed so straw yields are not considered in this or subsequent analyses. However, the responses observed in straw yields were similar to those reported for grain.

TABLE 2.12 Main effect and first order interaction of chickpea yield responses in Syria (kg/ha)

Treatment[1]			1985/86[2]		1986/87[2]
Time of sowing	(Early	Dec 85	1409**	Dec 86	1797**
	(Late)	Mar 86	1168	Jan 87	1335
Inoculation	(+)		1332*		1538*
	(0)		1265		1594
Weed control	(Chem)		1387**		1498**
	(Other)[1]		1196		1634
P_2O_5 (kg/ha)	50		1348**		1660**
	0		1229		1471
Sowing method	(SPP)		na		1641**
	(broadcast)				1490
LSD (0.05)			67		54

First Order Interaction

		Weed control		Sowing method	
		+	-	Bdcst	SPP
		**		**	
Time of sowing	(Early)	1572	1246	1661	1933
	(Late)	1227	1149	1320	1350
LSD (0.05)		94		76	

1. See Table 2.11 for details
2. * p<0.05
   ** p<0.01

Advancing the date of sowing resulted in substantial yield increases in both years quite consistently across locations and years, with 10 out of 14 trials giving significant responses. The response to early sowing was reduced in the first season due to a severe infestation of Heliothis spp at the pod formation stage in winter sown chickpea. Effects of inoculation were small and inconsistent: in the first season, 6 out of 8 trials showed a positive response, whereas in the second season all sites indicated a small negative response which was significant in the pooled analyses of variance.

Chemical weed control was clearly effective. In the first season it resulted in consistent yield increases compared with no weed control. As indicated in the introduction, weeds pose a more serious threat in winter planted chickpea, and this was again confirmed by a significant interaction between time of sowing and herbicide use. In the second season, chemical weed control was effective, but hand weeding gave significantly higher yields at 4 out of 6 locations. The relative merits of the two methods are discussed further in the next section where the economics of the two practices are compared.

Significant responses to phosphate were observed in both years, but the response was erratic with only 6 out of 14 sites showing positive responses. Significant interactions (not shown in Table 2.12) indicated that in the first year responses to phosphate were greater in the presence of weed control, and in the second year were greater in the early sown chickpea than in the later sown crop. Other research on wheat and barley has indicated clear relationships between native levels of available-P (Olsen-P) and responses to phosphate. However, in both years, no such relationship was found for chickpea. For cereals approximately 5ppm Olsen-P has been identified as the critical level above which responses will be small or absent, and in trials in which the phosphate was placed with the seed, Matar et al. (1987) have reported a critical level of 7ppm Olsen-P for chickpea. However, in these trials at one site with about 20ppm Olsen-P gave significant responses, and others with less than 5ppm gave no response at all. Currently, it is not clear why the conflicting results have been obtained, and more research is required.

In the second season, method of sowing was investigated. Drilling the seed with the Single Pass Planter gave substantial yield increases over broadcasting (discussed in more detail and with reference to other crops in Section 2.3.2 of this report.) However, as indicated in Table 2.12 there was a strong interaction between time of sowing and method of sowing, with far greater responses to drilling being observed in the early sowing treatments. Very wet soil conditions in the late sowing affected the efficiency of the planter indicating the importance of timing of operations on these heavy clay soils for the right field conditions.

2.4.5 Economic Analysis and Conclusions

In the second season (1986/87), one of the six sites produced extraordinarily high yields (about double the mean of the other five sites), and showed almost no response to main treatment factors. Observations from this favored location were, therefore, not included in the economic analysis. The mid-winter (January 1987) sowing at the five sites produced mean yields (1042 kg/ha) comparable to those obtained by nine farmers with spring sown local chickpeas (991 kg/ha) in another set of trials organized by FLIP this season. The early winter sowing, likewise, gave comparably higher yields in the two sets of trials, 1605 and 1574 kg/ha, respectively.

As in the previous season, the economic results follow the results for biological yields because the costs of all

Treatment number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Sowing Date: Winter (W), Spring (S)	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W
Rhizobium inoculation (0) (+)	0	0	+	+	0	0	+	+	0	0	+	+	0	0	+	+
Preemergence herbicide (0) (+)	0	0	0	0	+	+	+	+	0	0	0	0	+	+	+	+
Phosphate fertilizer (0) (+)	0	0	0	0	0	0	0	0	+	+	+	+	+	+	+	+

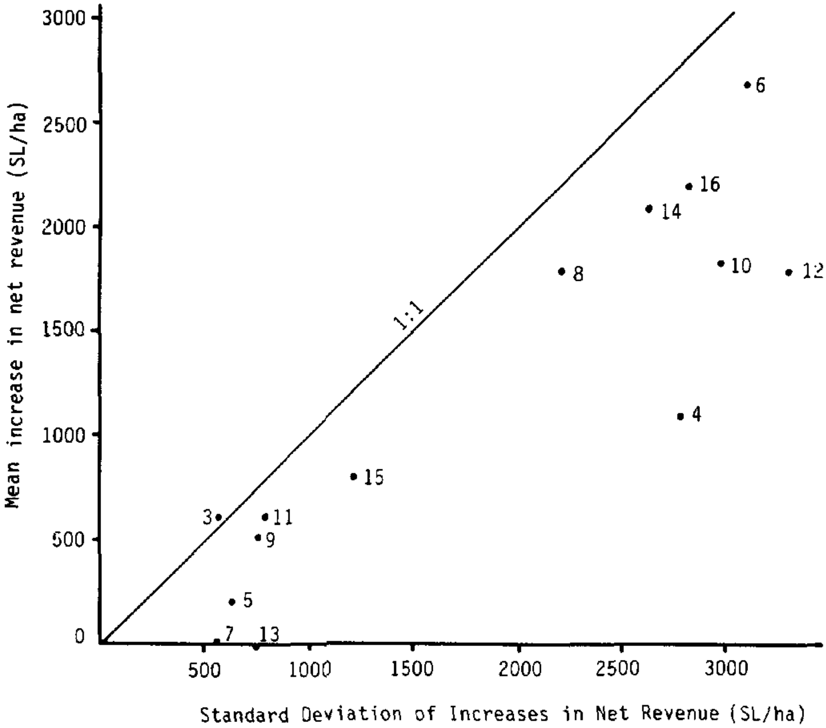

FIGURE 2.18 Risk analyses of chickpea agronomy treatments at eight locations in NW Syria, 1985/86

treatments were relatively low compared to crop values. In both seasons, the base treatments for economic analysis were those with the lowest levels of inputs. Average increases in net revenues were plotted against standard deviation of increases in net revenues for both season and shown in Fig. 2.18 and 2.19.

Net revenues for each set of treatments were calculated by assigning costs for each of the treatment elements (for field scale applications) and subtracting these from the products of

Treatment No.:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Sowing Method:	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S	B	S
Weed Control:	H	H	C	C	H	H	C	C	H	H	C	C	H	H	C	C	H	H	C	C	H	H	C	C	H	H	C	C	H	H	C
Phos. Fert.:	0	0	0	0	+	+	+	+	0	0	0	0	+	+	+	+	0	0	0	0	+	+	+	+	0	0	0	0	+	+	+
Inoculation:	0	0	0	0	0	0	0	0	+	+	+	+	+	+	+	+	0	0	0	0	0	0	0	0	+	+	+	+	+	+	+
Sowing Date:	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L

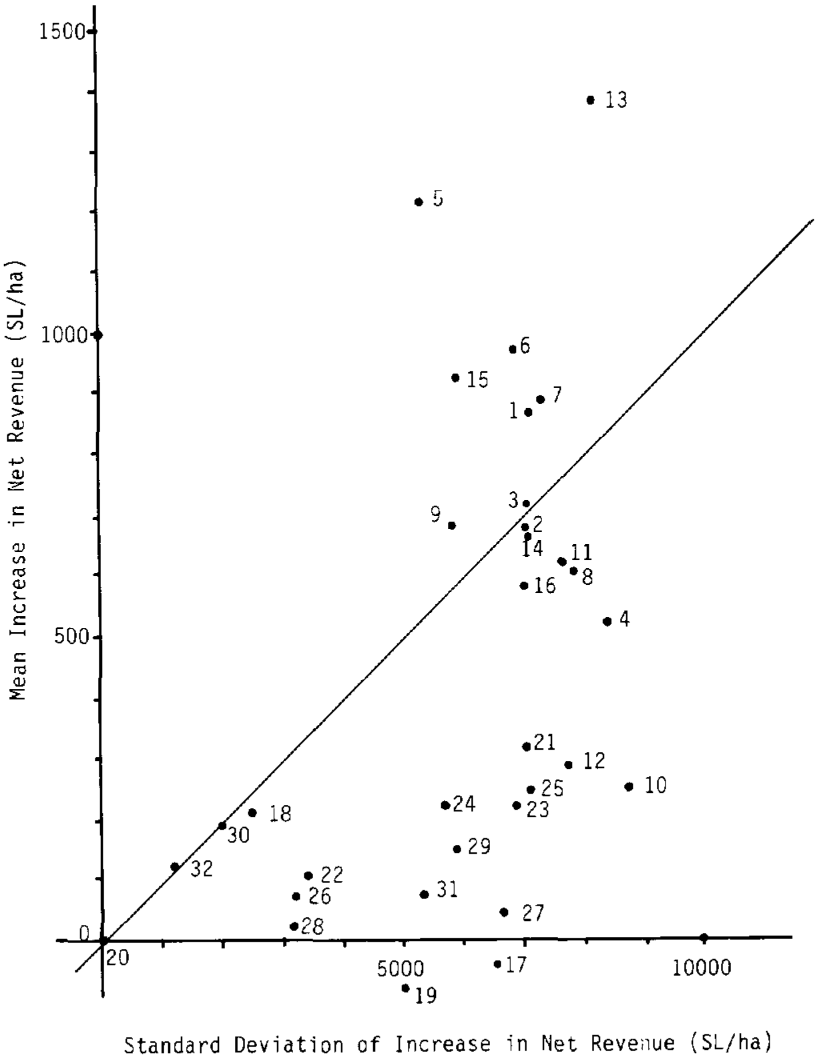

FIGURE 2.19 Risk analyses of chickpea agronomy treatments at six locations in NW Syria, 1986/87

seed price and yields. The base treatment in the first season was comprised of spring planting with no weed control, no fertilizer and no inoculation. In the second season, the base treatment for economic analysis was one sown by broadcasting over ridges in late winter, with chemical weed control and neither fertilizer nor inoculation.

Only four treatments among the 32 in the second season were the same as ones in the previous year (the ones which had given the highest increases in net revenue over the base treatment). These four common treatments were all sown in early winter by broadcasting over ridges, and all had chemical weed control. They were distinguished from each other by application, or non-application, of phosphate fertilizer and inoculant.

Results with the four common treatments in the second season were like those in the previous season, in the sense that they were closely clustered together in the dimensions of mean increase in net revenue and standard deviation of increase in net revenue. In both seasons, the poorer of the four treatments was the one without fertilizer but with inoculation (Fig. 2.18 and 2.19).

In both seasons, the four common treatments were characterized by highly variable responses across experimental sites; the standard deviations of increased revenues were at least 1.2 times the respective mean increases in net revenues. These variations were apparently due to differences between site environments.

The fact that results for the four common treatments were similarly distributed in the two years suggests the need to characterize the sites (e.g., on rainfall and soil type) in a way that would allow separate analyses for each type of site, and to control for non-treatment effects in future trials by selection of sites with common soils and climates.

Of course, even if all sites had the same soil and long-run climatic characteristics, somewhat variable results should still be expected due to differences in local sequences of weather events during the growing season, with frosts or heavier rains (for example) at some sites and not at others. This problem is discussed in more detail in the section on Project II, "agro-ecological characterization for management".

In spite of the variations across sites, there were some consistent trends over the two years. The first of these is the boost in net revenue from winter planting in early December with a new cultivar tolerant to cold and to Ascochyta Blight: the winter chickpea is established in time to take advantage of rains early in the season before the coldest part of the winter. Weed control was profitable in combination with early winter sowing in both seasons, with hand-weeding being more profitable than chemical weed control when the two methods were compared in the second season.

Hand-weeding was done two times at a cost of SYP 500/ha each time. Although hand-weeding was more effective than chemical weed control, the availability of labor to accomplish this work will likely be the deciding factor and is expected to vary from place to place. Therefore, it will be wise to continue the research on chemical weed control in the future. It is worth mentioning here that attention is being given by ICARDA to human health factors, in terms of safety of farmers handling pesticides and in terms of monitoring for chemical residue in the crop and soil.

Inoculation of seed with rhizobia gave mixed results in both seasons and, on average in each season, was unprofitable; the cost of this treatment was not covered by yield increases. However, when chickpea cultivation is extended to drier areas, where this crop has not been grown in recent decades, and populations of Cicer Rhizobium are not present, inoculation may become profitable. In the main chickpea growing areas this factor no longer needs to be included in the trials.

In both seasons, phosphate fertilizer was profitably applied to the chickpea crops sown in early winter. The effect, generally, was an increase in net revenue without a corresponding increase in income variability between sites: a stabilizing influence. Results were less consistent, however, in the cases of spring and late winter sowing; phosphate fertilizer was not always profitable. This shows the strong interactive effects of two agronomic factors (early sowing and phosphate fertilizer) made possible by the winter chickpea cultivar.

Compared to the traditional sowing method of broadcasting over ridges, use of the single-pass-planter gave a strong boost to net crop revenues in the case of early winter sowing. However, in the case of late winter planting, there was on average no increase in the net revenues, but a mixture of relative gains and losses across sites.

The need for more complete site characterization will be followed up in the 1987/88 season. This will allow separate biological and economic analyses for each ecological class of sites representing the main growing areas over the three years. This is expected to lead the way to simpler, larger-scaled and wider-spread farmer-managed trials in collaboration with FLIP and the Syrian Ministry of Agriculture and Agrarian Reform in the 1988/89 season. These trials, in turn, should lead to clear identifications of recommendation domains, by the Syrian national program, for agronomic practices which will take best advantage of the winter chickpea potentials for yields and farm profits under different agro-ecological conditions.

2.4.6 References

El Mott, M.S. 1984. Chickpea production in Syria. In proceedings of International Workshop in Ascochyta Blight and Winter Sowing of Chickpeas (M.C. Saxena and K.B. Singh, eds.), pp. 201-206, ICARDA, 4-7 May 1981, Aleppo, Syria.

FAO (Food and Agriculture Organization) 1984. FAO Production Yearbook, Vol. 38, Rome, Italy.

FLIP, 1986. Food Legume Improvement Program Annual Report, ICARDA, Aleppo, Syria.

FSP, 1986. Farming Systems Program Annual Report, ICARDA, Aleppo, Syria.

Harris, H.C. 1979. Some aspects of the agroclimatology of west Asia and north Africa. pp. 7-14 in Food Legume Improvement and Development (Hawtin, G.C. and Chancellor, G.J. eds.), ICARDA, Aleppo, Syria and IDRC, Ottawa, Canada.

Hawtin, G.C. 1975. The status of chickpea in the Middle East. In Proceedings of International Workshop on Grain Legumes. pp. 109-116, ICRISAT, 13-16 Jan., 1975, Hyderabad, India.

ICARDA. 1978. Annual Report - Weed Control Section 1977-78, Aleppo, Syria.

ICARDA. 1981. Annual Report, p 164, Aleppo, Syria.

Islam, R. 1984. Nodulation aspects of winter-planted chickpeas. In Proceedings of Int. Workshop in Ascochyta Blight and winter sowing of chickpeas (M.C. Saxena and K.B. Singh, eds.), pp. 159-166, ICARDA, 4-7 May 1981, Aleppo, Syria.

Kassam, A.H. 1981. Climate, soil and land resources in north Africa and west Asia. pp. 1029 in Soil, Water and Nitrogen in Mediterranean-type Environments (Montieth, J. and Webb, C. eds.), Martinez Nijhoff, Dr. W. Junk Publishers, The Hague, The Netherlands.

Keatinge, J.D.H. and P.J.M. Cooper 1984. Physiological and moisture-use studies on growth and development of winter-sown chickepas. In Proceedings of Int. Workshop in Ascochyta Blight and Winter Sowing of Chickpeas (M.C. Saxena and K.B. Singh, eds.), pp. 141-157, ICARDA, 4-7, May 1981, Aleppo, Syria.

Matar, A.E., Saxena, M.C. and Silim, S. 1987. Soil test calibration for phosphorus with five food and forage legumes in Syria. In Proceedings of the 2nd Regional Workshop on Soil test Calibration, ICARDA, 1-6 September 1987, Ankara, Turkey.

Saxena, M.C. 1984. Agronomic studies on winter chickpeas. In Proceedings of Int. Workshop in Ascochyta Blight and Winter Sowing of Chickpeas (M.C. Saxena and K.B. Singh, eds.), pp. 123-140, ICARDA, 4-7 May 1981, Aleppo, Syria.

Smith, R.C. and Harris, H.C. 1981. Environmental resources and restraints to agricultural production in a Mediterranean-type environment. pp. 31-57 in Soil, Water and Nitrogen in Mediterranean-type Environments (Montieth, J. and C. Webb, eds.), Martinez Nijhoff, Dr. W. Junk Publishers, The Hague, The Netherlands.

2.5 Water Management of Spring Wheat: Supplemental Irrigation

Eugene Perrier and Abdul Bari Salkini

2.5.1 Introduction

Supplemental irrigation contrasts with irrigation which supplies the entire water needs where rainfall is insufficient for plant growth during all, or most, of the growing season. In semi-arid areas, where the climatic risk to crop production is high, supplemental irrigation can alleviate risk, stabilize yields, and make possible the use of high inputs such as high yielding cultivars, fertilizers, herbicides, etc. More intensive cropping is promoted, and greater opportunity for choices in crop and soil management is created by its use.

By developing water supplies and systems for supplemental irrigation farmers provide themselves with an insurance against crop loss through drought. The resulting better and more stable yields normally lead to improvement of farm management and adoption of more sophisticated farming and marketing methods. For maximum yield in the region a wheat crop needs 350-450 mm of water. Supplementation to this level should ensure yields of at least 5 t/ha from existing improved genotypes, and food bring security which allows improvements in general technology.

Many agronomists and agricultural engineers schedule irrigation according to soil water availability at all stages of plant growth. However, consideration of economic concepts indicates that it is beneficial to irrigate at critical stages of plant development, and "limited water or deficit irrigation" can lead to efficient grain production (Shipley 1977, Marttin and van Brochlin 1985). In these methods both the water balance and the stage of crop development are used to schedule irrigation at the optimal time to maximize economic production.

The objectives of research and development activities are:

a. to improve supplemental irrigation practices;
b. to determine plant cultivars and levels of fertility that give response to supplemental irrigation;
c. to estimate consumptive use; and,
d. to determine irrigation scheduling requirements under local conditions.

Attainment of these objectives will ensure the effective and efficient use of water for economically increasing yields and sustaining crop production.

2.5.2 Growth Responses of Spring Wheat in the Near East and North Africa

Wheat is usually planted during November and December in the Near East and North Africa. Germination in moist soil, which can be ensured by supplemental irrigation, takes about 5 days. Crops that germinate in mid-November with adequate soil water establish good ground cover before low temperatures limit growth. They readily survive the winter as temperatures rarely fall below $-10^{o}C$. Stem, or culm, elongation begins in mid to late February when temperatures rise. Rapid crop growth and increasing vapor pressure deficits at this time accelerate the rate of water use. Plants reach the boot stage, when the tip of the flag leaf becomes visible (Kirkham and Kanemasu 1983, Finkel 1983) in mid to late March, and heading occurs normally in late March to mid-April, depending on the cultivar. Anthesis (flowering) follows within 1 to 2 weeks, and grain development takes place during May and early June.

Wheat plants are resistant to quite severe water stress during early growth, and during grain-filling. However, stress in the boot stage and during heading and anthesis will depress yield. These are growth stages when the crop canopy is increasing or complete and the rate of water use is high. Evapotranspiration rates increase from about 50% of pan evaporation at the start of stem elongation to 80 to 110% at heading and anthesis. Maximum soil water recharge from rainfall is recorded between mid-February and mid-March depending on the season and location (see, e.g., Section 2.3.3). After that time, a decrease in rainfall and the increased evapotranspiration rates leads to rapid soil water deficits in rainfed crops.

After anthesis the rate of water use diminishes to 20% of pan evaporation during grain-filling. However, in this stage the crop is sensitive to water stress which can result in shriveled grains.

As well as temperature, the rate of plant development, depends on four main factors of management (Shalhevet et al. 1976).

1. Early germination results in early heading; however, late germination may not delay heading (dependent on photoperiodism and other characteristics of cultivars);

2. Lack of water during the boot stage hastens maturation; however, deficiency of water earlier in growth may also affect the time of heading;

3. Nitrogen deficiency causes early heading;

4. Phosphate deficiency delays heading;

Two important questions for supplemental irrigation must be specified to manage the large variation in intra-seasonal water use by wheat in accordance with the stages of development when the plants are sensitive to soil water stress.

When should supplemental irrigation be applied to give the highest return? When the plant available water in the root zone is below 50% (Doneen and Westcot 1984). When to schedule this irrigation can be estimated by calculating the crop water balance and examining the stage of plant growth. Research should verify the existing farmers' method (Syria for example; adding one or two light supplemental irrigations each season) and compare them with alternatives which have been experimentally tested to determine recommendations for schedules and amounts.

How much water should be applied when plant available water falls below 50%. This question is probably best answered by analyzing historical weather records from the region. A water balance computed from these data identifies, as would be expected, a range in the number of irrigations required (ranging, for instance, from 0 to 15 at Aleppo), but a preponderance of seasons in which only one or two would be necessary to avoid a depression in wheat yield. In general, these supplemental irrigations would be required during the period when rainfall is declining and peak water demands are occurring (flowering to soft dough stage). Historical data show that in most cases, 20 mm applied at this time would prevent yield depression in spring wheat, but in some years of how rainfall and severe end of season drought, a second application of 20 mm would also be required.

2.5.3 Design for Supplemental Irrigation Research at Tel Hadya

To investigate concepts of supplemental irrigation that require verification, studies were implemented in the 1985/86 and 1986/87 seasons. An experiment was laid down in a split block design with 4 replications and 4 supplemental irrigation treatments.

The supplemental irrigation treatments, which were applied with gated pipe when the deficit in plant available water in the soil profile was 50% of the maximum storage capacity, were:

1. Rainfed (no irrigation)
2. Irrigated to replace 33% of the deficit
3. Irrigated to replace 66% of the deficit
4. Irrigated to replace 100% of the deficit.

The sub-treatments in 1985/86 were 4 levels of nitrogen (0, 70, 140, 210 kg N/ha), and in 1986/87 were 4 cultivars (Bread wheat: Sham IV and Mexipak; Durum wheat: Sham I and Sebou). In the first year, 40 kg N/ha were broadcast and incorporated at planting on the nitrogen treatments and the remainder was top dressed at tillering in mid-February. In 1986/87 40 kg N/ha were applied at planting and 60 kg were top dressed, and in both years 80 kg P_2O_5/ha were broadcast and incorporated at planting.

Rainfall at sowing time was inadequate in both seasons. An irrigation for germination was applied; in 1985/86 30 mm to all plots and in 1986/87 20 mm to all but rainfed plots. Scheduling of supplemental irrigation was done by the water balance method employing Class A pan evaporation measurements, and the estimates were verified with gravimetric soil samples or neutron soil moisture measurements.

2.5.4 Weather Conditions 1985-87

Figure 2.20 shows the weekly mean temperature for both seasons, from the first week of February to the last week of May. Temperature was above average in 1986 which hastened crop development. Stem elongation began in mid-January, heading occurred during mid-March and anthesis in early April (Table 2.13). In 1987, the lower temperatures were observed and these plant growth events occurred 15 to 17 days later. At the final stages of maturation, the temperature in 1987 exceeded that during 1986.

TABLE 2.13 Dates of occurrence of growth stages for wheat at Tel Hadya, 1986 and 1987

Year	Stage of growth		
	Vegetative	Heading	Anthesis
1986	10/01	17/03	3/04
1987	26/01	3/04	18/04

Total seasonal rainfall was the same in both seasons but the distribution differed, leading to the application of different quantities of supplemental irrigation (Table 2.14). In both years

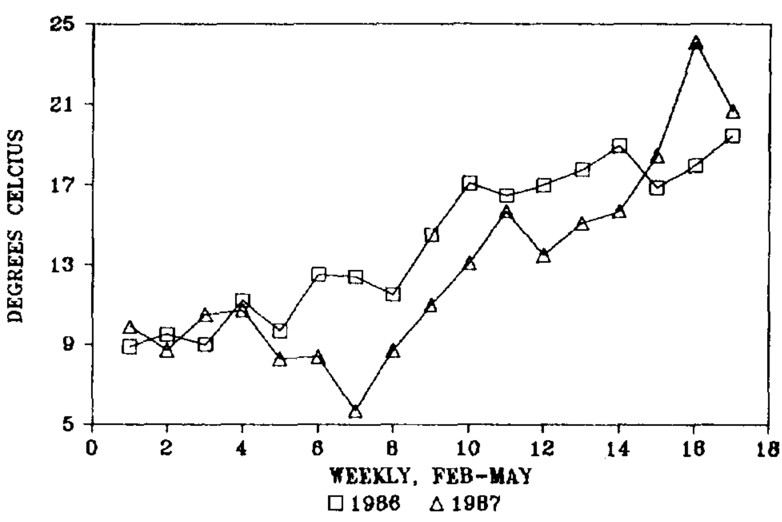

FIGURE 2.20 Weekly mean air temperatures at Tel Hadya, Syria, during 1986 and 1987

rain in January and early February provided good soil water storage. In 1986, intermittent rain continued to mid-May, but was insufficient to meet crop requirements during stress-sensitive growth stages, irrigation was applied on March 23 during heading and April 16 at the end of anthesis. Two further irrigations, on May 3 when the crop was in the soft dough stage and on May 18 during maturation, were applied but probably not required.

TABLE 2.14 Quantity of water (mm) applied and rainfall for the supplemental irrigation treatments for the 1985/86 and 1986/87 growing seasons at Tel Hadya

Irrigation levels	Rainfall	Irrigation at germination	Supplemental irrigation	Total
1985/86				
Rainfed	315	30	0	345
1/3rd replenishment	315	30	120	465
2/3rds replenishment	315	30	240	585
Total requirement	315	30	360	705
1986/87				
Rainfed	316	0	0	316
1/3rd replenishment	316	20	40	376
2/3rds replenishment	316	20	80	416
Total requirement	316	20	120	456

In 1987, good rain continued into March, but rain ceased after April 1. Two irrigations were needed; one on April 20 near the end of anthesis; and, one on May 7 when the wheat was in the milk stage to avoid yield depression through stress at these highly sensitive development stages. Table 2.14 shows the water added as supplemental irrigation, and the total available to the crops for the season.

The pattern of water demand, relative to Class A pan evaporation, is shown in Fig. 2.21, where the Crop Coefficient

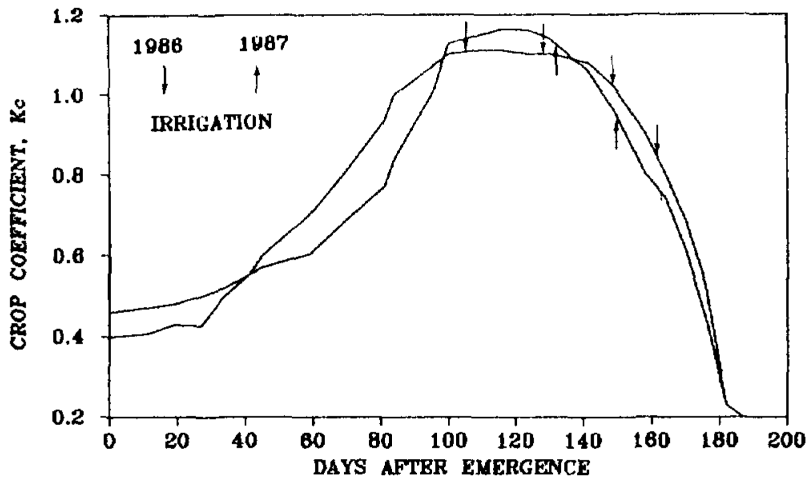

FIGURE 2.21 Seasonal variation of crop coefficient (Kc) of spring wheat at Tel Hadya, Syria, during the 1986 and 1987 seasons

(Kc) is plotted against days after emergence. This illustrates the increase in water demand which follows stem elongation, and reflects the difference between the two seasons. The advanced development in 1986 had a steeper increase than in 1987, and this, coupled with the different rainfall distribution, required irrigation 28 days earlier. The rate of water use by both crops was greater than pan evaporation for a prolonged period, especially in 1986. The shorter duration of maximum evapotranspiration rate in 1987 was caused by high temperatures in late May and the crop matured prematurely.

2.5.5 Results

Statistical analysis showed that there was no yield difference between the supplemental irrigation treatments in either year. This report compares the rainfed (RF) treatment and the first (33%) level of supplemental irrigation (SI). In the first year 70 kg N/ha enhanced yield but further N application had no effect.

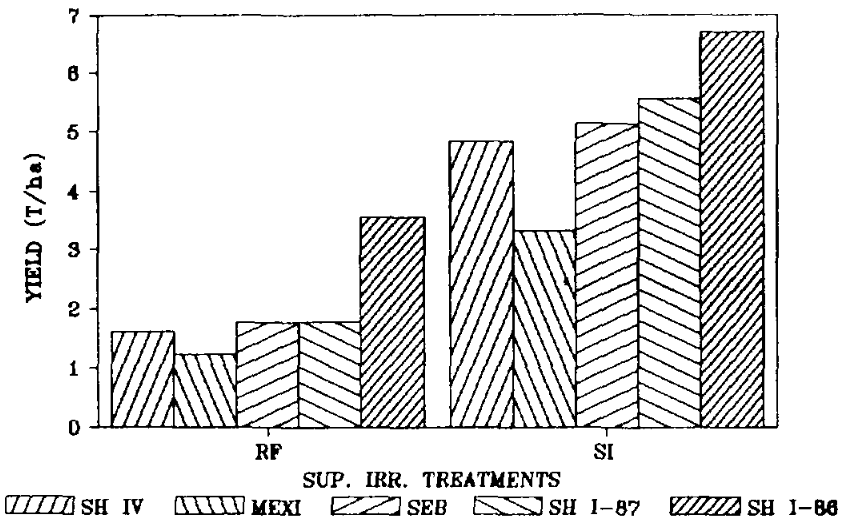

FIGURE 2.22 Grain yield of four wheat varieties under rainfed and 1/3 water deficit replacement in 1987, and Sham I in 1986

Grain yield of Sham I wheat at field moisture content (9-10% grain moisture) was increased by supplemental irrigation from 3.5 t/ha to 6.6 t/ha in 1986, and from 1.7 to 5.4 t/ha in 1987 (Fig. 2.22). Similar increases were recorded for Sham IV and Sebou in 1987, but Mexipak was less responsive to supplemental irrigation. These data emphasize that the timing of irrigation is as important a factor for increasing grain yield as the amount added. All cultivars demonstrated that growth under some water stress conditions did not limit grain yield when supplemental irrigation was available at key growth stages.

The difference in yield of the "rainfed" treatment between the two seasons can be attributed to the application of 30 mm of water to establish all plots in 1985/86. Early and timely crop establishment can be a major benefit of supplemental irrigation.

The components of yield (Table 2.15), show that tiller survival (head number), spiklet number (head length), and kernel weight (1000 grain weight) all contributed to the increased yield. Straw weight also increased, an important fact in an environment where straw provides feed for sheep flocks and can have a cash value almost the same as that of grain. The increase in straw yield was partly attributable to an increase of 10 cm in plant height induced by supplemental irrigation (data not shown).

TABLE 2.15 Summary results of plant components which contribute to yield formation

Variety	Heads/ha x 10^6		Head length (cm)		Weight/1000 grains (gm)		Straw wt. (t/ha)	
	RF	SI	RF	SI	RF	SI	RF	SI
1986								
Sham I	6.08	11.84	4.40	5.40	30.95	41.68	3.71	6.68
1987								
Sham IV	6.70	9.00	7.73	8.20	23.35	36.95	4.40	7.59
Mexipak	4.58	7.13	8.23	9.15	27.18	37.98	4.05	7.44
Sebou	5.86	7.65	7.00	7.18	27.40	51.20	5.51	9.07
Sham I	6.75	7.58	6.38	7.38	28.05	48.15	4.84	8.60

The 4 cultivars in the second season showed expected differences in weight/1000 grains, the bread wheat having smaller kernels than the durums. The reduction in grain size in the durum wheats in the rainfed treatment was more severe than in the bread wheats, possibly reflecting an inherent longer crop duration in the durums. Response in this growth component to supplemental irrigation accounted for the major part of the grain yield

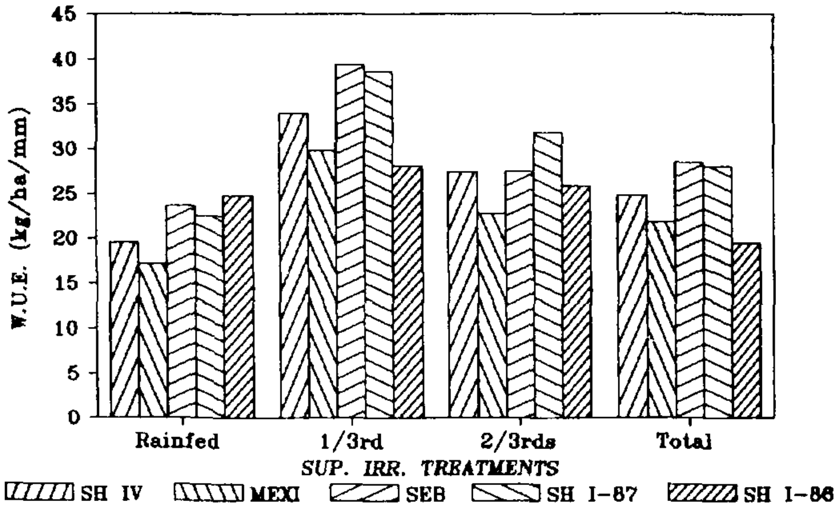

FIGURE 2.23 Water use efficiency of grain yield production of spring wheat under rainfed and supplemental irrigation at Tel Hadya, Syria in 1986 and 1987

response of the durum wheats, especially Sebou. The yield reduction of Sham I for 1987 is a function of the late season high temperature that forced the plants to early maturity.

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

$$WUE = \frac{\text{Biological yield (kg/ha)}}{\text{Total water applied (mm)}}$$

where the biological yield is the sum of grain and straw, and total water is the sum of precipitation and supplemental irrigation. Fig. 2.23 shows clearly the benefit in WUE achieved by the application of limited amounts of supplemental irrigation. If the response to supplemental irrigation is calculated as

$$WUE_{(irrig)} = \frac{\text{Increase in biological yield}}{\text{Irrigation water applied}}$$

Sham I produced 58 kg/ha/mm in 1985/86 and 124 kg/ha/mm in 1986/87.

2.5.6 Economics of Supplemental Irrigation of Spring Wheat

The economics of supplemental irrigation compares system costs with the market value of wheat grain, straw and stubble in the short-term. An irrigation should only be applied if the expected gain is greater than the cost of application.

Data by Soumi (1987) and pumping tests in the Aleppo Province of Syria reported by MAAR showed that the cost of water pumped was 0.34 SYP/m^3. Returns were estimated using values of 2.5 and 2.6 SYP/kg for bread and durum wheats respectively, and 0.85 SYP/kg for straw. Results of a partial budget analysis are shown in Fig. 2.24.

Supplemental irrigation increased net revenue for grain by approximately threefold, and more than doubled the net benefit.

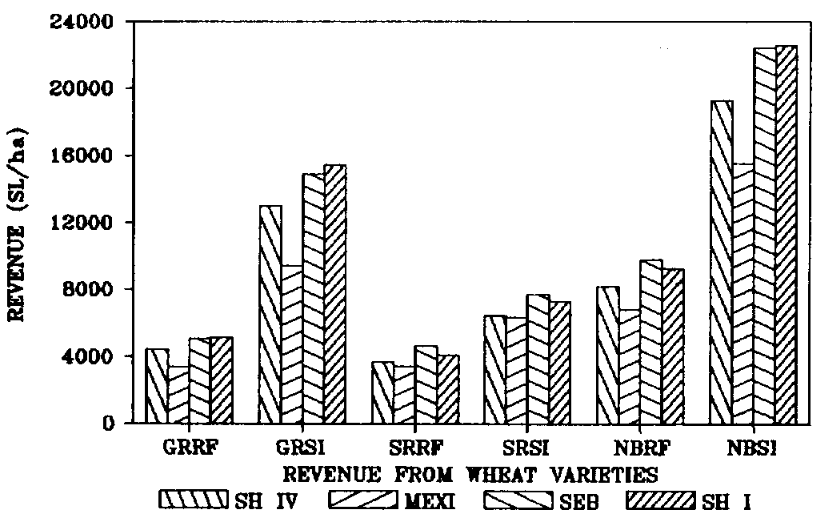

FIGURE 2.24 Partial budget analysis for supplemental irrigation of spring wheat varieties in 1987 at Tel Hadya, Syria

Whereas, in 1986/87, one cubic meter of precipitation produced 0.56 kg of grain and 1.5 kg of straw equivalent to 2.5 SYP. The application of one qubic meter of supplemental irrigation resulted in yield increases of 5.65 and 1.5 kg of grain and straw, respectively, which was equivalent to 19.3 SYP.

The estimated rate of return to capital investment was 5,670% in 1986/87 and 2,270% in 1985/86, making supplemental irrigation a most attractive investment. In areas where deep pumping increases the cost of water to 0.5 SYP/m^3, and where artesian water (Soumi 1987) is available, supplemental irrigation has high potential.

2.5.7 Discussion and Conclusion

Supplemental irrigation research at ICARDA demonstrated that yields are elevated and stabilized.

Differences in the temperatures and the distribution of rainfall in the two seasons illustrate part of the environmental uncertainty which is a feature of the region. Although total seasonal rainfall was the same in both years, the difference in distribution caused differences in timing of supplemental irrigation. This was exaggerated by the contrast in temperature in the two seasons, and the change in crop development rate which resulted. Irrigation of the crop at growth stages most sensitive to soil moisture stress, the timing of water applications differed by 28 days, for the first irrigation, between the seasons. If the practice of supplemental irrigation is to be effective and efficient, farmers should be aware of such differences and respond to them.

The data show differences between cultivars in their response to supplemental irrigation. Of the bread wheats, Mexipak, a very successful cultivar for rainfed conditions, was less responsive than Sham IV. The major difference between the two was in heads/ha, suggesting that Mexipak has an inherently lower tillering capacity than Sham IV. Sebou showed a greater response than the other durum wheat, Sham I. Again, Sham I is reliable in rainfed conditions. The differences between these two were an accumulation of small differences in the measured components of growth, indicating that Sebou is generally a more efficient genotype than Sham I. These data suggest that different cultivars may be needed for the two systems; rainfed and supplemental irrigation.

The response to nitrogen at only the first level of application, 70 kg/ha, in the first year would be, like all fertilizer trials, site specific. It was encouraging, however, that despite an increase in plant height which resulted from N application there was no lodging in the supplemental irrigation treatments. No lodging was observed in the second year and the cultivars tested were suitable in this respect for use with supplemental irrigation.

In all measurements, the 1/3 replenishment treatment for supplemental irrigation produced the same yield as treatments for 2/3 or full replenishment of water used in evapotranspiration. The consumptive use by the 1/3 replenishment treatment (Treatment 2) was 465 mm in the first year and 376 in the second. It has already been noted that two applications of supplemental irrigation in the first year probably were not necessary. If this was so, then the consumptive needs for maximum yield lie in the expected range of 350 to 450 mm of water.

These data show that supplemental irrigation scheduling for spring wheat is effective using water balance techniques with measurements of rainfall, pan evaporation and crop coefficient curves with estimates of rootage depth for the region. The standard guidelines should be followed for scheduling irrigations to replenish the water in the root zone when 50% of the available water has been used. The technique is an accurate indicator for scheduling irrigation but the quantity of water to be applied can be reduced to 1/3rd replenishment in the root zone with a higher water use efficiency. In the Near East and North Africa, spring wheat usually completes the vegetative and tillering stages of plant growth well before the end of effective rainfall, and well timed light applications of supplemental irrigation if needed at heading, anthesis, or milk stage can ensure an increased and stabilized yield.

The margin of return from supplemental irrigation is higher than the cost of capital investment and operation. The small volume of water, 60 mm or 600 m^3/ha, applied as supplemental irrigation with 20 mm at germination, 20 mm during anthesis, and 20 mm during the milk stage had a significant effect on yield when compared with yields of rainfed wheat. The net benefits derived from these increased yields with these low volumes of water applied reflects the impact supplemental irrigation can have on the production economics of rainfed wheat. In the long-term, supplemental irrigation research and policy development must reflect that the shortage of water is critical to agricultural production because population density is increasing exponentially. Supplemental irrigation is one method of managing this escalating shortage by applying only sufficient water to improve and stabilize yield to provide an adequate profit margin.

2.5.8 References

Bolton, F.E., 1981, "Optimizing the use of water and nitrogen through soil and crop management," pp. 231-248, In Soil Water and Nitrogen in Mediterranean-type Environments, Eds. J. Monteith and C. Webb, Martinus Nijhoff/Dr. W. Junk Publs., The Hague.

Cooper, P.J.M., 1983, "Crop management in rainfed agriculture with special reference to water use efficiency", Proc. 17th Coll. Int. Potash Inst., Bern, pp. 63-79.

Doneen, L.D., and D.W. Westcot, 1984, "Irrigation practice and water management," FAO Irrigation and Drainage Paper, 1 Rev. 1, FAO, Rome.

Doorenbos, J., and W.O. Pruitt, 1984, "Guidelines for predicting crop water requirements," FAO Irrigation and Drainage Paper No. 24, FAO/UNDP, Rome.

Finkel, H.J., 1983, "Irrigation of cereal crops," pp. 159-189, In CRC Handbook of Irrigation Technology: Volume II, Ed. H.J. Finkel, CRC Press, Inc., Boca Raton, Florida.

Kirkham, M.B., and E.T. Kanemasu, 1983, "Wheat", pp. 481-520, In Crop-Water Relation, Eds. I.D. Teare and M.M. Peet, John Wiley & Sons, New York.

Marttin, D., and J. van Brocklin, 1985, "The Risk and Return with Deficit Irrigation," ASAE No. 85-2594, 28 pp.

Shalhevet, J., A. Mantell, H. Bielorai, and D. Shimshi, 1976, "Irrigation of field and orchard crops under semi-arid conditions," Inter. Irrigation Inf. Center, Ottawa, Canada.

Shipley, J.L., 1977, "Scheduling irrigations with limited water," 5th Annual High Plains Grain Conference, Bushland, Texas.

Soumi, G., 1987, "Potentials for supplemental irrigation in SAR," paper prepared for ICARDA/FAO Regional Seminar, Rabat, Morocco.

3. PROJECT 2: AGRO-ECOLOGICAL CHARACTERIZATION FOR RESOURCE MANAGEMENT: ICARDA'S STRATEGY

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3.1 Goals and Objectives

In this project, our long term goals are to help ICARDA and national programs improve the efficiency, relevance and targetting of research through the application of techniques which both characterize agro-ecological variability and predict how such variability will interact with and modify the impact of new technology. We will attain this goal through the following medium term objectives:

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

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

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

3.2 Introduction

A major feature of rainfed farming at most locations in ICARDA's region is the wide year-to-year variation in local weather. Erratic rainfall sequences and unpredictable occurrences of extreme temperatures lead to great uncertainty in rainfed crop and pasture production, for individual farmers as well as at the national level.

The effects of weather variations are everywhere compounded by marked local diversity in land resources. Wide differences in elevation, slope and soil depth and stoniness are associated with contrasts in land use, agronomic practice and economic potential, often over short distances. These complicate the planning, conduct and interpretation of research, the extension of research findings and the formulation of effective agricultural policies.

At the farm level, soil and weather characteristics largely determine the limits of rainfed production possibilities. These limits may be modified by innovations such as new crop cultivars, supplementary irrigation, new tillage equipment and methods or newly available chemical fertilizers and pesticides. Economically optimum management decisions depend on the farm family's own objectives, on the physical limitations of the farm, and upon external conditions such as the availability and cost of inputs and the prices and marketing possibilities for outputs. Government policy influences these "external" conditions by provision of infrastructure (roads, seed multiplication agencies, etc.), by price and market interventions and by support of agricultural research and extension.

Farms having similar soil and weather conditions, and which are similarly managed, could be expected to have similar physical responses to a new technology: for example, the growth and yield characteristics of new plant cultivars under those conditions. Under different particular growth conditions and farmers' criteria of success, different cultivars will be considered best adapted.

Development, testing and documentation of quantitative methods for explicit characterization of recommendation domains for new farming technologies in integrated crop-pasture-livestock systems, is a high priority research area. We define a recommendation domain as a group of farms whose resources and management conditions are sufficiently similar that a recommendation tailored to those conditions could be profitably adopted by all in the group. "Domain" refers not only to a geographic delineation, but to the set of farmers' conditions under which the recommendation is valid; thus, it is specific to the particular recommendation and is characterized both in physical and economic terms. Such methods require integration of several quantitative approaches: station and survey data collection, weather generating models, crop growth models and farm management models.

Research and extension efforts may be targeted to specific agro-ecosystem conditions by the national program, resulting in "recommendation domains" for which the distribution of production outcomes can be predicted with some degree of confidence. This should be contrasted with the opposite approach of seeking a set of "universal recommendations" for a country or a region: an approach which gives unsatisfactory results when soil, climatic or management conditions are heterogeneous.

If "universal recommendations" are not suitable in a country with heterogeneous soil, climate and farm management conditions, then research and extension programs must be targeted towards specific research and recommendation domains (identified sets of conditions).

Soil and climatic descriptors are main elements in the identification of recommendation domains, and may be mapped with reasonable accuracy; it is not easy, however, to quantify and illustrate the stochastic aspects of environments associated with weather events. The complementary farm management descriptors such as land tenure, farm structures, economic constraints and agronomic and livestock husbandry practices, are also easily handled by clustering techniques. Both the physical and management characteristics are needed for full specification of recommendation domains.

It is clearly beyond ICARDA's mandate and capacity to produce detailed descriptions of recommendation domains for countries of the region. However, ICARDA is in a unique position *to develop suitable methods to do this work efficiently and* effectively, and to make these available to national programs. ICARDA's mandate is to improve production of barley, lentils, faba beans, wheat and chickpeas, and of pasture, forage and livestock associated with these crops across the heterogeneous farming conditions of North Africa and West Asia. Therefore, ICARDA has an obligation to work with national programs to assist in building their capacity to optimize agricultural policies, and research and extension efforts, for attaining their own goals of equity, production growth and efficiency. The integrating viewpoint of farm resource management is fundamental to success in reaching ICARDA's combined objectives of improvement in animal husbandry, agronomy and plant breeding.

According to the discussion above, agro-ecological characterization can be divided into "physical" and "management" aspects; and both need to be considered by national programs in targeting research and extension toward the various unique combinations of conditions under their responsibility. ICARDA's achievements and future goals in developing, testing and disseminating methods for agro-ecological characterization are summarized in the following sections.

3.3 Physical Characteristics

Monthly and annual rainfall, temperatures, soil types and topography have long been recognized as important to agriculture and have been mapped at various scales for parts of North Africa and West Asia. Publications showing annual and monthly rainfall isohyetes, and lines of equal temperature and evaporation are available (e.g., WMO/UNESCO/Cartographia, 1970; Gidrometeoizdat, 1978; WMO/UNESCO/Goscomgidromet USSR, 1981). The mean lengths of growing seasons were estimated for West Asia by Brichambaut and Wallen (1963) using temperature and potential evapotranspiration estimates, and for other parts of the ICARDA region, with the methods of Emberger (1955), by staff of the Arab Organization for Agricultural Development (AOAD 1978) and UNESCO/FAO (1963), among others. The FAO (1978, 1980, 1982) undertook agroclimatic studies using a simple model of the water balance of crops and mean monthly rainfall and temperature data. Such analyses define broad agroclimatic zones, which indicate long term constraints to, and potentials for, agricultural production.

However, the average climatic values embodied in zonation work do not depict the year-to-year variations in actual growth conditions which are so important in semi-arid environments. In rainfed farming, crop yields at a given site in any given year are the product of several factors, including a unique sequence of weather events. An important reason for characterization of a research site is to assist in the interpretation of field results in the context of longer-term occurrence of specific or extreme events. For example, the probability of critical rainfall amounts (or frosts) before or after given dates will influence the success of particular management practices, such as early sowing, or the choice of plant cultivars, such as frost tolerant medic for areas prone to frost (Keatinge, et al. 1985, 1986, Cocks and Ehrman 1987).

Probabilistic characterization of such events at experimental sites, combined with current field results, is needed for judgements on future research designs and, additionally for national programs, to guide the formulation of recommendations to farmers.

The effects of a series of growth conditions on a particular crop, over a number of years, can be estimated by long and costly multi-site field trials in the area. Alternatively, rapid simulation methods which take into account the soil, water, temperature and nutrient status of the crop at each stage of growth, can be used to supplement information from trials in fewer years and locations.

Growth simulation models require daily data on weather factors. Such data for long series of years are available from meteorological stations and few agricultural stations. These stations are often quite widely spaced. Therefore, a weather-generator (WG) model for interpolation to produce simulated daily weather data for a grid pattern of locations between the station sites, taking topography also into account, is being developed by ICARDA.

The WG model is intended to be offered to national programs for use in producing a basis for running growth simulation models at sites for which no adequate weather records are available. The WG model and actual soil data for the grid locations (or data inferred from soil maps) will provide a basis for estimating weather-determined probability distributions of yield for different cultivars of wheat or barley, whose growth parameters have been determined. The result will be a mapping of areas with common simulated yield distributions: the precursor for management choices. Survey methods are available for validation of the simulation results by "ground truth" from farmer interviews (Maerz 1987; Nordblom 1987).

The advantages of these methods are their speed and low cost in application. National programs could use such models for focusing their research and extension efforts on well identified target areas. For example, areas of high potential improvement may be identified where farmers' yield distributions are far below the simulated values. The WG and growth simulation models can also be used by national programs to produce probabilistic estimates of regional production at various times during the season... becoming more accurate as the actual weather data before harvest become available.

In the following sections, we consider the weather and soil data already and potentially available for agro-ecological characterization and describe the methods being used to enhance the data sets for their full exploitation in crop growth models.

Weather: One of the features of weather elements is that their values vary continuously over space and time. Notable exceptions are rainfall events which are discontinuous and highly stochastic in occurrence.

Data on rainfall, the most commonly measured variable, are usually available as daily values, but the intensity of rainfall is rarely measured. Temperatures are often recorded as daily maximum and minimum values, from which a mean is usually calculated (T max + T min)/2 with the (often unconscious) assumption that the daily fluctuations between the two are symmetrical. Synoptic records taken every 2, 3, 4 or 6 hours provide better information for crop growth models. Other elements are less widely recorded and, when they are, are reported as daily totals (evaporation, solar or net radiation), as values at a fixed time of day (vapor pressure, relative humidity, wet bulb temperatures, etc.), or in some summary form (e.g., wind flow as m/s or km/h).

In other words, weather data are normally summarized in some way at the time of collection; the continuous nature of the weather elements makes this only practical, but the result is that potentially valuable data, such as rainfall intensities, are not recorded. Data are further condensed for publication; in the process, the daily data are not always retained. Thus, it is sometimes difficult to find the long runs of daily records which are needed to adequately represent the variability in most marginal agricultural environments, and also needed to use models of crop growth to quantify the effect of that variability on crop yields.

Weather records, of necessity, are taken at a point in space; but there are standards for selection of meteorological station sites which aim to ensure the recorded values are representative of as wide an area as possible. For the sake of cost and convenience, these standards are often compromised and one should always be conscious of limitations to the spatial transferability of weather data. Furthermore, recording stations tend to be concentrated in the most densely populated areas, which may not be areas of importance to agriculture. Where they are, they frequently represent the most favorable farming areas; recording is much more sparce in marginal areas.

This is the current situation; what of the future? The advent of automatic agricultural weather stations makes it possible to scan sensors at regular short intervals and to acquire data which, although still summarized, give a better representation of crop growth conditions. This technology is being used more and more in agricultural research programs around the world, and is being adopted slowly by regular meteorological services. One reason for slow adoption is that a change to integrated recording will result in a discontinuity in the data. Because of volume, the data stored are unlikely to be more comprehensive than at present, unless very good economic grounds for an increase can be demonstrated. Therefore, for purposes of environmental characterization, we will probably need to continue using the type of data currently available, at least for the forseeable future.

The major problems in using the existing weather data in agro-ecological characterization are, as already indicated: the data are point specific, the network of meteorological stations is sparse in marginal areas, records for individual stations may be too short-lived to characterize variability, and there may be interruptions in the records. In order to overcome such problems, techniques have been developed for the simulation of long runs of stochastic daily weather data. These take existing records, analyze them to derive statistical descriptors for use, in conjunction with information on topography, to generate sequences of weather records for a greater number of years, to fill gaps in existing records, or to simulate daily weather for intermediate locations where no weather records exist (e.g., at Tel Hadya before 1977). The latter use is of key importance for our work on agro-ecological characterization. ICARDA's first step toward development of such a model was to generate a long-term stochastic rainfall record for Tel Hadya from parameters obtained through linear interpolation between those of the meteorological stations at Aleppo and Saraqeb (Dennett, Rodgers and Keatinge 1983).

Methods for weather data generation have recently been reviewed by Hutchinson (1987). Most begin with rainfall, partly because these data are most frequently needed; they are also the most difficult to model. The techniques involve analysis of daily records in terms of the probabilities that rain will occur on any day of the season or year. Markov chain models are used to incorporate short-term correlations where rainfall events typically occur over more than one day. Usually a first or second order Markov chain is adequate to represent these correlations.

From this, a matrix giving the transition probabilities of the possible sequences of rainfall states is estimated.

For example, for a first order Markov chain, the probabilities of the rainfall state on any one day being dry/dry, dry/wet, wet/dry, and wet/wet (where / is equivalent to "following"), are determined. The matrix can then be used with a random number generator to simulate sequences of rainfall events. Curves can then be fitted to the probability estimates to provide a compact way to store data: once the initial calculations have been done, the record for long runs of years can be stored as the coefficients of the curve parameters (Stern 1980). This form of summary has the particular advantage that it incorporates measures of uncertainty which are lost in more conventional summaries.

The generation of rainfall data requires the use of an appropriate model to give a random amount of rain that falls on a wet day. Various models have been used, but the gamma distribution is generally accepted as appropriate for this purpose. A less suitable method is to fit curves to the data on mean rain per rain-day throughout a season, and use these to generate rainfall amounts.

In areas with a sufficiently dense and well-distributed network of rainfall stations, interpolation techniques such as Kriging or Laplacian smoothing splines can be used to generate data for unknown sites lying between known points in order to build up a denser grid of information. It is at this point that topographical effects known to influence rainfall can be incorporated (Hutchinson 1987). However, in regions where the network is very sparse, it is not possible to use direct interpolation. In such cases, isoline maps must be drawn manually, utilizing topographic maps and perhaps satellite imagery to serve as guides to spatial trends of rainfall not reflected in the data (van der Laan 1986).

Modeling the other weather variables is easier because many can be taken to be normally distributed and, therefore, more amenable to statistical manipulation. However, models must take into account cross correlations among the weather variables, and reflect auto-correlations in the real weather series. Models with these capabilities have been developed and tested (e.g., see Richardson 1981; Godwin 1988). Interpolation methods can be applied to extend the spatial distribution of the data and to incorporate effects of topography, such as the well known correlation between temperature and elevation. For technical details on ICARDA's WG modelling directions, see Goebel (1986, pp. 122-128).

Soil: Soil data present some of the same problems as those for weather in that the spatial variability is great, and much of the data available for characterization is location specific (Brinkman 1987). Fortunately, except in special circumstances (e.g., where extreme erosion potentials exist, or where salinity problems may develop), temporal variability is negligible and can be ignored.

To characterize the effects of soils on development of stresses in plants, we need to know something of the physical status of the soil as it affects the water relations of the crop-soil system, and of chemical properties that reflect the nutrient status, pH, and salinity or other possible toxicities.

The first physical soil factors that need to be quantified are those which relate to infiltration and drainage. To some extent, these can be inferred from soil texture and, thus, from soil classification.

The second important physical characteristic we need to know is the capacity of the soil to hold plant-extractable water, as defined by Ritchie (1981). Perhaps surprisingly, this can be quite similar over a wide range of soil textures from clays to sandy loams (Ratliff, et al. 1983). The proportion of water that can be extracted before plant stress develops and the rate of release of soil water at low water contents also are relatively constant over a wide range of soil textures (Gardner, 1983). This means it is possible to infer soil water characteristics from soil classification with reasonable confidence that, even if the absolute values chosen differ slightly from reality, the water balance estimates will not be affected.

We also need to know soil depth to predict water balances. This is not very easy to characterize, especially in regions with a long history of soil erosion, as depth can vary enormously over short distances and the variation is not necessarily detectable from surface observations. We propose that one way to handle the problem in a characterization study is to predict yield for a range of soil depths and allow the user to choose the appropriate one; our rationale is that such information is usually part of local information knowledge. Alternatively, and more ideally, local knowledge should be incorporated in all analyses.

Chemical properties also can often be inferred from soil classification. However, like depth, they vary widely and unpredictably. Nutrient status, for example is suggested by what is known of the soil characteristics. However, it is known to vary quite substantially, depending on such factors as cropping history, prior fertilizer use, crop sequence, and topography. Computing power permitting, the best strategy again appears to be to look at more than one scenario and allow users to select the one appropriate to their needs, or, for preference, to have users supply this information for their own circumstances.

Combining Weather and Soil Data: The most effective way to combine data on weather and soil for agro-ecological characterization is to use dynamic plant growth models to integrate their effects on potential productivity. Crop models of various types now possess the capability to mimic plant behavior sufficiently well to predict crop growth and yield within, or very close to our ability to measure them (e.g., Stapper 1984; van Keulen and Seligman 1987; Ritchie et al. in press).

These models are essentially weather-driven using a limited number of weather variables. They model the impact of weather conditions on crop growth in time steps no longer than one day. The growth which they predict each day reflects the influence of soil and atmospheric conditions. By examining the predictions, we can identify much more closely what are the main factors controlling growth and yield development in particular environments, and develop hypotheses as how to best modify either the plant or the management to overcome limitations to yield. This aids in research planning.

The greatest value of models, however, lies in the ability they give us to examine the long-term impact of uncertainties in the weather on the yield of crops. We can estimate the cumulative probability distribution of yield of a crop in an area; the importance of this is that it allows us to estimate the risk associated with crop production (Anderson 1974). The risk may be expressed in biophysical terms as that imposed on yield by uncertainties in the weather, or yields may be converted to money equivalents for use in economic risk analyses.

3.4 Management Characteristics

It is recognized that physical aspects of the environment limit, but only partly determine, the productivity of crops or farming systems. Infrastructural, economic, and social conditions and political circumstances may strongly modify the range of feasible inputs, prices or market conditions, or even the possibility of farming (Brinkman 1987). For example, in some parts of this region one finds wheat growing in terraces on steep and arid mountain slopes, while in others, fertile valleys remain undeveloped. There are necessary physical characteristics for crop growth, but management aspects must be present before conditions are sufficient for successful crop and livestock production.

Management characteristics such as crop rotations and livestock feeding patterns, land tenure, farm structure or credit situations, can influence the appropriateness of innovations such as new cultivars, fertilizer regimes and chemical pest controls. Some of these characteristics may be beyond the farmer's control and require policy change and government intervention (i.e., for new infrastructure or land reform). Others may be traditional practices which can be changed by farmers if a convincing economic case is put before them. Management characteristics are location specific, even to the point of personal choices to meet the particular goals of a farming family.

Because it is impossible to tailor recommendations to each individual farm in the specification of recommendation domains, some practical level of aggregation and abstraction is needed. Rapid survey methods are available which permit reasonable clustering of management characteristics. Specific clusters of farming conditions, which are found within the larger soil/climate classes, can then be targeted for improvement by national programs of research and extension.

Standard farm management analyses, including partial budgeting, whole farm budgeting and linear programming with sensitivity tests, allow the pre-screening of promising technological innovations for economic viability with reference to an explicitly identified set of physical and management conditions

(Barlow et al. 1983, Nordblom and Thomson 1987). These methods, linking physical and management characteristics to test new technologies, lead to confident identification of recommendation domains by national programs.

ICARDA's development, testing and documentation of methods for practical "direction finding" in research and extension, linking physical and management aspects of agro-ecological characterization, is aimed for routine applications in the hands of national programs of this region. This is a challenging but realistic goal for the Center.

The response of national programs to date leads us to believe that they will be the main users of the methods developed at ICARDA. We will continue to support the work with training, and further methodological development, as the needs demand. In order to facilitate transfer of technology to other users in the region and elsewhere, all programming is to be well documented, user-friendly, and implementable on micro-computer systems maintained by the national programs and operated by them.

ICARDA's pioneering role in agro-ecological characterization will be well recognized by national programs of the region at the turn of the century: the development of predictive tools for interpolation of point-source weather data, and integration with soil, topographic, crop response and management data, will have been exploited in many areas, providing for more efficient direction of research and extension and fuller use of expensive field results than otherwise possible. It is expected that ICARDA will continue to be requested to assist national programs in development of tailored planning tools.

3.5 References

Anderson, J.R. 1974. Risk efficiency in the interpretation of agricultural production research. Review of Marketing and Agricultural Economics 43, 131-184.

Arab Organization for Agricultural Development. 1978. Agroclimatic Atlas of the Arab World. AOAD. Khartoum, Sudan.

Barlow, C., Jayasuriya, S., and Price. E.C. 1983. Evaluating technology for new farming systems: case studies from Philippine rice farms. International Rice Research Institute, Los Banos, Laguna, Philippines.

Brichambaut, G.P. de, and Wallen, C.C. 1963. A study of agroclimatology in semi-arid and arid zones of the Near East. World Meteorological Organization, Technical Note 56. WMO Geneva, Switzerland.

Brinkman, R. 1987. Agro-ecological characterization, classification and mapping. Different approaches by the International Agricultural Research Centers. In, Bunting, H.A. (ed). **Agricultural Environments.** Proceedings of the Inter-Center Workshop on Agroecological Characterization, Classification and Mapping. 14-18 April 1986 at rome. Commonwealth Agricultural Bureau International, Farnham Royal, UK.

Cocks, P.S., and Ehrman, T.A.M. 1987. The geographic origin of frost tolerance in Syrian pasture legumes. **Journal of Applied Ecology.** 24:673-683.

Dennett, M.D., Rodgers, J.A., and Keatinge, J.D.H. 1983. Simulation of a rainfall record for the site of a new agricultural development: an example from northern Syria. **Agricultural Meteorology** 29:247-258.

Emberger, L. 1955. Une classification biographique des climats. Rec. Trav. lab. bot. geol. zool., Faculte de Science, Montpellier, France. Series Botaniques 7:3-43.

FAO, 1978. Report on the agro-ecological zones project. Volume 2. Results for southwest Asia. World Soil Resources Report 48/1. FAO, Rome, Italy.

FAO, 1980. Report on the agro-ecological zones project. Volume 2. Results for southwest Asia. World Soil Resources Report 48/2. FAO, Rome, Italy.

FAO, 1982. Regional study on rainfed agriculture and agro-climatic laventory of eleven countries in the Near East region. World Soil Resources Report. FAO, Rome, Italy, 160 pp.

Gardner, W.R. 1983. Soil properties and efficient water use: an overview. Pages 45-64. In, Limitations to Efficient Water Use in Crop Production. (H.M. Taylor, W.R. Jordan and T.R. Sinclair, eds.). Agronomy Society of America, Crop Science Society of America, and Soil Science Society of America, Madison, Wisconsin, USA.

Gidrometeoizdat 1978. [Climatic Atlas of Africa]. 2 volumes. Leningrad, USSR (in Russian).

Godwin, D.C. 1988. Simulation of nitrogen dynamics in wheat cropping systems. Unpublished PhD thesis. University of New England, Armidale, N.S.W., Australia.

Goebel, W. 1986. Spatial climate modeling: objectives and methods. Farming Systems Program Annual Report for 1986. ICARDA-108En. ICARDA, Aleppo. pp. 122-128.

Hutchinson, M.F. 1987. Methods of generation of weather sequences. Pages 149-157. In Agricultural Environments. (H.A. Bunting, ed.), Proceedings of the Inter-center Workshop on Agroecological Characterization, Classification, and Mapping. Rome 14-18 April 1986. Commonwealth Agricultural Bureaux International, Farnham Royal, UK.

ICARDA. 1986. Annual Report for 1985. Aleppo, Syria.

Keatinge, J.D.H., Dennet, M.D., and Rodgers, J.A. 1985. The influence of precipitation regime on the management of three-course crop rotations in northern Syria. **Journal of Agricultural Science (Cambridge).** 104(2):281-287.

Keatinge, J.D.H., Dennet, M.D., and Rodgers, J.A. 1986. The influence of precipitation regime on the crop management of dry areas in northern Syria. **Field Crops Research.** 13:239-249.

Maerz, U. 1987. Methods to simulate distributions of crop yields based on farmer interviews. ICARDA-117En. ICARDA, Aleppo.

Nordblom, T.L. 1987. Farming practices in southern Idleb province, Syria: 1985 survey results. ICARDA-107En. ICARDA, Aleppo.

Nordblom, T.L. and Thomson, E.F. 1987. A whole-farm model based on experimental flocks and crop rotations in northwest Syria. ICARDA-102En. ICARDA, Aleppo.

Ratliff, L.F., Ritchie, J.T., and Cassel, D.K. 1983. Field-measured limits of soil water availability as related to laboratory-measured properties. **Soil Science Society of America Journal.** 47:770-775.

Richardson, C.W. 1981. Stochastic simulation of daily precipitation, temperature, and solar radiation. **Water Resources Research.** 17:182-190.

Ritchie, J.T. 1981. Water dynamics in the soil-plant-atmosphere system. Pages 81-96. In, Soil Water and Nitrogen in Mediterranean-type Environments. (J. Monteith and C. Webb, eds.). Martinus Nijhoff / Dr. W. Junk, The Hague, Netherlands.

Ritchie, J.T., Godwin, D.C., and Otter-Nacke, S. (in press). CERES-Wheat. A simulation model of wheat growth and development. Texas A&M University Press, College Station, Texas, USA.

Stapper, M. 1984. Simulations assessing the productivity of wheat maturity types in a Mediterranean climate. Unpublished PhD thesis. University of New England, Armidale, N.S.W., Australia.

Stern, R.D. 1980. Analysis of daily rainfall at Samaru, Nigeria, using a simple two-part model. Archiv Meteorologie, Geophysik, und Bioklimatologie Serie B 28:123-135.

van der Laan, F. 1986. Landscape Guided Climatic Inventory using Remote Sensing Imagery. FAO, Rome, Italy, AGRT:RSC Series 36. AGL/MISC/5/58. 49 pp.

UNESCO/FAO, 1963. Bioclimatic map of the Mediterranean zone. Arid Zone Research XXI. UNESCO, Paris, France. 58 p. and map 1:5 000 000.

van Keulen, H., and Seligman, N.G. 1987. Simulation of water use, nitrogen nutrition and growth of a spring wheat crop. PUDOC, Wageningen, Netherlands.

WMO/UNESCO/Cartographia. 1970. Climatic Atlas of Europe. Volume 1, Cartographia, Budapest, Hungary.

WMO/UNESCO/Goscomgidromet USSR. 1981. Climatic Atlas of Asia. Volume 1, Gidrometeoizdat, Leningrad, USSR.

4. PROJECT 3. ADOPTION AND IMPACT OF TECHNOLOGIES

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

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

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

4.1 Goals and Objectives

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

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

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

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

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

4.2 Food and Agriculture in West Asia and North Africa: Projections to 2000

Kutlu Somel[1]

4.2.1 Introduction

Economic planning for the future requires in the first instance projections on relevant indicators. These will provide estimates of demand, production, input and investment requirements as well as criteria on which to base allocation and policy decisions. Many institutions are undertaking such studies of projections to the approaching end of the millenium. The Food and Agriculture Organization of the United Nations (FAO) produced a first version of its projections to 2000 in FAO (1981). The base year for this study was 1975. Considering that significant changes had occurred in agriculture in the developing countries, a revision of this study was undertaken with 1983 as the base year. Such a recent base year and the consequent reduction of the projection horizon to 17 years is expected to improve the robustness of the forecasts. The report of the study was submitted to the 1987 FAO Conference in FAO (1987).

Here, we shall look at the results of the Agriculture: Toward 2000 (abbreviated from hereon as AT2000) revision for West

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(1) This paper is based on the Agriculture: Toward 2000 study undertaken by the Global Perspectives group at the Food and Agriculture Organization of the United Nations. The project was headed by Dr. Nikos Alexandratos and the simulation modeling coordinated by Dr. Jelle Bruinsma but many contributed to the study. The author was seconded by ICARDA to participate in this study during his sabbatical leave in 1986/87. The views presented in this paper do not necessarily reflect the policies of ICARDA, FAO and their donors and belong solely to the author who is responsible for its contents including any errors that remain.

Asia and North Africa (WANA) (2). AT2000 focused on 93 developing countries but also touched upon China, developed market economies and European centrally planned economies.

An important objective in this paper is to provide information on which the planning of research priorities in WANA can be based. The results are presented in the regional aggregate. Research scientists are aware of the wide diversity that exists in WANA in the physical and socio-economic environments. This awareness needs to be complemented by the stock of knowledge at hand to identify critical areas of research as well as the priorities among these research areas.

Presentation of results in regional aggregates will prevent a priority evaluation among countries. However, the underlying major agricultural systems of WANA can be identified from the regional aggregate. Research geared to provide relevant technological options for these major agricultural systems can also be identified.

The plan of discussion is as follows. In the next section the projections of demand for major agricultural commodities will be presented followed by a discussion of production, input and investment requirements. The problem of meeting the large food deficits in WANA will be the main theme of the concluding section.

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(2) The regional classification of WANA is not used in AT2000 but it covers the AT2000 region of Near East and North Africa plus some countries in East Africa and West Asia. These countries are: Afghanistan, Algeria, Cyprus, Egypt, Ethiopia, Iran, Iraq, Jordan, Lebanon, Libya, Morocco, Pakistan, audi Arabia, Sudan, Syria, Tunisia, Turkey, Yemen Arab Republic and Yemen People's Democratic Republic.

4.2.2 Demand for Agricultural Commodities in WANA

When consumers are disaggregated into different income classes and rural-urban distinctions, one can get a fairly good understanding of the factors that influence demand. The following aggregate picture is then presented with the caveat that it hides such distinctions.

The growth of aggregate demand for a commodity is influenced by three factors:

$$g_d = g_P + eg_y$$

Here g is the growth rate and the subscripts denote demand (d), population (P) and income per capita (y). The income elasticity of demand is denoted by e. Hence, the growth of demand is equal to population growth plus income growth weighted by the income elasticity of demand. In general, the income elasticities for food are lower than those for other commodities and the income elasticities for staples are lower than those for other foods.

In WANA, population is projected to increase from 408 mill in 1983 to 627 mill in 2000 and GDP per capita (in 1980 US dollars) from $1175 to $1425. This implies annual growth rates of 2.6 percent and 1.1 percent respectively for population and per capita income.

The average daily per capita calorie consumption in WANA is 2550 Kcal which is considerably above the Basic Metabolic Rate (BMR) minimum (Table 4.1). However, there is a wide range observed among countries in WANA from under 1650 Kcal in Ethiopia to over 3500 Kcal in Libya as well as within countries. These averages should under no circumstances be interpreted as absence of undernutrition or malnutrition.

TABLE 4.1 Structure of total demand for major agricultural products in WANA (mill.MT)

Agricultural Commodities	Food Demand		Feed Demand		Total Demand		Deficits (-)		SSR (%)	
	1930	2000	1983	2000	1983	2000	1983	2000	1983	2000
Wheat	53.3	80.5	4.4	9.6	69.1	105.4	-21.6	-33.9	69	68
Rice	11.0	17.2	-	-	11.0	18.4	-1.2	-2.9	90	84
Maize	6.2	9.6	5.7	13.4	18.2	25.2	-4.8	-11.2	71	70
Barley	3.4	5.3	11.5	27.6	19.3	37.4	-5.5	-11.2	71	70
Coarse grains	15.3	24.7	18.6	43.8	40.2	76.3	-10.3	-22.9	73	70
Cereals	75.4	116.6	23.1	53.4	116.6	193.9	-32.6	-58.9	71	70
Sugar	11.4	20.7	0.2	0.4	12.1	21.8	-4.3	-7.8	68	64
Pulses	3.1	4.6	0.4	0.4	4.1	5.7	0.2	0.2	107	103
Vegetable oils	4.0	7.5	0.1	0.1	4.7	8.9	-2.5	-5.7	44	36
Cotton (lint)	-	-	-	-	1.5	2.3	0.7	0.7	146	130
Beef	2.6	4.4	-	-	2.6	4.4	-0.6	-0.9	77	80
Mutton	2.3	3.9	-	-	2.3	3.9	-0.3	-0.3	89	91
Poultry	2.0	4.5	-	-	2.0	4.5	-0.5	-0.3	77	94
Milk	28.0	47.2	3.9	6.6	35.5	59.8	-6.5	-11.4	82	81
Meat	6.9	12.9	-	-	6.9	12.9	-1.3	-1.5	81	88
Kcalories/ capita/day	2550	2715	503	736	3526	3893	-958	-1172	73	70

Source: AT2000 files and FAO Supply Utilization Accounts files.

The average per capita income in WANA is higher than that of the 93 LDC in AT2000. This contrast of $1175 vs $780 is projected to be narrowed in 2000 to $1425 vs $1086. The higher level of income influences some aspects of food consumption. For example, the higher income elasticity livestock products are consumed at a higher per capita level than in the 93 LDC as a whole: meat at 17 kg vs 12 kg; milk at 69 kg vs 44 kg. The basic staple wheat is consumed at more than two and a half times the average in the 93 LDC; 131 kg vs 51 kg. Pulses are an important source of protein for the poorer segments of the population but on the average consumed at a lower rate than that in the 93 LDC: 7.6 kg vs 9.2 kg.

One salient characteristic of high income levels is the switch from direct to indirect consumption of cereals. As incomes increase the higher income elasticity of demand for the indirect consumption of cereals becomes the driving element of the demand for cereals while the direct demand stabilizes or decreases. This indirect demand for cereals is the derived demand for the use of cereals as feed for livestock.

This development is observed clearly in WANA (Tables 4.1 and 4.2) where the per capita indirect use of cereals for feed is 57 kg vs 31 kg for the 93 LDC. The direct food demand for cereals is driven entirely by population growth. On the other hand feed demand grows at virtually double the population growth rate because of the demand generated by high incomes and higher income elasticities. Of course, this is more so for coarse grains and particularly for barley. Three quarters of the barley grown or consumed in the 93 LDC is in WANA. It is characteristically utilized in the integrated barley-livestock systems observed in the drier areas of WANA where small ruminants (sheep and goats) form the livestock component.

TABLE 4.2 Projected demand growth rates and implicit income elasticities for major agricultural commodities in WANA (1983-2000)

Agricultural Commodities	Annual Growth Rates (%)			Implicit Income Elasticities		
	Food Demand	Feed Demand	Total Demand	Food Demand	Feed Demand	Total Demand
Wheat	2.5	4.6	2.5	-0.10	1.82	-0.04
Rice	3.1	-	3.1	0.50	-	0.45
Maize	2.5	5.1	3.8	-0.04	2.25	1.12
Barley	2.6	5.3	4.0	0.06	2.35	1.24
Coarse grains	2.8	5.2	3.8	0.25	2.27	1.12
Cereals	2.6	5.1	3.0	0.03	2.19	0.41
Sugar	3.6	4.1	3.5	0.88	1.32	0.85
Pulses	2.4	-0.4	2.0	-0.17	-2.60	-0.49
Vegetable oils	3.7	4.1	3.9	1.02	1.32	1.16
Cotton (lint)	-	-	2.3	-	-	-0.24
Beef	3.1	-	3.1	0.43	-	0.43
Mutton	3.2	-	3.2	0.56	-	0.56
Poultry	5.0	-	5.0	2.16	-	2.16
Milk	3.1	3.1	3.1	0.49	0.48	0.49
Meat	3.7	-	3.7	1.01	-	1.01
Kcalories/cap/day	0.4	2.3	0.6	-1.93	-0.27	-1.74

Note: The projected population growth rate is 2.57 percent per year and the projected annual growth rate of per capita income is 1.14 percent.

Source: AT2000 files based on FAO Supply Utilization Accounts files.

Three commodities are also projected to have growth rates higher than population: sugar, vegetable oils and livestock products. All three have high implicit income elasticities. Poultry meat in particular is expected to face high growth in demand. As poultry production is highly dependent on coarse grains used as feed, it will generate substantial demand, particularly for maize. Mutton, which is preferred more in WANA than the 93 LDC as a whole, will maintain its share in the demand for red meat. Most of the milk demand is for cow milk but ewe's milk is an important source of high quality animal protein in rural areas where it is consumed in preserved dairy products such as yogurt and cheese (Somel and Mokbel, 1986).

Certain pulses, such as lentils, chickpeas and faba beans are important as protein sources in diets in WANA, particularly in urban areas and among the poor. However, on average, the per capita consumption of pulses is projected to decrease as livestock products become the preferred source of protein with higher incomes.

In general, food demand in WANA is projected to be characterized by the maintenance of the direct per capita consumption rates of staples but high rates of indirect consumption of cereals for feed and high rates of consumption of livestock products.

4.2.3 Agricultural Production in WANA

In WANA, agricultural production is constrained by land and water resources. Only a quarter of the land is under irrigation (Table 4.3) and in rainfed areas rainfall exhibits substantial variation between years as well as between areas. Currently, over nine tenths of land reserves are in Sudan (75 percent) and Ethiopia (16 percent) and the quality of these land reserves is relatively inferior. In the rest of WANA, the limits of agricultural land have been reached. Therefore, increases in production can come about essentially through yield and cropping intensity increases. In fact, these two sources will account respectively for 72 and 21 percent of total crop production increases in WANA. This implies both higher use of improved technologies and more intensive use of land, particularly reduced fallow. Furthermore, irrigated areas have to increase by 14

TABLE 4.3 Land resources in WANA (mill ha)

	Low Rainfall	Uncertain Rainfall	Good Rainfall	Problem Lands	Naturally Flooded	Desert	Irrigated Areas	Total
1983								
Rainfall use	38.5	15.0	22.8	17.0	12.7	-	-	106.0
Irrigated use	6.6	2.2	1.5	1.0	4.7	19.4	35.4	35.4
Total use	45.1	17.2	24.3	18.0	17.4	19.4	35.4	141.4
Reserves	9.4	9.8	7.7	29.2	4.7	13.4	65.6	
Use/total potential (%)	83	64	76	38	79	81	73	68
Harvested area (a)	16.4	9.7	16.8	11.7	6.8	-	3638	98.2
Cropping intensity (%) (a)	42	65	74	69	54	-	104	69
2000								
Rainfed use	38.0	15.3	22.6	18.0	12.7	-	-	106.6
Irrigated use	7.3	2.8	2.1	1.1	4.8	22.2	40.3	40.3
Total use	45.3	18.1	24.7	19.1	17.5	22.2	40.3	146.9
Reserves	9.3	8.9	7.4	28.0	4.7	1.8	8.5	60.0
Use/total potential (%)	83	67	77	41	79	93	83	71
Harvested area (a)	17.0	11.6	19.3	12.7	7.0	-	45.9	113.4
Cropping intensity (%) (a)	45	76	85	70	55	-	114	77

Notes: a. Refers to rainfed agriculture in non-irrigated areas.

Source: AT2000 files: the land classification is based on FAO agro-ecological zoning which reflects both soil quality and length of growing period, FAO (1987), p 126, cf Table 4.6 below.

percent so as to allow a 25 percent increase in harvested irrigated areas.

Cereals (Table 4.4) cover the largest area in WANA. Between the two main cereals, wheat is projected to shift out of drier areas and to be replaced by barley which has a biological advantage in terms of adaptation to dry areas (Table 4.6). The shift to wetter areas and use of improved technologies will allow wheat to maintain long term yield growth trends and improve over more recent production trends. The area increase in barley will contribute to production increases but the major source of change will be yield growth brought about by the diffusion of improved technologies. Currently, wheat commands the largest share in fertilizer use with 29 percent but barley gets only 8 percent. By 2000, wheat will increase its share to 31 percent but barley will become the second major user of fertilizer with 13 percent. In per hectare terms this means that wheat will increase fertilizer use from 51 to 140 kg/ha and barley will increase from 35 to 122 kg/ha. Due to its importance mainly as poultry feed but also to some extent as cattle feed, maize will also gain importance in production. The same can be said for rice which is becoming the status cereal is WANA.

The growing demand for sugar will be partly met by production increases stemming from modest yield increases in sugarbeet and sugarcane. In pulses, modest yield increases are projected as well. In vegetable oil crops, the relative importance of olive oil will decline as other sources (soybeans, sunflowers, maize, groundnuts, sesame and cotton seed) increase their share in production. However, olive oil should still remain as a most important source of vegetable oil.

In livestock production (Table 4.5), increases in productivity will also be important. For example, in meat production, 44 percent of the growth will be due to increases in

TABLE 4.4 Crop production in WANA (a)

	1967/63			1981/85			2000			Production Growth Rate (%)			Area Growth Rate (%)			Yield Growth Rate (%)		
	Prod.	Area	Yield	Prod.	Area	Yield	Prod.	Area	Yield	61-85	75-85	81/85-2000	61-85	75-85	81/85-2000	61-85	75-85	81/85-2000
Wheat	25.1	27.6	0.9	47.9	33.1	1.5	71.5	33.6	2.1	3.3	1.6	2.4	0.8	-0.1	0.1	2.5	1.7	2.3
Rice	5.0	2.2	2.3	9.6	3.1	3.1	15.4	3.9	4.0	3.0	0.7	2.8	1.6	0.3	1.2	1.4	0.4	1.6
Maize	5.1	3.7	1.4	8.5	4.0	2.1	14.2	4.9	2.9	2.5	2.0	3.0	0.5	0.7	1.1	2.0	1.4	1.9
Barley	9.7	10.7	0.9	14.3	12.7	1.1	26.1	15.5	1.7	2.1	2.9	3.6	0.8	2.3	1.2	1.2	0.5	2.4
Coarse grains	22.7	23.9	1.0	30.9	285	1.1	53.3	32.3	1.7	1.6	1.3	3.3	0.7	1.5	1.0	0.9	-0.1	2.3
Cereals	52.8	53.7	1.0	88.4	63.8	1.4	140.2	69.8	2.0	2.6	1.4	2.8	0.8	0.6	0.5	1.8	0.8	2.2
Sugarbeet	4.3	0.2	21.6	19.3	0.6	30.5	35.6	0.9	37.6	6.8	2.7	3.7	5.2	2.5	2.4	1.5	0.2	1.2
Sugarcane	20.6	0.5	39.6	50.2	1.1	45.1	87.4	1.6	54.5	4.0	4.1	3.3	3.6	3.5	2.2	0.5	0.6	1.1
Pulses	3.2	4.5	0.7	4.3	5.3	0.8	5.9	6.0	1.0	1.3	2.1	1.9	0.8	1.8	0.8	0.5	0.3	1.1
Oil crops (b)	2.0	1.2	1.6	2.7	3.0	0.9	4.1	5.2	0.8	1.7	-0.4	2.5	4.7	0.6	3.3	-2.8	-1.0	-0.8
Soybeans	0(c)	0	0.9	0.3	0.1	2.2	1.0	0.4	2.5	18.0	13.3	6.8	13.1	8.5	6.1	4.4	4.4	0.7
Sunflowers	0.1	0.1	0.8	0.8	0.6	1.2	1.3	1.1	1.2	9.6	4.4	3.5	7.9	3.3	3.4	1.6	1.1	0.1
Groundnuts	0.4	0.4	1.2	0.7	0.9	0.8	1.5	1.3	1.1	3.3	-6.6	4.3	4.9	-3.2	2.1	-1.5	-3.4	2.1
Sesame	0.3	0.7	0.5	0.4	1.2	0.3	0.4	1.1	0.4	0.4	-2.6	0.8	2.6	-0.6	-0.2	-2.2	-2.0	1.0
Seed cotton	4.3	4.0	1.1	6.6	4.3	1.5	8.5	5.0	1.7	1.7	2.9	1.5	0.2	0.5	0.9	1.5	2.3	0.7

Notes: a. Production in mill MT, Area in mill ha, Yields in MT/ha.
b. This is oil crops other than the four stated beneath and for WANA, it is essentially olive oil.
c. 0 means less than 0.05 mill MT, or less than 0.05 mill ha.

Source: AT2000 files.

TABLE 4.5 Livestock production in WANA

	Meat Production (mill MT)			Number of Animals (mill)			Off-Take Rate (%)			Carcass Weight (kg/an)			Meat Production Growth Rate (%)			Livestock Nos. Growth Rate (%)		
	61-63	83-85	2000	61-63	83-85	2000	61-63	83-85	2000	61-63	83-85	2000	61-85	80-85	2000	61-85	80-85	2000
Cattle and buffaloes	1.2	2.1	3.5	88.2	120.9	150.0	12.8	15.6	18.4	107	109	126	2.4	3.6	3.3	1.4	1.3	1.4
Sheep and goats	1.2	2.0	3.6	251.3	355.3	490.2	35.5	40.8	43.6	13	14	17	2.6	2.9	3.7	1.6	0.4	2.0
Poultry	0.3	1.7	4.3	198.5	662.9	1130.0	169	240	287	1.0	1.1	1.3	7.8	10.0	6.0	5.3	9.8	3.4

	Meat Production (mill MT)			Number of Animals (mill)			Milk Productivity (kg/ha)			Milk Production Growth Rate (%)			Livestock Nos. Growth Rate (%)		
	61-63	83-85	2000	61-63	83-85	2000	61-63	83-85	2000	61-63	83-85	2000	61-85	80-85	2000
Cow and buffalo milk	13.3	23.3	39.0	18.0	28.6	38.7	742	814	1008	2.6	2.6	3.3	2.1	1.5	1.9
Sheep and goat milk	4.1	6.3	9.2	71.9	110.5	140.4	57	57	65	2.2	0.4	2.3	2.2	0.6	1.5

Source: AT2000 files.

TABLE 4.6 Agro-ecological distribution of wheat, barley and pulses production in WANA

	Low Rainfall			Uncertain Rainfall			Good Rainfall			Problem Areas		
	Area	Yield	Prod.	Area	Yield	Prod.	Area	Yield	Prod.	Area	Yield	Prod.
1983												
Wheat	2458	0.6	1378	2775	1.1	2928	6715	1.5	10129	5321	1.6	8398
Barley	4251	0.6	2735	2442	1.3	3196	1552	1.7	2590	2311	1.1	2593
Pulses	1199	0.3	402	599	0.7	446	1481	1.0	1548	579	0.8	475
2000												
Wheat	1838	0.7	1294	3056	1.8	5529	6048	2.1	12614	4627	2.2	10135
Barley	4338	0.9	3815	2951	1.9	5752	2066	2.6	5287	3132	1.8	5525
Pulses	1300	0.4	538	711	0.9	639	1769	1.2	2203	604	0.9	533

	Naturally Flooded			Total Irrigated			Total		
	Area	Yield	Prod.	Area	Yield	Prod.	Area	Yield	Prod.
1983									
Wheat	5200	0.9	4655	10913	1.8	19995	33382	1.4	47483
Barley	675	0.9	609	1470	1.3	1858	12701	1.1	13581
Pulses	105	0.6	60	1370	1.0	1422	5332	0.8	4352
2000									
Wheat	4734	1.3	6265	13260	2.7	35654	33565	2.1	71491
Barley	1129	1.1	1280	1854	2.4	4485	15469	1.7	26145
Pulses	202	0.7	144	1414	1.3	1840	5999	1.0	5897

TABLE 4.6 Continued.

Notes:

1. Area in thousand ha, yields in MT/ha, production in thousand MT

2. 1983 is average of 1982-84, hence there are differences with Table 4.4.

3. The land classes in AT2000 are defined (FAO, 1987, p 126) using suitability classes from the FAO Agro-Ecological Zone study. The four suitability classes - very suitable, suitable, marginally suitable and not suitable - are related to the anticipated yield as a percentage of the maximum attainable under optimum agro-climatic and soil conditions.

   The definition of the six land-water classes is as follows:

   Low rainfall rainfed land: Rainfall providing 1-119 growing days, soil quality very suitable, suitable or marginally suitable.

   Uncertain rainfall rainfed land: Rainfall providing 120-179 growing days, soil quality very suitable or suitable.

   Good rainfall rainfed land: Rainfall providing 180-269 growing days, soil quality very suitable or suitable.

   Problem lands: The term is used to designate areas with excessive moisture and/or unsuitable soils. In these areas rainfall provides more than 269 growing days, soil quality is very suitable, suitable, or marginally suitable. Also included in this class is that part of the 120-269 growing days zones where soil rating is only marginally suitable.

   Naturally flooded land: Land under water for part of the year and lowland non-irrigated paddy-fields (gleysols).

   Irrigated lands: These comprise both fully irrigated lands which are equipped for irrigation and suitable drainage and not suffering from water shortages and of partially irrigated lands which are equipped for irrigation but lacking drainage or reliable water supplies or with low quality and reliability of distribution.

   Another land class is desert lands which are not suitable for agriculture except under irrigation. The four rainfed land classes are alternatively called arid and semi-arid, dry sub-humid, moist sub-humid and humid in the order above.

carcass weight with the rest equally divided between herd increases and increases in the off-take rate. The shift to intensive livestock production, gradual as it may be, will allow less inputs to go for maintenance and more for productivity.

It is also hoped that intensification will reduce the dependence on the fragile grazing resources in the steppes and the marginal lands and halt or even reverse the environmental degradation process arising from exploitative stocking rates. Productivity increases and intensification both imply increased importance for the input of veterinary services and management.

The requirements of such intensive crop and livestock technologies imply high growth rates in input use (Table 4.7). The use of chemical and mineral inputs as well as improved seeds will increase substantially.

Agriculture in WANA is highly mechanized. While labour use as well as the labour utilization rate is projected to increase, the historical growth in tractors will continue to be important. Tractor use will increase in intensity as arable land per tractor decreases and tractors work more per unit area with higher intensity of cropping.

The production increases in WANA and its input requirements have serious implications for agricultural investment (Table 4.8). Investment in primary agriculture will total nearly $180 bill between 1983-2000. Irrigation and mechanization alone will account for three quarters of crop investment. Investment in livestock production, comprising of herd increases and meat and milk storage, production and processing facilities, is projected to entail over $60 bill.

The investment definitions in AT2000 are quite comprehensive but may cover certain allocations that should not be charged all to agriculture. Multiple purpose hydro-electric dams,

TABLE 4.7 Input requirements in WANA

	1983	2000	1983-2000 Growth-Rate (%)
Total fertilizer (mill MT)	5.9	14.9	5.6
N	3.8	9.5	5.6
P_2O_5	1.9	4.9	5.7
K_2O	0.2	0.5	6.5
Fertilizer/ha of harvested land (kg)	59.9	131.6	4.7
N	38.5	83.7	4.7
P_2O_5	19.5	43.2	4.8
K_2O	1.9	4.8	5.6
Plant protection (1980 $mill)	1166	1686	2.2
Cereal feed (mill MT)	23.1	53.4	5.1
Agricultural labour (mill man days)	7802	11306	2.2
Labour utilization rate (mandays/year)	117	141	1.1
Tractors (thousands)	1035	1608	2.6
Arable land (ha)/tractor	137	91	-2.3
Traditional cereal seed (mill MT)	3.8	2.5	-2.3
Improved cereal seed (mill MT)	2.3	4.3	3.8

Source: AT2000 files.

tractors used for transportation, etc. are examples. Some investments, particularly those at the farm level, may not involve

TABLE 4.8 Agricultural investment requirements in WANA 1983-2000 (1980 $ bill)

	Net	Gross
Land development (a)	0.6	10.8
Irrigation	57.1	78.2
Permanent crops	5.5	7.7
Tractors and equipment	29.0	35.9
Working capital	0	7.4
CROP INVESTMENT	102.1	150.7
LIVESTOCK INVESTMENT	1.1	27.1
INVESTMENT IN PRIMARY AGRICULTURE	103.3	177.7
SUPPORT INVESTMENT (b)	34.4	120.3
TOTAL AGRICULTURAL INVESTMENT	137.7	298.0
Incremental capital/output ratios (ICOR) (c) (ratio)		7.6
Agricultural investment rate (d) (%)		21.7

Notes: (a) Includes development of arable land, soil and water conservation and flood control. Net pertains only to flood control.

(b) Includes investment in processing, transport and marketing.

(c) Gross primary investment/increase in GDP.

(d) Annual average of gross primary investment as % of agricultural GDP.

Source: AT2000 files.

actual cash outlays but such activities would have positive opportunity costs. Even with these caveat, it cannot be denied that investment requirements by 2000 pose serious challenges. The high incremental capital-output ratio (ICOR) of 7.6 dispels the myth that agriculture is not a capital-intensive sector. It also implies that probably unprecedented agricultural investment rates of over 20 percent of agricultural GDP will have to be maintained. As some investments will be quite bulky, this burden will increase substantially in certain periods.

The question whether these challenges are surmountable depends on the commitment to implement changes on many fronts.

4.2.4 Policy Implications

The policy implications relate to agricultural research and the development of agricultural productive capacity.

Research priorities would necessarily have to be linked to the pivotal areas of projections. These can be summarized under four major areas:

a. Wheat
b. Feedstuffs
c. Livestock production
d. Irrigation and water management

These will be elaborated upon in reverse order.

Before this however, two commodities will be touched upon. These are sugar and vegetable oils. It is conjectural if the region has much comparative advantage in sugar production. While investments in sugarbeet production and sugar production are politically popular, in most areas the sugarbeet land may have better uses which may generate more funds than necessary to import sugar from the international market. In vegetable oils, the sources are diverse and ecological adaptability has to be explored in the expansion of oil crops. These should be attractive crops due to the high demand for cooking oil but also because of the feed value of by-products.

In very few places in the world are land constraints as binding as in WANA. It is also a fact that major parts of the region are under rainfed agriculture while the major part of agricultural production is in irrigated areas.

The projected production increases are dependent upon using the scarce water resources (whether from irrigation or rainfall) more efficiently and in combination with other inputs such as fertilizer in order to raise both yields and cropping intensity. Hence, increasing water use efficiency should be a primary focus of research. Ways of using land more intensively need to be explored. In particular, replacing fallows with food and forage legumes in rotation with cereals appears to have potential.

Livestock production in WANA currently is carried out under a quite extensive mode. Production in the drier areas depends on grazing, usually over large areas which are viewed as a free good from the "commons", i.e., communal grazing areas. Can the livestock production increases projected for WANA be achieved without radical changes in production technology and management?

It appears that current research efforts predominantly are within the technological frame of the existing extensive livestock production systems. The point has already been made that these extensive systems cannot be perpetuated without drastic protective measures against the adverse effects they will have on the environment. It would imply that research for the 21st century's needs would have to look at the alternative of intensifying livestock production. Intensification here is used to mean less dependence on extensive grazing on the "commons" and more dependence on feedstuff production in viable areas of production. Admittedly, intensification is a relative matter of degree but complete feedlot sheep production is neither implied nor envisaged in the nature of things in the foreseeable future in

WANA. Even with this qualification, it would seem that the research problems of a higher degree of intensification of livestock production are somewhat different from those of the current extensive systems. The change of focus would have implications for management research, changes in the quality and quantity of veterinary service inputs and in the crops involved.

There is also the need for policies not to increase and preferably to reduce the pressure of livestock production on marginal areas and the steppes with tenuous environmental balances. It is possible that increased feed availability may result in increasing herd sizes rather than increasing intensification. Increased herd sizes with the same practices as currently practiced would cause ravaging environmental damage in the marginal areas and the steppes which would now be grazed by larger numbers of livestock. Therefore, the increased feed available should be primarily a substitute for such grazing areas in order to arrest environmental damage. This is one aspect of intensification of livestock production that is implied.

The crops that are used as feedstuffs, particularly for sheep production in the dry areas, are few with barley having an overwhelming dominance. The response of the current systems to increased feed demand has been to produce more barley by continuous cropping or expanding into marginal areas both with serious effects on soils. Research should be able to increase the crop mix primarily by introducing new options in forage legumes as feed crops and as elements in crop rotations. These forage legumes would also have beneficial effects on soils through biological nitrogen fixation.

Finally, wheat, which is in a class by itself, should be supported both by maintenance research and by efforts to advance the production frontier. In some places, wheat is grown in rotation with food legumes, mainly lentils and chickpeas. Again, these food legumes would enhance biological nitrogen fixation.

Research on forage and food legumes can hence be also justified from the perspective of long term viability and sustainability of agricultural production.

Despite the need for massive undertakings and accelerated change, the agricultural sector will not be able to meet the demand in WANA as is also the case currently. Deficits are projected to continue in all commodities except pulses and cotton. In pulses, the surplus is illusory because a considerable portion of pulses in WANA is produced in surplus in Turkey and most countries are in deficit status.

In many commodities, even when self-sufficiency ratios remain stable or improve, the absolute magnitude of the deficits will increase. Major deficits are forecast for wheat, coarse grains, sugar, vegetable oils and livestock products (Table 4.1).

Food self-sufficiency is stated as a policy objective in many countries in WANA. With a few exceptions, this will be a difficult and possibly infeasible task within this century. Hence, the dependence on food imports will continue. However, this can be a matter of degree and the question remains on the opportunity costs of meeting demand through domestic production as opposed to imports, mainly from outside the region. Currently, agricultural prices are depressed in international markets due on the one hand to the surpluses created in developed market economies, particularly in the EEC and north America through extensive subsidy schemes, and on the other hand due to the limits imposed on LDC exports by protectionist measures and market satiation. The production subsidies in the developed countries have distorted international prices to such low levels that the lowest cost producers of some commodities, e.g., dairy products in New Zealand, may be driven out of the market and become importers.

The general tendency in the developing countries under these conditions of depressed prices is to import, provided there are resources which can generate the funds for imports.

However, the long term prospects would counsel caution. First, there are increasing pressures within the developed countries to reduce subsidies and surpluses. Second, many studies provide clear illustration of positive global economic and welfare effects as a consequence of the reduction of such protective measures in the developed countries. Finally, while imports in LDC may provide relief in the short run, these are competitive with domestic production in many instances and may influence the development of agricultural productive capacity adversely. Invariably this is overlooked due to the priority given to the provision of cheap food to urban consumers, not without due regard to the political pressures that these concentrated urban populations can generate.

If prices are depressed because of distortions in the market which should not be expected to last, it may be desirable to invest in domestic agriculture for the long run. For WANA, even with the projected large deficits, substantial investment in agriculture will be necessary in any case. In addition, measures have to be taken in WANA against the exploitative methods of agriculture that have serious consequences in environmental degradation. The current price and policy environment does not appear to provide adequate incentives to reduce environmental degradation.

WANA faces important challenges in reorganizing a dynamic agricultural sector, beset by uncertainties stemming from both climatic and price sources, to one that will meet the demands of growing economies. Solutions will come from a commitment for improving both the technological structure as well as the economic conditions in the agricultural sector.

4.2.5 References

FAO (1987). Agriculture: Toward 2000 (Revised Version 1987), Food and Agriculture Organization of the United Nations, C87/27, Rome, July 1987.

FAO (1981). Agriculture: Toward 2000, Food and Agriculture Organization of the United Nations, ESD Series No: 23, Rome, 1981.

Somel, K. and Mokbel, M. (1986). The Importance of Livestock in Rural Welfare, ICARDA Discussion Paper 19, Aleppo, April 1986.

4.3 Fertilizer Use on Barley in North Syria. Yield Gap Analyses and Potential Impact

Ahmed Mazid and Kutlu Somel

4.3.1 Introduction

The potential of fertilizer to increase barley yields in Syria was discussed in a workshop held by Soils Directorate of Syrian Ministry of Agriculture and the Farm Resource Management Program of ICARDA, in March 1984. As a result of this workshop a joint project was initiated between the Soils Directorate and FRMP. The objective of this project is to assess the biological and economic effects of nitrogen and phosphorus fertilizer use on barley through multiple season - multiple location trials on farmers' fields in northern Syria. The experiments have been complemented by a survey. 129 farmers were monitored during three seasons (1984/85, 1985/86 and 1986/87) with two visits. These visits were directed to three groups of farmers: the farmers collaborating with the project, others from the same village and others from neighbouring villages.

In this report we illustrate why actual farm yields, on the average, are so much lower than the potential yields obtained from the on-farm trials and what the potential impact would be if the farmers applied fertilizer in northern Syria especially in zones 2 and 3.

4.3.2 Yield Gap Analyses

The yield gap between potential and actual farm yields arises due to biological and/or socio-economic constraints (De Datta et al. 1978). It is clear from Fig. 4.1 that there are substantial yield gaps, both in zones 2 and 3, between actual farm and on-farm trial yields during 1984/85 and 1985/86 seasons (the actual farm yields in 1986/87 are not available yet). It appears that farm yield can be increased by around 142-168% in zone 2 and 136-211% in zone 3. Of this potential increase 630-919 kg/ha in zone 2 and 250-800 kg/ha in zone 3 are directly attributable to fertilizer use, the remainder of the potential increase being due to other management factors.

Since these trials were researcher managed, and were specifically designed to examine soil and climatic interactions with fertilizer responses, other management factors were kept at an optimum level. For example at every site and in each season initial cultivation was done by the farmer, but the final seedbed was prepared with a spiked-tooth harrow immediately prior to sowing. Barley seed, treated with Vitavax, was sown at the rate of 100 kg/ha using an Oyjord plot planter. The phosphorus fertilizer and half of the nitrogen was drilled with the seed. The remaining nitrogen was top-dressed at the tillering stage. Weeds were controlled by a single application of Bromaxynil at the time of top dressing (MAAR and ICARDA).

In contrast, Table 4.9 summarizes farmers' practices and illustrates why a yield gap due to other management factors arises.

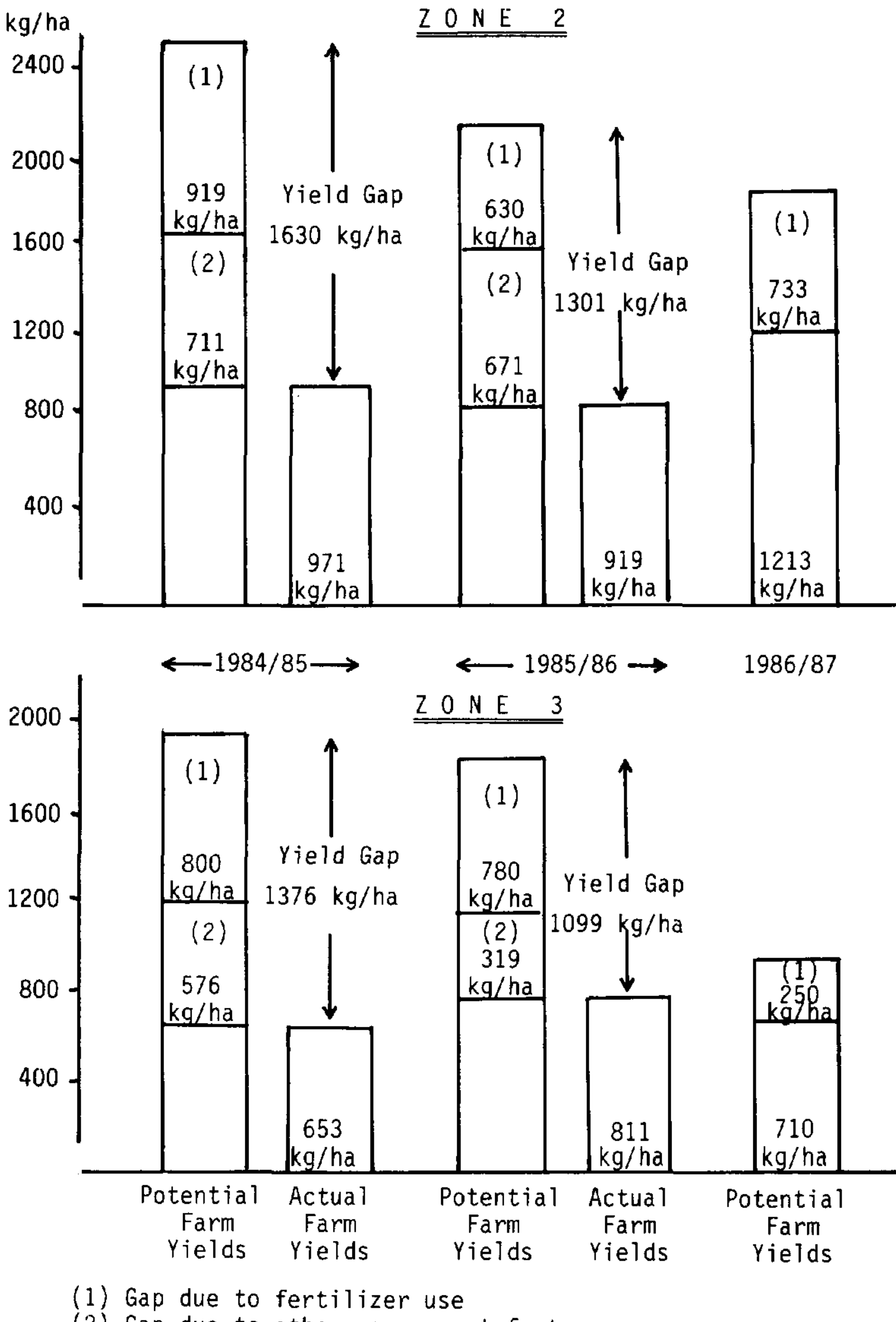

FIGURE 4.1 Yield gaps in barley grain yields, SD/FRMP trials

TABLE 4.9 Farmers' practices (% of farmers during 3 years N=129)

	Zone		Region		
	2	3	North West	North East	Total
1. Cultivation before autumn	31.7	18.2	25.4	24.1	24.8
2. Cultivation during autumn	30.2	30.3	23.9	37.9	30.2
3. Two cultivations (1+2)	28.6	33.3	25.4	37.9	31.0
4. No pre-sowing tillage	9.5	18.2	25.4	0.0	14.0
5. Rotation: barley/fallow	66.7	74.2	70.4	70.7	70.5
continuous barley	46.0	54.5	43.7	58.6	50.4
6. Average seed rate (kg/ha)	121	106	113	113	113
S.D.	(32)	(20)	(31)	(23)	(27)
7. Variety: local (Arabic Aswad)	63.5	57.6	28.2	100.0	60.5
local (Arabic Abiad)	36.5	42.4	71.8	0.0	39.5
8. Use of treated seed	3.2	4.5	5.6	1.7	3.9
9. Manual broadcasting of seed	38.1	47.0	76.1	1.7	42.6
10. Mechanical broadcasting of seed	31.8	30.3	11.3	55.2	31.0
11. Drilling of seed	30.2	22.7	12.7	43.1	26.4
12. Weed control	7.7	7.3	12.8	0.0	7.5
13. Grazing all over barley field at green stage	42.9	13.6	25.4	31.0	27.9
14. Used fertilizer on any crop in the past	46.0	33.3	47.9	29.3	39.5
15. Used fertilizer on any crop other than barley during the monitored year	34.9	25.8	33.8	25.9	30.2
16. Using P_2O_5 on barley	14.3	4.5	8.5	10.3	9.3
17. Using N at planting time on barley	9.5	3.0	7.0	5.2	6.2

It appears that there were differences among the farmers' practices by zones and regions. Also it is clear that about 50 percent of the farmers use a continuous barley rotation. The comparison of average grain yield of the no fertilizer treatment, in the on-farm trials, between barley/fallow (B/F) rotation and continuous barley (B/B) indicates that grain yields obtained from B/F rotation were 62% higher in zone 2 and 30% higher in zone 3 than those from the B/B treatment.

About 40 percent of the farmers reported they had used fertilizer on some crop in the past, more so in zone 2 than in zone 3. This indicates that 60 percent of the farmers apparently have no experience at all of fertilizer use. The percentage of farmers who applied fertilizer on barley was less than 10. Farmers gave many reasons for not using fertilizer on barley; 29 percent reported shortage of funds, 25 percent indicated risk as the reason, 17 percent answered that they had no experience or funds, 7 percent said fertilizer was unavailable and 11 percent reported other factors.

On the other hand, the average phosphate fertilizer rate, where it was applied to barley by farmers, was 84 kg/ha of Triple Super Phosphate (46% P_2O_5) with standard deviation of 31 kg/ha, and the average nitrogen fertilizer rate was 67 kg/ha of Urea (46% N) with standard deviation of 33 kg/ha. These rates are less than the preliminary indications of economic optima derived from the on-farm trials. Other components of management in the trials, such as seed treatment, sowing with a drill and weed control are currently seldom used by farmers (Table 4.9) and in combination would also have contributed to the observed yield gap.

4.3.3 Potential Impact

The farmers main reaction to the trials is manifested in changes in fertilizer use. It must be emphasized that these trials were not demonstrations nor part of an extension effort. They were on-farm trials which are an integral part of research with a farming systems perspective (Somel et al. 1986). The farmers reported that the trials were beneficial, successful and interesting. Among the monitored farmers, fertilizer use on barley in the following season increased from 11% to 35% within 1984/85 season, and from 5% to 21% within 1985/86. Another 35% in 1984/85 and 47% in 1985/86 season would have liked to use fertilizer but faced various problems. The actual use of or interest in fertilizer was higher among those who were able to observe the trials.

The potential impact on fertilizer use on barley was estimated. The following formula was applied (Tully 1987):

$$\Delta P = \sum_{i=1}^{n} \Delta Y_i \ S_i \ M_i \ A$$

where: P = production

Y = mean yield increase obtained under zone i

S = size of rainfed barley area planted in zone i

M = factor reflecting management in zone i (range 0-1)

A = rate of adoption (range 0-1)

The data used are based on the following:

i, calculations for zone 2 and 3 are made separately. Further subdivision of zones 2 and 3, according for instance to crop rotation and soil type, is feasible and would improve the accuracy of the predictions.

Y, average yield increases in on-farm trials comparing no fertilizer with the economic optimum. Also it is possible to use average increase in net revenue due to fertilizer to estimate the effects on rural income

M, calculated as the ratio of actual farm yields to no fertilizer treatment in the trial

A, is calculated at three levels, 50%, 70% and 90% adoption.

The on-farm trial data indicated that the average increases in grain, straw and net revenue per hectare due to fertilizer during the last three years were:

	Zone 2	Zone 3
Grain (kg)	761	610
Straw (kg)	1540	1190
Net revenue (SL)*	1380	790
Net revenue (US$)**	63.2	38.7

The average rainfed barley area is about 348 thousand hectares in zone 2 and about 338 thousand hectares in zone 3. The factor reflecting management was estimated as 0.58 in zone 2 and 0.62 in zone 3 from 1984/85 and 1985/86 data.

The calculation of ΔP (grain, straw and net revenue) is presented in Table 4.10 for the different adoption rates.

This discussion is somewhat crude because it looks at averages. These averages are based on both systematic influences of the experimental factors and the environmental factors (such as

TABLE 4.10 Predicted grain, straw and net revenue of barley yield increase due to fertilizer use in zone 2 and 3

	Percent Adoption		
	50	70	90
Grain (thousand tones)	140.7	196.0	253.3
Straw (thousand tones)	280.4	392.6	504.7
Net revenue (million SL)[1)]	221.8	310.5	399.2
Net revenue (million US$)[2)]	10.4	14.6	18.7

1) using local prices for both barley grain and straw as well as fertilizer
2) using C.I.F. international prices for barley and fertilizer

* using local prices for both barley grain and straw as well as fertilizer

** using C.I.F. international prices for barley and fertilizer rainfall, soils, etc.). The variability of the environmental factors influences uncertainties in production planning both at the national and the farm level. The probability of adoption must be discounted further due to the risk-increasing effects of such uncertainty. The results should then be viewed with this warning because we have not yet studied the effects of variability on adoption.

In conclusion, this brief report outlines a simple and conservative way in which on-farm trial data can be used to provide a realistic assessment of the potential long term impact of new technologies under test. In the example given here, it is clear that fertilizer use on barley would have a substantial impact on increasing sheep feed supply and rural income in the barley/livestock farming systems of Syria, but that other improvements in management could also play an important role.

4.3.4 References

De Datta, S.K., Gomez, K.A., Herdt, R.W. and Barker, R. 1978. Methodology for an integrated experiment survey on rice yield constraints. The International Rice Research Institute.

MAAR and ICARDA, Collaborative research project report on fertilizer use on barley in northern Syria, 1985/1986.

Somel, K., Matar, A., Harris, H., Cooper, P., Keatinge, D., Mazid, A. (ICARDA) and Karim J.A. and El Hajj, K. (MAAR). Fertilizer use on rainfed barley in northern Syria. Paper presented at the Third ICARDA Regional Farming Systems Research workshop, Islamabad, 7-10 April 1986.

Tully, D. Estimating the potential impact on production of new technologies. Paper prepared for the 14th ICARDA Program Committee meeting, Khartoum, January 20-30, 1987.

5. INTERNATIONAL COOPERATION

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

Two major strategies for international cooperation has been developed, as already indicated in Section 1.3.2. First, together with ICARDA's other programs, we seek to establish "systems oriented" cooperative research targetted towards the four broadly defined farming systems of our region. In doing so, we recognize that substantial variability in socio-economic, biological and environmental factors will exist within these broadly defined areas, and thus we do not attempt to transfer technology directly from equivalent systems in Syria where most of our experience currently lies. Rather, we use that experience, both of research findings and research methodology to establish projects with realistic objectives, a FSR perspective and efficient applied research methodologies.

Secondly, we believe that we have made substantial progress in specific areas of resource management, and that we have much to offer the region in this respect. Thus, although we would ideally wish to foster FSR in all our cooperative work, we have also established networks of cooperative activities which focus on single components of resource management. Wherever and whenever possible, we hope, in the future to build a systems perspective into these networks.

In this report, we present an update of some of our most important activities we are undertaking in collaboration with national scientists within the region. Our major on-going collaborative project with the Syrian Soils Directorate, which examines fertilizer use on barley in dry areas, is not specifically reported in this section, but its potential impact has been discussed in Section 4.3. The biological and economic data of this research have been reported in substantial detail in previous annual reports, and is referred to extensively in Section 2.2 of this report.

5.1 Investigation of Alternative Agricultural Water Management Practices in Northwest Egypt

Eugene Perrier and Sobhi El-Naggar

5.1.1 Introduction

Agricultural development within the Northwest Coast of Egypt requires assessment of the area's human population, land and water resources, and development potential: keeping in mind the degradation hazards. Advantage in agronomic production methods which are technically and economically feasible are being investigated; but, an increased investment in the benefits of water harvesting is needed for long-term improvement and stabilization of the barley-livestock production system. Water harvesting farming for barley and hence livestock production represents a significant component of economic output.

A common practice throughout most of the region is intensive utilization of crop residues by grazing of sheep, goats, and camels during the fallow period. Weeds and shrubs are customarily allowed to grow to supply additional forage along with the crop residues. The intensive grazing practice leaves the soil surface bare and powdery during much of the fallow period, and highly vulnerable to severe wind and water erosion (FAO 1970). The calcareous sandy desert soils of the Northwest Coast of Egypt have low fertility. Any effective management system should provide adequate nutrients to match the water supply in order to achieve the maximum yield potential.

The development potentials of this region are considerable; with some programs in progress. Nonetheless, soil and water resources are poorly used and agronomic research data is lacking in the region. Existing crop and livestock production techniques follow traditional practices which should be upgraded.

5.1.2 Project Development

The goal of the cooperative activity of the Soil and Water Research Institute, ARC, Egypt and the Farm Resource Management Program of ICARDA with the support of Ford Foundation, is to evaluate the rainfed areas of the Northwest Coast of Egypt for implementation of water management alternatives to stabilize yield and improve productivity of basic food crops. The initial objectives are to identify constraints for the implementation of water harvesting farming technology, and the potential development of water management for rainfed agriculture with linkages to production agronomy within small scale farming systems. All problem definitions must proceed from the reality of water scarcity. Rainfall is the principal source of water in the region and all other resource needs diminish in importance beside this constraint to agricultural production.

The project emphasizes variables that isolate problems in existing farming systems, identify constraints to potential development, and support an evaluation of the effect of water harvesting farming on rainfed agriculture.

The long term goal of the initial research is to administer technical and socio-economic surveys for the collection of baseline data to evaluate alternative water management practices for integration of water harvesting into rainfed farming for economic development in the Northwest Coastal Region of Egypt. This survey has the following objectives:

1. Describe the farmer's environment and farming practices which prevail within rainfed farming and water harvesting agriculture;

2. Investigate the current farming systems for probable acceptance of technical innovation and improvement of water management practices;

3. Ascertain major constraints of farming systems in rainfed farming and water harvesting agriculture; and,

4. Evaluate resources which are available for economic development and integration of water harvesting into local farming systems.

As determined by data analysis of these surveys, economically acceptable methods of exploit scarce water resources of the region will be developed which require interdisciplinary planning of water use for both actual and expected water demands. A limited quantity of water in extended areas of the Northwest Coastal Region of Egypt coincides with extensive use of marginal natural resources. The scope of these surveys is related to conservation of natural resources as well as economic benefits.

5.1.3 Population of the Northwest Coast

The total population in the East and West Mersa Matruh and Sidi Barrani districts is 86,000 according to the 1985 census. Of these, which includes the Bedouin, 27,000 live in the urban vicinity and 59,000 live in rural areas. Approximately 80% of the Bedouins are engaged in sheep and goat herding and the cultivation of barley, vegetables, and orchards. About 15% depend on commerce and transport as a source of income and the remaining 5% work for the government or private employers.

The inhabitants of the Northwest Coast of Egypt are Awlade Aly tribes who came to the north of Africa with the Islamic invitation. In successive migrations, two groups settled in the north of Tunisia, these were the Bani Helal and the Bani Seliem. Conflicts between the two groups forced a separation and the Bani Helal moved westward and the Bani Seliem moved eastward to Cyrenaica in eastern Libya.

In Cyrenaica, Okar El-Sherief of the Bani Seliem tribe married the daughter of a Bani Helal leader and two sons were born: Aly El-Kabeer and Zoweibi. Aly El-Kabeer was reared in Cyrenaica and married two wives. The first wife had one son, Aly El-Abiade, and one daughter, Khadiga. The second wife had one son named Aly Ahmer. The daughter, Khadiga, married her cousin, Gomaa ibn Kaabe.

The grandfathers: Aly El-Abiade, Aly El-Ahmer, Zoweibi, and Gomaa, are the founders of the tribes Aly El-Abiade, Aly El-Ahmer, El-Senena, and El-Gomeiate. They lived in an extended household; grazed their livestock in one place; and, retained the same customs, traditions, and mode of life. Because of this, the Bedouins called them the "Awlade Aly Tribes". Their genealogy is shown in Fig. 5.1. They developed laws, "Dorpet Awlade Aly" that are still valid today.

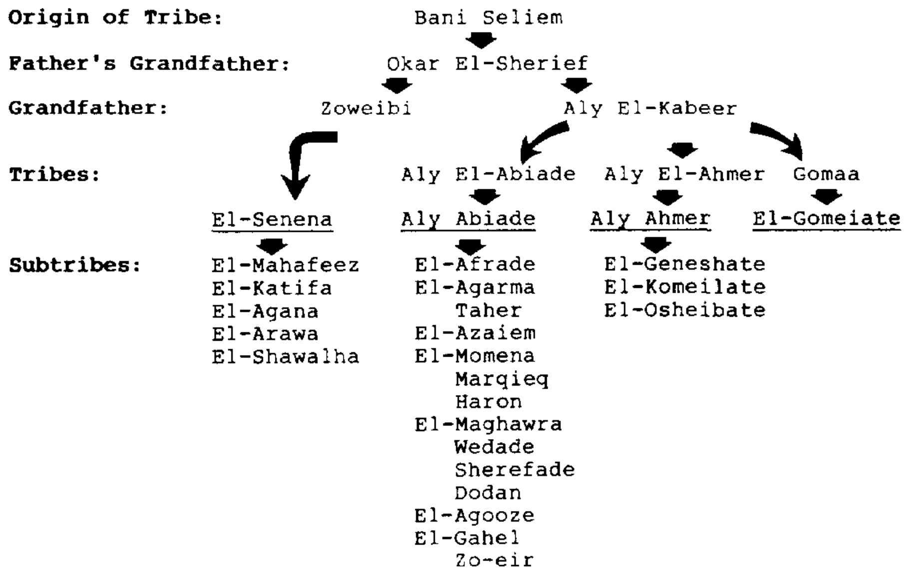

FIGURE 5.1 Genealogy Chart of the Awlade Aly Tribes*

In 1670, some of the Awlade Aly tribes and their followers from El-Morabtin tribes moved from Cyrenaica to the Northwest Coast of Egypt. New conflicts arose and the tribes formed an arbitration committee called "Maglis Orfy." The chiefs reached an agreement based on a complex combination of factors for land distribution among the different tribes.

After arbitration, every tribe or subtribe controlled a specified area of land which could extend for many square kilometers. To designate land boundaries, chiefs used natural land marks such as low or high plateaus, rocky areas, wadis, and other physical demarcations which would not be affected by climate

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* El-Morabtin tribe, followers of the Awlade Aly tribes, have a genetic connection but without a common ancestor.

or time. They issued documents indicating boundaries of the land area for each tribe. The land could then be inherited by descendants without inciting conflicts.

Today, all lands belong to the Egyptian state and the Bedouins hold these lands in trust. They cultivate these lands but cannot sell them on the open market. The original boundaries between tribes still exist. The lands of each tribe can still be inherited by the descendants without conflict. The agricultural areas are divided between the families of each tribe but the grazing area remains communal.

The Bedouins who live in the area can be divided into three main groups: (a) Sedentary; (b) Semi-nomadic; and, (c) Nomadic:

a) Sedentary: The settled populations are concentrated in the urban areas. The main economic activity in this area focuses on agriculture and pasture. Some additional economic activities have appeared lately such as construction, carpentry, plumbing, civil services, tourism, and trading. The householder chooses the form and nature of his dwelling that can accommodate his needs and suit his lifestyle.

b) Semi-nomadic or recent settler: These people are widely dispersed over the interior and live in a form of isolated, or individual dwellings where extended families settle near their landholdings. Some of the recent settlers live in association in compact camps in their tribal areas. They prefer to live in scattered permanent houses but may own a tent for summer and special occasions. These recent settlers are still engaged in livestock and crop production.

c) Nomadic Tent Camps: These Bedouins live deep within the desert some kilometers from the main road between Alexandria and Salloum. They are engaged in livestock herding only and are tent dwellers who count their population in terms of the number of tents and describe their settlements in terms of tents. The tent camps are separated by 4 to 5 kilometers from the next tent group. The herding units are considered social units which are almost self sufficient economically. In the years of good rainfall, the Nomadic Bedouin cultivates barley inside the tribal lands or in the interior in the communal grazing areas.

There are three main administrative districts: an area east of Mersa Matruh, an area west of Mersa Matruh, and Sidi Barrani. Table 5.1 shows the distribution of the population by tribal affiliation throughout the three districts.

TABLE 5.1 Bedouin population distribution in the rural areas

Tribe	Mersa Matruh (East & West)	Sidi Barrani
Aly El-Abiade	8665	3683
Aly El-Ahmer	1345	3485
El-Senena	3939	3229
El-Gomeiate	4725	
El-Morabtin:		
a) El-Kotaan	2775	5563
b) El-Morabtin	9436	2926
TOTAL	30,885	18,886

The Egyptian State established settlements for the Bedouins in 1959 and organized the central cooperative society in 1967. The central cooperative society has the authority of a rural bank and can give loans to Bedouins. There are 35 local cooperatives supervised by the central cooperative society, and distributed according to tribal membership and geographical location. The cooperatives are multipurpose and support the Bedouins with agronomic inputs, crop and animal marketing, and assist with supplemental feeds for livestock. There is one center for agricultural extension in each of the local cooperatives which help farmers dig wells and construct dikes.

5.1.4 Land Area and Land Use

The area under investigation lies about 230 km along the coast from Ras El-Hekma in the east beyond Sidi Barrani to Ras El-Seiyadi in the west, and extends between 50 to 80 km inland. The coastal plain is narrow or absent. The southern tableland slopes gently northwards and is 200 m above sea level at Salloum. The area has 218 wadis in a hydrographic network. The region includes 1.26 million hectares and can be divided into three distinct agricultural activity areas as shown in Table 5.2.

TABLE 5.2 Distribution of agricultural activity areas into three distinct strips

Strip	Distance inland (km)	Type of Agri. production	Livestock production	Water Supply
1. Coastal	5-10	fruit, vegetables	Sheep, goats	Sanias, galleries, sheet and wadi runoff
2. Barley	10-20	fruit, barley	sheep, goats	sheet runoff
3. Rangeland	20-50 >50		sheep, goats, camels	rainfall

1. The coastal strip extends 10 km inland where trees and vegetables are cultivated, with sanias, galleries, and cisterns as the main water sources. There are three main water supplies in the area: desalinization stations; ground water; and rainfall.

There are four stations to desalinize the sea water located at Sidi Barrani, El-Negeila, Mersa Matruh, and Ras El-Hekma. The Bedouins use this water for drinking only because the state charges 1.82 $US (4 EL) for one cubic meter.

Groundwater suitable for agriculture and domestic use exists in shallow non-arteisan aquifers which are recharged directly by rainfall and infiltration of surface runoff. Artesian water is generally brackish in this area. The rate of discharge of dug or drilled wells and collecting galleries depends on the depth, nature, and location of the aquifer (Freeze and Cherry 1979). Water lifting is done by buckets, shadoofs, small pumps, or windmills. Windmills are being abandoned and replaced by small mechanically driven pumps. It is estimated that a dug well, 10 m deep, can irrigate 1.26 ha at a cost of 0.10 $\$US/m^3$.

Groundwater stored in the coastal sand dunes is exploited by collecting galleries. The estimated cost of pumping from the galleries is about 0.03 $\$US/m^3$ which includes costs of construction, operation, and maintenance of the gallery and pumping unit. Of the total income received from this land area, 44% is from fruit tree production, 45% results from sheep and goats, 5% from vegetables, 1% from barley production, while the remaining 5% of income is from off-farm activities.

2. The barley strip is located 10 to 20 km inland, where existing land use is cropped to barley, scattered fruit trees, and grazing. Rainfall infiltrates into the soil; whereas, the excess water flows over the surface as sheet or wadi runoff. Most Bedouins have cisterns and dikes to store this runoff. Each household has two or three cisterns: domestic, livestock, and irrigation with a capacity ranging from 100 to 3000 m^3 or more. The cost of excavating cisterns is 4.55 $US/$m^3$ or roughly 5,000 $US for a 1000 m^3 cistern. Dikes have been constructed in many wadis to prevent the flow of runoff from reaching the sea and to facilitate winter watering in the spreading zones and range improvement areas. Fruit trees provide 45% of the Bedouin's total income, sheep and goats contribute 41%, barley contributes 12%, and the remaining 2% is from off-farm activities. Trees are becoming more important than herding because of wadi development, the excavation of cisterns, and construction of dikes.

3. The rangeland strip, 20 to 80 km inland, is used for communal grazing of sheep, goats, and camels. This area is highly degraded without enough rainfall for economic water harvesting. The estimated annual rainfall is less than 50 mm.

5.1.5 Weather for the Northwest Coast

In the Northwest Coast of Egypt, the last rainfall-runoff and barley harvest was recorded in 1982, and prior to that time, in the 1979 and 1973 seasons. Most barley-livestock farming is designed for rainfed agriculture. During low rainfall years, the intrinsic topography of the fields assures some barley grain is harvested every year to sustain next year's seed; however, the stubble is grazed every year. Only once in every five years is enough barley produced with a surplus yield for sale or animal feed. In the camel grazing areas which are 70 km inland, the last significant pasture production occurred in 1979 because the higher rainfalls of 1982 did not reach this region.

The convective rain storms from the Mediterranean Sea occur throughout the winter months and the effects of arctic fronts during December and January are similar to those of other Mediterranean climates. Climatic data from the region shows an average annual rainfall of 140 mm.

Data collection is an important step in the early phases of any small scale water harvesting project. The need is underscored for extensive records of daily rainfall and evaporation at each study site. General soils data on the physical and chemical properties gives a view of the potential for agriculture within the region. Several sets of monthly data along the Northwest Coast of Egypt were analyzed and evaluated to present a descriptive profile of climatological information. The data set ends in the 70's but it does allow a perspective of the rainfall patterns which can be expected in the region.

The convective rain storms from the sea occur in the fall and early spring. The seasonal distribution of the mean monthly rainfall is similar for the three coastal cities: Mersa Matruh, the major city in the region, Sidi Barrani, and Salloum in the west on the Libyan border. The mean monthly rainfall in Table 5.3 shows that the study area has a deficit rainfall for agronomic production and that forage production on the upper coastal area is severely restricted. Mersa Matruh and Sidi Barrani receive at least 30 mm in December and January the months of heaviest rainfall; whereas, Salloum receives only 20 mm.

The mean monthly rainfall collection by water harvesting would start in November and would stop by March (Table 5.3). In the best years, values show that rainfall should not limit crop growth but in most years rainfall will be severely deficient.

TABLE 5.3 Mean annual, mean monthly, and 5-year, 10-year, and 25-year monthly-recurrence rainfall (mm), for Mersa Matruh (63 yrs), Sidi Barrani (39 yrs), and Salloum (47 yrs) in the Northwest Coastal Region of Egypt

CITY	Annual			Monthly	Monthly recurrence rainfall (mm)		
Month	Mean	Max.	Min.	mean	5-year	10-year	25-year
MERSA MATRUH:	140	386	34				
Sep				2	2	5	11
Oct				14	18	49	87
Nov				24	41	49	73
Dec				30	54	72	96
Jan				34	60	79	122
Feb				19	36	45	60
Mar				13	21	26	41
Apr				3	4	7	24
May				2	4	9	17
SIDI BARRANI:	148	336	41				
Sep				0	0	1	3
Oct				18	37	55	72
Nov				24	41	48	64
Dec				34	58	68	102
Jan				31	52	78	98
Feb				22	37	62	90
Mar				13	22	36	47
Apr				3	5	10	22
May				4	5	16	24
SALLOUM:	104	324	4				
Sep				1	1	4	12
Oct				11	17	40	67
Nov				23	27	47	86
Dec				22	41	52	92
Jan				20	37	51	84
Feb				12	21	33	46
Mar				9	15	23	44
Apr				3	5	6	21
May				4	4	14	26

Rainfall data is only a part of the information needed for designing a small-scale water harvesting system; measurements of pan evaporation or solution of the Penman equation for evapotranspiration are also required (Perrier 1986). Monthly values of reference crop evapotranspiration, ET_o, (mm) are shown in Table 5.4 for the growing season (Doorenbos and Pruitt 1984). The entire Northwest Coastal Region has a stable climate with increases in ET_o progressing westward from Mersa Matruh to Salloum which has the highest water demand of the three cities. The ET_o is always greater than amount of rainfall for the region. Estimates for the seasonal water balance for field crops specific to a given site are needed to design a water harvesting system.

TABLE 5.4 Monthly reference crop evapotranspiration, ET_o, data (mm) for three cities in the Northwest Coast of Egypt

City	NOV	DEC	JAN	FEB	MAR	APR	MAY
Mersa Matruh	86.1	84.6	80.3	92.4	121.5	140.7	160.9
Sidi Barrani	89.4	91.5	91.8	103.0	131.8	153.3	161.8
Salloum	97.8	104.8	100.8	112.6	152.5	156.6	162.8

5.1.6 Development Potential for Water Harvesting

Many farm sites within the barley strip are of ancient development for water harvesting, possibly for Roman times. In fact, the region was known as the bread basket (wheat) of the ancient Roman Empire (FAO 1970). If this were true, then the water harvesting skills of the Roman engineer were highly developed. The simplest explanation proffered by many scientists suggests that a climatic change has occurred within this region. Inevitably, many different cultures have passed through and made their mark on the region. Where catchment basins appear to have been developed, roads are seen crossing the basins diminishing the effectiveness of any rainfall collection except during the most severe storms. The use of traditional farming practices have degraded this region and re-establishment of economic barley-livestock production will be a slow and tenuous process.

For water harvesting, a catchment basin with a compacted soil surface requires a threshold runoff value of 6 mm before collection would occur, i.e., as a rule-of-thumb, 6 mm of rainfall would be lost to the processes of wetting, micro-surface storage, and evaporation. To design effective water harvesting systems, some factors should be known in greater detail such as daily rainfall and daily pan evaporation data. These data permit calculation of the collectible rainfall in connection with catchment basin design.

The importance of daily rainfall can be seen in Fig. 5.2 for three years of record for Mersa Matruh. In general, the design of a catchment basin specifies the threshold value of rainfall needed for runoff. If a catchment basin were ridged, compacted, and surface sealed, the threshold value would be 3 mm or less, for example, in a rainfall of 10.2 mm, at least 7.2 mm would be collected. Using this criteria, during 1979 at Mersa Matruh there were 11 collection storms and in both 1980 and 1981 there were 9 collection storms for each year. During 1979 a potential of 72.7 mm could have been collected, in 1980, 41.8 mm, and in 1981, 45.1 mm. If a catchment basin were constructed on a 3:1 ratio, that is, three times the size of the area to be cultivated, then for 1979, with a total rainfall of 129.8 mm, the collected water would have been 129.8 + (3 x 72.7) = 347.9 mm/ha. In 1980 with 113.8 mm of annual rainfall, the collection would have been 239.2 mm/ha, and in 1981 with 82.3 mm of rainfall the collection would have been 217.6 mm/ha. These calculations are quite conservative as the average annual rainfall for Mersa Matruh is 140 mm and the three years examined are below the annual average.

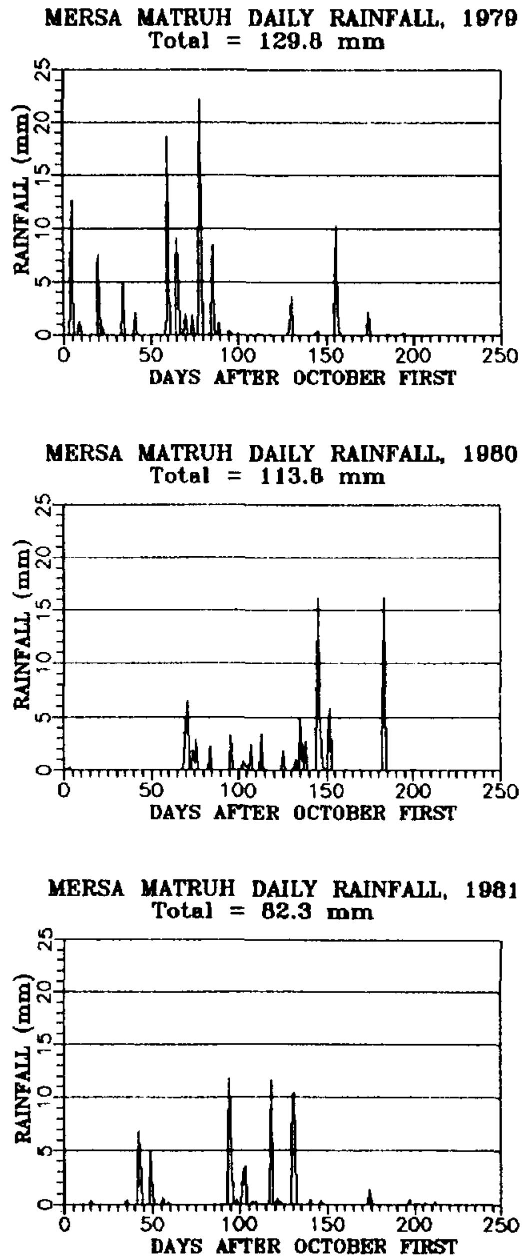

FIGURE 5.2 Daily rainfall amounts for Mersa Matruh, N.W. Egypt, for three consecutive seasons

In 1979 the bulk of collectible rainfall from October through December was 64.8 mm. In 1980, only 6.9 mm fell during this period, and in 1981 only 7.3 mm. Direct application of runoff to fields does not necessarily provide an adequate supply of water during the heading and flowering stages of barley. Although for these years, there would have been adequate water collected for germination, in 1979 where only 7.9 mm could have been collected in the spring. Some water storage in soil or a check dam would have been required to prevent plant-water stress.

If the design and construction of a catchment basin gives a threshold value greater than 3 mm then much less rainfall would be harvested. In many soil catchments, 6 mm is a common threshold before collection occurs. For the above example, during 1981 the driest year, there would only be 6 collection storms with a potential of 23 mm of rainfall collected. To grow barley which needs 250 mm of well distributed rainfall for "good" yield, then a collection basin of 7:1 would be needed for 243.3 mm. A 7:1 collection basin under natural conditions, such as rock faces or other uncultivable runoff areas with minimum maintenance, may be economically realistic for many locations.

The 10-year recurrence rainfall (Table 5.3) is usually adequate for the economic design of a catchment basin or storage facility (Frasier 1987). A 10-year recurrence rainfall for Mersa Matruh can increase the average amount of water received by 72 mm (Hjelmfelt and Cassidy 1975). A catchment basin with a 3 mm threshold value, a 3:1 design criteria, and a 10-year recurrence rainfall needs a cistern or check dam with a capacity of 2,000 m^3 to conserve the water supply to cultivate one hectare for barley production. However, for cost efficiency, an overflow or spillway would have to be designed into the storage facility to control excess runoff as shown by the 25-year recurrence rainfall which could have a collection of 4,440 m^3.

5.1.7 Discussion and Conclusion

With population growth, shortages of food and other agricultural products will increase if the level of technological output continues at its present rate in the Northwest Coast of Egypt. Rainfed production methods which are technically and economically feasible must be continued. However, an increased investment in the benefits of water harvesting farming must be made as an alternative towards food security in the future.

Advances and investments in water management practices will have to be balanced against development of improved marketing and support facilities for rainfed agriculture. Development should be targeted towards small scale farming systems that diminish non-technical constraints which produce and dispose of surplus within the country's existing infrastructure.

Minor changes in rainfall distribution patterns in Northwest Egypt cause dramatic fluctuations in yield. This sensitivity to the stochastic nature of low rainfall climate does not permit farmers control over agricultural production. Any method which will increase the amount of rainfall infiltrating into the soil will increase productivity. Moisture conservation technology is concerned with reducing runoff to negligible amounts, retarding direct evaporation from the soil surface, limiting transpiration by weeds, and using the bulk of the rainfall for crop transpiration or water storage within the soil profile for later use by the crop. Optimal water storage in soil requires that an adequate amount of rainfall infiltrate to the depth of roots, with the remainder of the water stored in the soil, check dam or cistern for later distribution. Selection of appropriate water harvesting farming systems depends on the evaluation of rainfall quantity, distribution and intensity, as well as site topography, soil, and labor skills and supply.

If the design of a water harvesting system presents a farmer with too big a burden and too little profit, the system is likely to fail. In areas where water harvesting is not fully understood or accepted because of various socio-economic factors, system design is extremely critical. The selected water harvesting system must support a positive economic alternative to existing conditions if farmer acceptance is to be expected.

5.1.8 References

Doorenbos, J., and Pruitt, W.O. 1984. "Guidelines for predicting crop water requirements". FAO, Irrigation and Drainage Paper No. 24, Rome, Italy.

FAO/UNDP, 1970. "Preinvestment survey of the Northwestern Coastal Region: Rpts 1-6". United Arab Republic. ESE: SF/UAR 49, FAO, Rome.

Frasier, G.W. 1987. "Water harvesting for collecting and conserving water supplies". In Alfisols in the Semi-Arid Tropics: a Consultant's Workshop, ICRISAT, Patancheru, Andhra Pradesh, India.

Freese, R.A., and Cherry, J.A. 1979. "Grounwater". Prentice-Hall, Inc., Englewood Clifffs, New Jersey, USA.

Hjelmfelt, A.T. and Cassidy, J.J. 1975. "Hydrology for engineers and planners". Iowa State Univ. Press, Ames, Iowa.

Perrier, E.R. 1986. "Small scale water harvesting schemes: design criteria". ASAAE, 86-2502, St. Joseph, MI

5.2 Contrasts in Barley Production Northern Syria and South East Turkey

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5.2.1 Introduction

A survey of barley producers was conducted by ICARDA for the 1981/82 season in northern Syria. Subsequently, a survey of barley producers was conducted by researchers from Cukurova University, with support from ICARDA, in south east Turkey for the 1984/85 production season.

The survey areas are contiguous; in Syria, they cover the provinces of Hassakeh, Raqqa, Aleppo, Homs and Hama, and, in Turkey, the provinces of Gaziantep, Sanliurfa and Mardin. In Syria, the sampled provinces have over 90 percent of barley production area. In Turkey, the three provinces have only 9 percent of the barley production area.

The two barley surveys in Syria and Turkey were conducted in different years. In spite of this, comparing the results should provide interesting contrasts about barley production practices. A more detailed comparative study, planned for 1987/88, will explore the contrasts in barley production between the two areas further and in terms of statistical analyses. The present discussion is only along broad lines.

The political border between Syria and Turkey delineates differences in the physical production environment as well as social and economic differences. Some salient aspects of these differences are presented below. In the discussion, Turkey is used to mean south east Turkey and Syria is used to mean northern Syria.

5.2.2 The Physical Environment

In Turkey in three provinces the winters are mild and the summers are hot and dry. Precipitation is predominantly in the form of rainfall. It has a unimodal annual distribution and occurs between October and May with the peaks between December and April. Average October to May rains range from 437-550 mm. The survey area was divided into three areas which exhibited average rainfall patterns as follows: Zone A 300-400 mm, Zone B 400-500 mm, Zone C 500+ mm. Soils in Turkey, as determined from the sample, are of good quality; most were deep soils with fine texture, and the land is level.

In contrast, the survey area in Syria focused on Zone 2 (250-350 mm rainfall but not less than 250 mm two thirds of the years), Zone 3 (250+ mm rainfall but not less than 250 mm in half the years) and Zone 4 (200-250 mm rainfall and not less than 220 mm in half the years). The winters are mild but frosts can be observed and the summers are extremely hot. Rainfall occurs mostly between November and April. Soils are of average quality, about equally distributed between deep, medium and shallow soils, flat and medium sloped land, with medium to fine texture as determined from the sample. Soils are low in organic matter and also in soil available P. Average Olsen-P is 5.8 ppm in 0-20 cm, with 80 percent of the sampled plots having less than 7 ppm.

These differences reflect on cropping patterns. In Syria, integrated barley-livestock production dominates but in Turkey wheat dominates the system; it covers more area than other crops and is considered to be the most important activity by farmers.

5.2.3 Social and Economic Differences

One interesting contrast that may be related to these trends is that the relative price of N fertilizer to barley in

Turkey in 1983/84 was slightly less than that in Syria in 1981/82 while that of P_2O_5 was almost half. However, the relative prices in Turkey increased drastically in 1984/85.

In Syria, there were restrictions on fertilizer allocation to the dry barley production areas but in Turkey there were no administrative restrictions on fertilizer allocation.

In terms of farm resources, Syria has larger average farm size, larger average barley area, more barley parcels (i.e., fragmentation) than Turkey, and the largest barley plot from which technical measurements were taken is larger on the average in Syria. Turkey appears to have higher ownership of machinery and equipment but this may be a misleading contrast given the widespread use of custom services and sharecropping in Syria. The availability of off-farm employment and hence off-farm income appears to be higher in Turkey.

5.2.4 Differences in Barley Production Practices and Yields

Major production factors are summarized in Table 5.5 for the two areas under comparison. In both areas, continuous barley is the main rotation on the largest barley plot but barley-fallow is the other principal rotation in Syria while barley-wheat and barley-other crops rotations are important in Turkey. The better environmental conditions and the widespread availability of fertilizers in Turkey may have reduced the advantages of fallowing.

Land preparation in Turkey appears, on average, to involve more tillage. In both areas, land preparation is almost all conducted with tractors.

Average seed rates are over 50 percent higher in Turkey, apparently a reflection of better environmental conditions. In

TABLE 5.5 Comparison from the barley production surveys in northern Syria (1981/87) and south east Turkey (1984/85)

	N. Syria	S.E. Turkey
Sample size	153	181
Total farm area (ha)	52	40
Total barley area (ha)	24	12
Number of barley plots	2.7	2.0
Largest barley plot area (ha)	14	7
Most important activity (%)		
Barley	40	18
Livestock	38	8
Wheat	18	44
Rotation on largest plot (%)		
Barley-barley	40	40
Barley-fallow	37	12
Barley-wheat	0	18
Seed rate (kg/ha)	107	164
Broadcasting (%)	17	9
Drilling (%)	36	67
Usual planting date (%)		
After first rains	8	37
Before first rains	75	21
Fertilizer use on largest plot (%)		
N	9	82
P_2O_5	11	84
Barley yields		
N. Syria (1980/81)	887	-
N. Syria (1981/82)	463	-
S.E. Turkey (1983/84)	-	1570
S.E. Turkey (1984/85)	-	1520

both areas farmers use predominantly their own seeds but in Turkey nearly half the farmers use chemical seed treatment, a practice that is virtually non-existent in barley production in Syria. This again would be an apparent reflection of the higher probability of seed borne diseases in the more moist production environment in Turkey. In both areas two-row black barley varieties dominate but in Turkey less than 10 percent of the farmers use six row varieties as well. A paradoxical contrast is that in Syria most farmers (75 percent) plant before the first rains but in Turkey this is not the case; most (37 percent) plant after the first rains and over 40 percent plant regardless of first rains or vary planting time each year. In Turkey, planting is more mechanized and the use of proper seed drills higher.

The most striking contrast is in fertilizer use. In Turkey fertilizer use (both N and P_2O_5) is widespread but in Syria, it is confined to Zone 2 and mostly to Hama province. Clearly, this is both a reflection of the differences in the physical environment and fertilizer policies. Weed infestation, though minor, is higher in Syria but this may be a reflection of chemical weed control in Turkey which needs to be assessed. Farmers in Turkey have identified weeds to be a major problem and are using weed control. The fact that the Turkish farmers tend to delay planting until after the first rains may, in part, be associated with weed problems. In the 350-500 mm rainfall zones of Syria, wheat growers also delay planting to allow weeds to germinate which are subsequently killed by the seedbed preparation tillage.

In Syria mechanical harvesting is lower (44 vs 93 percent) but this may be due to a high proportion of plots (35%) that were not harvested. By the same token, in Syria, grazing instead of harvesting appears higher and this may be a reflection of differences in seasons. (Grazing at the green stage is higher in Turkey, probably a reflection of greater vegetative growth under better environmental conditions.) Yields are not exactly comparable due to seasonal differences but they are obviously higher in Turkey. A better basis for comparison would be long term yield expectations which need to be assessed.

5.2.5 Preliminary Conclusions

The two barley production surveys in northern Syria and south east Turkey indicate differences arising from both the physical and the socioeconomic environment. This is reflected to some extent in what farmers consider to be important factors that prevent higher yields. Rainfall is important in both areas but soils come second in Syria while weeds are second in Turkey. In economic factors, in Syria managerial problems rank first while in Turkey, problems associated with the availability (not the price) of inputs rank first. Further analysis of causes and effects should provide interesting comparisons. This analysis should consider the variation that exists within each area as well as the contrasts between.

5.3 Soil Test Calibration Network

Abdallah Matar

In June 1986, ICARDA, the MidAmerica International Agricultural Consortium (MIAC) and the International Development Research Center (IDRC) sponsored the first regional workshop on soil test calibration under rainfed agriculture. The meeting was held in Aleppo. The 17 participants were from Cyprus, Jordan, Morocco, Pakistan, Syria, Turkey, Canada, The Netherlands and the United States of America. The papers presented by the participants on soil fertility and soil test calibration have been subsequently published (P. Soltanpour ed. pp. 177). At that meeting the participants unanimously approved the following statements and recommendations.

1. That a regional soil test calibration network was needed to increase fertilizer use efficiency on cereal, food legume and forage production under rainfed agriculture in North Africa and West Asia and that ICARDA should be the primary coordinator of the network.

2. That a regional soil test calibration project should be initiated for North Africa and West Asia and the proposal, written by ICARDA, should be submitted to potential donors.

3. That an ad hoc scientific committee be appointed to write guidelines for a regional project in soil test calibration, with joint fertilizer experiments to be conducted by countries of the region.

4. That a soil test calibration workshop be conducted yearly for participants to present the previous year's results of fertilizer experiments, plan next year's research and devise fertilizer recommendation guidelines,

Later in 1986, ICARDA submitted to United Nations Development Program (UNDP) a project proposal on soil test calibration for possible funding. UNDP agreed to sponsor the regional workshops and training courses aimed at improving the proficiency of national scientists in soil fertility research.

The second regional workshop on soil test calibration was held in Ankara, Turkey in September 1987. It brought together 27 participants representing 12 countries to discuss the results of research based on the common experimental design of the previous season. The participants included staff from ICARDA, national scientists from the region and some soil experts from Holland, USA and Canada. The discussions focused mainly on correlations between $NaHCO_3$-extractable P (Olsen-P) in soil and responses by barley and wheat to applications of phosphate fertilizer. This focus reflects the key role played by the two cereal crops in the region and the P-deficient status of most unfertilized agricultural lands. Responses by food and forage legumes to phosphate fertilizer were also discussed, and comparisons between the Olsen method of extracting P ($NaHCO_3$) and other cheaper and less time-consuming methods were also considered. Several contributions dealt with the response of cereals to N fertilization and related the findings to the tests for mineral and nitrate-N in the soil. The research papers presented at the workshop will again be published by ICARDA.

The experimental data from the first year of the network's research enabled the participants to tentatively classify soils according to whether cereals and legumes could be expected to respond to applications of phosphate fertilizer. This classification is based on values obtained by the Olsen test of surface soil samples (0-20 cm). The participants formulated the following preliminary recommendations:

a) Olsen-P less than 5ppm, add 50 to 60 kg P_2O_5/ha
b) 6 to 10ppm, add 30-40 kg P_2O_5/ha
c) more than 10ppm, plant without adding P

Ultimately, recommendations such as these will result in more efficient use of phosphate fertilizer and major savings to the farmers in the region. For example a recent soil fertility survey in the wheat growing areas of Syria showed that a large proportion of the soils which have been fertilized and cropped regularly now have residual levels of P equivalent to more than 10ppm and yet farmers still apply high levels of phosphate fertilizer. In contrast, in the drier barley growing areas, phosphate deficiency is wide spread (Olsen-P<5.0ppm) and yet currently few, if any, farmers have access to fertilizer. Clearly re-allocation of phosphate fertilizer from wheat to barley growing areas in Syria would have a substantial impact. The implications of this is currently the subject of an on-going study at ICARDA. Similarly in Tunisia, tests of vertisols indicate that current levels of Olsen-P exceed 15ppm.

These recommendations will be improved in the year to come as more experimental data becomes available, and interactions between crop, soil, climate and fertilizer responses become better understood and quantified.

Preliminary findings from studies of nitrogen application on wheat and barley in the region indicate that tests for mineral and nitrate-nitrogen are well correlated with levels of nitrogen in grain and total biological yields. The critical levels of nitrate-N in the top 0-60 cm of the soil, above which responses would not be expected, appears to be 50-60 kg/ha. These results are of interest since most agricultural institutions in the region are using total N in soils as the N test and this has proved to be a poor indicator for N recommendation. More work is required to confirm and extend this information and to develop a model that can be used for estimations of how much nitrogen is required by cereal crops. Such a model will need to consider rainfall, crop rotation, soil tests, target yields and other environmental factors.

During the Ankara workshop, the initial guidelines for joint fertilizer experiments of the first season, were reviewed and again adopted by participants. The participation of Tunisia, Algeria and Iran in the network during 1987/88 is under serious consideration by their National Scientists.

In conclusion, we feel that the regional network on soil test calibration is gaining great momentum. It is helping to bring together national soil scientists working on soil fertilization, and enables them to discuss similar work conducted under various agro-ecological conditions of the region. The potential for expansion of the network to cover more countries and more national scientists within each country is considerable.

5.4 Agricultural Labor and Technological Change: A Regional Network

Dennis Tully

In the WANA region, mechanization of agriculture began during the Second World War and continued, with policy and market incentives, in subsequent decades. Most countries reached maximal cultivated area, using tractors and harvesters, by the 1970s, although small areas of draft tillage persist. Mechanization coupled with the industrialization policies of the 1950s and 1960s, which created employment in urban areas, caused many agricultural laborers to leave rural areas and migrate to cities. Of the remaining labor force, large numbers migrate seasonally to work abroad or in urban areas. Agricultural work is increasingly carried out by women and the elderly, who are unable to find other employment opportunities.

These changes have been particularly noticeable in rainfed agriculture, which is characterized by highly seasonal labor demands as well as relatively low labor productivity. These factors, coupled with small holding sizes, lead farmers to try to maximize their incomes from non-agricultural pursuits.

As a result, labor replacing technologies are usually of interest to owners of small as well as large farms. Such technologies are often made available economically to small and medium-sized farms via custom operators, who may be private operators, cooperatives, or government agents.

A significant question remains concerning the impact of labor- replacing technologies on the landless rural labor force. It is not clear how important agricultural labor is in the overall employment calendar of landless families. On the other hand, rural unskilled labor seems to be becoming less available, which is leading to changes in farm choices. For example, the cultivated area of lentils is declining; farmers cite the high cost and problems associated with manual harvesting.

The Agricultural Labor and Technological Change project was undertaken to assess the relevance of these issues to ICARDA and agricultural research generally. Through cooperation between ICARDA and scientists of West Asia and North Africa, the present project is:

> Preparing a review of available data on the impact of technological change on employment and labor, and the importance of labor issues to technology choices.
>
> Supporting field research on these topics by scientists in national institutions.
>
> Establishing a network of regional scientists working on adoption and impact issues in agriculture.

The review of available data includes: regional overview papers on Labor Markets in Nonagricultural Sectors; Mechanization, Off-farm Employment, and Agriculture; and Changing Availability and Allocation of Household Labor, as well as country review papers on Turkey, Cyprus, Syria, Jordan, Iraq, Yemen Arab Republic, Tunisia, and Morocco. Most manuscripts have been received, and the current season will see the completion of writing, editing and publication of the data base review as a book.

Eight proposals for research projects by national scientists have been accepted and funded (with funds from Ford Foundation and IDRC). ICARDA will provide overview and technical support.

All projects are to be complete and reported by 30 June 1988. They include the following:

Jordan: Impact of Technology on Employment in Rainfed Farming in Irbid: Faculty of Agriculture, University of Jordan (M.S. Thesis).

Turkey: Household and Hired Labor and Optimal Crop Choice in Konya: Faculty of Agriculture, Ankara University.

Turkey: Aspects of Labor Affecting Choice of Technologies by Farmers; Department of Economics, Middle East Technical University.

Algeria: Emploi Global et Technologies Agricoles: Centre de Recherches en Economie Appliquee pour le Developpement.

Tunisia: An Inquiry into the Bases of the Acceptance and Rejection of Technical Change: A Case Study of a Tunisian Rural Community. University of Missouri, Columbia (Ph.D. thesis).

Tunisia: Mechanisation Agricole et Transformations Socio Economiques dans l'Agriculture d'une Region du Semi-aride Tunisie: INRAT.

Morocco: Les Implicationes des Mutations Technologiques sur l'Emploi et le Systeme Agricole dans la Region de Karia Ba Mohamed: Faculte des Sciences Juridiques, Economiques et Sociales, Universite Mohamed Ben Abdellah, Fez.

Morocco: La Mecanisation et l'Emploi Agricole en Zone Aride et Semi Aride: Cas de la Haute-Chaouia: Direction de Developpement Rural, IAV Hassan II.

Other activities which contribute to the project's research goals are technically supported by input from the coordinator, and may be included in a final compilation of studies. These include:

Syria: ICARDA studies on: (1) time devoted to management as a function of farm size and off-farm employment; (2) effects of technological changes in agriculture on employment of rural landless.

Syria: ICARDA/Ford Foundation study of Household Level Economic Processes.

Morocco: Study with INRA/USAID Aridoculture Center on custom services in mechanical operations.

A workshop is planned at the completion of the case studies to bring together the national scientists and ICARDA staff who will together assess the results. It is hoped that this will lead to recommendations for research policy vis-a-vis employment and labor availability, and identify important areas for additional research.

5.5 Supplemental Irrigations Systems of the Near East and North Africa

Eugene Perrier

The science of supplemental irrigation is a pioneer in the domain of agriculture but its impact on production economics of rainfed cereals in semi-arid regions is being recognized (see Section 2.5). Many countries of the Near East and North Africa are actively establishing internal organizations to administer the ramification of this technology. Presently, information is lacking in the region concerning farm production practices using supplemental irrigation, i.e., costs, constraints, and economic prospects of small-scale water management alternatives.

The Farm Resource Management Program (FRMP) at ICARDA with the support of Ford Foundation and the International Development Research Center (IDRC, Canada) is coordinating national scientists from 12 countries in the collection of secondary data and the administration of surveys at the national level. The 12 participating countries in the Near East and North Africa are:

1. Algeria	5. Jordan	9. Pakistan
2. Cyprus	6. Libya	10. Syria
3. Iran	7. Morocco	11. Tunisia
4. Iraq	8. North Yemen	12. Turkey

A structured questionnaire was provided to national scientists for collecting baseline data in each country for determining design parameters for the improvement of rainfed farming and the integration of supplemental irrigation and water harvesting into local farming systems. The scope of these surveys is related to possible economic benefits as well as the conservation of natural resources. After conducting surveys with agricultural extension personnel within uniform agro-ecological zones, the national scientists prepared manuscripts for presentation at a seminar held in Rabat, Morocco in December 1987.

The responsibilities undertaken by the national scientists are:

1. collection and assessment of secondary data sources at the national level;

2. administration of precoded questionnaires with agricultural extension personnel in uniform agro-ecological zones;

3. a review of current literature about supplemental irrigation within the country;

4. preparation of a manuscript for the seminar which incorporates the following categories of information:

   a. a description of the farmer's environment and farming practices of rainfed and supplemental irrigation agriculture;

   b. an evaluation of the current farming practices for acceptance of technical innovation and improvement using water management techniques;

   c. identification of major constraints to rainfed and supplemental irrigation agriculture;

   d. assessment of the impact of supplemental irrigation on rainfed agriculture; and,

   e. an inventory of national resources which are available for agricultural development with integration of supplemental irrigation into local farming practices.

A report will be developed entitled "Supplemental Irrigation Systems of the Near East and North Africa," using the secondary data sources, manuscripts, and analyses from the surveys. The report will describe existing supplemental irrigation systems including a literature review, an examination of secondary data sources, and results of surveys administered to agricultural extension personnel within uniform agro-ecological zones for ICARDA mandate countries.

The uniform agro-ecological zone is defined as a homogeneous region having the same non-varying form of agricultural science. They are concerned with the interrelationship or patterns of farming practices and climate within a designated geographical boundary. Interest spotlights rainfed areas which use or potentially could use supplemental irrigation. In addition, some of the zones may contain water harvesting farming systems and information on these systems is important to the potential for development of agricultural production within the country.

As water is the major constraint to rainfed farming in the Near East and North Africa, this is the major component when selecting uniform agro-ecological zones. Three farming systems are being considered:

1. rainfed farming is defined as management of crop production under natural rainfall: no water added;

2. supplemental irrigation farming is defined as a management technique which is used in an area where a crop can be grown by natural rainfall alone but additional water stabilizes and improves yield. Whether to irrigate or not is decided purely on the estimated profitability of doing so; and,

3. water harvesting farming is a management technique for collection of natural rainfall from a modified or treated area to either maximize or minimize runoff whichever method is selected for a specific site.

In the agro-ecological zones under investigation, rainfall is of major importance but soils, vegetation, and cultural practices which are similar must also be considered. In the formulation of plans for future development of water resources in semi-arid regions for agronomic production, three system components are underscored. The kind of farming practices which can be supported by the environmental resources of the region; the type of agricultural production which maintains an ecological equilibrium when providing crop yield stability over time;

and, the human population size which can be sustained by the physical and biological characteristics of the land area with a guarantee of food security and the opportunity of achieving an optimal life style.

The use of supplemental irrigation can alleviate climatic risk factors in semi-arid regions by increasing choices for soil and crop management which can stabilize plant water requirements and, therefore, yields. Supplemental irrigation is being developed in the Near East and North Africa, but the level and extent of development are not adequately documented. The activities of the project will highlight existing practices which offer means of improving rainfed agriculture with the implementation of supplemental irrigation where water supplies from surface and undergrounds sources exist or where water harvesting can increase these supplies. The final report will examine supplemental irrigation in detail from both technical and socio-economic perspectives to identify potential areas of improvement and development.

5.6 Livestock Management in Goubellat, Tunisia; Potential for Improvement.

R. Khaldi (INRAT, Economist) and
G. Khaldi (INAT, Livestock Scientist)

5.6.1 Introduction

Since 1983, Tunisian national scientists have been collaborating closely with ICARDA in a specially funded project which addresses the problems faced by multi-enterprise small farms in the semi-arid regions of Tunisia. Goubellat province, about 80 km southwest of Tunis, was chosen as the project area. A multidisciplinary team of Tunisian and ICARDA scientists was assembled, and has developed a program of on-farm survey and experimentation designed to identify constraints faced by farmers and test, in their fields, potential solutions to overcome their problems. A description of the project area, its environment and important characteristics of the farming systems has been previously reported (ICARDA 1985).

Increasingly, the project has identified the wheat/sheep interface as being a potential area in which substantial improvements and impact could be achieved which would be of direct benefit and interest to the farmers in the project area. Over 80% of the farmers in the area own livestock of some sort, with sheep being most numerous.

During the 1986/87 season, 26 farmers owning sheep were questioned about their livestock production practices and the costs and benefits involved. Ten of these farmers were also involved in a more detailed study which assessed the impact of several improved sheep management strategies on livestock performance and economic benefit. In this short report, we highlight the important findings of this study.

The improved management system was tested as a package which consisted of the following:

1) Rams were separated from ewes one month before mating. Improved rams from INRAT were then introduced.

2) Flocks received the following sanitary treatments:

   a) Vaccination against enterotoxemia

   b) Prophylactic treatments against gastro-intestinal and pulmonary helminths

   c) External parasite treatment, both curative and preventative.

3) Old and non-productive ewes were culled.

4) 30 kg of commercial concentrate was fed to each ewe over a *100 day period, starting at lambing time.*

5.6.2 Results

The removal of the farm ram from ewes one month before mating, and the subsequent introduction of improved rams from INRAT resulted in a shorter lambing period due to the "ram effect". 80% of lambs were born within a one month period in these flocks. This shortening of the lambing season simplified flock management and allowed lambing to coincide with the period when native pasture was available.

The performance of modified management flocks and check flocks are compared in Table 5.6 using a t-test to determine significant differences between flock performance indicators.

TABLE 5.6 The effect of an improved livestock management package on flock performance in Goubellat, Tunisia

	Check flocks	Modified management flocks	Level of significance
Number of flocks[1]	15	10	-
Fertility rate (%)	91.5	96.1	5%
Prolificacy rate (%)	112.2	119.7	5%
Fecundity rate (%)	102.5	115.0	1%
Sterility rate (%)	4.8	3.1	ns
Abortion rate (%)	3.7	0.8	5%
Adult mortality rate (%)	1.1	5.3	5%
Lamb mortality rate (%)	5.2	2.9	ns
Weaning rate (%)	97.2	111.7	1%

1) One of the check flocks was considered an outlier and excluded from the analysis due to a 50% adult mortality rate.

The analyses indicate that the improved management package significantly improved almost all aspects of flock performance. Fertility rate, prolificacy rate (number of lambs per 100 fertile ewes) and fecundity rate (number of lambs per 100 ewes in the flock) were all significantly increased in the modified management flocks. Abortion rate was significantly reduced. There was no significant difference in lamb mortality between the two groups, but there was a significant increase in adult mortality in the modified management flocks which is difficult to explain.

Weaning rate (the number of weaned lambs per 100 ewes in the flock), an overall measure of productivity, was also significantly increased.

An economic evaluation of the two management systems was undertaken. This evaluation consisted of a comparison of costs and economic returns for each system of management. The calculations were based on data concerning flock size, labour cost, pasture cost, price of lambs and the cost of sanitary treatments (Table 5.7).

The total costs of the two management systems were not significantly different, but lamb sales generated substantially more revenue on a "per ewe" basis in the modified management flocks. This was largely due to the greater number of weaned lambs per ewe (see Table 5.6), but was in part due to better finish and appearance at sale leading to better market prices. As a result, net revenue was increased from 14.4 to 24.9 TD/ewe through the use of the improved management package.

5.6.3 Conclusion

The demand for livestock products in Tunisia is likely to increase steadily in the future as the population increases and

Table 5.7 Economic analyses of improved flock management in Goubellat, Tunisia (Tunisian Dinars/ewe)

	Check flocks	Modified management flocks	Level of significance
Number of flocks[1]	15	10	-
Feed costs	26.4	23.6	ns
Labor costs	12.0	15.4	10%
Treatment costs	0	1.0	-
Total costs	38.4	40.0	ns
Lambs revenue	50.8	63.1	1%
Wool revenue	2.0	1.8	1%
Gross revenue	52.8	64.9	1%
Net revenue	14.4	24.9	10%

1) See note of Table 5.6

the process of urbanization continues. A substantial proportion of this demand will have to be met by increased livestock production from the small farms of Tunisia. The results of these studies indicate that this challenge can be economically met through improved flock management by these farmers.

6. TRAINING AND AGROTECHNOLOGY TRANSFER

Mohamed Bakheit Said

A major constraint to agricultural research and development in countries of ICARDA's region is the shortage of trained manpower to conduct independent research focussed on the needs of individual countries. FRMP's training activities are directed primarily towards improving the national programs research capabilities to overcome this constraint. It is aimed at a range of target groups from planners and senior scientists through to research technicians. Wherever possible, we utilize our on-going research program as a working demonstration. Our training has the following long term goal:

To foster, through individual and group training, workshops and collaborative research programs, improved research methodology in resource management, and an appreciation of Farming Systems Research as a practical, applied and logical approach for determining research priorities and solving agricultural problems for all research disciplines. This goal will be attained by the following mid-term objectives:

1. To provide, through workshops and seminars, information and training in the philosophy and application of FSR to senior research scientists and young professionals to assist in the introduction and adoption of FSR within National Program departments and projects.

2. To provide training in specific aspects of FSR and components of resource management to research assistants and technicians through our residential course, short courses and individual training.

3. To develop regional networks of scientists who are working on common resource management problems in order

to enhance communication and information exchange, and the application of FSR.

4. To continue to attract young professionals from the region for postgraduate studies and postdoctoral assignments at ICARDA.

5. To initiate and organize, in cooperation with other International Agencies and Institutes of Advanced Learning, International Conferences and Seminars which brings together world expertise and addresses major issues of importance in the management of farm resources in drought-prone rainfed farming systems.

During 1986/87 season, FRMP staff were involved in a range of training and agrotechnology transfer activities designed to meet these objectives. These activities are outlined in details in subsequent sections.

6.1 Residential Training Course

The seven-week residential training course in Farming Systems Research and Resource Management is one of the main components of the training and agrotechnology transfer program in FRMP. It is offered annually at the headquarters site at Tel Hadya. The second residential course was held during the period 15 February - 5 April 1987. As in the previous year the course was designed so that trainees would be instructed in principles of FSR methodology through the general course, but would also receive specialized training in selected topics through the specialist courses. Six specialist courses were offered this season. These included crop agronomy, on-farm livestock trials, soil moisture, soil fertility, socio-economics and supplemental irrigation. The training activities included lectures and practical field and laboratory work. During the last week of the course, participants were asked to prepare, present and discuss country reports in order to enhance communication and information exchange. The course was attended by 15 participants representing Egypt, Jordan, Kuwait, Oman, Pakistan, Sudan, Syria, Tunisia, North and South Yemen.

After two years' experience we decided to remodel the course to ensure its accuracy and relevance to national programs. Thus, in 1988 the residential course will consist of a two-week general course (instead of three-week) as an introduction to farming systems research methodology followed by 2 four-week specialist courses that will cover crop agronomy and soil moisture. During the seventh and last week of the course, participants will be asked to identify problems in their own countries and using the knowledge they have learnt in the course, design studies to solve those problems.

Looking ahead, the residential training course will be continued for training research support staff in general principles of FSR methodology and to provide them with specialized training in their fields of agricultural research.

6.2 Short Courses

These courses focus on specialized problems or topics. During 1986/87 two short courses were conducted by the program. The first one was the Soil and Plant Analyses Training Course which was held at Tel Hadya during the period January 18-29, 1987. This is the second season this course has been organized. As in the previous season the course objectives were: (1) to provide participants with sound technical knowledge in methods of soil and plant analysis, (2) to compare the methods of analysis commonly used in the region and (3) to correlate results of soil analyses with plant response. In fulfilling the above objectives, emphasis was given to soil nitrogen and phosphorus being the most significant constraints which limit food production in countries of ICARDA's region. The course curriculum included lectures and practical field and laboratory activities. The course, aimed at senior research assistants in soil and plant analyses, was attended by eleven participants from Syria, Jordan, Algeria, Tunisia, Egypt, Ethiopia and Sudan.

The second one was the Training Course in Neutron Probe Usage which was organized, in cooperation with the Syrian Atomic Energy Commission, at Tel Hadya during the period April 12-16, 1987. The objectives of the course were to provide training in (1) the theory of neutron methods of measurements of soil water, (2) field techniques for the use of neutron probes, (3) the use and interpretation of soil water data and (4) safety measures for neutron probe use. The course consisted of theoretical and practical sessions. The theoretical sessions included lectures on (1) the principles of instrument design and water measurement, (2) procedures for site calibration of the instrument, (3) soil water estimation from instrument readings and (4) water budgeting using field data. In the practical sessions, the calibration and use of the neutron probe was demonstrated. The course was attended by twelve participants from four countries of the region including Syria, Turkey, Tunisia and Morocco.

Short specialized courses will continue and increase. To supplement the training carried out at headquarters, more attention is expected to be given to in-country training specially in countries having collaborative research programs with ICARDA. In 1988 FRMP will organize two in-country training courses emphasizing the tendency towards having courses organized in collaboration with national programs for their staff. Once the technical competence of the national trainers is upgraded and they have obtained sufficient experience in conducting these courses, the organization of in-country training becomes the responsibility of national programs with assistance from ICARDA in the form of advice in the planning stage and the provision of training materials.

6.3 Individual Training

Included in this type of training are the university degree-related and unrelated. In the degree-related category, FRMP has continued to attract postgraduate students who carry out research projects that both contribute to the Center's goals and to the research goals of national programs. During 1986/87 season FRMP staff supervised the thesis research of eleven postgraduate students: 7 MSc and 4 PhD. Names, countries, degrees, cooperating universities and thesis topics of these students are given in Table 6.1. Four of these students will complete their studies before the beginning of 1988.

Degree-related training, supported by ICARDA graduate research training program and other funding sources, is expected to continue and increase. In this connection female postgraduates would be encouraged. The program is currently seeking special funding to support a collaborative MSc training program with Reading University in soil water management.

In the individual non-degree training component, training has been provided to both senior and junior scientists. Individual trainees numbered 9 during 1986/87 season. The training periods ranged from 1 week to 1 year. Table 6.2 shows names of participants, countries, subjects and duration of training courses. The interest in specialized individual non-degree training will increase with the increase of the academic qualifications of the applicants.

TABLE 6.1 Individual training, degree-related

Name	Country	Degree	Cooperating University	Thesis topic
U. Maerz	Germany	PhD	Hohenheim	Multivariate analysis of farming systems
S.A. Magid	Sudan	PhD	Hohenheim	Economics of faba beans in new areas
O.B. Shoaib	S.Yemen	MSc	Aleppo	Herbicide/fertilizer effect on wheat
H.M. Dahroug	S.Yemen	MSc	Aleppo	Wheat agronomy
F.S. Yousef	Sudan	MSc	Gezira	Faba beans marketing in Sudan
T. El-Masri	Jordan	MSc	Jordan	Forage legume production
J. Sting	Germany	MSc	Hohenheim	Economics of annual medic pastures
F.J. El-Mahmoud (Miss)	Syria	MSc	Aleppo	Soil test calibration for phosphorus
A. Ben Achour	Tunisia	PhD	Missouri (Columbia)	Labor & adoption of technology
E.K. Al-Karablieh	Jordan	MSc	Jordan	Labor & adoption of technology
T. Razzouk	Syria	PhD	Aleppo/ Nottingham	Wheat extension in Syria

6.4 Workshops

An important component of our training and agrotechnology transfer program is the organization of at least one annual workshop aimed at senior scientists and research planners in national programs. These workshops have covered a wide range of

TABLE 6.2 Individual training, non degree-related

Name	Country	Subject	Duration
T. Tesso	Ethiopia	Socio-economics	4 weeks
H. Chattouna	Tunisia	Survey methods	3 weeks
S. Abdenour	Tunisia	Survey methods	4 weeks
M. Ibrahim	Algeria	Survey methods	1 week
S. Nour (Miss)	Algeria	Survey methods	1 week
B. El-Bunny (Miss)	Syria	Data analysis	2 weeks
M. A. Safi	Syria	Harvesting technique	4 weeks
A. M. Hussein	Syria	On-farm fertility trials	1 year
W. N. Shehadi	Syria	On-farm fertility trials	1 year

topics and they have contributed to the dissemination of existing research information and to the planning of our programs.

During the period 1-6 September 1987, the second regional workshop on soil test calibration was held at the Soils and Fertilizer Research Institute in Ankara, Turkey. The workshop objectives were: (1) to facilitate professional contact among scientists in the region who are conducting research on calibration of soil tests by field experiments under rainfed conditions, (2) to critically review, discuss and evaluate the previous work accomplished in West Asia and North Africa on soil test calibration carried out with the specific purpose of correlating the results of soil analysis in the laboratory to expected fertilizer response in the field, (3) to discuss the results of the joint program of 1986/87 season of the regional network on soil test calibration and (4) to formulate the workplan for regional experimentation and cooperative work need among countries of the region in 1987/88 season. The workshop was funded by ICARDA and UNDP and was attended by 27 participants representing Turkey, Syria, Jordan, Cyprus, Tunisia, Algeria, Morocco, Iran, Pakistan, ICARDA, World Institute of Phosphate and the Institute of Soil Fertility in Holland.

6.5 Miscellaneous Activities

As in the past, FRMP staff contributed to other programs' training courses through (1) lectures and practicals on approaches to FSR and (2) lectures and practicals on weed control principles and methodology.

As an adjunct to our training program, the production of manuals and training material in various languages is badly needed for the center use and for requests by national programs. Currently a specially funded postdoctoral fellow is producing two such manuals on "How to conduct on-farm trials" and "How to conduct farm surveys". More of these manuals and modules are currently under consideration.

The program continued to attract visiting scientists and postdoctoral fellows from the region to enable them pursue in-depth research using ICARDA's facilities and in collaboration with the program's staff. During 1986/87 season, three visiting scientists and three postdoctoral fellows from the region were provided such opportunities. Areas of study included data analysis, faba beans economics in Egypt, economical fertilizer allocation in Syria, diagnosis for design of rainfed farming in NW Egypt and the production of training manuals. We will seek to continue our specially funded program which provides training and postdoctoral assignments for social scientists within the region. In 1987/88 season, FRMP plans to provide opportunities to six regional visiting scientists to discuss or work on topics related to their national priorities.

A number of scientists from countries of the region or outside the region visited the program during the season and participated in discussion on topics of mutual interest. FRMP scientists also visited many countries of the region for meetings and discussion with scientists of national programs.

7. PUBLICATIONS

7.1 International Journals 1982-1987

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

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

Cooper, P.J.M., Keatinge, J.D.H., and Hughes, G. (1983). Crop evapotranspiration -- a technique for calculation of its components by field measurements. **Field Crops Research.** 7:299-312.

Cooper, P.J.M., and Gregory, P. (1987). Soil water management in the rainfed farming systems of the Mediterranean region. **Soil Use and Management.** 3, 57-62.

Cooper, P.J.M., Gregory, P., Tully, D., and Harris, H. (1987). Improving water use efficiency of annual crops in the rainfed farming systems of West Asia and North Africa. **Experimental Agriculture.** 23, 113-158.

Cooper, P.J.M., Gregory, P., Keatinge, J.D.H., and Brown, S. (1987). Effects of fertilizer, variety and location on barley production under rainfed conditions in northern Syria. II. Soil water dynamics and crop water use. **Field Crops Research.** 16, 67-84.

Dennett, M.D., Rodgers, J.A., and Keatinge, J.D.H. (1983). Simulation of a rainfall record for the site of a new agricultural development: an example from northern Syria. **Agricultural Meteorology.** 29:247-258.

Dennett, M.D., Keatinge, J.D.H., and Rodgers, J.A. (1984). A *comparison of the rainfall regimes of six sites in northern* Syria. **Agricultural and Forest Meteorology.** 31:319-328.

Gregory, P., Shepherd, K.D., and Cooper, P.J.M. (1984). Effects of fertilizer on root growth and water use of barley in northern Syria. **Journal of Agricultural Science (Cambridge).** 103:429-438.

Harmsen, K. (1984). Nitrogen fertilizer use in rainfed agriculture. **Fertilizer Research.** 5:371-382.

Hughes, G., Keatinge. J.D.H., and Cooper, P.J.M. (1987). Solar radiation interception and utilization by chickpea crops in northern syria. **Journal of Agricultural Science (Cambridge).** 108, 419-424.

Jones, M.J. (1987). Plant population and sorghum production in Botswana. I. Results of experiment station trials. **Experimental Agriculture.** 23:335-347.

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

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

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

Keatinge, J.D.H., and Cooper, P.J.M. (1984). Physiological and moisture use studies in growth and development of winter sown chickpeas. **World Crops Production.** 9:141-157.

Keatinge, J.D.H., Dennett, M.D., and Rodgers, J.A. (1985). The influence of precipitation regime on the management of three-course crop rotations in northern Syria. **Journal of Agricultural Science (Cambridge).** 104:281-287.

Keatinge, J.D.H., Neate, P.J.H., and Shepherd, K.D. (1985). The role of fertilizer management in the development and expression of crop drought stress in cereals under Mediterranean environmental conditions. **Experimental Agriculture.** 21:209-222.

Keatinge, J.D.H., Dennett, M.D., and Rodgers, J.A. (1986). The influence of precipitation regime on the crop management of dry areas in northern Syria. **Field Crops Research.** 13:239-249.

Keatinge, J.D.H., Chapanian, N., and Saxena, M.C. The effect of improved management of legumes in a legume-cereal rotation on field estimates of crop nitrogen uptake and symbiotic nitrogen fixation in northern Syria. **Journal of Agricultural Science (Cambridge).** (In press for 1988)

Koudsieh, S., Harris, H., and Bin Shuaib, O.S. 1986. The effect of nitrogen, phosphorus and herbicides on weed infestation and wheat production. **Res. J. Aleppo Univ.** 8:175-195 (Arabic with English Summary).

Matar, A.E., Garabet, S., Riahi, S., and Mazid, A. (1987). A comparison of four soil test procedures for determination of available phosphorus in calcareous soils of the Mediterranean region. **Communications in Soil Science and Plant Nutrition.** 19: (in press).

Nordblom, T.L., Ahmed, A.H., Miller, S.F., and Glenn. D.M. (1985). *Long-run evaluation of fertilization strategies for dryland wheat in northcentral Oregon: simulation analysis.* **Agricultural Systems.** 18:133-153.

Perrier, E.R. (1987). A model of heat, mass and momentum flow in stomata. **Physiologia Plantarum.** (Accepted)

Perrier, E.R., and Wilding, L.P. (1986). An evaluation of computerized methods for field uniformity studies. **Advances in Agronomy.** 39:265-312.

Shepherd, K.D., Cooper, P.J.M., Allan. A., Drennan, D., and Keatinge, J.D.H. (1987). Growth, water use and yield of barley in Mediterranean type environments. **Journal of Agricultural Science (Cambridge).** 108, 365-378.

7.2 Workshops and Seminars 1987

Cooper, P.J.M., Gregory, P., Tully, D., and Harris, H. 1987. Improving water use efficiency of annual crops in the rainfed farming systems of West Asia and North Africa. Paper presented at International Symposium on Improving Winter Cereals under Temperature and Salinity Stress. Cordoba, Spain, October 1987.

Cooper, P.J.M., Harris, H., and Goebel, W. 1987. Climatic variability and food production in West Asia and North Africa. Paper presented at the International Symposium on Climate and Food Security. New Delhi, India, February 1987.

Harris, H., and Goebel, W. 1987. Quantifying weather and soil effects on crop production. Paper presented at International Symposium on Improving Winter Cereals under Temperature and Salinity Stress. Cordoba, Spain, October 1987.

Harris, H., Goebel, W., and Cooper, P.J.M. 1988. Crop genotype-environment interaction. In Drought Tolerance in Winter Cereals. J.P. Srivastava, E. Porceddu, E. Acevedo and S. Varma (eds). John Wiley & Sons, Chichester, England.

Hobbs, J., Anderson, J., Dillon, J., and Harris, H. 1987. The effects of climatic variations on agriculture in the Australian wheat belt. In The Impact of Climatic Variations on Agriculture. Volume 2, Assessments in Semi-Arid Regions. M.L. Parry, T.R. Carter and N.T. Konijn (eds). Reidel, Dordrecht, The Netherlands.

Jones, M.J., and Harris, H. 1987. Climatic variability and agronomic management in Mediterranean barley-livestock farming systems. Paper presented at International Symposium on Climate and Food Security. New Delhi, India, February 1987.

Jones, M.J. 1987. Interpretation and utilization of data from on-farm fertilizer trials for situations in which soil-test values are not available. Paper presented at Second West Asia and North Africa Soil Test Calibration Workshop. Ankara, Turkey, September 1987.

Matar, A.E., Saxena, M., and Silim, S.A. 1987. Soil testing as a guide to phosphate fertilization of five legumes in Syria. Second Regional Workshop on Soil Test Calibration. Ankara, Turkey, September 1987. (in press)

Matar, A.E., Jabour, E., and El-Hajj, K. 1987. Prediction of barley response to fertilizers by means of soil nitrogen and phosphorus tests. Second Regional Workshop on Soil Test Calibration. Ankara, Turkey, September 1987.

Nordblom, T.L. 1987. Crop-livestock systems in Egypt with respect to rice research. Paper presented at the International

Symposium on Rice Farming Systems: New Directions, held at Sakha, Egypt, February 1987.

Nordblom, T.L. 1987. The importance of crop residues as feed resources in West Asia and North Africa. Paper presented at the Workshop on Plant Breeding and the Nutritive Value of Crop Residues, held at ILCA, Addis Ababa, Ethiopia, December 1987.

Pala, M. 1987. System approach for crop production in high elevation areas. Paper presented at International Symposium on Problems and Prospects of Winter Cereals and Food Legumes Production in High Elevation Areas of West and Southeast Asia and North Africa. Ankara, Turkey, July 1987.

Pala, M., and Matar, A.E. 1987. Soil Test Calibration with N and P for wheat under Dryland Conditions in Syria. Paper presented at the Second Regional Soil Test Calibration Workshop. Ankara, Turkey, September 1987.

Pala, M., Tully, D., Rassam, A., Mazid, A., and Cooper, P.J.M. 1987. Fertilizer and herbicide effects on farmers' wheat production in Northwest Syria. Paper presented at the Farming Systems Symposium: "How Systems Work". Fayetteville, Arkansas, USA, October 1987.

Perrier, E.R. 1987. An evaluation of soil water management on an Alfisol in the semi-arid tropics of Burkina Faso. Proceedings of the Consultants Workshop, ICRISAT, Patancheru, India, October 1987.

Perrier, E.R., and Salkini, A.B. 1987. Agricultural Potential for Water management in the Syrian steppe. Symposium on Water Resources Planning and Management, Univ. of Aleppo, December 1987.

Perrier, E.R., and Salkini, A.B. 1987. Water management of spring wheat: supplemental irrigation. Technical Consultations on Supplementary Irrigation in the Near East and North Africa, Rabat, Morocco, FAO/ICARDA, December 1987.

Perrier, E.R., and Salkini, A.B. 1987. Supplemental irrigation as an integral component of farming systems. Paper presented at the "XIII International Congress on Irrigation and Drainage", Casablanca, Morocco, September 1987.

Somel, K. 1987. The importance of barley in food production and demand in West Asia and North Africa. Paper presented at the Workshop on Small Ruminants, ICARDA, November 1987 (forthcoming in proceedings).

7.3 Research Reports and Miscellaneous 1987

Maerz, U. Methods to simulate distributions of crop yields based on farmer interviews. ICARDA-117En. ICARDA, Aleppo, August 1987.

Matar, A.E., Harmsen, K., and Garabet, S. 1987. Determination of particle size distribution in soils: comparison of results obtained by the hydrometer vs. the pipette method. ICARDA A-121 En.

Nordblom, T.L., and Thomson, E.T. 1987. A whole-farm model based on experimental flocks and crop rotations in northwest Syria. ICARDA-102 En. ICARDA, Aleppo, January 1987.

Nordblom, T.L. 1987. Farming practices in southern Idleb province, Syria: 1985 survey results. ICARDA-107En. ICARDA, Aleppo, March 1987.

8. FARM RESOURCE MANAGEMENT PROGRAM STAFF LIST AS AT DECEMBER 1987

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APPENDIX A

Observations and Recommendations of ICARDA's EPR, 1983 (AGD/TAC;IAR/83/12 Rev. 1)

Since ICARDA's last EPR, considerable evolution and maturation has occurred within the Farming Systems Program, and most recently the Program has taken a new name, Farm Resource Management. Together with this new name, the program has re-structured its core research activities to provide greater emphasis and research focus on resource management. Our restructured program is described in other sections of this document. However, in undertaking this re-organization, we have not abandoned our conviction of the essentiality and relevance of farming systems research in our region, nor have we substantially changed the major areas of research focus which have been developed over the last ten years. Thus in spite of the evolution within the program, the observations and recommendations of the 1983 EPR remain relevant to our on going research and future plans.

At several points (e.g., paras 326, 328, 338) the panel stressed the value of FSR within ICARDA and the importance of the Center maintaining a systems perspective to its research. It also stressed the importance of collaboration between programs to satisfactorily achieve this (para 342). However, it strongly recommended (para 339) that such a systems orientation should focus on the practical goal of assisting National Programs to develop improved farming practices rather than the study of the process of FSR per se.

With regard to the specific activities of the program, the panel noted and approved the Program focus on the resources and constraints of farming families (para 272), and our major research objective of identifying strategies to improve and stabilize farming systems in the region by increasing the technical and economic efficiency of the management of those resources (para 274).

In discussing both the technical and economic resources which formed the focus of our research, the panel often referred to the importance of improved crop management strategies for greater water use efficiency (e.g., para 27, 601, 604) and commended the emphasis placed on this by the program and its achievements (para 329). The role of fertilizer in improving water use efficiency was noted (para 330) and this work was encouraged. The use of soil-test calibration was highlighted (para 299) and we were encouraged to initiate such studies. Tillage, soil conservation, shallow soils (para 338), problem soils with poor physical conditions (para 304), yield decline under continuous cereal production (para 303) and supplemental irrigation (para 500) were all specifically mentioned as resource management issues which should be addressed in greater detail by the program in identifying strategies for improved water use efficiency. The panel concluded that the program should continue to strengthen its work in this field (para 601, 604, 605) and strongly recommended that ICARDA should seek to become recognized as a Center of Excellence in the field of crop water use efficiency (para 579).

The need for ICARDA, to understand the physical and economic structure of the region it serves was highlighted (para 289), and the panel identified agro-ecological characterization (para 290) and comparative studies of agricultural policies in the region (para 291) as two high priority areas to which ICARDA should devote more attention. In both these topics they suggested that we should seek to cooperate with other institutions who were involved in similar activities. They recognized the need for data collection as an essential first step, but emphasized the need to develop techniques which allowed active exploitation of such data for both analytical and descriptive purposes (para 336). The role of crop growth simulation models and the need to integrate their use with climatic analyses was recognized as an important component of agro-ecological characterization (para 297). The panel also noted that in developing new technology, and assessing its potential impact at the farm level in environments which exhibit pronounced temporal and spatial environmental variability, ICARDA should become more concerned with the issues of whole farm productivity and stability (para 280). They supported the program's intention to pay more attention to these questions, and specifically noted that "risk analyses" was particularly appropriate in the environment in which we work (para 333). They also recognized the importance of research into technology change and its association with rural labor, and welcomed the program's increasing interest in this field (para 334).

Under the heading "Overall Assessment" in the executive summary (para 20), the panel stated "... it was pleased to observe that the work carried out by ICARDA showed a sound appreciation of the physical, biological and socio-economic environment of the areas towards which current research programs have been directed. This is largely a consequence of the farming systems approach adopted as an overall theme by ICARDA."

APPENDIX B

CGIAR Priorities and Future Strategies

During recent years the CGIAR has critically reviewed its research priorities and strategies. These considerations were concluded in May 1986, and the records of this process has been made available for the consideration of all Centers. They are substantial, detailed and lengthy, and it is both impossible and inappropriate to discuss all the issues raised in this document. Nevertheless, some important issues of special relevance to resource management were highlighted. These are summarized here, and related to our on-going research and future plans.

The report reiterates the long-term CG goal of income generation for the most needy, with emphasis on least favoured environments, and admits that much of the CGIAR effort to data has been concentrated on more favoured areas. It also puts a new stress on the importance of the sustainability of production increases. With regard to research strategy, it suggests a problem-solving approach in a multidisciplinary context, with on-farm trials forming a vital component; and it suggests increased collaboration with advanced specialist institutions, more network activity with national programmes and more inter-Center cooperation.

Current FRMP activities and plans for the future accord well with all of this thinking. A major focus is on the barley-livestock systems of the driest areas, where most of the very poorest farmers are found. Our systems philosophy ensures a multidisciplinary approach, considering the farm as a functional unit; and we are tackling the problem of low and declining productivity by factor research, both on farmers' fields and research station, with the aim of using resources more efficiently, particularly moisture and nutrients. We are now proposing to use our experience in this work to help establish, in cooperation with national programmes, new research projects in areas of similar conditions elsewhere in the region. An ICARDA-based network will help to transmit ideas and results between scientists working in such areas. A similar initiative is being considered for the areas with wheat-based systems; and we are already coordinating a regional network for the calibration of soil-test methods, with an initial focus on wheat.

In respect of inter-Center cooperation, FRMP initiatives were behind the Agro-ecological Characterization Workshop in Rome in April 1986, and what was started there will continue. We see the *environmental characterization of* our Region as an important "upstream" ICARDA activity, with the coordination of methodology with other Centers and with various international agencies (e.g., FAO, WMO, IBSNAT) as an essential adjunct.

The CGIAR proposes a conceptual framework for research comprising a multi-dimensional matrix, in which the vectors are *exemplified by disciplines, factors, and commodities*. <u>This is fine, except we feel that one additional vector, that of time, should be included</u>. Commodities are rarely produced in isolation. Crops are grown in time sequence, and, particularly in a difficult environment, the nature of that sequence can be important, e.g., for the efficiency of water use, fertilizer needs, the build-up of weed flora. Livestock production depends on a time sequence of feed supply involving crops, crop residues and communal grazing. And both crop and livestock husbandry practices can have good or bad cumulative effects over time on environmental resources and this is at the heart of the sustainability issue. The program approach to date has been to focus several disciplines (e.g., crop physiology, agronomy, economics) on to particular problem factors (e.g., water-use efficiency, fertilizer strategy, rotations) within systems (time sequences) of several commodities. This research perspective appears to us well worth retaining.

We note that the CGIAR finds the "commodity focus" to have been useful as a way of building "a strong team approach". FRMP has used instead a "system productivity focus". In view of the way commodities interact within a productive system, this seems to us to be a good way to approach the goal of income generation. In fact, we feel that we have come close to the CGIAR ideal of investigating commodities in a farming systems context. FRMP's plans are for an increased stress on factor-based research while maintaining the multidisciplinary focus on system productivity.

Consideration of CGIAR's priorities and future research strategies has led us to the encouraging conclusion that the evolution of thought within FRMP has in many respects proceeded along very similar lines to those of the CGIAR. We have found some differences of emphasis in methods, stemming from the realities of agriculture in a difficult environment, but none that conflict with CGIAR recommendations.

APPENDIX C

Agricultural Systems of West Asia and North Africa

Steppeland and Native Pastures

Native pasture is defined as that land which is used primarily for the grazing of small ruminants. Where rainfall exceeds 250 mm it includes land which is too steep, too stony, or where the soil is too shallow for arable agriculture. In West Asia this zone is usually associated with the foothills and slopes of mountain ranges, while in North Africa it may also be associated with with sandy soils. The vegetation is dominated by annual grasses, legumes, and herbs, the perennial vegetation being severely degraded. Below 200 m, steppeland and native pastures include most of the land surface, although at the wetter margin there is an increasing tendency to sow barley. Land is communally owned, replacing the old tribal control which broke down earlier this century. Restrictions to open access may exist, especially in high-rainfall areas. Originally a shrub steppe or even savannah woodland, it is now characterized by ephemeral vegetation of very low productivity. Soil fertility is usually higher than in wetter areas.

Stocking rates are difficult to estimate, but probably reach 1 sheep/ha in higher rainfall areas. Native pastures rarely support livestock on a year-round basis, being grazed in winter (low-rainfall areas) or spring (high-rainfall areas). For this reason farming systems using native pastures are integrated with the wheat-based and barley/livestock systems.

There is evidence of degradation in both arable and marginal lands. The original tree and shrub vegetation has disappeared to be replaced mainly by annual plants. Productivity of marginal lands is related to the number of plants and the presence or absence of annual legumes. Especially in the dry areas legumes are rare and plant numbers are substantially below optimum. Notwithstanding the degraded vegetation and obvious signs of erosion, soils on marginal land are substantially more fertile than arable soils, indicating severe reduction of soil productivity in the latter. Continuous barley growing is detrimental to yield; however, this practice is becoming increasingly common.

Rehabilitation of dry marginal lands is possible by planting edible shrubs, especially several species of Atriplex. A crude economic analyses based on observed stocking rates, indicates that the returns from investments in edible shrubs may exceed 20%. In wetter areas use of phosphate on native pasture may also be economically viable.

Barley/Livestock Farming Systems

Adjacent to the dry steppe (between approximately 200 and 350 mm rainfall), livestock (principally sheep and goats) production continues to be the dominant enterprise and provides the bulk of farmers' income through sales of dairy products, meat, and wool. Barley is by far the most common crop and is grown under no input conditions, with both grain and straw being utilized as livestock feed. Throughout the region, a barley/fallow rotation still predominates, but increasingly, fallow is being regarded as an inefficient use of land by farmers, and with greater availability of mechanization for tillage operations, continuous barley production is becoming more common, despite being detrimental to yield.

Native pastures form an important component of the annual feeding cycle of livestock in the winter and spring with smaller flocks utilizing local grazing areas and weedy fallows, and large flocks spending a substantial part of the year in the steppeland. Flocks are mobile and, in summer, after harvest, graze crop residues, in years of abundance. In dry years they are moved to the higher rainfall wheat-based systems and irrigated areas where local farmers lease out the grazing of cereal stubbles and other crop residues.

Potential production in these areas is low and more variable than in the wheat-based systems. Few national governments have developed policies which favor the introduction of improved technology in the drier areas, and yet throughout the region urbanization of rural populations and rising incomes is leading to increased demand for livestock products.

Due to the uncertainty of production and lack of available technology, few farmers are prepared to invest in costly inputs and have in the past responded to increased demand for livestock products by cultivating more and more marginal land for barley production and overgrazing natural pastures. These factors severely threaten the natural resource base of WANA. Many farmers are forced to seek off-farm employment to supplement and secure their income.

Wheat-Based Systems

In the higher rainfall areas (between approximately 350 and 600 mm average seasonal rainfall) wheat is the dominant crop. Bread wheat predominates in higher rainfall areas, but durum wheat forms the basic staple food in the drier areas of this zone. A wheat/fallow rotation is widespread, but in the wetter areas and on good deep soils wheat is grown in rotation with food legumes and summer crops such as melon, maize, sesame and cotton. Chickpea predominates in the wetter areas and lentil in the drier parts. Tree crops are often an important source of income, particularly on the smaller farms. On farms with livestock, barley is grown, with both grain and straw being utilized as feed together with other crop residues such as wheat stubble and lentil straw. Local native pastures, on hilly terrain and weeds and volunteer cereals on fallow land are grazed as well. Where local water supplies exist (wells, seasonally filled dams or rivers), supplemental irrigation of both winter and summer crops is profitable and is becoming increasingly common.

Potential crop production is high in the wheat-based systems and farmers are financially more secure. NARSs have allocated most of their research and development resources to these areas, and have in many cases been successful in developing improved technology, supported by agricultural policies which have allowed their rapid adoption by farmers.

Irrigated Farming Systems

In the driest regions where annual rainfall is below 150 mm farming is only possible under irrigation where surface water or groundwater is available. The main examples of such farming systems are along the Nile River in Northern Sudan and Egypt, along the Euphrates in Syria and Iraq, along the Jordan River, and in Saudi Arabia. Less common is cultivation based on water harvesting and wadi farming. Examples of this are found in Yemen Arab Republic and NW Egypt. Associated with irrigated farming systems is extensive grazing on native pasture where livestock (camels, goats, sheep and cattle) is seasonally dependent on crop residues from irrigated agriculture.

Irrigation allows greater control of growing conditions than rainfed systems, stabilizing output over time. However, irrigation systems need to be designed and operated on a scale and a cost that cannot be managed by a single farmer.

In the ICARDA region wheat is often found in irrigated cropping patterns. However, cotton and other cash crops (sugar-cane, sugar beets), and berseem in Egypt, are often more important to farmer incomes.

There is considerable inter-dependence among the cropping systems. Crop residues from high rainfall or irrigated systems are used for livestock in low rainfall systems. Such transfer of feed is often subsidized.

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