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Impact of Modern Agricultural Technologies on Durum Wheat Production in Syria

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Ministry of Agriculture
and Agrarian Reform

International Center for
Agricultural Research
in the Dry Areas

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Foreword

Increasing the production and nutritional quality of food while preserving and enhancing the resource base in the dry areas is one of the main goals of ICARDA. The development and release of improved, high-yielding, and stress-resistant wheat varieties in Syria has been a key milestone in reaching this goal. The new varieties benefit farmers through productivity improvements and production stability when integrated with sustainable natural resource management practices.

Since ICARDA's research seeks to enhance producer and consumer welfare through increasing the productivity, stability, and profitability of agriculture, improved varieties of wheat and the associated production practices must be technically, economically and socially acceptable to farmers in the dry areas. In recent decades, Syria has been experiencing major changes related to the intensification of agricultural production. These changes have important implications for the design of wheat production technology.

Availability of new wheat varieties is an important factor that determines the adoption of the new durum wheat production technology developed by ICARDA in collaboration with the Agricultural Research Directorate of the Syrian Ministry of Agriculture for different agroecological zones of Syria. On the other hand, it is also important to consider the impact of new cultivars in relation to the adoption of new agronomic practices including irrigation, mechanization, chemical fertilizers, herbicides, and seed rates on durum wheat varieties.

As part of ICARDA's continuing efforts to understand the factors that encourage acceptance of the improved technologies developed by the ICARDA in partnership with the Syrian national program, the current study presents an assessment and analysis of the impact of modern technologies on durum wheat production in Syria.

ICARDA hopes that the findings of this study will be useful in further enhancing the adoption of new varieties and production technologies of not only wheat but also of other crops.

Prof. Dr Adel El-Beltagy
Director General
ICARDA

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This report summarizes the efforts of many people over many years. It presents the findings of the impact of modern technologies on durum wheat production in Syria. The results in this report are based on surveys on wheat production jointly implemented by ICARDA and the participating national research programs in Syria, especially the Socioeconomic Research Department and its divisions in the provinces.

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All opinions and conclusions presented in this paper are those of the authors and do not necessarily reflect those of ICARDA, the Syrian Ministry of Agriculture, or any other institution.

Summary

Wheat is the most important food commodity in Syria, since it is a substantial source of energy and protein in the local diet. During the period 1991-1995, the annual average area planted with wheat was about 1.5 million hectares, which is equivalent to 27% of the total cultivated land area. In Syria, wheat is grown in areas that range from wet to very dry.

The country was self-sufficient in wheat 40 years ago. Expansion of the area cultivated with wheat allowed Syria to be a net exporter of this crop until the 1950s. However, growth in domestic demand, due to a population increase that was not accompanied by an increase in either wheat yield/ha or in area under cultivation, has meant that Syria no longer produces a surplus. Wheat and flour, therefore, have become the most important agricultural imports. In terms of its self-sufficiency in wheat, during the period 1985-1989, Syria produced about 72% of its total domestic requirement.

Since 1990, however, there has been a shift in agricultural policy in Syria. New focus is being placed on enhancing the productivity of both durum and bread wheat through the use of high-yielding varieties, chemical fertilizers, and pest-control measures suited to local conditions. Irrigation infrastructure has improved, extension and credit institutions have become available, and farm mechanization is being encouraged. Consequently, wheat production in Syria has exceeded demand since 1993.

In Syria, agricultural research on wheat is either conducted by the Scientific Agricultural Research Directorate, the Directorate of Irrigation and Water Use, or the Soil Directorate of the Ministry of Agriculture and Agrarian Reform, or by the Syrian Universities. Most of the wheat research undertaken by these institutions was done in collaboration with the International Center for Agricultural Research in the Dry Areas (ICARDA). ICARDA also carries out research on wheat, and has played an important role in the agricultural development process. The results obtained from research on sustainable wheat production have influenced the improvement and development of agricultural technologies appropriate to farmers. During the last few years, these technologies have had a clear impact, in terms of substantially increasing total wheat production at the national level, and in allowing these increases to be sustained.

Stress-tolerant durum wheat varieties developed by the ICARDA/CIMMYT durum wheat improvement program for West Asia and North Africa (WANA) have been adopted by the national agricultural program in Syria. These varieties were tested on-farm under farmers' conditions using multi-year trials conducted as part of collaborative research programs. The varieties 'Cham-1', 'Cham-3' and

‘Cham-5’ were adopted by the national agricultural research program and multiplied for farmers. At present, it is estimated that more than two-thirds of the total area devoted to durum wheat in Syria is planted with these varieties.

An estimate of the impact modern agricultural technology on wheat production in Syria suggested an increase of 1.66 million tonnes (1 tonne = 1000 kg) of durum wheat. This is equivalent to an increase in national income of about 17.4 billion Syrian Lira annually (US$348 million at the exchange rate of 1 US$ = 50 SL). About 34% of this increase is due to the impact of the use of improved varieties, 24% to fertilizer, 23% to irrigation, and 19% to improvement in land and crop management practices.

Interestingly, and in contrast to the experiences of many other countries (where large farmers have tended to benefit the most), in Syria the benefits of the use of modern technologies in durum wheat production have accrued to all farmers (small, medium and large).

1. Introduction

Wheat is the most important food commodity in Syria, since it is a substantial source of energy and protein in the local diet. During the period 1991-95, the annual average of the total area devoted to wheat production was about 1.5 million hectares (MAAR, 1996), which is equivalent to 27% of the total amount of cultivated land in Syria; durum wheat constituted about 80% of the total area devoted to wheat. In Syria, wheat is grown in areas which range from wet to very dry, but is basically grown in agricultural stability Zones 1 and 2[1], as well as in irrigated areas.

The country was self-sufficient in wheat 40 years ago (Mazid, 1994; Mazid, 1997). Indeed, expansion of its wheat-cultivated area allowed Syria to be a net exporter until the 1950s. However, growth in domestic demand, due to a population increase, was unaccompanied by an increase in wheat yield or in area planted to wheat. Instead, there was an increase in the production of vegetables, fruits, and industrial crops at the expense of the wheat-cropped area. Because of this, Syria no longer produces a surplus. Wheat and flour have, therefore, become the most important agricultural imports. In terms of its self-sufficiency in wheat, during the period 1985-1989 Syria produced about 72% of its total domestic requirement.

Since 1990, Syria's agricultural policy has paid special attention to wheat production, with the twin objectives of improving the living standards of producers and achieving wheat self-sufficiency. Planning concentrates on improving the productivity of the existing wheat-producing land. Research is directed towards adapting modern, high-yielding varieties (HYVs) of wheat, used in conjunction with chemical fertilizers, herbicides, and pest control measures, to Syrian conditions. Extension and credit institutions have been organized, and farmers are encouraged to mechanize production.

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[1] Syria covers a total 18,518,000 ha, divided into five agricultural stability zones according to average annual rainfall. The zones are defined in terms of stability for rainfed crops production, and to some degree the probability of rainfall.

Zone 1: annual rainfall over 350 mm; divided into two areas:
a. Annual rainfall over 600 mm, where rainfed crops could be successfully planted.
b. Annual rainfall 350-600 mm and not less than 300 mm during two-thirds of the monitored years. It is possible to get two seasons every three years. The main crops are: wheat, legumes, and summer crops. This zone accounts for about 15% of the country.

Zone 2: annual rainfall of 250-350 mm and not less than 250 mm during two-thirds of the monitored years. It is possible to get two barley crops every three years. Wheat, legumes, and summer crops can also be planted. This zone accounts for 13% of the country.

Zone 3: annual rainfall of 250 mm and not less than 250 mm in half of the monitored years. It is possible to get one or two growing seasons every three years. The main crop is barley, but legumes can be grown. This zone accounts for 7% of the country.

Zone 4: annual rainfall of 200-250 mm and not less than 200 mm in half of the monitored years. It is suitable for barley or for permanent grazing. This zone accounts for 10% of the country's area.

Zone 5: The rest of the country. Not suitable for rainfed crops. It includes desert and steppe, and covers 55% of the country.

The Syrian government has initiated various infrastructure projects to provide irrigation facilities. Pump wells and other on-farm irrigation systems were developed by the government and the private sector.

The reform of the agricultural price policy for inputs and outputs has contributed to encouraging farmers to adopt new agricultural technologies relevant to wheat. Therefore, policy makers and planners have achieved their goal of having farmers adopt modern wheat technologies. Mechanical tillage, planting and harvesting, use of HYVs, fertilizer application, and chemical weed and pest control have become common practice for most farmers. This is reflected in the rise that has occurred in yield per unit area, and the notable success achieved with regard to attaining wheat self-sufficiency. In Syria, total wheat production has exceeded domestic need since 1993.

2. Objectives of the Study

The Socioeconomic Department of the Directorate of Scientific Agricultural Research, and the Ministry of Agriculture and Agrarian Reform (MAAR), in collaboration with the Natural Resource Management Program (NRMP) at ICARDA, conducted a multi-year study on the adoption and impact of improved wheat production technology. The study aimed to:

- Develop baseline measures for use in the adoption of improved wheat-production technology by farmers in different agroecological zones.
- Describe the adoption and impact levels of wheat technology according to the socioeconomic characteristics of farmers and farming systems.
- Assess reasons for the adoption of, or failure to adopt particular technologies.
- Identify factors contributing to yield differences apparent when assessing technologies in research trials and in on-farm trials.

Primary data were collected during three seasons, through a field survey, which included nine provinces (representing about 91% of the national wheat area).

There are many reasons why the national agricultural institutions, along with the international and regional organizations concerned with agricultural research, focus their attention on adoption and impact studies. Such reasons include improving the efficiency and performance of new technology, strengthening the links between the institutions developing that technology and agricultural policy, and measuring the returns from investment made in research and extension.

Most of the academic studies on technology adoption assume that the technology developed is appropriate and suitable for farmers. Such studies tend to focus upon defining the characteristics of the farmers wishing to adopt such technology

(CIMMYT, 1993). However, a more complex method is desirable. In addition to descriptions of the adoption pattern, consideration should be given to whether or not the technology is suited to the needs of farmers. This type of study aims not only to make a certain technology successful, but also to increase the effectiveness of research and extension by meeting the actual needs of the farmers.

3. Wheat Trends

National statistics on wheat area and production from 1973 to 1997 have shown the following trends:

- There was no significant increase in wheat area; indeed, until 1990, there was a general decline in the total area planted to wheat (Fig. 1).
- There was increased use of HYVs of wheat under both irrigated and rainfed farming systems (Figs. 2 and 3).
- There has been a substantial expansion in the area of irrigated wheat at the expense of rainfed wheat.
- There was a large fluctuation in total production from year to year (Fig. 4).

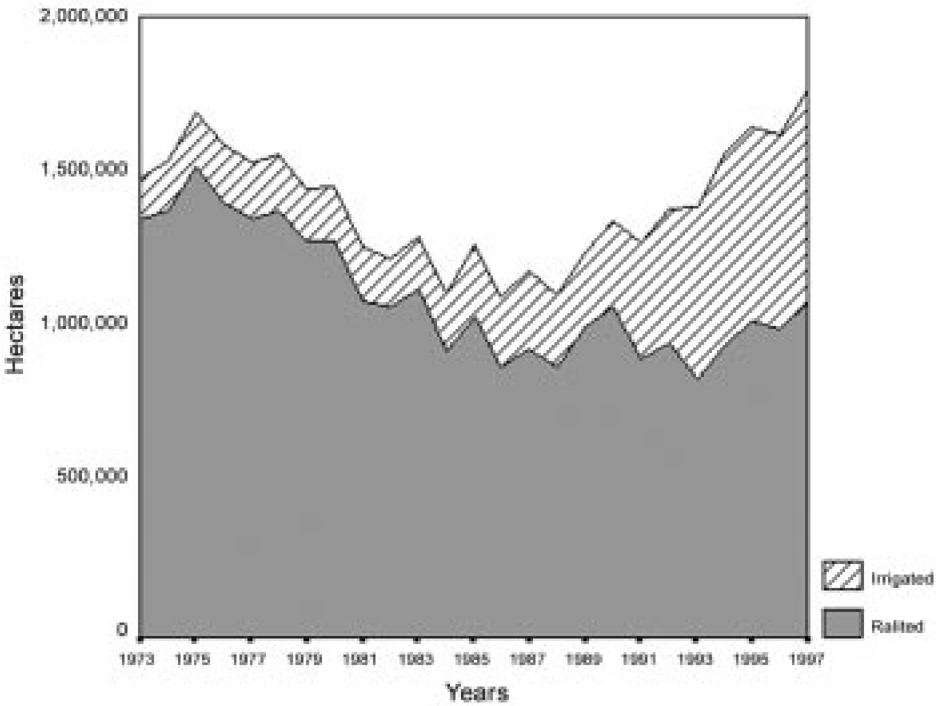

Figure 1. Wheat area in Syria

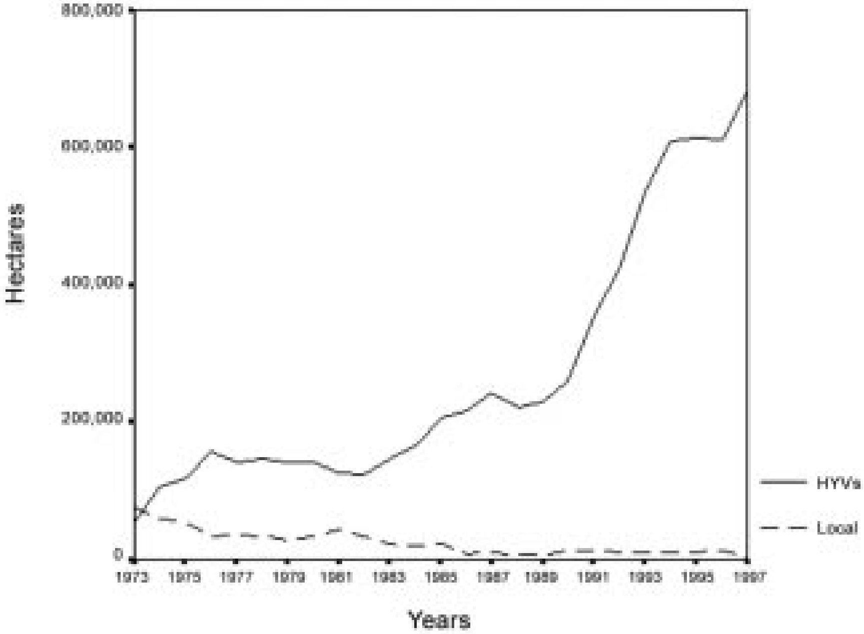

Figure 2. Areas of high-yielding and local varieties of irrigated wheat

Figure 3. Areas of high-yielding and local varieties of rainfed wheat

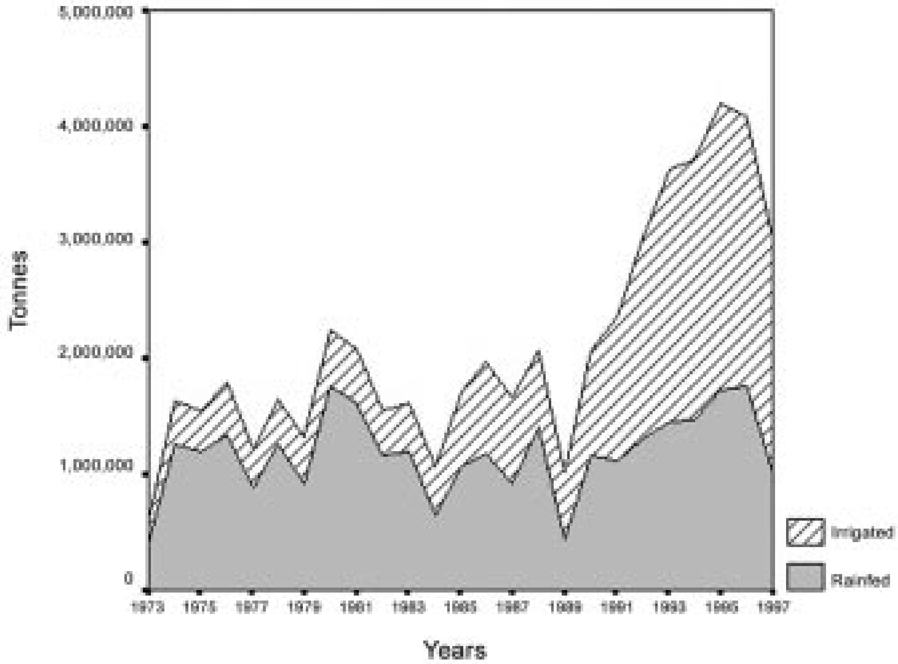

Figure 4. Wheat production in Syria

There has been a clear improvement in irrigated wheat yields; rainfed yields are less easily interpreted (Fig. 5). Adjusting yields for rainfall variation according to water use efficiency indices shows no significant trend either upward or downward. However, yields of HYVs were better than those of local varieties under both rainfed and irrigated conditions.

Between 1991 and 1998 there was a clear increase in both area and production of wheat in Syria. The total area cultivated with wheat increased by 36%, from 1.27 million hectares in 1991 to 1.72 million hectares in 1998. Whilst the irrigated area increased by 86%, the rainfed area only increased by 15%. Total wheat production increased by 75%, from 2.35 million tonnes to 4.11 million tonnes. Average yields per hectare also increased during this period, from 1.85 t/ha in 1991 to 2.40 t/ha in 1998 (a 30% increase).

The growth of the area producing irrigated wheat in Syria has been remarkable. In 1973, the area planted to irrigated wheat made up 9% of the total wheat area. This figure had reached 20% by the late 1980s, and in 1998 represented about 40% of the total area producing wheat. The area of irrigated wheat increased from 369,000 hectares in 1991 to 690,000 hectares in 1998 (87%). In 1998, irrigated wheat made

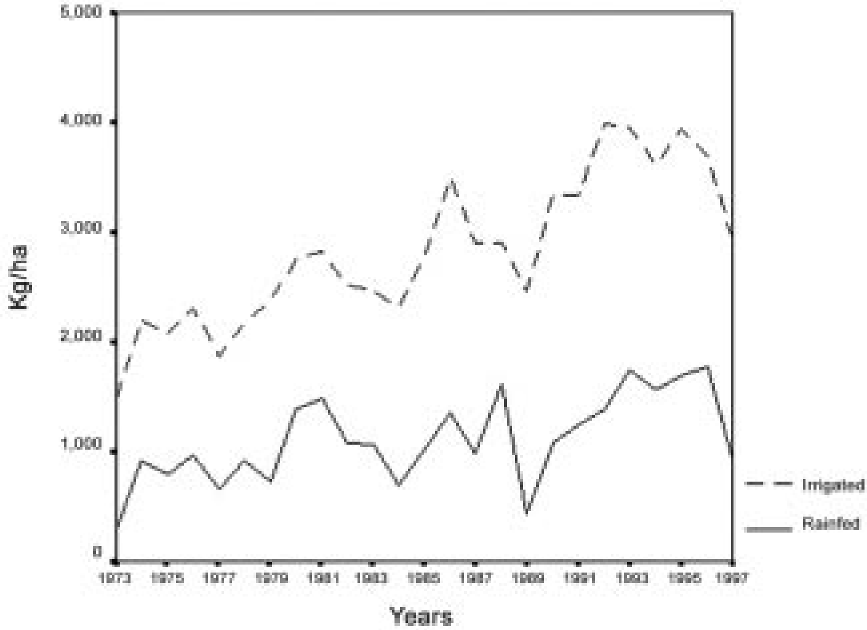

Figure 5. Yields of irrigated and rainfed wheat in Syria

up 40% of the total wheat area, and production represented 60% of the country's total (4.11 million tonnes in 1998). The statistics of the Ministry of Agriculture did not differentiate between full and supplemental irrigation.

However, for a better understanding of wheat production trends at the national level, and to avoid the influence of year-to-year fluctuations, the average annual area, production and yield of wheat per unit area were calculated for three-year periods. Between 1977-79 and 1995-97, the average annual area of wheat increased by 11%: the yield per unit area increased by 145%. These increases caused total production to increase by 170%.

Assuming (1) that no new technology had been developed for growing wheat, and (2) that the available technology resulted in average yields that were the same as those that were obtained in 1977-79, then present wheat yields would be the same as those during that period. Therefore, in order to achieve the annual average of total wheat production that was obtained during 1995-97, more than four million hectares would have to be allocated to the growing of wheat. However, modern agricultural technologies used on wheat in Syria have 'saved' (i.e. reduced this figure by) about 2.5 million hectares (Fig. 6). This saved area can be allocated to other crops.

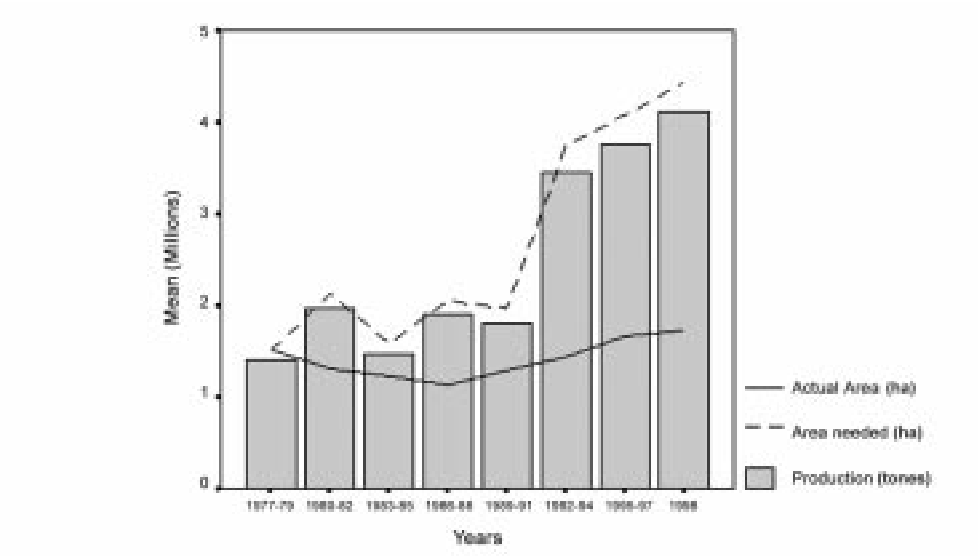

Figure 6. Wheat in Syria: Area Saved and Production Reached

4. Scientific Agricultural Research on Wheat

Scientific agricultural research in Syria is considered to be the main avenue for agricultural development programs and increasing food production. Due to the importance scientific research has, with regard to increasing food resources and improving agricultural development, the agricultural policy of the Syrian Arab Republic provides all the support this important sector requires in order to achieve food security and face the fast growth of the country's population.

Agricultural research in Syria plays an important role in the agricultural development process, whether it is organized by the Scientific Agricultural Research Directorate, the Directorate of Irrigation and Water Use, the Soil Directorate of the Ministry of Agriculture and Agrarian Reform, the Syrian Universities, the International Center for Agricultural Research in the Dry Areas (ICARDA), or by other international or regional organizations. Research on wheat has resulted in the development of agricultural technologies appropriate to farmers. These technologies have had a clear impact, in terms of the substantial increase that has occurred in total wheat production at the national level during the last ten years.

The Directorate of Scientific Agricultural Research has carried out, since its establishment, much research and many experiments on durum wheat. Such research included, in addition to agronomic research trials, the breeding and selection of high-yielding lines that are resistant to diseases and pests. Through the national breeding program, some high-yielding varieties developed by the program (such as the Jezirah-17 cultivar) have been released in the country. The Soil

Directorate has also conducted multi-year, multi-location trials on wheat fertilization. The Irrigation and Water Use Directorate has obtained many results related to the irrigation of wheat.

The Syrian Ministry of Agriculture and Agrarian Reform cooperates with ICARDA through a collaborative research and training program. The major goals of the collaborative program are: to carry out the necessary, basic and applied research required for the improvement of wheat, barley, faba bean, lentil, chickpea, and pasture and forage crops; to evaluate the different farming systems common in Syria and discover ways of improving these systems; to carry out socioeconomic studies in order to understand factors that influence the adoption of new agricultural technologies by farmers, and to identify the constraints that affect the diffusion of new technologies. Training national scientists is also a major component of the cooperative program.

Collaborative research has also been undertaken by the Syrian National Program and International Agricultural Research Centers (IARCs) such as CIMMYT (Centro Internacional de Mejoramiento de Maiz y Trigo) and ICARDA. One instance of such collaborative research aims to enhance durum wheat productivity and production in a stable and sustainable manner for the benefit of resource-poor farmers.

4.1. Development of Stress-Tolerant Varieties

A collaborative program was initiated within the CIMMYT/ICARDA durum breeding program located at ICARDA, Aleppo, Syria. The main objectives of this program (Nachit et al., 1998) are (1) to develop productive genetic materials that combine high grain quality with resistance to the main abiotic and biotic stresses present in the WANA region, and (2) to use the available genetic variation found in local landraces and wild relatives.

Genetic factors (such as resistance or tolerance to biotic and abiotic stresses) are critically important to the maintenance of both a high yield and yield stability in wheat. To enhance wheat production, the collaborative program run between the Syrian National Program and the joint CIMMYT/ICARDA wheat improvement programs aims to identify new wheat cultivars with better yield, yield stability, quality, disease resistance and tolerance to abiotic stresses than the varieties currently being cultivated.

The breeding methodology followed emphasized the following:

- A targeted crossing program, aimed at broadening the genetic base of the crop by selective exploitation and utilization of exotic material and landraces.
- Multi-location testing, to expose the germplasm to the biotic and abiotic stresses that are prevalent in the region.

This methodology proved to be successful in identifying superior cultivars adapted to each durum wheat cultivation zone in Syria. Selected cultivars generally combine high yield potential and stress tolerance, and hence tend to have high yield stability. This feature is the result of them being input-efficient when grown under conditions of limited resources in stress environments, and input-responsive under favourable environmental conditions. In addition, durable resistance, from historically proven resistant sources, has been bred into these cultivars in order to give long-term crop protection against major diseases, particularly rusts. Thus, the cultivation of such new cultivars tends to be environmentally friendly, as it eliminates the use of those environmentally toxic chemicals that are widely used to control wheat diseases.

4.2. Improved Soil and Crop Management Technologies

ICARDA research results in WANA (Cooper and Gregory, 1987; Cooper et al., 1987; Harris et al., 1991) have emphasized the importance of achieving early crop cover through early sowing, selection of varieties with rapid early winter growth (under cool conditions), adequate fertilization, and an adequate plant density (e.g. a narrower row spacing). Proper land preparation is necessary for better crop establishment and sustainable, higher crop production. However, decisions about tillage operations (i.e. date, method, equipment, etc.) are not related to durum wheat farming alone, but are also influenced by weather variability, the crops in rotation, and other factors. Farmers are well aware of these implications, and adopt those land preparation practices that are most appropriate to their economic conditions.

In Syria, and in other similar areas of the world, there have been many indications that early crop establishment and early canopy development are associated with higher durum wheat yields (Bolton, 1981; Cooper et al., 1987). Extending the duration of the effective growth period, which results in higher yields, is only made possible by earlier sowing (Pala, 1991). However, early sowing is only advantageous if emergence also occurs early and if the crop can survive potential drought conditions at the seedling stage. It has been calculated that, in northern Syria, each one-week delay in sowing after the beginning of November reduces wheat yields by 4% (Stapper and Harris, 1989). Nevertheless, farmers delay planting because of variable rainfall early in the season; they recover the loss caused by such a delay in planting by providing supplemental irrigation later in the growing season.

Since, in general, Syrian soils have low fertility, as in, for example, many dry areas in WANA (Ryan and Matar, 1992), judicious use of fertilizer is particularly important. Extensive work undertaken in Syria during the 1980s (Cooper et al., 1987) demonstrated the efficacy of appropriate fertilization, with regard to the production and water-use efficiency of winter-sown crops, especially wheat and barley.

In addition to experiments run on research stations, ICARDA and the Syrian Soils Directorate conducted during 1986-1990 a four-year multi-location study in northern Syria (MAAR and ICARDA, 1990). This study was conducted to test the results of the on-station trials under on-farm conditions, and also to see how the results would be multiplied in farmers' fields on a large scale. Results from 70 sites in farmers' fields indicated widespread wheat response to N-fertilizer, which was associated with an increase in rainfall ; however, the response to P was not significant (Pala et al., 1996). Barley also responded to N when there was an increase in rainfall; however, unlike wheat, its response to P was more obvious in relatively drier areas (Jones and Wahbi, 1992).

The study provided a clear strategy that could be used by Syrian decision-makers to prioritize fertilizer allocation in order to improve fertilizer-use and water-use efficiency, and so increase yields of the staple crops (wheat and barley). Wheat growers tend to apply more N-fertilizer than is recommended. Recommended quantities of N-fertilizer vary with conditions and are as follows: 30 kg N/ha in dry years to 60 kg N/ha in wetter years in rainfed areas and 100 kg N/ha under conditions of supplemental irrigation (Pala et al., 1996; Oweis et al., 1998). Overuse of N-fertilizer does not affect wheat yield, but does have an effect on the benefit obtained by farmers.

Previous research results, obtained by ICARDA through collaborative studies undertaken with the Directorate of Irrigation in farmers' fields, have shown that substantial increases in rainfed crop yields occur in response to the application of relatively small amounts of water (Oweis, 1997; Oweis et al., 1998). Average increases in wheat grain yield under low (234 mm), medium (316 mm), and high (504 mm) annual rainfall at ICARDA's Tel Hadya station were, respectively, about 400%, 150%, and 30% when additional quantities of water were used (about 180 mm, 125 mm, and 75 mm, respectively).

5. Diffusion of Modern High-Yielding Wheat Varieties

HYVs of wheat accounted for about 8% of the total wheat-producing area in 1973. Most of these varieties were used in irrigated areas (i.e., in 41% of irrigated areas, as compared with their use in 5% of rainfed areas). Some of the earliest varieties introduced to Syria were Florence Aurore and Senator Capelli, which have been officially reclassified as local varieties. These were later replaced by Jouri-69 and Mexipak, the latter being released prior to 1973. Between 1973 and 1993, 14 new varieties were released, 8 of which were durum wheat and 6 bread wheat. To a limited degree, the varieties were targeted at different environments: Zone 1, Zone 2, full irrigation in any zone, or a combination of Zones 1 and 2 (Table 1). Associated technologies, such as fertilizer, are based on zones rather than on varieties. Seed is multiplied by the General Organization for Seed Multiplication (GOSM) under contract with producers, and is made available to farmers by GOSM. The seed is usually treated for seed-borne diseases and pests before sale.

At the national level, under both rainfed and irrigated conditions, the wheat yields of HYVs were higher than those of local varieties. Although HYVs of durum wheat demonstrate a definite advantage over local wheat in rainfed areas, the largest contribution to increased durum wheat productivity in Syria is made by the combination of irrigation with high-yielding varieties.

Table 1. High yielding durum wheat varieties in Syria.

Variety	Release date	Target environment	Experimental yield averages (various years)
Jouri 69	1970	Irrigated & Zone 1	-
Gezira-17	1974	Irrigated & Zone 1	4.5 t/ha (Irrigated) 3.0 t/ha (Rainfed)
Bohouth-1	1980	Irrigated & Zone 1	5.0 t/ha (Irrigated)
Cham-1	1983	Irrigated & Zone 1	4.5 t/ha (Irrigated)
ACSAD 65	1986	Zone 1 & Zone 2	
Cham-3	1987	Zone 2	2.5-3 t/ha
Bohouth 5	1987	Irrigated & Zone 1	7.5 t/ha (Irrigated)
Cham 5	1993	Zone 2	3-3.5 t/ha

Source: FRMP Annual Report 1991.

The first new improved ICARDA wheat line to be approved by the Syrian national program was released to farmers in 1983. Syria released this durum line (Waha) under the name Cham-1. It is a derivative of a cross received from CIMMYT, and was identified as a promising line through yield-testing trials. It was officially released after four years of testing and evaluation in farmers' fields in

Syria, which was undertaken by the Syrian Ministry of Agriculture and Agrarian Reform, in collaboration with ICARDA.

In 1983, the Syrian national program also accepted a bread wheat line developed by ICARDA and released it under the name of Cham-2 (ICARDA, 1983). After being identified as a promising line, it was tested in the region through ICARDA's International Nurseries Network. Four years of tests were run in farmers' fields in irrigated and rainfed areas of Syria, in a collaborative program undertaken by the Syrian Ministry of Agriculture and ICARDA. The line proved to be consistently higher yielding than the Mexipak cultivar. Seeds were multiplied by the General Organization for Seed Multiplication and made available to farmers. It was recommended that Cham-1 be used in Zone 1, and that Cham-2 be used in Zone 1 and in irrigated areas in any zone.

The official acceptance of high-yielding varieties developed by ICARDA has been continued by the national program in Syria. Varieties are tested under on-farm conditions by means of multi-year trials conducted by the collaborative program mentioned previously. Cham-3 and Cham-5 (durum wheat varieties) and Cham-4 and Cham-6 (bread wheat varieties) were adopted and multiplied for use by farmers. It is estimated that, currently, more than two-thirds of the total area of both bread wheat and durum wheat grown in Syria is planted with the Cham varieties.

6. Survey Sample and General Characteristics

The formal survey sample was selected on the basis of published wheat production statistics. Farmers were randomly selected, using a multi-stage sampling procedure, according to stability zone and contribution made to national wheat production. For the purpose of characterization and classification, the sample was grouped into five regions: (i) the Western Region; (ii) the Al-Ghab Region; (iii) the Al-Jazirah Region; (iv) the Al-Furat Region; and (v) the Hauran Region (Fig. 7). Farmers in the sample were located in stability Zones 1 and 2, except for Al-Furat farmers, who were located in Zones 4 and 5 and rely on full irrigation from the Euphrates River. Farmers were asked to answer questions with reference to the largest wheat plot they owned, as experience shows that the largest plot provides the most accurate data.

The study lasted three seasons: 1990/91, 1991/92 and 1992/93. A questionnaire was developed, and 230 farmers were interviewed during each season. About 688 farmers were sampled over the three seasons.

Table 2 shows the distribution of the sample by region and farm size. In general, the Western Region demonstrated the distribution expected between small and medium-sized farms. Farms in Hauran tended to be neither very small nor very

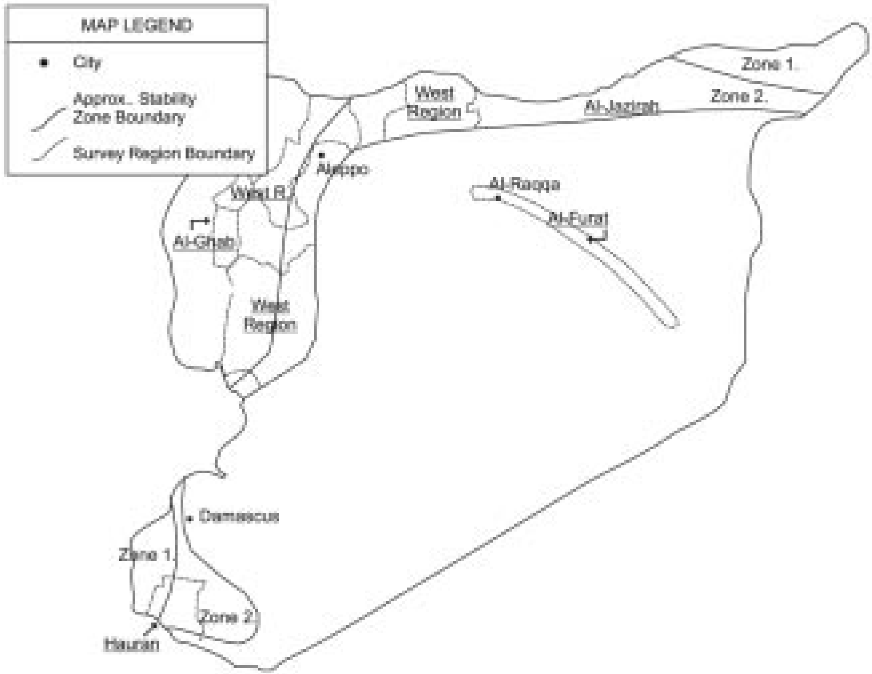

Figure 7. Stability Zones and Survey Regions

large, while farms in Al-Jazirah were medium to large. In Al-Ghab and Al-Furat most farms were small because of their recent history of agrarian reform, irrigation development, and settlement in the area.

Some interesting findings emerged, with regard to land use and cropping systems, according to region and farm size (Table 3). Hauran, for example, is an area where wheat is grown traditionally, with large fallow areas and a wide range of crops. Al-Jazirah is the major wheat producing area, with some 81% of the arable land planted to wheat and barley. In addition to wheat, industrial crops (such as cotton and sugar beet) are grown in Al-Ghab and Al-Furat. The Western Region is largely similar to Hauran, but without much fallow. Instead, other crops, mainly vegetables, have been introduced to replace fallow. The introduction of supplemental irrigation into the Western Region has enabled land use to be more intensive than in Hauran.

Fifty-five percent of the farmers sampled had access to at least one source of irrigation (such as a canal, river or well). This figure is high compared with Syria as a whole. It is impossible to quantify any sample bias regarding access to irrigation, because there is no data available at the national level regarding the number of farmers who have access to irrigation.

Table 2. Sample distribution (%): by region and farm size.

Farm Size (ha)	West Reg.	Al-Ghab	Al-Jazirah	Al-Furat	Hauran	Total
Number of farmers	271	41	269	42	65	688
Farm size (ha)						
0–5	17.0	75.6	7.1	50.0	6.2	17.6
> 5–10	23.6	7.3	15.6	40.5	20.0	20.2
> 10–20	32.1	7.3	22.3	4.8	32.3	25.1
> 20–50	21.4	7.3	29.0	4.8	35.4	23.6
> 50	5.9	2.4	26.0	-	6.2	13.2
Total	**39.4**	**6.0**	**39.1**	**6.1**	**9.4**	**100.0**

Table 3. Land use (% of arable land, averaged over 3 years), in relation to region and farm size.

	Average farm size (ha)	Wheat Durum	Wheat Bread	Wheat Total	Barley	Legumes	Forage	Feed crops	Tree crops	Other
Region										
Western Region	19.2	20	5	25	27	11	1	9	16	12
Al-Ghab	7.8	54	2	56	1	1	1	0	37	4
Al-Jazirah	49.0	42	13	55	25	3	-	-	9	7
Al-Furat	7.2	36	25	61	1	-*	1	-	36	1
Hauran	21.0	34	ns	34	5	21	4	5	11	20
Farm size (ha)										
0–5	3.2	54	6	60	6	4	-	2	25	2
5–10	8.0	38	9	47	14	8	1	5	22	4
10–20	15.4	31	6	37	23	9	2	6	17	6
20–50	33.0	36	7	43	18	8	1	4	14	11
> 50	118.6	37	13	50	29	4	-	1	8	9
Mean	29.6	36	10	46	24	6	1	3	12	8

* The percentage is very low

Three trends were noted from the survey results. First, the area of irrigated wheat is increasing, while there is, at the same time, a general decline in the total area of wheat. Second, supplemental irrigation is more widespread than full irrigation. Third, most farmers do not choose the wheat varieties they grow according to their response to irrigation. In other words, farmers in the irrigated area see no difference between varieties in terms of their response to irrigation.

Since the statistics of the Ministry of Agriculture do not distinguish between durum and bread wheat, the results of the survey were relied upon in order to estimate the cultivated area for each type of wheat (Table 4). About 68% of the total wheat area was used to grow HYVs of durum wheat, while about 21% was used to grow HYVs of bread wheat. Local varieties of durum wheat constituted about 10% of the total wheat area, while local varieties of bread wheat accounted for about 1% (Table 4). There were clear differences in the distribution of each species according to geographical region, irrigation system, and farm size.

Given the importance of durum wheat in Syria and the relative advantage attached to its production, analysis is restricted to farmers who grow durum wheat. Such farmers made up about 85% of the total sample.

Table 4. Distribution of different wheat varieties (% of arable land) according to region and water regime (% of area planted to wheat), and according to farm size.

	HYVs of durum	HYVs of bread	Local varieties durum	Local varieties bread
Region				
Western Region	63	18	18	1
Al-Ghab	96	4	0	0
Al-Jazirah	72	22	5	1
Al-Furat	58	42	0	0
Hauran	20	-*	80	0
Water Regime				
Full Irrigation	82	18	0	0
Supplemental Irrigation.	88	10	2	0
Rainfed Zone 1	58	32	11	0
Rainfed Zone 2	66	15	16	2
Farm size (ha)				
0–5	82	9	9	0
> 5–10	70	19	11	0
> 10–20	67	17	15	-
> 20–50	73	17	10	-
> 50	66	24	9	1
Mean	68	21	10	1

* The percentage is very low.

7. Recommended Technological Package for Durum Wheat Production

Table 5 presents the technological package for durum wheat production in Syria that has been recommended since 1989 (MAAR, 1989). The recommendations are made according to variety, and also according to whether the cultivar is high-yielding or local. Such recommendations tend to advocate an increase in inputs for HYVs. The package recommends six full irrigations in Al-Furat and El-Jazirah (rainfall in these areas is insufficient to produce wheat), one or two supplementary irrigations (to supplement rainfall at critical times) in the Western Region, two or three irrigations in Zone 1, and four irrigations in Zone 2 (the latter two being in the Dara province). Each irrigation entails the use of about 750 m^3 water/ha.

Table 5. Recommended technological package for wheat production in Syria (1989).

	Irrigated		Rainfed			
			Zone 1		Zone 2	
	HYV	Local	HYV	Local	HYV	Local
Land preparation (tillage)	2	2	2	2	2	2
P_2O_5 rate (kg/ha)	100	70	80	50	30	30
P_2O_5 application date	At the 2nd tillage		At planting			
N rate (kg/ha)	150	100	80	60	50	50
N application times	3	3	2	2	2	2
Seed rate (kg/ha)	180	120	150-170	100	120	100
Planting date	15 Nov.-30 Dec.		15 Nov.-30 Dec.			
Herbicide application	Desirable when the plant is 20 cm tall		Desirable when the plant is 20 cm tall			

8. Use of Modern Technologies with Durum

8.1. Irrigation

There has been a remarkable increase in irrigation in Syria, which has doubled since 1973. The area of fully irrigated wheat expanded from 130 thousand hectares or 9% of the total area planted to wheat in 1973, to about 275 thousand hectares or 20% in 1990. This study provides clear evidence that, when given the opportunity and the means, farmers will adopt irrigation, because of the benefit they receive in terms of a higher yield and profit (Salkini, 1992). The survey shows that about 85% of farmers with access to a water source irrigate their wheat crop or a part thereof. The rest, mostly from Al-Ghab, Hauran, and the Western Region, do not irrigate their wheat crop. Rather, they use the water available to them to increase the yield of more valuable crops, such as cotton and vegetables. Of the farmers who irrigate their wheat, 39% use full irrigation, 58% use supplemental irrigation, and 3% use both methods.

The traditional technique of flooding was the dominant method used by most farmers when irrigating their wheat. Less than 10%, most of whom live in the Western Region, use sprinklers and supplemental irrigation. It was noticed that most farmers tend to increase the number of irrigations given to more than the recommended number.

8.2. Mechanization

Wheat producers use mechanization intensively. Of the farmers surveyed, 98% use a tractor for tillage before seeding, while 69% use some sort of machinery for seeding, the rest (mostly smallholders) rely on hand broadcasting. About 88% use a combine harvester to harvest their wheat. However, manual harvesting was used to a significant extent in Hauran, as well as in small plots in Al-Furat, where a harvester combine is difficult to use. Table 6 shows the distribution of surveyed farmers by number of tillage operations and harvesting method.

Table 6. Farmer's practice: number of tillage and harvesting method, according to region and irrigation regime used (% of farmers).

	Tillage No.			Harvesting method	
	1	**2**	**3**	**Combine**	**Manual**
Region					
Western Region	15	56	29	88	12
Al-Ghab	0	61	39	100	0
Al-Jazirah	10	71	19	100	0
Al-Furat	18	65	17	68	32
Hauran	50	42	8	51	48
Irrigation Regime					
Full Irrigation	10	69	21	91	9
Supp. Irrigation.	5	55	40	94	6
Rainfed Zone 1	23	62	15	87	13
Rainfed Zone 2	22	61	17	83	17
Mean	16	61	23	88	12

8.3. Fertilizer

About 86% of the farmers surveyed apply phosphorous to durum wheat. This rate was more than 90% when irrigation was used, and was about 80% in the case of rainfed agriculture. The regional distribution of non-phosphate fertilizer users was fairly even, except in Al-Ghab, where 55% of the farmers did not use phosphate. This can be explained by the fact that the amount of phosphorous available in the soil was relatively high, so the response to phosphorous was slight in that region.
Farmers use nitrogen fertilizer more than phosphorous. Only 7% of farmers, mostly from Hauran and Zone 2, do not use nitrogen (Table 7). Fifty nine percent of the farmers surveyed use two applications of nitrogen fertilizer, one at planting and one at tillering; most of them were irrigating wheat. Some of the farmers in Zone 2 apply nitrogen in one lot, either at seeding or tillering.

Table 7. Farmer's practice: fertilizer application, according to region and irrigation regime used (% of farmers).

		Nitrogen			
	Phosphate	Not used	At planting only	Top dressing only	Both
Region					
Western Region	87	5	11	25	59
Al-Ghab	45	0	16	7	77
Al-Jazirah	88	9	9	19	64
Al-Furat	96	0	11	7	82
Hauran	87	18	54	10	19
Irrigation Regime					
Full Irrigation	98	0	8	7	84
Supp. Irrigation	91	4	10	14	72
Rainfed Zone 1	80	5	11	31	53
Rainfed Zone 2	80	17	29	17	38
Mean	86	7	15	19	59

Phosphate fertilizer rates were close to those recommended both for irrigated areas and for Zone 2, but were lower than the recommended rate in Zone 1. Farmers use nitrogen fertilizer at rates that are slightly higher than those recommended (Table 8). Farmers in Al-Ghab in particular tend to increase nitrogen fertilizer rates to levels above those recommended.

Table 8. Farmer’s practice: average fertilizer rate (kg/ha).

	Average N	Average P_2O_5
Region		
Western Region	107	75
Al-Ghab	203	53
Al-Jazirah	100	72
Al-Furat	180	116
Hauran	28	35
Irrigation Regime		
Full Irrigation	165	105
Supp. Irrigation	152	104
Rainfed Zone 1	89	55
Rainfed Zone 2	45	38
Mean	105	70

8.4. Herbicides

Of the major external inputs, herbicides had the lowest adoption rate. About 42% of the farmers had used a herbicide at least once. The majority of non-users were located in Al-Jazirah (84%), Al-Furat (68%), and Hauran (57%). Herbicides were most popular in Al-Ghab (87% of farmers used them) and the Western Region (62% of farmers used them).

8.5. Seed Rates

Table 9 summarizes the seed rates used by farmers and their seed sources according to region and method of irrigation. It is clear that farmers in all regions, and under all irrigation methods, use rates which are higher than the recommended ones.

Durum producers in Syria tend to rely on the General Organization of Seed Multiplication (GOSM) for seed. About two-thirds of the sample reported that GOSM is their only source of pure and dressed seeds. This rate was higher amongst farmers who grew wheat under irrigation than it was amongst farmers who grew it under rainfed condition. The farmers in Al-Ghab, Al-Jazirah, Al-Furat, and Hauran rely on GOSM more than do those in the Western Region.

Table 9. Farmer's practice: seed rate, and seed sources (% of farmers).

	Seed rate (kg/ha)	Seed source			
		Own	Market	GOSM	More than one source
Region					
Western Region	212	22	13	52	14
Al-Ghab	298	0	3	87	10
Al-Jazirah	240	14	4	73	9
Al-Furat	277	4	7	82	7
Hauran	162	22	3	71	3
Irrigation regime					
Full Irrigation	306	5	2	83	10
Supp. Irrigation	266	6	8	72	13
Rainfed Zone 1	206	28	9	58	6
Rainfed Zone 2	164	20	9	60	11
Mean	225	17	7	66	10

8.6 Preceding Crop

Farmers were asked about the crop preceding their wheat crop. They were asked only about the previous crop that had been planted in the largest of their plots that were currently planted to wheat. Table 10 shows the distribution of answers in terms of the previous crop, region, and irrigation system.

Table 10. Farmer's practice: previous crop in the largest of their plots that were planted to wheat at the time of the survey (% of farmers).

	Summer crop	Legumes	Fallow	Cereals	Other	More than one crop
Region						
Western Region	47	20	8	12	8	5
Al-Ghab	55	3	0	19	10	13
Al-Jazirah	35	5	7	45	1	7
Al-Furat	79	0	0	4	11	7
Hauran	21	27	44	2	6	0
Irrigation Regime						
Full Irrigation	75	1	0	14	5	5
Supp. Irrigation	66	2	3	15	3	11
Rainfed Zone 1	33	28	6	21	6	6
Rainfed Zone 2	10	14	29	39	6	3
Mean	41	13	11	23	5	6

Forty one percent of farmers grow durum wheat after a summer crop such as cotton, vegetables, or melon; 23% after a cereal crop; 13% after a legume crop; 11% after fallow; 5% after other crops, and 6% after more than one crop. There were significant differences according to region and irrigation system. Most of the farmers in Al-Ghab and Al-Furat grow wheat after summer crops such as cotton. In the Western Region, wheat is grown after a summer crop or a legume crop. In Hauran, most of the farmers grow wheat after fallow, followed by a legume crop and then a summer crop. Forty five percent of Al-Jazirah farmers reported that they grow wheat continuously on the same land.

More than two-thirds of the surveyed farmers grow wheat after summer crops, such as cotton, if full or supplemental irrigation is available. For rainfed farming in Zone 1, wheat is grown after a summer crop such as melon and watermelon (33%), or after legumes (28%); 21% of the farmers in this zone reported that they grow wheat continuously. In Zone 2, 39% of the sample said that they grow wheat continuously, while 29% said that the land lay fallow prior to wheat. About a quarter of the sample in Zone 2 grows wheat after a summer or a legume crop.

9. Adoption of New Varieties

Adoption of new varieties by wheat producers is more complicated than the adoption of other components of the technological package. There has been a significant increase in the total area planted to improved varieties over the past 20 years. In our survey, adoption of HYVs conformed to published agricultural statistics.

The survey enabled us to look at adoption patterns of HYVs in several ways. First, we looked at the general distribution of varieties. Table 11 shows both the percentage of areas planted with each variety of durum and the percentage of farmers using each variety during the 1990/91, 1991/92 and 1992/93 cropping seasons. The cultivars Cham-1 and Cham-3 ranked first in terms of durum-cultivated area. They cover about 63% of the total area planted with durum wheat. About 56% of wheat producers grow these two varieties, which are the result of scientific collaboration between the Scientific Agricultural Research Directorate and ICARDA.

Second, we looked at variety distribution in terms of water regime: rainfed, supplemental irrigation, and full irrigation (Table 12). This invites comparison with the target environments listed in Table 1. For example, Cham 3, which is targeted at Zone 2, is in fact grown extensively in Zone 1 and under irrigated conditions (both supplemental and full).

Third, we looked at the distribution of cultivars among durum wheat producers. Twenty four percent of the surveyed farmers grow Cham 1, and 22% grow Cham 3.

Table 11. Distribution of durum varieties in Syria (averages for 1990/91, 1991/92 and- 1992/93 cropping seasons).

Variety	% of durum wheat area	% of farmers
Gezira-17	3	9
Cham-1	33	24
Cham-3	30	22
Bohouth-1	4	12
Bohouth-5	1	3
ACSAD-65	13	16
Jouri -69	3	9
Other HYVs of Durum	-*	2
Local varieties	13	7
Total	100	100

* The percentage is very low.

Table 12. Distribution of durum varieties according to water regime in Syria (% of durum area in 1993).

Variety	Rainfed		Supp. irrigation	Full irrigation	Total
	Zone 1	Zone 2			
Gezira-17	1	3	4	12	4
Cham-1	28	34	34	35	32
Cham-3	26	33	26	33	30
Bohouth-1	4	1	7	7	4
Bohouth-5	-*	-	1	5	1
ACSAD-65	23	5	19	7	13
Jouri-69	2	2	7	-	3
Other HYV Durum	1	0	2	-	-
Local varieties	16	23	1	0	13
Total	100	100	100	100	100
% of Cham varieties to total durum HYV's	65%	86%	62%	69%	71%

* The percentage is very low.

Local durum varieties are grown by 7% of farmers; some farmers grow more than one variety. The average number of varieties per farmer is 1.4.

Fourth, we looked at the weighted average age of HYV developed by Brennen and Byerlee in 1991 for different areas. This average is a useful measurement (Brennan and Byerlee, 1991) for comparing the rate of varietal change and replacement over time and across regions. The weighted average age of the HYV sample was 6.8 years. It was rather high in the Al-Furat Region and amongst small farmers, which means that when small farmers in the Western Region adopt one of the HYVs, they tend to continue growing this variety rather than switching to a new one. Table 13 shows the distribution of farmers using high-yielding durum wheat varieties according to the date of adoption.

Table 13. Distribution of farmers using HYV durum varieties, in relation to the length of time since date of adoption (%)

	1–5 years	6–10 years	11–15 years	>15 years
Region				
Western Region	30.6	47.8	18.5	3.2
Al-Ghab	2.9	51.4	25.7	20.0
Al-Jazirah	57.4	31.4	4.4	6.9
Al-Furat	20.7	31.0	24.1	24.1
Hauran	100.0	0	0	0
Farm size (ha)				
0–5	22.6	46.2	21.5	9.7
> 5–10	34.1	46.6	12.5	6.8
> 10–20	52.1	26.6	10.6	10.6
> 20–50	51.0	34.0	9.0	6.0
> 50	46.3	42.6	7.4	3.7
Water regime				
Full Irrigated	37.5	35.4	8.3	18.8
Supp. Irrigated	32.0	45.3	17.2	5.5
Rainfed Zone 1	41.9	39.5	12.9	5.6
Rainfed Zone 2	58.0	30.9	9.9	1.2
Mean	41.0	38.7	12.6	7.7

10. Technologies Associated with High-yielding Varieties

Adoption of new varieties is usually accompanied by changes in crop management practices. Practices most frequently cited were use of the following: chemical fertilizers, herbicides, and new agronomic practices. HYV adopters were asked whether they had changed their production practices when they adopted the new varieties. A majority reported that they made at least one change; others said they made more than one change (Table 14). An increased seed rate is the change most frequently associated with HYV adoption. Increased fertilizer use is also common when adopting new varieties.

Table 14. Change in practice associated with HYV durum adoption (% of farmers surveyed).

Change	Time since adoption date				Total
	1–5 years	6–10 years	11–15 years	>15 years	positive reply
Increased seed rate	73	64	63	63	67
Increased use of phosphate fertilizer	60	55	59	52	57
Increased use of nitrogen fertilizer	60	62	67	64	62
Increased number of tillage operations	42	38	33	46	40
Increased herbicide use/rate	18	32	40	36	28
Shifted HYV to more fertile soil	8	16	26	24	15
Yield increase estimated by farmer	44%	60%	76%	49%	54%

11. Impact of Technology on Durum Wheat Production

Based on the data collected from the survey over three seasons, a production function has been developed, using multiple regression analysis, which links the productivity of each hectare with multiple variables (such as rainfall, HYV, number of irrigations, quantity of applied nitrogen fertilizer, previous crop, and application of herbicides). The regression equation obtained was significant ($P<0.001$). Table 15 shows the values of the coefficients of the production function. This function explains about 53% of the variation observed in durum wheat yield/ha in Syria.

Table 15. Estimation of durum wheat production function in Syria based on wheat survey data (1991–1993).

Label	Coefficient	SE	Variable
N	6.47	2.2	N added (kg/ha)
N^2	-0.005	0.007	Square of N added
Rain	1.91	0.5	Rainfall rate (mm)
IRR1	1044.9	175.0	Using 1-3 irrigations (1=Yes) (0=other)
IRR2	1755.6	170.0	Using 4-6 irrigations (1=Yes) (0=other)
IRR3	1430.4	248.0	Using more than 7 irrigations (1=Yes) (0=other)
Variety	847.4	149.0	Variety (1=HYV) (0=local)
Herbicide	302.5	114.0	Herbicide Application (1-applied) (0-No)
Precrop	659.5	123.0	Previous crop (0-cereals) (1-other)
Constant	-198.6	219.0	

Adj. R^2 = 0.532; F(9,528)= 69***

The multiple regression analysis indicates that application of herbicides may increase average yield by 302 kg/ha. Improved varieties may increase the yield by 847 kg/ha compared with local varieties. Growing durum wheat after legumes or a summer crop increases yield by about 659 kg/ha, in comparison with growing durum wheat continuously in the same field. Each 1 mm of rainfall increases durum yield by 1.91 kg. The use of 1 kg of elemental nitrogen unit increases yield by about 6.5 kg. This increase slows with the application of N fertilizer until the optimal limit is reached, then production decreases.

Farmers were divided into three groups in terms of the number of irrigations applied. The first group includes those who irrigate their fields 1-3 times annually (supplemental irrigation). The second includes those who irrigate their fields 4-6 times annually (full irrigation). The third group includes those farmers who irrigate their wheat more than seven times a year (more than the recommended amount of irrigation). The multiple regression analysis showed that, with supplemental irrigation, the expected yield increase is 1049 kg/ha. With full irrigation, the increase is about 1755 kg/ha. If the number of irrigations is more than is recommended, the expected yield will be 1430 kg/ha.

Based on the above production function, and after substituting the variables with the average values of data collected, the impacts of the most important technological components of durum wheat cultivation were estimated, namely: irrigation, cultivar, fertilizer, and factors relating to crop and land management. Figures 8, 9, and

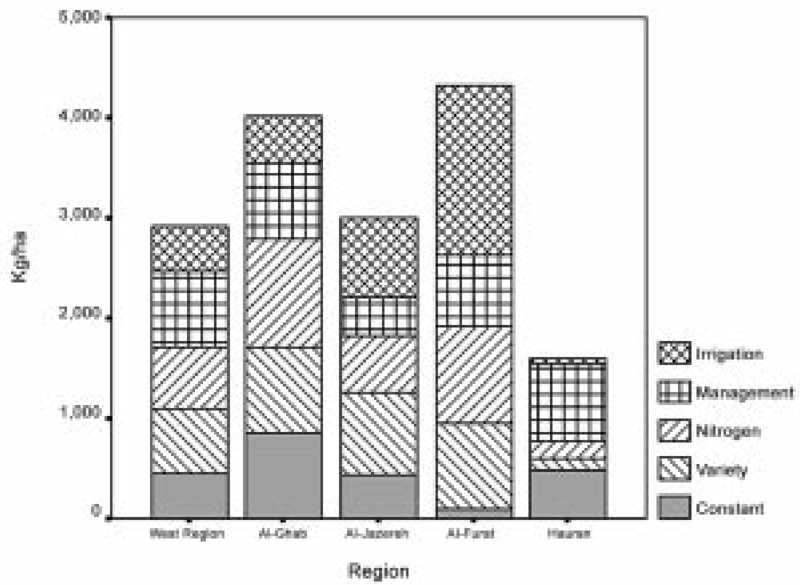

Figure 8. Effect of technological package components on durum wheat yield by regions

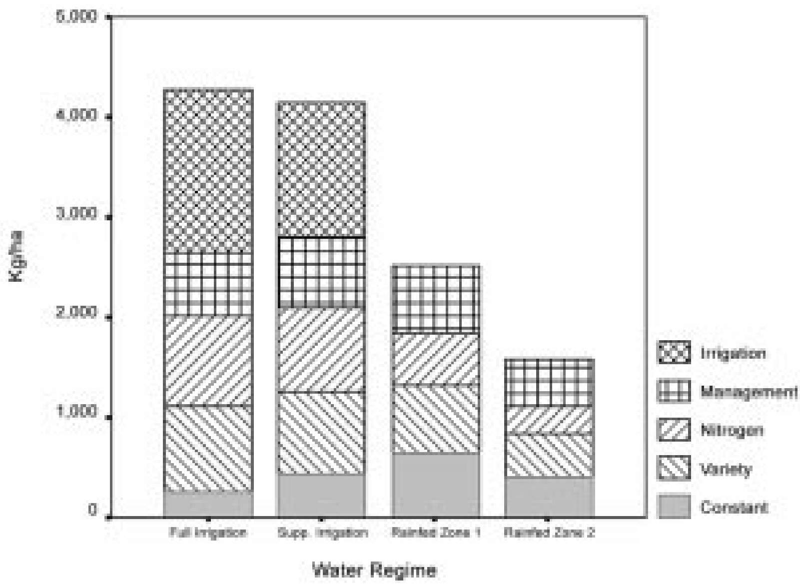

Figure 9. Effect of technological package components on durum wheat yield by irrigation regimes

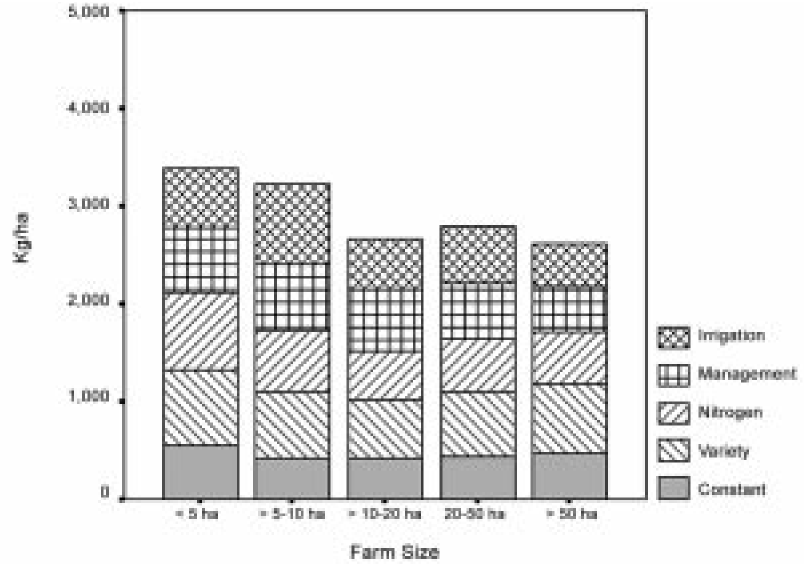

Figure 10. Effect of technological package components on durum wheat yield by farm size

10 give estimates of the impacts of the components of the integrated package on durum wheat. These estimates are given according to region, irrigation method, and farm size.

The impact of irrigation on productivity was more significant at Al-Jazirah and Al-Furat than it was in the Western Region and Al-Ghab. The impact of fertilizers in Al-Ghab was higher than in other regions. The impact of improved varieties was notable in all regions except Hauran, due to a delay in introducing the improved varieties into that region.

The effect of the various components of the package on total productivity was identical in the irrigated areas, the supplemental irrigation areas, and Zone 1. In Zone 2, the total impact was less than in the other areas.

Agricultural technology affected all groups of farmers: small, medium and large landholders. This is a more positive result than was experienced in some countries, where improved technology benefited large landholders much more than it did small farmers.

At the farm level, the average increase in net 'revenue' (expressed in kg/ha) resulting from each component of the technological package was estimated by deducting the 'cost' of the component from its yield increase. Due to the difficulty of estimating costs relating to crop management, it was assumed that the cost of crop management equals 40% of the total increase resulting from use of that component. Table 16 shows such estimates. Increases were higher in the irrigated areas and the areas of supplemental irrigation than they were in the non-irrigated areas.

Table 16. Estimated average increase in net 'revenue' (in kg/ha) at the farm level due to use of the technological package and its various components (kg/ha).

	Variety	Nitrogen	Irrigation increase	Management	Total
Water regime					
Full Irrigation	688	582	1073	380	2723
Supp. Irrigation	687	547	782	423	2439
Rainfed Zone 1	595	347		404	1346
Rainfed Zone 2	390	193		278	0861
Region					
Western Region	556	405	305	454	1720
Al-Ghab	692	693	161	452	1998
Al-Jazirah	702	380	489	232	1803
Al-Furat	703	625	1076	426	2830
Hauran	97	123	40	467	0727
Mean	610	390	377	368	1745

The net revenue/cost ratio was higher in the rainfed areas than it was in the irrigated areas; this is an indication of the economic profitability of investment in rainfed agriculture.

A preliminary estimate was made of the impact that modern agricultural technology has had on durum wheat in Syria; the increase in national income as a result of such technologies was also calculated. The following formula was used:

$$\text{Total increase} = \sum Ar_j * A_i * X_i$$

where: Xi = the increase obtained from technological component i in the package; Ai = the adoption rate of technological component i; and Arj = the average area planted to durum wheat in area j.

The preliminary estimate was that an increase of 1.66 million tonnes had occurred in the production of durum wheat. This is equivalent to an increase in national income of about 17.4 billion Syrian Lira annually (US$ 348 million at the exchange rate US$ 1 = 50 SL).

About 34% of this increase is due to the impact of the use of improved varieties, while about 24% is due to the application of fertilizer, 23% to irrigation, and about 19% to land and crop management (Table 17). Approximately 31% of the increase

Table 17. Estimated annual increase in durum wheat production, on a national level, due to modern technologies used on durum wheat in Syria (000 tonnes).

	Area	Increase				Total
	(000 ha)	Variety	Nitrogen	Irrigation	Manag-ement	increase
Full Irrigation	197	136	115	211	64	526
Supp. Irrigation	216	145	113	169	78	505
Rainfed Zone 1	324	162	107		103	372
Rainfed Zone 2	353	111	57		60	228
Total	1,090	554 (34%)	392 (24%)	380 (23%)	305 (19%)	1,631 (100%)

came from supplemental irrigation areas, 32% from fully irrigated areas, and 37% from rainfed areas.

In assessing the rate of return from agricultural research and extension, specifically the adoption of modern agricultural technologies, data on the cost of research are needed. In this study, there were difficulties in estimating the research costs related to durum wheat improvement in Syria. First, several national research institutes[1] are involved in durum wheat improvement and their activities incorporate more than one crop, which makes it difficult to single out durum wheat research costs. Second, the CIMMYT-ICARDA durum wheat improvement program for Syria is part of a regional program covering WANA, so isolating the costs relating to Syria alone is difficult. However, the research cost of durum wheat improvement in Syria has to be much smaller than the US$ 348 million gross research benefit, and a high rate of return from agricultural research on durum wheat improvement can be presumed.

Despite this remarkable increase, there still exists a productivity gap between potential yield and actual yield. Further effort should be made to close this gap, either through agricultural research or through extension. Improving the productivity and efficiency of water use of wheat is also an important issue, and requires more research.

1 Such as the Agricultural Research Directorates, the Irrigation and Water Use Directorate, the Soil Directorate, and Universities.

12. Conclusion

Substantial progress has been made in durum wheat research and production in Syria. However, there will be continuous pressure by policy makers to increase yields further and close the yield gap in the long-term. Sustainable durum wheat production can be achieved if varieties tolerant to biotic and abiotic stresses are developed and are suited to the environment. Such varieties would need to be used in conjunction with improved soil, crop and water management technologies, which would need to be adopted and applied by farmers. It is a constant and never-ending challenge. Adoption of the technologies by farmers depends upon policy makers being aware of improved technologies, upon good linkage between research/extension work, and upon farmers participating in on-farm trials and demonstrations. Human capacity building across all the stakeholders will be necessary if sustainable crop production is to be achieved.

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