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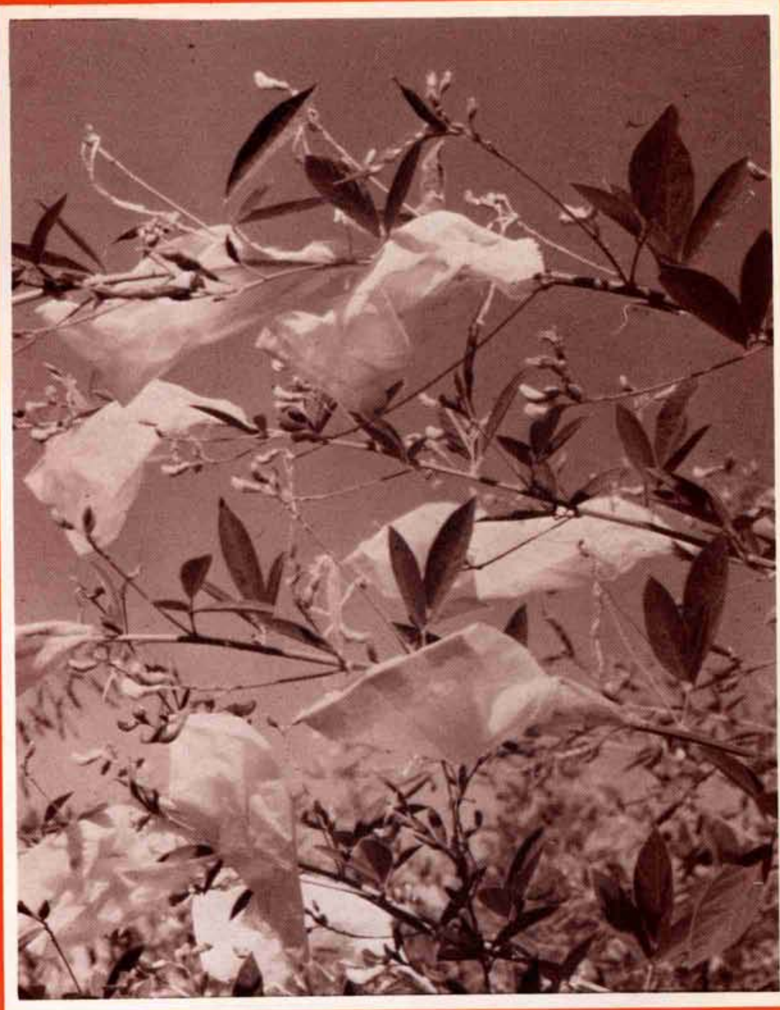

Food Legume Improvement and Development

Proceedings of a workshop held at The University of Aleppo, Syria, 2-7 May 1978

Geoffrey C. Hawtin and George J. Chancellor, Editors

CANADA

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Section I

An Introduction to Food Legumes in the Region

Some Aspects of the Agroclimatology of West Asia and North Africa

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The region of West Asia and North Africa, which is ICARDA's primary concern, lies very roughly between latitudes 5°N and 43°N and longitudes 10°W and 70°E. It can be broadly divided into main zones of agricultural production: a temperate plateau area, comprising the highlands of Turkey, Iraq, Iran, and Afghanistan; and a lowland area, bordering the Mediterranean and extending inland in areas adjacent to the plateau.

The whole region is characterized by a typical "Mediterranean"-type climate: winter rainfall alternating with summer drought. However, considerable climatic variability occurs throughout the region as a result of the influence of the major geographical features, which include the Mediterranean, the Black and Caspian seas, the mountains of northwest Africa, and the plateaus.

This general climatic pattern means that dryland agriculture in West Asia and North Africa is primarily devoted to temperate crops. The discussion that follows is thus based upon the assumption that ICARDA's main research concern is to improve the productivity and stability of temperate grain and forage crops under dryland agricultural conditions. Attention is concentrated on two major agroclimatic factors, namely, moisture availability, which is considered the most important constraint to crop distribution and yield throughout the world, and temperature, which is also an important consideration in this respect. Such a focus is not meant to imply that other features of the climate are not important in determining agricultural production and strategies for its improvement. Daylength, for example, varies significantly over such an extensive region, and radiation levels vary both with season and altitude. Thus, considerations of photoperiod sensitivity and radiation-limiting periods in some plateau regions are of great importance in crop improvement. However, the effects of these factors are generally considered to be secondary in importance to moisture availability and temperature and for this reason are omitted from the present discussions.

The broad patterns of temperature and precipitation in the region are highlighted in this paper and aspects of their variability are discussed in relation to crop production. Relations between rainfall and soil moisture availability, and between soil moisture, temperature, and crop water requirements are also considered to illustrate the interactions between these components and pose questions of relevance to the development of research programs.

Temperature

Variations in temperature occur with latitude and longitude, decreasing from south to north and from east to west, and, most importantly, with altitude. There are large and obvious contrasts between plateau and lowland regions in this respect.

Low temperature limitations to cropping occur in the plateau regions of Turkey, Iran, and northeastern Iraq. Air and soil temperatures both fall rapidly in the autumn (Fig. 1) and unless the rains are sufficiently early there may be problems of establishment of winter crops before the soil temperature becomes too low for germination, or of crop survival if establishment is insufficient prior to snow cover. Over much of the plateau this snow cover persists for several months and crop growth is not resumed until its dispersal with the rapid rise in temperature in the spring. In the lowland areas, however, winter temperatures are not severe; daytime air maxima appear sufficient to promote photosynthesis in temperate species (Fig. 1) and, although night temperatures often fall below 0° C, some vegetative growth can thus be expected during the winter. Soil temperatures during the crop-growing season do not appear to be limiting in these areas.

Throughout the region there is a risk of crop damage through late frosts during the flowering period. There are marked differences between the plateau and lowland zones in the time at which this risk occurs, and within each zone topographical variation may contribute to differences in the length of the frost risk period (Table 1).

Maximum temperatures increase rapidly in the spring throughout the region (Fig. 1). Although it is difficult to identify a high temperature level critical to crop growth, mean maxima greater than 30–32 °C are frequently experienced in the lowland areas and can be expected to impose a limit on yield potential by hastening crop maturity. Again, relatively localized variations in the time at which extreme high temperatures are experienced are observed (Table 1).

The degree and duration of low temperatures dictate obvious and well-recognized needs for crop types with differing levels of temperature tolerance (spring vs. winter varieties) in the contrasting lowland and plateau zones. However, less obvious differences (illustrated by data for northern Syria in Table 1) are also apparent and may determine the success or failure of different varieties at specific locations. Although such data require further examination to verify that these differences are real and not just artifacts of the siting of the meteorological stations in relation to their immediate topography, they do indicate apparent differences of 2–3 weeks in the duration of favourable growing conditions in a relatively localized area. This suggests the need for a diversity of crop varieties to permit the fullest utilization of local environments.

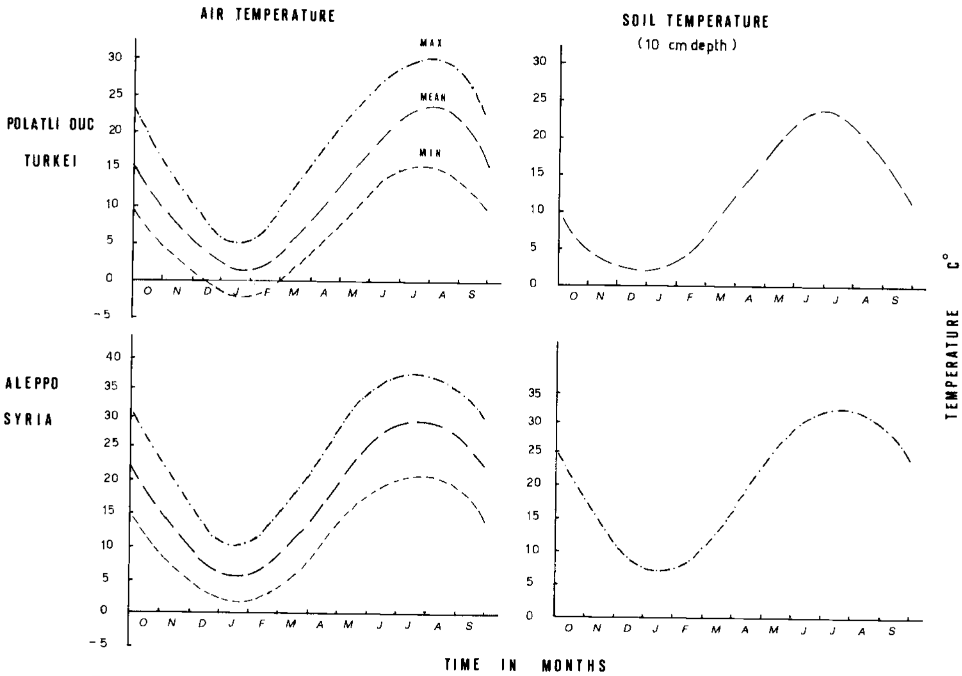

Fig. 1. The seasonal pattern of air and soil temperatures at two locations in West Asia.

TABLE 1. The timing of the occurrence of low and high temperature extremes at four locations in northern Syria.

	Location			Timing of last	Timing of first	Timing of first
Name	Latitude	Longitude	Altitude (m)	frost; T min ≤ 0 °C[a]	T max ≥ 33 °C[a]	T max ≥ 36 °C[a]
Hama	35° 08′	36° 45′	309	3rd wk Mar	3rd wk Apr	2nd wk May
Aleppo	36° 11′	37° 13′	392	1st wk Apr	3rd wk Apr	3rd wk May
Tel Abaid	36° 42′	38° 57′	355	2nd wk Apr	2nd wk Apr	3rd wk May
Kamishly	37°03′	41° 13′	452	1st wk Apr	4th wk Apr	2nd wk May

[a] With a frequency of 1 year in every 13 (based on 13 years of daily temperature data). Source: Monthly Climatological Data, Bureau of Meteorology, Damascus, Syria.

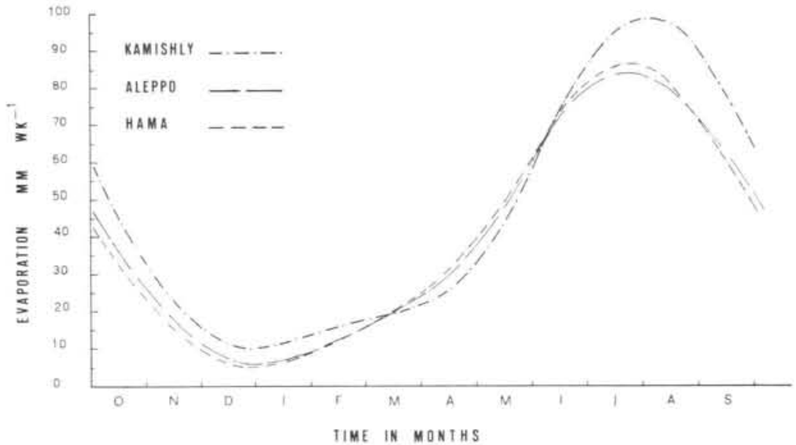

Fig. 2. Seasonal pattern of evaporation at three locations in northern Syria.

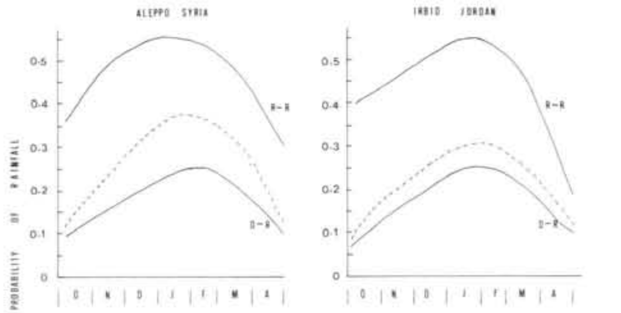

Fig. 3. The probability of daily rainfall at two locations. D-R represents probability of rainfall on day N given that there was no rain on day N−1. R-R represents probability of rainfall on day N given that there was rain on day N−1. Broken line represents independent probability of rainfall on any day.

Evaporation

Because several different techniques are used to measure evaporation within the region, further work is necessary to enable absolute comparisons to be made between locations. In general, however, it can be anticipated that the trends will follow those of temperature fluctuations, showing a decrease in evaporation from south to north and with increasing altitude. Evaporation can furthermore be expected to increase with distance from maritime influences.

The seasonal pattern, common to all the parts of the region, can be illustrated using data from northern Syria (Fig. 2), the major feature being the rapid rise in evaporation rate in the spring, associated with the temperature increases at this time, and, also, in much of the region, with the occurrence of hot dry winds.

Precipitation

Precipitation throughout the region is confined to the period from October to June, but there is considerable variation in its distribution according to location and topographical influences. Reliable rainfall commences earliest in the area adjacent to the mountains of Turkey and in the Azerbaijan region of Iran, and the reliability of early rain decreases with latitude across the region; some areas of Jordan receive their first reliable rainfall only in December. A reversal of this pattern tends to occur with the end of the rains, this being earliest in the south and later in the northern areas, particularly in northeast Iraq and adjacent regions of Iran, where the rainfall peak occurs in spring. A similar pattern appears to hold in a west to east traverse of the northern coastal areas of Africa. The rainfall season is thus considerably shorter in southern and eastern areas of the region, and may be confined to 3 or 4 months only in parts of Jordan. Although isolated coastal areas adjacent to mountains in North Africa, Lebanon, Turkey, and Iran may receive in excess of 1000 mm of precipitation per year, the annual total over the bulk of the region is below 800 mm and in much of the cropping area under consideration varies between 200 and 500 mm. Most precipitation in the plateau areas occurs as snow.

Furthermore, across the whole region and particularly as the annual total decreases, the rainfall is highly variable, the coefficient of variation on monthly data being as high as 50% in inland areas of Jordan, Iraq, Syria, and much of North Africa. In terms of agriculture it is thus important to consider the probability of rainfall and its distribution throughout the season. This has been examined for two locations, Aleppo (Syria) with an annual average rainfall of 470 mm, and Irbid (Jordan) with an average of about 320 mm, using rainfall data for periods of 13 and 40 years, respectively (Fig. 3).

For Aleppo the probability of rain "today" given that "yesterday" was dry is low at the beginning and end of the season (0.1) and rises to 0.25 in midseason, whereas data from Irbid indicate a somewhat lesser chance of rain throughout the season in this more southern area. Given that there was rain "yesterday," the probability of rain "today" is considerably higher at both locations. At Irbid the probability of successive rain days early in the season is slightly greater than at Aleppo. This difference is not evident in midseason, and the probability declines sharply, so that by late April it has dropped well below the Aleppo figure. The higher probability of rain on day n+1, given that day n was wet, illustrates an important feature of the rainfall pattern throughout the region, that is, that rain tends to occur as "rain events" of 2 or more days rather than as isolated falls. Also illustrated by these figures is the tendency for an earlier close to the rain season in the southern areas.

The second stage of such a rainfall analysis involves a consideration of the mean rainfall for each class of rain day (wet following dry, or wet following wet). At Aleppo the mean rainfall is of the order of 6 mm per rain day and does not differ significantly throughout the season or between classes. In contrast to this, rainfall per rain day varies considerably at Irbid, rising to a maximum in midseason and thereafter showing a marked decrease, with a trend toward higher rainfall on one day if the preceding day is wet (Fig. 4).

In addition to the means and probability functions, estimates have also been made of

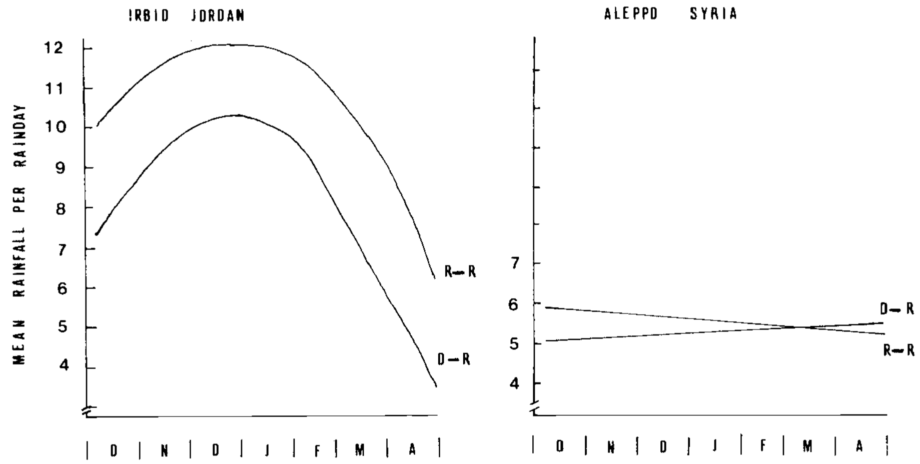

Fig. 4. Mean rainfall per rain-day at two locations.

the distribution of the data about the mean values represented by the fitted lines. In general, these tend to follow a gamma distribution and estimates of the parameters of the gamma functions have been made.

Work is currently under way on the development of techniques for the estimation of the probability and variability of specific events, such as the onset of the rains and hence of expected crop sowing dates, or the occurrence of dry spells of varying duration at critical stages of crop growth throughout the season. Results of these analyses should provide more solid information concerning the risks associated with cropping in the various parts of the region, and in turn may be expected to provide indications of crop types and agronomic practices best suited to the minimization of these risks.

Soil Moisture

Early in the season, when the rainfall is light and sporadic, a proportion will be lost from the soil surface through evaporation. However, moisture is lost readily only from the surface 2–4 cm and once a wetting front has been established below that depth, soil moisture will accumulate with cumulative rainfall. The amount of moisture stored subsequently will depend upon the quantity and intensity of rainfall, the infiltration capacity of the soil, and soil depth. Moisture losses can be expected either through runoff, if the rainfall intensity exceeds the infiltration rate of the soil, or through runoff or deep drainage if the moisture content of the soil approaches field capacity. Where most of the precipitation falls as snow this pattern may be modified by the effects of soil freezing on infiltration.

With a knowledge of this pattern of soil moisture accumulation, information on soil type and depth, and data on the amount and distribution of rainfall, it is possible to predict the total quantity of moisture that will be available for crop growth and its distribution throughout the cropping season. However, a number of specific considerations concerning aspects of the above components vary between locations and will affect the accuracy of predictions. Firstly, there is the question of "effective" rainfall, which is particularly important during early soil moisture build up (i.e., how much rain is required during a rain event to increase the store of soil moisture). The analysis of rainfall presented in this discussion includes all registrations of greater than 0.1 mm and will therefore overestimate the probability of "effective" rainfall. To more accurately predict probabilities of moisture availability from rainfall records, such an analysis must incorporate information to allow "noneffective" rain events to be discounted. Other considerations relate to soil water storage and infiltration capacity. These include the available moisture storage capacity of soils (that moisture stored in the rooting zones of specific crops); the proportion of total rainfall actually stored in the soil as opposed to that which is lost through evaporation and runoff; the effect of varying rainfall intensities and infiltration rates; and the proportion of the moisture accumulated in the rainy season that can be stored, if necessary through a summer drought.

Answers are available to some of these questions in some parts of the region, and in other areas work is under way in an attempt to quantify and expand the present state of knowledge concerning soil–water relations. A coordination of this information with climatic data for the region should provide a basis for achieving a better understanding of the ways in which the most efficient use may be made of the available water resources in dryland farming.

Crop Water Use

The crop water balance depends upon the relative relation between precipitation and water loss from the soil through evaporation and evapotranspiration. An examination of this balance using Penman estimates of monthly evapotranspiration has revealed two critical periods: the first early in the season, determining sowing date; and the second during the flowering and seed-filling stages of crop growth. This situation is general throughout the region, even in the northern areas that have a much greater spring rainfall but also experience lower temperatures and hence a longer duration of cropping.

The general pattern of water use through the annual crop cycle is illustrated in Fig. 5. Early in the season water use is low, although some is usually lost as a result of soil disturbance at sowing. As the leaf area expands, the rate of transpiration increases to a potential maximum, which normally occurs at or about flowering. Where water is not limiting, this maximum rate will be maintained for a period of about 2–3 weeks (both rate and duration being species dependent), after which, with increasing crop maturity and the progressive senescence of leaves, the rate decreases rapidly. Any stress during the vegetative or early reproductive stages of growth can be expected to modify the maximum rate attained, but the general pattern would still remain similar. Estimates from various studies in the region indicate that there will normally be adequate moisture available during the early stages of crop growth and thus that crops will develop high leaf areas and a consequently high evapotranspiration potential. However, the annual termination of rainfall and increase in evaporation tends to coincide with the time at which this high potential is reached and thus the time of greatest crop water demand. Although there is always some reserve of soil moisture available at this time, it is rarely adequate to meet the crop needs, and thus considerable stress may occur. Any strategy for improving the efficiency of water use must consider how best to fit the pattern of crop water demand into the pattern of moisture availability to increase the likelihood of moisture availability at critical periods. Such a consideration requires data on the total amount of water needed for

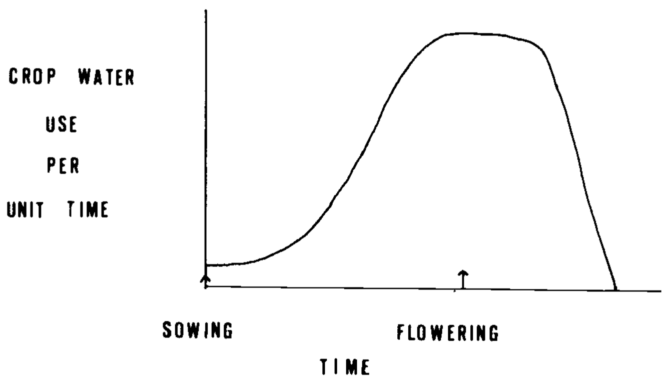

Fig. 5. Typical pattern of water use by annual crops during a growing season.

an "economic" yield and the quantity required at the key times in the crop growth cycle (e.g., at sowing and at flowering and seed fill). A quantification of soil moisture accumulation, storage, and availability and of water use throughout the season for different crops and locations is thus essential to a better understanding of the potential and the limitations of the dryland water resources in the region.

This information should enable the development of agronomic practices designed to modify moisture use patterns. Obvious factors influencing water use and requirements, and which are subject to manipulation, include: weed control to minimize unproductive water use; selection of varieties with maturities that best fit into the pattern of moisture availability (within the constraints imposed by the probability of late frost); timing of sowing; modification of seeding rates to give more optimum plant populations (current rates for cereals in the Aleppo province appear to be unduly high); the interaction of sowing date and rate; and plant nutrition (especially nitrogen status). In the short term the use of a combination of suitably modified practices should lead to a more efficient use of the available moisture and to improved yield stability, if not actual increases.

In the longer term a logical approach to crop improvement would seem to first require an understanding of the crop growth environment interactions as they affect water use. This would enable the development, through breeding programs, of varieties able to make the best use of the available resources to be put on a more solid base.

The improvements possible may be envisaged as being achieved in one of two ways: by drought avoidance or through drought tolerance. Drought avoidance involves the modification of crop growth patterns so that the critical periods of crop water demand coincide more nearly with times of higher rainfall probabilities. The extent to which this is possible is governed largely by the frost tolerance of the crop, the frost risk posed by the environment, and the degree of frost damage that is acceptable. Obviously a requirement for zero frost risk would call for varieties with a longer growing season and consequently higher water requirements than if a small risk of frost were acceptable.

Drought tolerance, on the other hand, refers to the possession by plants of physiological or morphological characters that enable either the production of a greater quantity of dry matter per unit of water used or the fuller utilization of the available water resources. At present the application of developments based upon this concept is hampered by the lack of a more detailed knowledge of the adaptive mechanisms of plants and their effects on yield potential under field conditions. The presence and the relative benefits of the physiological responses known to influence water use efficiency; the role of root systems in drought tolerance; and the relations between shoot and root growth and yield potential are some of the aspects requiring urgent consideration in studies of these adaptive mechanisms. In recent years, however, significant developments have been made in the study of the relations between soil and plant water status, environmental conditions, and plant shoot and root responses, and in the prediction of their effects on crop yield potential. Such advances are contributing considerably to current development efforts, which are mainly focused on the screening of crop varieties originating in the region and in other drought-prone areas (and those that are expected to have evolved mechanisms for adaptation to moisture stress) and should in the future be able to provide a basis for the planned synthesis of plant types designed to optimize their use of the available soil moisture.

Conclusions

There is a considerable wealth of data available relating to climatic conditions throughout the region. These data have been studied on a broad scale in assessments of the region and in more detail for a particular area by various authors, and techniques for further appraisal in relation to periods of critical importance in determining crop yield appear to be available. Further information is undoubtedly available on soil moisture storage in the region, and a collation of this through cooperating national programs would considerably strengthen assessments of the potential provided by the physical environment. Data on plant water use appear to be less available, but are essential in considerations of the water balance of the various crops. Crop water balance, as affected by rainfall distribution (together with other climatic factors), soil moisture storage, and atmospheric moisture demand, must be considered as the key to crop productivity in the ''dry areas.'' It is thus essential that a consideration and understanding of the interaction between the components of agriculture and those of the climate should proceed alongside and as part of crop improvement efforts in the region. Without such an approach, the degree of real improvement in the agriculture of West Asia and North Africa will always be severely limited.