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CROP NUTRIENTS FOR SUSTAINABLE AGRICULTURAL PRODUCTION IN THE DROUGHT-STRESSED MEDITERRANEAN REGION

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"Crop nutrients for sustainable agricultural production in the drought-stressed mediterranean region"

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Abstract

Most areas of the world where rainfall is limiting are characterized by low agricultural output and, ironically, high population growth rates that generate increased food demand. Arid and semi-arid regions permit a range of vegetative biomass production, from rainfed crops to native pasture, and sparse steppe shrubs to true desert. Given the harsh climatic conditions in areas such as West Asia-North Africa, where less than 10% of the land area is amenable to rainfed cropping, soil resources are fragile and cropping conditions precarious. Yet with appropriate manipulation of soil fertility and crop management within a systems context, including breeding of improved cultivars, conservation tillage, and rotations, substantial production increases can occur at the farmer's level. While irrigation has increased considerably in the past few decades, having a major impact on crop yields, surface and ground water sources are *limited*.

Applied research specific to the region has shown that crop output can be considerably enhanced with adequate nutrition, most of which has to be added as commercial fertilizer. The substantial yield increases that have taken place in several countries of the region have been attributed to three factors: *water*, *fertilizers*, and *improved varieties*. Technologies that potentially produce such high yield increases include identification of *nutrient stresses* and taking corrective action, and, where appropriate, adapting the plant to the soil conditions. If managed properly, innovative cropping systems to overcome these constraints can improve rather than degrade soil conditions.

Regardless of the advances in biotechnology, crop adaptation, and integrated cropping systems, chemical fertilizers will, in future, play an even greater role in the nutrition of both rainfed and irrigated crops in Mediterranean agriculture. Crop nutrition research will have to keep pace with agronomic developments. The future challenge in soil fertility-crop nutrition lies as much in overcoming obstacles to technology transfer as in generation of new knowledge.

Introduction

Despite the advances that have been made in agricultural production through research and technology transfer in the past half century, many areas of the world still fail to meet the nutritional needs of their people (Borlaug, 2003); in some countries the specter of hunger and malnutrition looms large, the food supply-demand equation is unbalanced by excessive population growth. Many of the world's poorest countries reside in the low rainfall arid to semi-arid regions. The International Center for Agricultural Research in the Dry Areas (ICARDA), based in Aleppo, Syria, focuses primarily on a major rainfed area of the world, i.e., the Mediterranean area, where settled agriculture and Western civilization began and where several of the world's major food crops such as cereals and legumes have evolved (Damania et al.,1998). The Center works in conjunction with the national agricultural systems in the various countries in its mandate region of West Asia- North Africa (WANA), merging into Central Asia, with linkages in other dryland areas of the world.

ICARDA's research is aimed at *germplasm enhancement, production systems management, natural resources conservation and development, socioeconomic policy, and institutional strengthening* of the national agricultural research systems. Despite the potential of irrigation to increase yields, crop output is limited by water availability from surface or groundwater sources. Therefore, for the Mediterranean region and other semi-arid areas of the world, dryland cropping, which depends on limited rainfall, will continue to be important for the lives of many and to merit research attention in order to meet the goal of self-sufficiency and contribute to poverty alleviation.

Notwithstanding the controlling influence of limited moisture -- from rainfall or residual in the soil -- an adequate supply of nutrients can have a major impact on yield in most years (Cooper et al.,1987; Ryan, 2002). Given the impoverished natural state of most soils, as a result of exploitive farming ("nutrient mining") for millennia since the beginning of settled agriculture, nutrients must invariably be added in the form of commercial chemical fertilizers. *The extent to which manures and other organic sources of nutrients (Ryan et al.,1985a), or indeed "miracle" alternatives (Ryan et al., 1982) can contribute to crop production is limited--and will continue to be so.*

In keeping with arid to semi-arid soils throughout the world, the soils of the Mediterranean area are deficient in major and essential elements such as nitrogen (N) and phosphorus (P) and several micronutrients, but are generally well supplied with potassium (K) and both calcium and magnesium. The purpose of this paper is to reflect a cross-section of the author's work on soil fertility and crop nutrition in the Middle East region; it is not intended as an exhaustive review, but rather to capture the major issues related to crop nutrition. As a background to an exposition of the role of nutrients in the region's agriculture, a brief description of its environment, soil resources, and cropping systems is pertinent - all influence in one way or another how efficiently nutrients are used.

Weather, Cropping Systems, and Soil

Despite the common features of limited rainfall and harsh production environments, considerable variation exists in the WANA region (Kassam, 1981). Much of the area is desert and scrubland. Where rainfall ranges from 200 to 600 mm year^{-1} rainfed cropping is generally practiced, but there is much inter-annual and seasonal variation (Harris, 1995). Within Syria, a range of rainfall zones exist, thus reflecting weather conditions in most of the Mediterranean region. Complete crop failure is common, especially in the low rainfall areas, i.e., less than 200 mm, and drought is an ever-present threat. However, crop growth conditions and evaporative demand are influenced by elevation and landmass. Highland areas are cold, often with snow and severe frost, as are inland areas which tend to have a continental climate.

Strategies for crop improvement have to consider the variation in agroecological zones (Ryan et al., 2006). In addition to weather-induced biophysical constraints, i.e., drought, cold, heat, other limitations include salinity and shallow soils with low moisture - retention capacity. Furthermore, as a result of the low organic matter (Ryan,1998), most soils are inherently low in N and invariably deficient for crops.

The farming systems that has evolved in the region are based on cool-season, winter rainfall (Cooper et al.,1987). Cereals predominate, with barley in the drier areas, bread wheat in the more favorable zones, and durum wheat in the intermediate rainfall zones. Forage and food legumes, notably chickpea and lentil, are grown extensively and in rotation with cereals. The area of fallow land is rapidly diminishing due to land-use pressure, with continuous cereal cropping becoming more common. Livestock production, mainly sheep, is usually associated with cereal growing, with grazed stubble and straw a feed source (Harris,1995). While the area of irrigated land is increasing, it is small by comparison with the rainfed area; with limited surface water sources and rapidly depleting groundwater, rainfed farming will continue to be dominant.

Several socioeconomic factors compound the biophysical constraints, i.e., small and fragmented land holdings, weak agricultural educational and technology infrastructure, poor credit facilities, and low inputs of fertilizers and other farm chemicals (Gibbon, 1981). While some farms are modern, many are traditional with low output, and are more prone to the vagaries of weather.

Soil properties are related to climatic conditions, past and present. At least six of the world's major soil orders are represented in the region, ranging from deep fertile Vertisols to shallow Inceptisols and true desert Aridisols (Matar et al., 1992). Despite such variability in soil types, the soils have several common features; most have considerable amounts of calcium carbonate, reflecting the calcareous parent rocks and the weak weathering environment. This, in turn, induces deficiencies of P and micronutrients (Matar et al., 1992). Most soils are low in organic matter (Ryan, 1998), reflecting low root biomass, grazing of residues, and high soil temperatures which promote organic matter mineralization. Thus, in most soils, the reserve of N is low, as is mineral N, i.e., nitrate and ammonium.

Given the low soil reserves of the major elements and the crop demand, most countries in WANA have experienced substantial increases in fertilizer use, especially N and P. As most soils are relatively well supplied with K (Ryan et al., 1997), fertilizer K input has been low or moderate, especially for the dominant cereal crops (Ryan and Mazid, 2003). For example, from the low base in the 1970s to 25 years later, N fertilizer use increased by 15 to 20-fold; the figure for P was about 10 to 15- fold.

Nitrogen: The Dominant Element

For crop nutrition, N is the element which is needed most; with increasing cropping intensification, it is indispensable in today's agriculture. Given its economic, and, indeed environmental importance, N has been the focus of intense study, both in developing and developed countries. In the context of WANA's dryland region, some background generalizations from Harmsen (1984) are worthy of mention and are still relevant and reflected in later publications (Ryan and Matar, 1992; Ryan,1997; Ryan, 2004)

The crucial question for the early research was to determine the nutritional needs of the crop for N and how much and how effectively fertilizer should be applied. The many factors involved include; costs and availability, expected yields and economic benefit, crop variety and its requirement system, and soil N mineralization/immobilization. Well established facts show that ammonium (NH_4) is subject to biological transformation, nitrate ($N0_3$) is mobile downward with the wetting front and upward with capillary rise, and the crop $N0_3$ uptake is correlated with soil $N0_3$. Nitrogen-use efficiency is influenced by source, application rate, method and timing. Possible losses from the system include volatilization induced by high soil pH with urea or ammonium fertilizers, denitrification and leaching, the latter processes being of little significance due to the low rainfall environment.

From its early days, ICARDA's research focused on N efficiency, a consideration still valid today. The goal of good N management is to increase N- use efficiency; currently, values in the WANA dryland area range from 20 to 70%. With these generalizations, it is relevant to examine the course of N research at ICARDA. While the concerns were mainly in Syria, there were parallel situations in other WANA countries (Ryan and Matar,1992; Ryan, 1997). This brief review does not purport to do justice to the full literature on N research from the region.

Dryland Nitrogen Research

Most of the early priorities on N research emerged from a workshop at Tel Hadya (Monteith and Webb, 1981). Among the issues identified were; the role of soil moisture in relation to N; fluxes and transformations of N in soil; biological N fixation and rhizobial inoculation; native fertility levels, tillage systems, fallowing, and rotations in relation to N; as well as the need for baseline soil data in field trials and identification of agro-ecological zones to facilitate technology or information transfer. Thus, the scene was set for a wide range of N-related studies involving most field crops.

The initial field trials at ICARDA's main station, Tel Hadya, and at sub-stations in higher and lower rainfall zones showed clear responses to fertilizer N for barley and wheat in all but the driest areas. Fertilization also increased water-use sufficiency (Matar et al., 1992). There was a yield relationship with seasonal rainfall which was modified by available soil nutrients. In other agronomic studies with cereals, high N application exacerbated drought stress during the grain-filling period and thus increased the proportion of shriveled grain. Nitrogen response was related to variety, while the effect of splitting N application depended on rainfall conditions. Nitrogen application was related to percent vitreousness in durum wheat, and thus, enhanced quality as well as yield (Mahdi et al., 1996).

Apparent N uptake efficiency was related to rainfall, being 30 to 40% at the drier sites (<300 mm), about 60% at Tel Hadya (330 mm), and greater than 80% at the wetter (>400 mm) sites. Actual N recoveries, using N-15, were 95% at Tel-Hadya (48% plant, 46% soil), and 80% at the drier Breda site. Most of the recovered soil N was in the top 0 to 20 cm layer. In an analysis of N and crop response data, Harmsen (1984) showed agronomic efficiencies of 52.5 to 96.8 kg grain per kg N uptake, apparent recovery fractions of 0.10 to 0.36, and N harvest index of 0.33 to 0.66. Clearly, there was room to improve efficiency.

Sampling after a year's fallow revealed more mineral N per hectare than in cropped plots, presumably from mineralization. Seasonal differences were observed for mineral N, with flushes occurring in late fall after the initial rains; a decrease in NH_4-N with time was attributed to immobilization biomass, and not due to nitrification. The ratio of NH_4/NO_3 was apparently related to rainfall. Soil N loss by volatilization is also a potential concern in calcareous soils due to enzymatic hydrolysis or urea to ammonia gas (Ryan et al., 1981); however, under cool-season, field conditions, volatile losses were relatively low, ranging from 11 to 18%, and decreased with increasing rainfall and clay content (Abdel Monem et al., 1999).

Considerable attention was given to cool-season legumes, which are grown alternatively with cereals. A key question was how much N crops such as chickpea and lentil fix, and how much is left over for the succeeding cereal crop? Improved cultural practices increased biological N fixation (BNF) from 55 to 69%, but the figure was less as rainfall decreased; legumes contributed at least 10 kg N to the next cereal crop. Using non-nodulating chickpea and barley as reference crops, Beck et al. (1991) estimated % Ndfa (percent N derived from the atmosphere) at 70% for pea and lentil across all stations. Marked differences in % Ndfa existed for winter (72%) compared to spring chickpea (26%). Inoculation with appropriate strains of rhizobia increased Ndfa from 52 to 72%. Despite the contribution of BNF for chickpea, there was a net loss of N from the soil when all the biomass was removed from the field.

After the initial trials at ICARDA's stations, a logical progression was to conduct on-farm trials, in collaboration with the Syrian Soils Directorate, across the rainfall zones and soil types in the cereal-growing area of northern Syria. The 4-year series with wheat and barley showed some clear trends (Pala et al., 1996). Where no other factor is limiting, yields were related to seasonal rainfall, especially on flat, deep soils. In other soils, this relationship would be modified by soil properties, such as slope and texture, which influence soil moisture. Responses to N increased with rainfall, i.e., 3% at >250 mm, 24% at 250 to 400 mm, and 32% at >400 mm. However, there was rarely any residual effect of applied N, in contrast to P, which tends to accumulate with time. Over range of 40 sites, $N0_3$-N in the top 0-60 cm was best correlated with yield. A critical soil $N0_3$-N level was considered as 8 mg kg^{-1} following a legume or a low-yielding cereal yield, and 15 mg kg^{-1} after a summer crop or a high-yielding cereal yield.

Nitrogen in Long-Term Rotation Trials

Following the findings from the early on-station and on-farm trials, it was essential to take a wider longer-term view and assessment of farming systems. Thus, the "systems" approach spawned several long-term trials which were established in the mid 1980s. While ICARDA had a comparative advantage in conducting such trials, a few others were already in existence in the WANA region, and several similar ones were to follow in other countries (Ryan,1997; Ryan and Abdel Monem,1998)). While the initial years of the rotations were production-oriented, this gave way to the notion of *sustainability* and *indicators of soil quality*.

The main trial, "Cropping Systems Productivity", described by (Harris, 1995) involved durum wheat alternated with legumes, fallow or continuous wheat; sub-treatments include N application rates (0,30,60,90 kg ha^{-1}) and grazing intensities (no grazing, medium, and heavy). The trial involved several parameters: *biomass and grain yield; economics, soil physical, chemical and biological properties; water relations; and diseases.*

Conclusions regarding the role of N are as follows (Harris,1995). Yields consistently increased with added N in the cereal phase; responses were low, only 30 kg N ha^{-1}, in dry years, and up to 90 kg ha^{-1} in favorable years. Responses also were conditioned by the preceding crop, and the extent to which it influences soil moisture, being highest after fallow. Significantly, N influenced soil properties and was, in turn, influenced by the rotation. Thus, with increasing rates of N, soil organic matter increased, and therefore the reserve of organic N (Ryan,1998).

The legume-based rotations produced more soil N than either continuous cereal or fallow. In concomitant laboratory studies, soil from medic rotations produced higher mineralization rates (Ryan et al., 2003); measurements *in situ* revealed the same trend. Associated with added N and indeed the rotation was a positive effect on soil physical properties (Masri and Ryan, 2006), i.e., reduced dispersion and increased aggregate stability.

In addition to on-going sampling of all plots in this 23-ha trial on a yearly basis, we are currently examining N mineralization from each rotation (unfertilized, un-grazed), using bare (2 x 3 m) micro-plots. Periodic sampling of the profile to 1 m revealed the net outcome of mineralization. Temperature and moisture data were recorded. Several times during the growing season, mineralization was measured by dilution of N-15 over an 8-day period. Samples were measured in the laboratory for biomass and labile N and C, reputedly more sensitive indicators of soil organic matter changes.

So far, seasonality has a strong influence on soil data. Total mineral N only began to increase with increasing soil temperature; it declined again as the soil dried out. The highest amount of N released, irrespective of these trends, come from medic and vetch rotations. Biomass N had a similar rotation effect, but was more sensitive to temperature and decreased when the soil dried out. Again, the effect of the medic and vetch rotation was large. Thus, the residues of these crops had higher sources of soil N and supported greater bacterial activity.

Nitrogen in Irrigated Systems

The past decade has seen a dramatic increase in the area of irrigation, not only in arid area with insufficient rainfall to grow any crop, but has encroached onto traditional rainfed areas, especially for wheat—crops such as cotton, potatoes, and sugar beet are only grown under irrigation. As the main water source is groundwater, and as water tables are showing a consistent decline, the sustainability of groundwater irrigation is in question. In view of water scarcity, research has focused on improving efficiency of use, especially with supplemental irrigation and trickle or drip irrigation (Ryan, 2000a).

Several field studies have shown that water use in terms of crop production could only be optimized when combined with adequate N fertilizer use (Oweis et al.,1998; Garabet et al., 1998). More recent work (Ryan et al., 2006) showed that where untreated urban wastewater was used for irrigation, the amount of N and P needed as fertilizer could be reduced or eliminated as this water source is rich in nutrients; wastewater is the only source of water that is increasing in the Middle East, where all other sources are diminishing.

Phosphorus

Second to N in importance for crop production in dryland agriculture, P is one of the most complex elements. As the soils of the WANA region are mainly calcareous, the chemistry of P is dominated by calcium carbonate. Thus, in their natural state, soils of the region are inherently low in available P, though not necessarily in total quantities of the element (Ryan,1983). The chemical reactions of P in soils covers volumes; the most recent review was that of Matar et al.(1992) for the Mediterranean region and that of Ryan (2003) specifically for Syria.

Earlier work from the region showed that iron oxides, although recurring in small amounts, have a disproportionate influence on the initial reactions of soluble or fertilizer P in soils (Ryan et al.,1985b) as well as the longer-term reversal reactions (Ryan et al.,1985c). These reactions dictate the efficiency of fertilizer use as well as the changes that take place with continued fertilization. Thus, P research was another major thrust in ICARDA's research agenda.

Much of the early work in Syria (Matar et al., 1992) and throughout the region (Ryan and Matar, 1992) showed the ubiquity of crop response to applied P fertilizer in the field. The soil test calibration program at ICARDA identified the Olsen $NaHC0_3$ test as most suitable for the region's soils and critical levels as a guide to fertilization (Ryan and Matar, 1992). In contrast to N, fertilizer P was shown to be relatively more effective in drier areas; fertilizer P also promoted greater water-use efficiency (Matar et al., 1992); in addition soil organic matter was shown to enhance its availability (Habib et al., 1994). While mycorrhizae were shown to favorably influence crop P uptake, the effect was minor and was not a substitute for fertilizer (Ibrikci et al., 2004). Consequently, fertilizer use dramatically increased in most countries of the region. Indeed, work recently reported (Ryan and Matar,1992; Ryan,1997) indicates that due to P buildup from fertilization, many soils are now well supplied with P and need only maintenance levels of P, if at all.

In the past few decades, much has been learned in relation to P fertilizer use (Ryan, 2002; 2004): identification of soil test levels, responses to crops in different environments, most efficient methods of application, and long-term residual value of P fertilizers. In that context, the issue of providing laboratory facilities to provide reliable and valid analyses is paramount (Ryan, 2000b). The challenge now is to implement what we know and to transfer such technology to the end-user, the farmer. The focus of P research in the future will be in irrigated agriculture and the development of soil test criteria and overcoming obstacles to efficient use associated with fertigation (Ryan, 2000a).

Potassium

As one of the trilogy of major crop nutrients, potassium is seen as of limited importance for dryland farming in the WANA region, and probably similar regions elsewhere. This largely stems from the fact that such soils are relatively rich in K, as the pedo-genetic environment does not favour weathering or significant leaching. Surveys of a range of dryland stations across northern Syria bear out this contention, with all being well above the critical level (Ryan et al., 1997). In addition, such soils have the capacity to release plant available K over a long time. This does not exclude the possibility of localized problems with K deficiency in sandy soils, while responses to K are probably with irrigation, especially for high K-demanding crops such as potatoes and sugar beet. *Regardless of how rich the soil is, the supply of nutrients is finite*; ultimately, what is removed by crops has to be *replaced* by added nutrients—for most situations, that amounts to the use of fertilizers.

Micronutrients

Given the low crop yields limited by water, and the dominance of N and P as crop growth constraints in the past, it is not surprising that there was little initial interest in micronutrients as limiting factors in the overall scheme of crop production. Nevertheless, there are several soil factors that promote micronutrient stresses - either deficiency or toxicity. The main factor inducing metal deficiencies is calcium carbonate, with its associated high pH and consequently reduced solubility of these metals, mainly iron and zinc, and, to a lesser extent, manganese and copper. Therefore, the perception of the importance of micronutrients has now changed.

Extensive studies with cereals by Cakmak (2004) in Turkey showed that the problem of Zn deficiency was widespread, with serious implications not only for crop production, but also human health. Research on Zn in forage legumes, suggest that deficiency may also be common in Syria (Materon and Ryan,1995). Low levels of soil organic matter can exacerbate the problem, as does the transition from superphosphate to more concentrated and forms, with less Zn as an incidental contaminant. Soil surveys and the use of soil information from existing data bases can help indicate areas where micronutrient deficiencies are likely to occur (Ryan et al.,1996).

While boron (B) is generally not deficient on such a large scale as Zn, it is widespread in some countries of the region such as Pakistan (Rashid and Ryan, 2004). However in contrast to Zn, the opposite to deficiency does occur in some locations - too much or toxic levels. This problem often goes undetected as it is characterized by sub-surface accumulations (Ryan et al., 1998) and the fact that the range between too little and too much soluble B is narrow. Unfortunately, little can be done in terms of soil amelioration to solve this problem; adaptation of resistant cereal cultivars poses a possible solution (Yau et al.,1997). Fortunately, many cereal landraces are resistant to B toxicity to varying degrees and the process of transferring such resistance genes to improved cultivars is relatively simple.

With increasing cropping intensification and the elimination of other nutrients as crop growth-limiting factors, increasing attention will be given to micro-elements, especially under irrigated conditions. Indeed, given current trends in human nutrition, greater attention will be given to the role of microelements in the entire food chain, from the soil through the plant, and ultimately the human being, as indicated by an ameliorating effect of Zn on the neurotoxin endemic in grasspea, a legume crop of last resort in times of famine in countries such as Ethiopia and Bangladesh (El-Moneim et al., 2000). Future research will no doubt be focused on this area of relevance to human nutrition.

Conclusions

The past decades have witnessed major changes in the agriculture of the lands bordering the Mediterranean, mainly a transition from a traditional, centuries-old, dryland, cereal-livestock system to a more diverse one characterized by chemical inputs, especially fertilizers. The dramatic increases in crop production that has occurred in several countries of the region—Syria is now self-sufficient in cereal production for the first time—are attributed primarily to *better nutrition through fertilizer use and more water through irrigation , and to a lesser extent*, *better varieties.* While the issue of water will continue to be problematic due to the precarious nature of water sources, fertilizers will continue to increase in importance, to an extent that is controlled by water availability.

The soil fertility-crop nutrition research conducted over the past three decades, mainly at ICARDA, has contributed greatly to our scientific knowledge of the region's agriculture, identifying crop nutrient constraints and elucidating various aspects of the soil – plant nutrient behavior. This accumulated knowledge has led to more efficient use of crop nutrients, such as band application of P fertilizers, more effective timing of application in relation to the crop's needs, and minimizing nutrient losses through leaching, runoff and volatilization. Similarly, developments in fertigation have led to more efficient fertilizer use. Soil testing, along with associated correlation and calibration have provided a more rational basis for efficient fertilizer use, thus promoting better economic returns for the farmer and avoiding environmental damage due to excessive nutrient use. The benefits of integrated fertilizer use within rotational cropping were clearly shown, as was the potential of fertilizers to enhance soil quality and crop nutrient enhancement for human nutrition.

While much has been learned in the area of crop nutrition in Mediterranean agriculture, challenges will continue to emerge as agriculture changes and evolves in response to broader influences at the global level that impinge upon the region. One cannot ignore government policies that influence produce prices and fertilizer availability. As in the West, where society is becoming more urbanized and people are becoming more divorced from the process of food production, the challenge is to inform the public at large of the essential role of fertilizers in their lives and to dispel the unfortunate myths that indicate the contrary. *The research conducted in the Mediterranean region, as reflected in this brief overview, provides compelling and convincing evidence of the indispensability of fertilizers for the region's agriculture and for society as a whole.*

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Crop Nutrients for Sustainable Agricultural Production in the Drought-Stressed Mediterranean Region

John Ryan*

Laureate, IFA 2006 Crop Nutrition Award

Presented at 74TH Annual Conference of the International Fertilizer Industry Association Cape Town, South Africa, June 5-7, 2006

*** International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo - Syria**

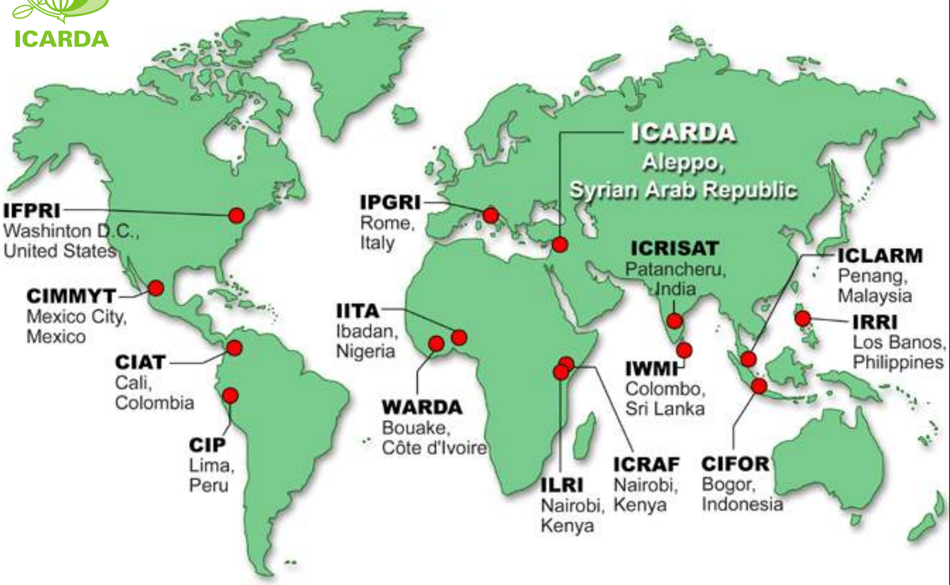
ICARDA

Dedication:

To the memory of Mr Samir Masri
An Outstanding, Exemplary, and Committed Colleague, and Personal Friend

March 18, 1948---February 15, 2006

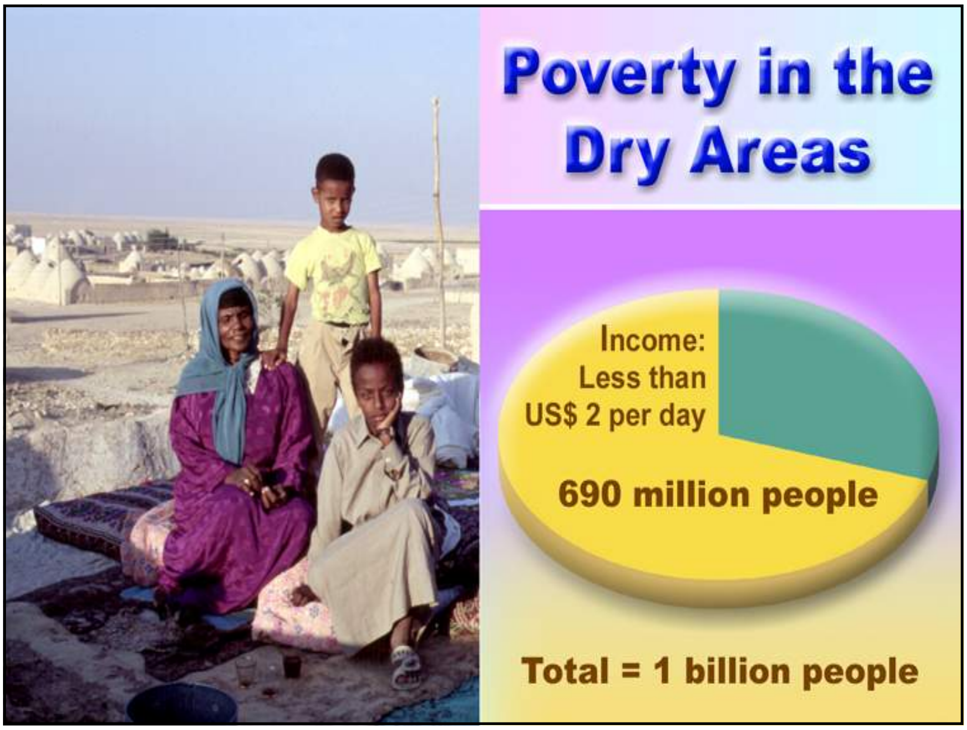
The CGIAR Centers

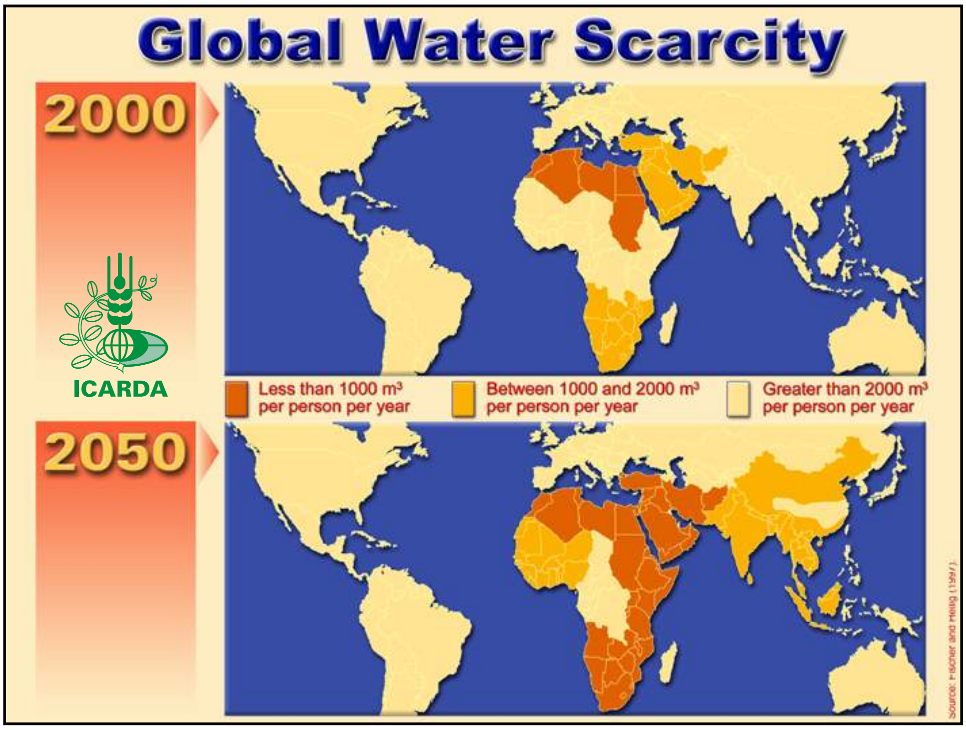


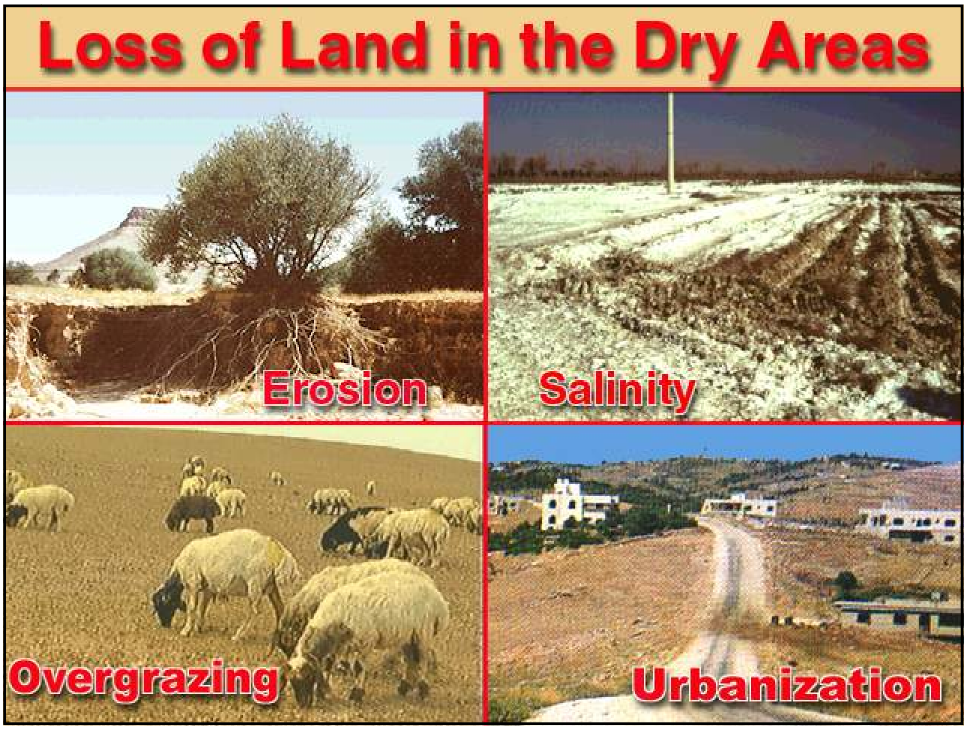
Challenges

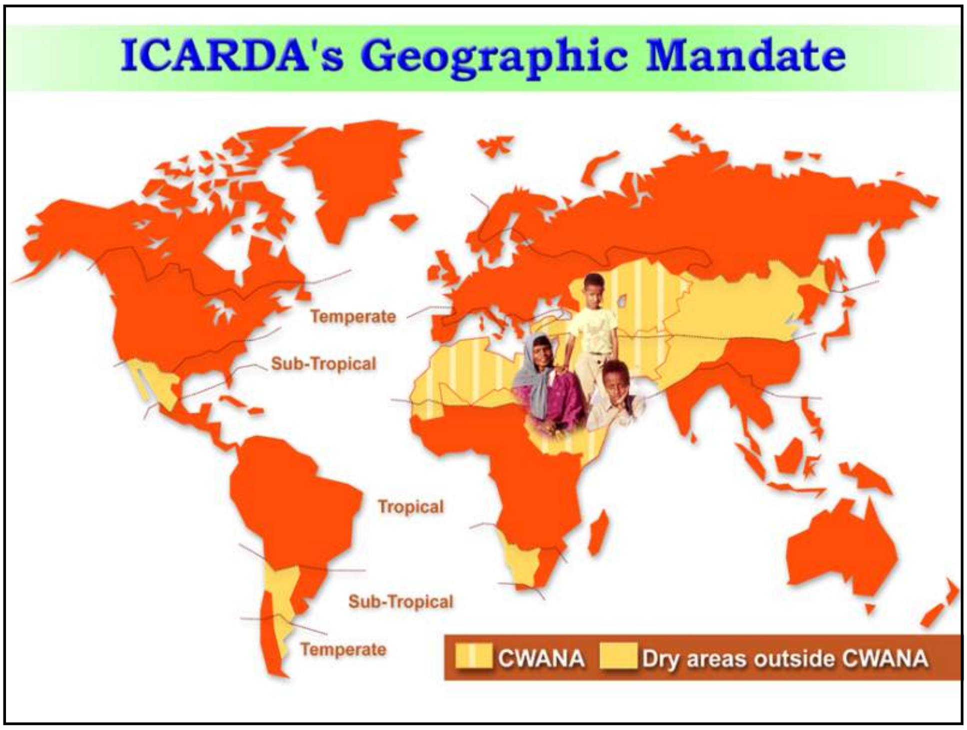
- Poverty
- Population growth
- Rural to urban migration
- Fresh water scarcity
- Land degradation
- Loss of agro-biodiversity

- Global warming
- Diversity of agro-ecologies
- Weak research infrastructure
- Inadequate investment in research
- Weak information technology infrastructure and capacity


Poverty in the Dry Areas
Income: Less than US$ 2 per day
690 million people
Total = 1 billion people


Global Water Scarcity
2000
ICARDA
Less than 1000 m³ per person per year
Between 1000 and 2000 m³ per person per year
Greater than 2000 m³ per person per year
2050

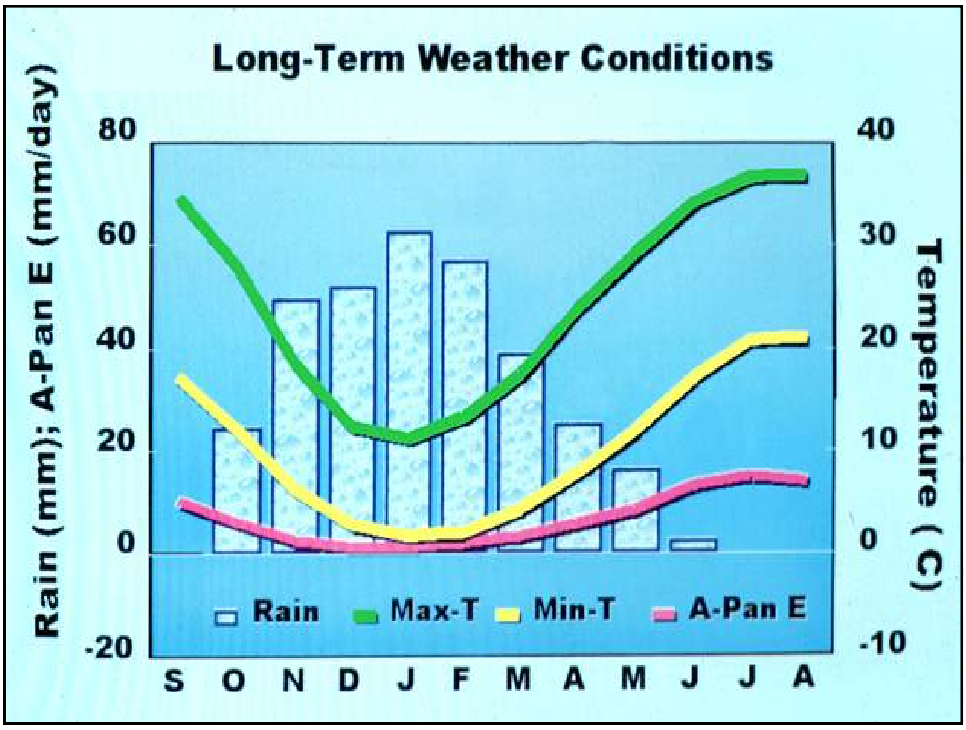

Loss of Land in the Dry Areas
Erosion
Salinity
Overgrazing
Urbanization

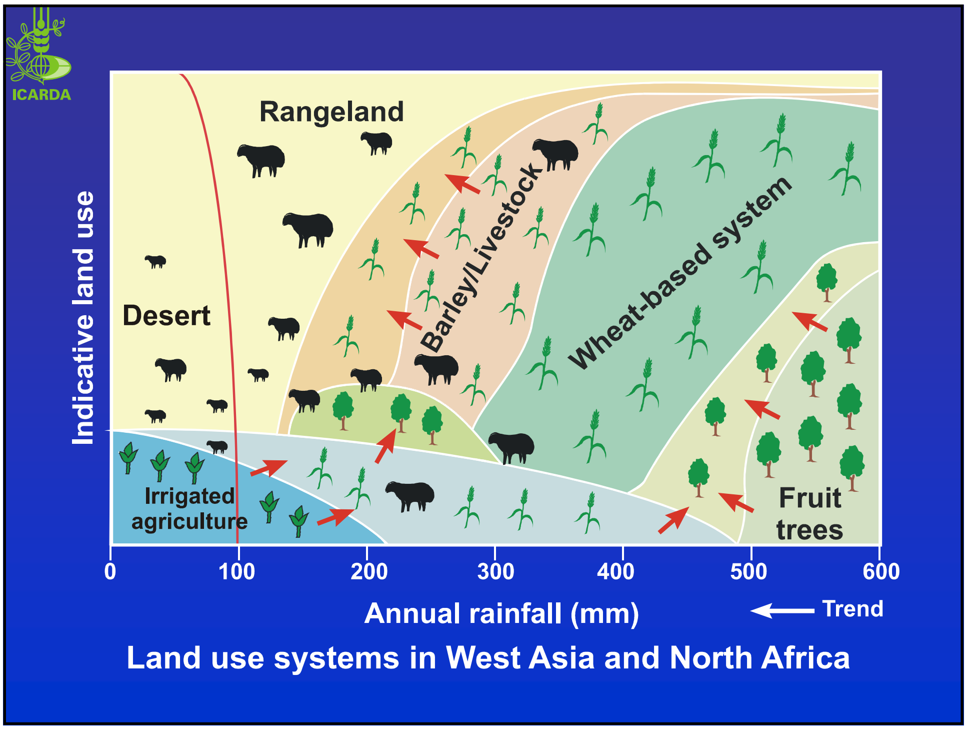

ICARDA's Geographic Mandate
Temperate
Sub-Tropical
Tropical
Sub-Tropical
Temperate
CWANA
Dry areas outside CWANA

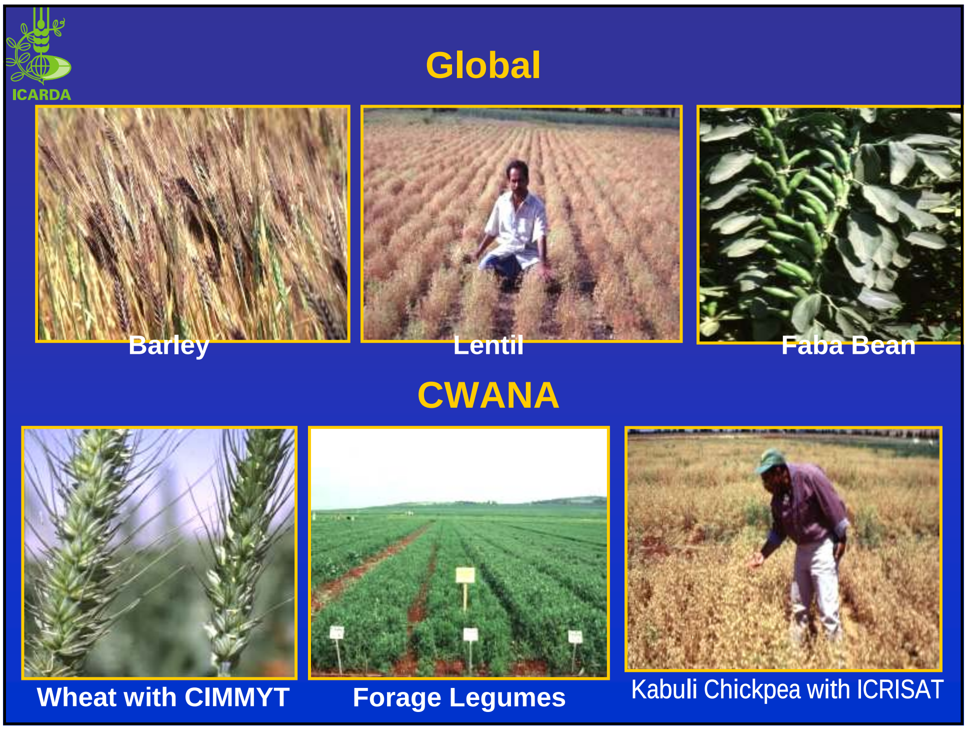

ICARDA
Kazakhstan
Uzbekistan
Kyrgyzstan
Tajikistan
Turkmenistan
Turkey
Tunisia
Cyprus
Syria
Iraq
Iran
Afghanistan
Lebanon
Jordan
Pakistan
Morocco
Algeria
Libya
Kuwait
Egypt
Bahrain
Qatar
UAE
Saudi
Arabia
Oman
Mauritania
Eritrea
Sudan
Yemen
Ethiopia
Somalia

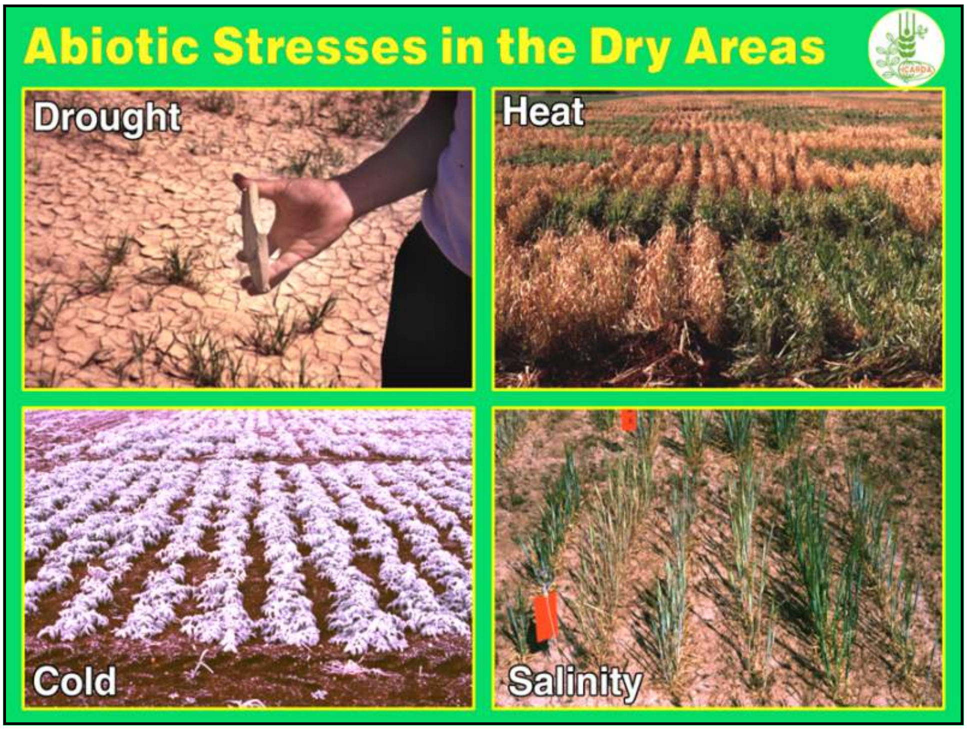
ICARDA

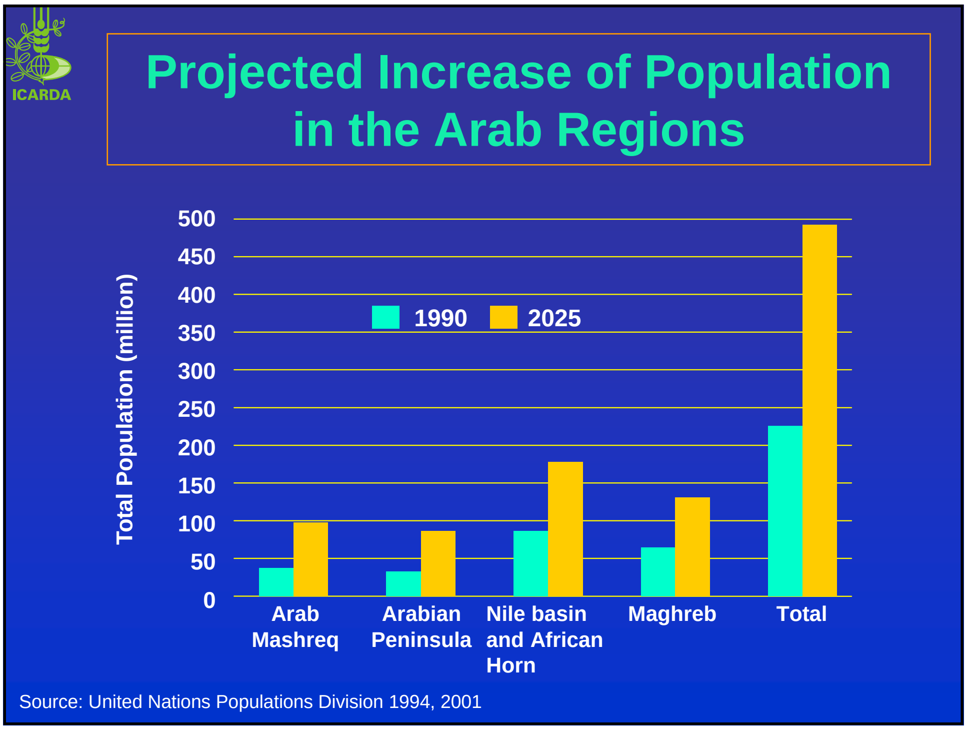

Ancient Middle
Eastern Civilizations


Long-Term Weather Conditions
Rain (mm); A-Pan E (mm/day)
80
60
40
20
0
-20
40
30
20
10
0
-10
Temperature (C)
Rain
Max-T
Min-T
A-Pan E
S O N D J F M A M J J A


ICARDA
Indicative land use
Rangeland
Desert
Barley/Livestock
Wheat-based system
Irrigated agriculture
Fruit trees
0
100
200
300
400
500
600
Annual rainfall (mm)
Trend
Land use systems in West Asia and North Africa


ICARDA
Global
Barley
Lentil
Faba Bean
CWANA
Wheat with CIMMYT
Forage Legumes
Kabuli Chickpea with ICRISAT


Abiotic Stresses in the Dry Areas
Drought
Heat
Cold
Salinity
ICARDA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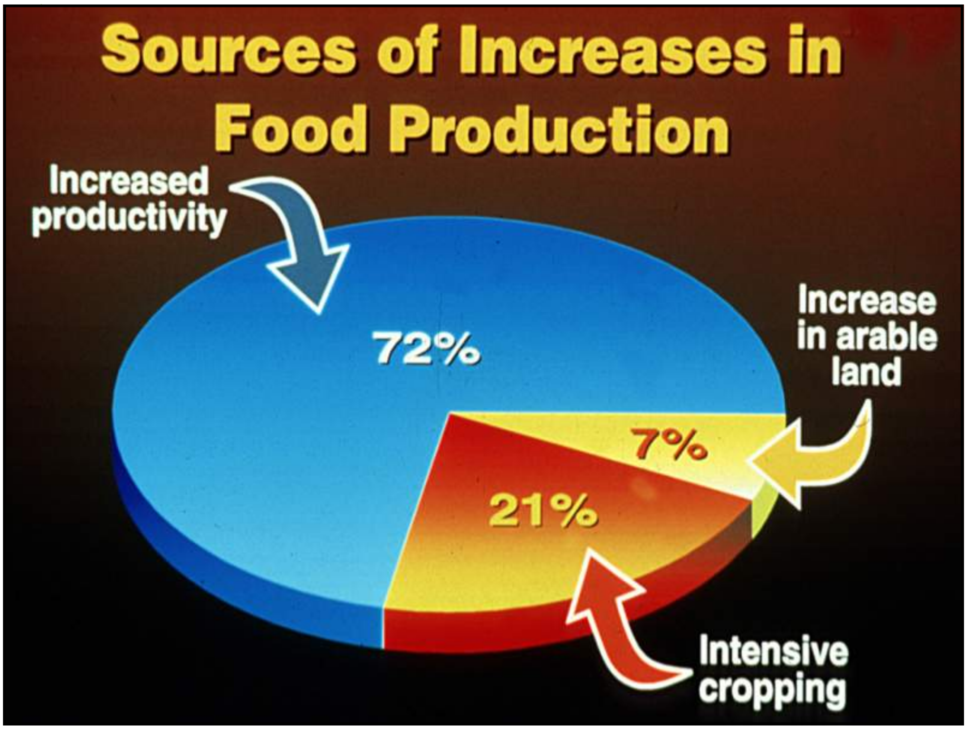
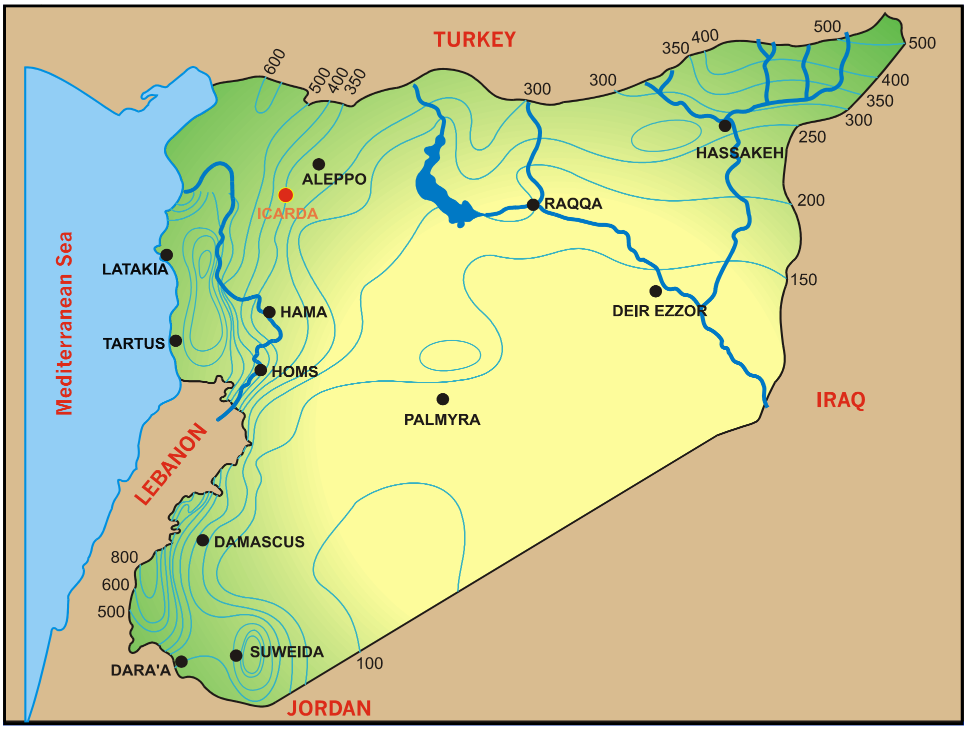
Projected Increase of Population in the Arab Regions
Total Population (million)
500
450
400
350
300
250
200
150
100
50
0
1990
2025
Arab Mashreq
Arabian Peninsula
Nile basin and African Horn
Maghreb
Total
Source: United Nations Populations Division 1994, 2001



Sources of Increases in Food Production
Increased productivity
72%
Increase in arable land
7%
21%
Intensive cropping



TURKEY
IRAQ
JORDAN
LEBANON
Mediterranean Sea
ALEPPO
ICARDA
LATAKIA
HAMA
TARTUS
HOMS
PALMYRA
RAQQA
HASSAKEH
DEIR EZZOR
DAMASCUS
SUWEIDA
DARA'A
600
500
400
350
300
300
350
400
500
500
400
350
300
250
200
150
100
800
600
500

Soils

- Most of the world soils order:
  - Aridisols, Vertisols, Inceptisols, Entisols, Mollisols, Alfisols
- Depth important criteria for water relations.
  - Related to landscape position.
- Low organic matter.
- Chemically – weakly weathered, mainly calcareous.
- Limited ground cover

Trends Related to Nutrient Use

1970s

- Most cropping systems rainfed (cereals, legumes).
- Minimal use of chemical fertilizers.
- Fallow to conserve moisture
- Limited machinery use.

1990s

- Increased use of irrigation (full, supplemental) in rainfed areas.
- Substantial fertilizers input.
- Reduced fallow, increased monoculture.
- Greater cropping diversity - nuts, fruits, medicinal plants.

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Main Nutrient Constraints

- Nitrogen
- Phosphorus
- Micronutrients
  - Zinc
  - Iron
  - Boron

Nitrogen Research (1)

- Characterized N dynamics in soil
- Identified possible loss mechanisms;
  - Leaching, runoff, volatilized
- Quantified N fixed from atmosphere by legume crops.
  - Factors affecting BNF
- Nitrogen in relation to crop quality (protein, “yellow berry”)

Nitrogen Research (2)

- Crop response in relation to rainfall.
- Soil test levels: nitrate.
- Factors related to nitrogen – use efficiency.
- N in rotation systems:
  - Less N needed
  - Improvements in soil quality
- Fertilizer N increased soil organic matter.

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Phosphorus (1)

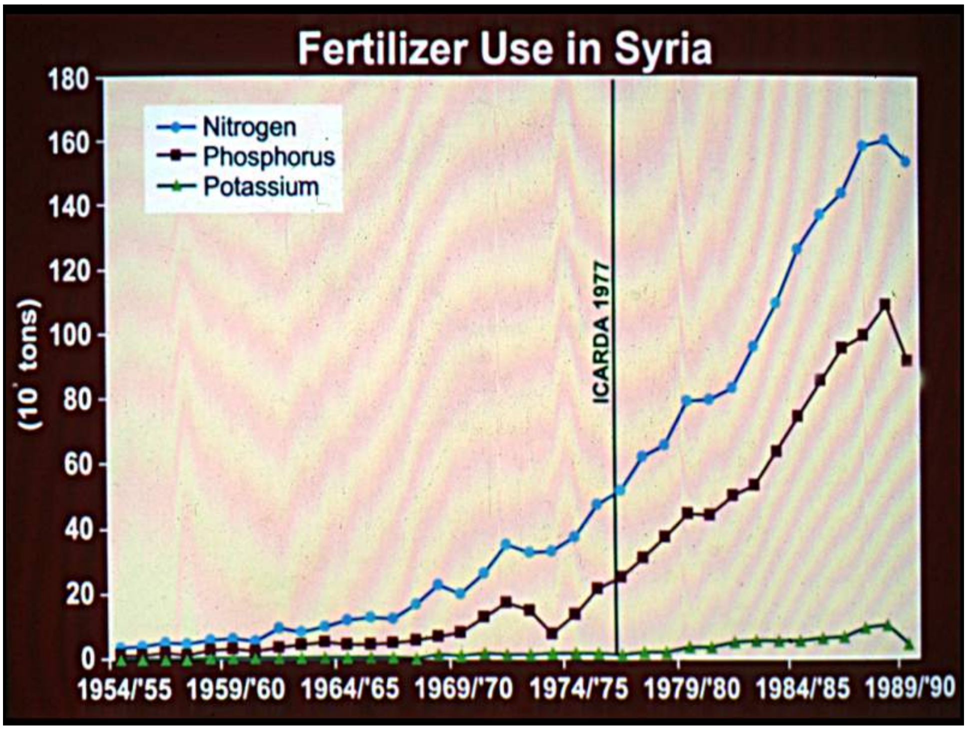
- Soils inherently deficient due to high $CaCO_3$ and pH – reduced P solubility.
- Deficiency widespread prior to common use of fertilizers.
- Evidence of P buildup from fertilizers use.
- Need for maintenance P fertilizer.
- Chemical reactions of P fertilizers with soil constituents characterized.

Phosphorus (2)

- Influence of organic matter and iron oxides
- Critical soil test level for dryland crops: 5-7 ppm
- Demonstrated crop growth responses (cereals, legumes) in farm trials
- Need for P in favorable areas (>400 mm) response even in dry areas (<250 mm)
- Positive but limited role for mycorrhiza
- Problem with application in drip system

Potassium, Calcium, Magnesium

- No problems with Ca, or Mg:
  - Soil high carbonates
- K deficiency rare based on numerous studies from region.
  - High levels of available K
  - K-supply power: high
  - Soils, weakly weathered
- Possible problem in sandy soils, high K-demanding crops (potatoes, sugar beet)
- Possible relationship with drought tolerance, diseases



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Micronutrients

Zinc

- Deficiency widespread in Turkey
- Soil factors promoting deficiency
  - Calcium carbonate, low organic matter, fertilizer type
  - Soil tests can identify areas of likely deficiency

Iron

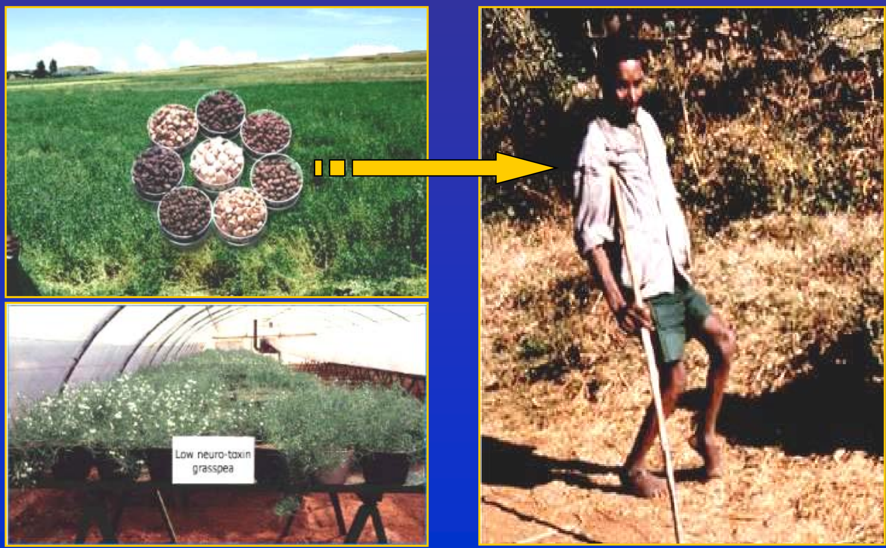
- Deficiency endemic, common in legumes, some crops adapted.

Boron

- Deficiency common in Pakistan
- Toxicity can occur
- Plant breeding for adaptation


M. rigidula
P 135
Nitrogen
Zn
M. rigidula
P 135
Nitrogen
no Zn
M. rigidula
P 0
Nitrogen
no Zn

Grasspea causes Neurolathyrism



Challenge Program: Biofortification

- New approach to conducting research within CGIAR system.
  - *Water and Food, Generation (Biodiversity), Harvest Plus (Biofortification)*
- Biofortification – micronutrients ("Harvest Plus")
  - Nine international centers, national agricultural systems
  - Breeders, agronomists, chemists, nutritionists, social scientists
  - Funding of projected $ 90M to address nutritional poverty
  - Nutrients: Iron, Zinc and Vitamin A
- Builds on CGIAR "Micronutrients" Project

Boron

- **Method:** Hot-water soluble B
- **Problem:** Toxicity more of a problem than deficiency
- **Observations:**
  - High soil B concentrations in several locations in Syria, Turkey, and North Africa.
  - Generally accumulate with depth, patterns vary.
  - Symptoms on plants similar to foliar diseases.


II-1B
W/F
86-95
W/M


R1
120m
1.5 m 1.5 m فاصل 1.5 m 1.5 m
2L/S
1L/S

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Nitrogen in Irrigation

- Optimum application rates and water – use efficiency established.
- Application times in related to crop growth identified.
- High N level in wastewater used for irrigation
- Possible loss of N as ammonia in sprinkler systems

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Wastewater for Irrigation

- **Sewage Effluent:** the only growing source of water in a water-deficit region – potential source of nutrients.
- **Case Study:** Quake River near Aleppo.
- **Analysis of:**

  Water: NO_3, NH_4, Total N, K, P, Zn, Mn, Cu, Fe, B.

  Soil: Olsen-P, N forms, extractable K, DTPA micronutrients, HWS-B, salinity.

- **Conclusion:** Adequate N, P, K for crops in irrigation water no problems with salinity or excess NO_3.

Soil Testing/Laboratories

- Appropriate tests developed for macro and micronutrients.
- Field calibration for fertilizer recommendations.
- Promoted concept of soil/plant analysis in regional laboratories.
- Highlighted need for quality assurance, standardization, control.
- Soil labs can serve all analyses related to agriculture.
- Need for public/private support for lab facilities.

CONCLUSIONS

- Future crop production in Mediterranean agriculture will depend increasingly on ***chemical fertilizers***, irrigation water, and improved varieties.
- The accumulated knowledge from applied research has set the basis for better crop management and more efficient use of resources.
- The extent to which the Middle East region can fully exploit its agricultural potential depends on enabling government policies that affect commodity and fertilizer prices.

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Fertilizers and Africa

"The magnitude of nutrient mining in SSA is enormous"

"There are simply not enough organic manures and crop residues available to replenish and maintain soil fertility"

"A strong case can be made that increased fertilizer use in SSA is one of the most "environmentally friendly" things we can do"

"Thus, chemical fertilizers must be placed at the center of soil fertility restoration and management strategies in Africa"

-- Norman Borlaug, Nobel Laureate, 1970, "Feeding A World of 10 Billion People: The TVA/IFDC Legacy", 2003.