Renewable Agriculture and Food Systems: 19(1); 30–34 DOI: 10.1079/RAFS200356

Wheat farming in Syria: An approach to economic transformation and sustainability

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Accepted 10 June 2003 **Research Paper**

Abstract

Sustainability has recently become an ingrained concept in crop production systems worldwide, and is the cornerstone of research programs of the global network of research centers operated by the Consultative Group of International Agricultural Research (CGIAR), which functions in collaboration with the various national agricultural research systems. One of the major CGIAR centers, the International Center for Agricultural Research in the Dry Areas (ICARDA), focuses mainly on dryland agriculture, but increasingly on irrigation, in its mandate area of West and Central Asia and North Africa. ICARDA has collaboration programs with its host country, Syria, the cradle of civilization and of settled agriculture, and the center of origin of many of the world's major crops, notably cereals and pulses. Wheat is, and has been, the most important commodity food in Syria. The Center's goal is to enhance wheat productivity in a sustainable manner for the benefit of the country's resource-poor farmers and society as a whole. Wheat is grown on about 1.5 million ha or 27% of the total cultivated land in Syria, mainly under rainfed conditions (300–500 mm annual rainfall), which are increasingly experiencing supplemental irrigation, while drier (<200 mm) areas are fully irrigated. Improved cultivars generally combine high yield potential and stress tolerance and tend to have high yield stability, being input-efficient under limited resources in stress environments and input responsive under favorable environments. Such varieties are tested under farmers' conditions through multi-year multi-locations. Other aspects of the ICARDA–Syrian collaboration wheat program include improved tillage, with an emphasis on conservation systems, adequate fertilization, and improved agronomic practices, e.g., early sowing in relation to rainfall conditions, optimum row spacing and plant population, and adequate weed control. This vigorous collaborative research–technology transfer program has produced a major shift in wheat production in Syria, from traditional low-input practices with landrace or improved cultivars to widespread adoption (two-thirds of wheat area) of modern cultivars along with improved production technology. As a result of such efforts, national income has substantially increased, and Syria has become a net exporter of wheat. Thus, the collaborative efforts of an international research center and its host country have shown clearly that there is an alternative to a traditional, low-output agriculture and its associated ills.

Key words: Syrian agriculture, wheat production technology, rainfed and irrigated cropping

Introduction

Now that we are into the Third Millennium, humankind is probably better fed than at any time in history, notwithstanding the substantial growth in the world's population, especially in developing countries[1]. Nevertheless, major disparities exist, with most developed countries having food surpluses and their attendant economic implications, while large segments of the world, especially Africa, are plagued by declining per capita production and consequent hunger and malnutrition. While agricultural research has contributed largely to helping the world feed its 6 billion people, the question is 'Can it continue to produce the spectacular achievements as in the past?' Even if we can move off the global crop production plateau, can it be done without causing irreparable damage to the very resource base that sustains agriculture?

Thus, the concept of 'sustainability' has emerged in the agricultural and social science literature. While definitions of sustainable agriculture are many and varied[2], most of them center around 'the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the natural resource base and avoiding environmental degradation'. Sustainable agricultural systems are designed to use existing soil nutrient and water cycles, and to harness naturally occurring energy flows for food and feed production[3,4]. What is anathema to sustainability is resource degradation that can occur in the production process, e.g., soil erosion, declining water quality and loss of biodiversity.

The origins of settled agriculture can be traced to the Middle East, indeed most of the major food crops of the world, including wheat, evolved there. Today the region is beset with the dilemma of feeding its burgeoning populations in a resource-poor, environmentally harsh environment[5]. The irony is that this food-deficit area of the world was once the cornucopia of plenty. Notwithstanding the daunting challenges facing agriculture in the region—especially the southern and eastern fringes of Mediterranean Sea—much hope has been pinned on agricultural research as a means of transforming traditional agriculture to a modern, more productive and environmentally friendly version.

The establishment of the International Center for Agricultural Research in the Dry Areas (ICARDA) in Aleppo, Syria, in 1977, reflected the hopes for agricultural research to deliver positive change to its mandate region of North Africa and West Asia, and specifically the host country, Syria. ICARDA is one of 16 autonomous agricultural research centers worldwide that are operated under the auspices of the consultative Group for International Agricultural Research (CGIAR) based in Washington, DC. The overall goal of this global network of centers is to promote sustainable agricultural development in poorer countries of the world, leading to poverty alleviation and environmental protection. All centers operate in collaborative mode with the national agricultural research systems in their respective mandate areas.

ICARDA has particularly strong links with regional scientists, especially within Syria, where it has formal agreements and active research and technology transfer programs with various departments within the Ministry of Agriculture and Agrarian Reform. While the Center is concerned with all aspects of dryland agriculture—cereals, pulses, forage crops, animal husbandry, natural resources (land, soil, water) and biodiversity—a major focus has been, and continues to be, on wheat, both winter/spring wheat (*Triticum aestivum* L.) and hard or durum wheat (*T. turgidum* var. *durum* L.). This paper reviews briefly wheat production trends in Syria, constraints to achieving sustainable self-sufficiency and strategies to improve wheat genetically and develop better soil and crop management.

Wheat Production

Wheat is the most important commodity food in Syria in terms of area and importance, since it is the major source of energy and protein in the local diet. Bread derived from wheat is a staple 'staff of life' in Syria, which has one of the world's highest per capita consumption figures. Currently, about 1.5 million ha, equivalent to 27% of the total cultivated land in Syria, are sown to wheat. Rainfed wheat is mainly grown in the relatively wetter areas (300–500 mm annual rainfall) as well as dry areas (<200 mm) that are irrigated[6]. Supplemental irrigation is increasing in former rainfed areas, where water sources, either from surface or groundwater, are available[7].

Fifty years ago, Syria was self-sufficient in wheat. Expansion of the wheat-cultivated area allowed Syria to be a net exporter until the 1950s. However, because of growth in domestic demand due to population increase (over 3% and one of the highest levels of population growth in the world), which was accompanied by a parallel increase in wheat yield and/or the area planted to wheat, Syria did not produce any surplus in the late 1980s, and had to import wheat and flour; for instance, the self-sufficiency rate for wheat during the period 1985–89 was about 72% of the total domestic requirement[8].

Recognizing the urgency of the situation, Syria's agricultural policy has, since the 1990s, paid special attention to wheat production. In order to improve producers' living standards and to achieve self-sufficiency, government planning concentrated on improving the productivity of the existing wheat land. Emphasis was placed on adopting modern stress-tolerant improved wheat varieties, and using chemical fertilizers and weed and pest control measures suitable for Syrian conditions. Extension and credit institutions were organized to fulfill these requirements, while farmers were encouraged, through subsidies and price controls, to mechanize production. The government also initiated various infrastructural projects to provide irrigation facilities; water wells and other on-farm irrigation systems were developed by both the public and the private sector. The appropriate price policy for inputs and outputs contributed to encouraging farmers to adopt the new agricultural wheat technologies. Modern approaches to production, e.g., mechanical tillage, planting and harvesting, use of stress-tolerant varieties, fertilizer application, chemical weed and pest control and optimum crop rotation, have become common to most farmers.

This newly adopted strategy is reflected in the rise of wheat yield per unit area and wheat self-sufficiency; since 1993 total wheat production has exceeded domestic needs. The value of this increase is currently about US$400 million; of this figure, 32% is attributed to improved varieties, 18% to fertilizer, 27% to irrigation and 23% to better land and crop management. About 30% of the impact came from fully irrigated areas, 30% from supplemental irrigation areas and 38% from rainfed areas.

In this context, it is pertinent to examine the role of international centers such as ICARDA and CIMMYT (Central International Center for Maize and Wheat Improvement, Centro International de Mejioramiento de Maiz y Trigo), in collaboration with Syrian institutions, in spearheading research that has improved, and continues to improve, wheat production in Syria.

Development of Stress-Tolerant Varieties

Genetic factors, such as resistance or tolerance to biotic and abiotic stresses, are critically important for wheat improvement programs aimed at identifying new wheat cultivars with better yield, yield stability, quality, disease resistance and tolerance to abiotic stresses than the varieties currently under cultivation[9].

The breeding methodology followed by ICARDA/CIMMYT emphasized a targeted crossing program aimed at broadening the crop genetic base by selective exploitation and utilization of exotic material and landraces, and by multi-location testing to expose the germplasm to the prevailing biotic and abiotic stresses throughout the wheat-growing areas of Syria. The cropping zones are dictated by rainfall: zone A (>350 mm), mainly wheat; zone B (250–350 mm), mixed cereals, legume rotations, fallow; zone C (<250 mm), barley and fallow. Selected cultivars adapted to each wheat cultivation zone in Syria generally combine high yield potential and stress tolerance and hence high yield stability[10].

This feature is the result of being input-efficient under limited resources in stress environments and input responsive under favorable environments. In addition, durable resistance from proven resistant sources is bred into these cultivars to give long-term crop protection against major diseases, particularly rusts, thus reducing the use of potentially environmentally harmful chemicals that are used to control wheat diseases[11].

Adoption of Improved Varieties

Stress-tolerant wheat varieties accounted for about 8% of the total wheat area in 1973; most were used in irrigated areas, i.e., 41% compared to 5% in rainfed areas. Some of the earliest varieties introduced to Syria were officially reclassified as local varieties and were later replaced by improved varieties, e.g., Mexipak. After 1973, the pace of varietal development quickened, with 14 new releases (eight durum, six bread wheat, by 1993). To a limited degree, the varieties were targeted to different environments, e.g., 300–500 mm rainfall zone or full irrigation. Fertilizer use was based on zones rather than varieties and yield potential or soil test levels, although criteria are now available upon which to base nitrogen (N) and phosphorus (P) fertilizer application rates[12]. Seed is multiplied by the General Organization for Seed Multiplication, under contract to producers, and made available to farmers; it is usually treated for seedborne diseases and pests before sale.

The wheat yield of stress-tolerant varieties was higher, at the national level, than local varieties, under both rainfed and irrigated conditions. Although stress-tolerant wheat varieties were superior to local wheat cultivars in rainfed areas, the largest contributor to increased wheat production in Syria is the combination of stress-tolerant varieties and irrigation. A significant milestone in wheat development in Syria was the first durum wheat line developed by ICARDA in 1983, a derivative of a cross from CIMMYT, approved by the national program and released after 4 years to farmers as a new variety, i.e., Waha, under the name of Cham 1. This was the first in a series of Cham (old Arabic name for the greater Syrian region) varieties (Cham 1 to 6) developed since then by ICARDA, all of which outyielded the older Mexipak standard variety. Some of the new varieties were targeted to specific environments, e.g., Cham 1 in drier areas (<350 mm) and Cham 2 in wetter areas and with irrigation. These varieties are grown in about two-thirds of the total wheat area in Syria.

Improved Soil and Crop Management Practices

Until recently, cultivation practices in the Middle East were traditional and primitive—having changed little for centuries, e.g., animal traction, hand sowing, little or no fertilizer, except manure, manual weed control and harvesting and threshing. Research in the region, including Syria, by ICARDA and the national programs demonstrated the advantages of improved management in terms of early sowing, establishment of early canopy cover, adequate plant population and row spacing, suitable tillage and chemical weed control[13]. Indeed, considerable efforts are now being made to promote soil-conserving, lower energy-requiring conservation tillage systems[4].

The time of sowing was one of the most contentious issues, given the variability in rainfall, especially at the break of season. If rain after crop emergence (November–December) is not adequate, complete crop failure can occur. Nevertheless, on average, delaying sowing was estimated to reduce yield potential by 4% for each week after early November[14].

A major factor in wheat yield increases in the past few decades has been the use of fertilizer. Syrian soils are inherently low in available P due to high pH and calcium carbonate ($CaCO_3$) contents[15]. Much of the early soil fertility research by ICARDA and national partners demonstrated the value of P fertilization, especially with banding[12]. Similarly, N fertilization was another indispensable component of crop management[16]. As elsewhere, a significant portion of current yield levels is attributed to fertilizer use.

That both N and P fertilizers are now well adopted by Syrian farmers is largely due to extensive multi-year (4 years), multi-location (70 sites) research–technology transfer trials across the main rainfall zones in northeastern Syria[17]. In these trials, response to N was directly related to rainfall, while response to P was relatively higher as rainfall decreased[18]. Thus, recommendations for fertilizer application rates are guided by rainfall zones.

Irrigation: Full or Supplemental?

When ICARDA was founded in 1977, most of Syrian cropland was rainfed, except where irrigation was possible near the Euphrates River, and to a lesser extent from underground water. The intervening years have witnessed a dramatic increase in irrigation, especially from pumping of groundwater and from newly developed projects involving surface sources. Given declining water resources, the current focus is on sustainable use of water in agriculture; thus, the concept of supplemental irrigation, i.e., stabilizing acceptable crop yields by judicious amounts of water during the growing season[7].

A large-scale 4-year trial with both bread wheat and durum wheat at ICARDA's main station at Tel Hadya demonstrated the value of supplemental or 'deficit' irrigation[19,20]. Average grain yield increases were 400% in a dry year (234 mm) with 180 mm irrigation water; 150% in a medium year (316 mm) with 125 mm water; and 30% in a high-rainfall year (504 mm) with 75 mm water. The widespread adoption of supplemental irrigation (40% of rainfall area in 1996) has been a major factor in the increase of wheat yields from 1.25 to 3 t ha^{-1}. Over half of the national average wheat output of 4 million tonnes is attributed to irrigation combined with improved varieties. Following a season of above-average and well-distributed rainfall (478 mm versus 330 mm on average at Tel Hadya Research Farm of ICARDA), the cereal forecast for 2002–2003 is estimated to be a record 6 million tonnes.

Sustainable Crop Management with Rotations

As desirable as it is to have high wheat output, it is equally important that the elevated level of production be sustained without detriment to the productive capacity of the resource base, i.e., soil[21]. While no land can sustain high crop yields indefinitely without inputs, practices such as rotations can contribute to yield sustainability[22]. Historically, in the Middle East, alternating cereal cropping with fallow helped ensure acceptable yields, largely by breaking the cereal disease cycle and improving water-use efficiency[23]. The use of legumes in place of fallow has also been practiced.

The past few decades have witnessed a drastic decrease in fallow land in Syria, due to increased land-use pressure from population growth. This has given way to continuous cropping, an alarming trend with an obvious threat to sustainability[2]. From its inception, most of the research at ICARDA focused on solving this dilemma with the outcome of long-term rotation trials[22]. The conclusions from several cropping systems trials offer viable alternatives to monoculture[24]. It was demonstrated that total output from the rotation could be increased by including feed and forage legumes[25]. Specifically, lentil with wheat was most economic; water use in the system was optimized by legumes; and N-use efficiency was enhanced. By comparison with continuous cropping, all alternatives considered performed better in terms of yield[22]. These encouraging observations confirmed those from various other cereal rotation trials in the Mediterranean.

While the benefits of rotations are well known in terms of disease and weed control, limited observations from ICARDA trials indicated that the cereal-cyst nematode (*Heterodera avena*), take-all (*Gaeumannomyces granimis* var. *tritici*) and the wheat ground beetle (*Zabrus tenebroides*) all decreased in incidence with a legume/cereal rotation compared with continuous cropping with wheat.

An unintended outcome of these trials was the positive effect of some forage legume rotations such as vetch (*Vicia sativa*) and medic (*Medicago sativa*) on soil organic carbon content[26]. Thus, an improved production system also had environmental spin-off by increasing carbon sequestration and thereby contributing to mitigating global warming. The added organic matter was also associated with improved soil physical structure. It was of interest to note that while fallowing once every 2 years maintained crop yields, the practice was associated with the lowest organic matter levels, presumably as a result of mineralization during the fallow year with no root biomass input.

Much of what has emanated from the long-term wheat trials on-station has been tested in farmers' fields for potential adoption. The past few years have witnessed a rapid expansion of vetch-growing in place of fallow or continuous wheat in northern Syria, a practice that not only puts cereal production on a sound footing but also promotes animal output—the other major component of traditional Syrian agriculture. With wider adoption of legumes, such as vetches, in cereal cropping[27], the impact on national output will, in all probability, be considerable.

Conclusions

This brief report highlighted a major shift in wheat production in a typical developing country in terms of its traditional agriculture and overall economic development. The catalyst to such change was the establishment of an international agricultural research center, ICARDA, the strategy of which was to work in collaboration with scientists from the various national programs in its mandate region of North Africa and West Asia. The intensive programs with Ministry of Agriculture and Agrarian Reform staff in Syria tackled all aspects of dryland cropping and, recently, with increasing emphasis on irrigation and water use. The research involved was both basic and applied, with a large capacity-building and technology-transfer component. With an initial focus on experimental station work across the range of rainfall zones (200–500 mm), later emphasis was on farmers' fields and farmer involvement in technology assessment.

The twin research approaches involved *breeding for improved germplasm* (yield stability, drought and disease resistance/tolerance) and *improved management* (agronomy, fertilization, mechanization). The doubling of wheat output in Syria within two decades, and the transformation from a food-deficit economy to a self-sufficient one, which is now exporting wheat, is testament to the success of this collaborative research partnership. While many of the technologies or practices are largely implemented, others, such as adaptation of legume/cereal rotations, are likely to impact at the national level in future.

The strategy adopted in Syrian agriculture can serve as a model for development elsewhere. The approach was one of examining traditional low-output agriculture and promoting an alternative modern package of practices, and, in so doing, it involved an alternative way of thinking on the part of farmers and administrators, as much as anything else.

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