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Elements of Climate – Their Relevance to Crop Productivity and Fertilizer Use Planning in the Semiarid Tropics[1]

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Abstract

High-yielding varieties, balanced fertilizer application, and adequate water supply are the three important factors for higher crop production. In the semiarid tropics (SAT), water is the primary constraint for crop production mainly in shallower soils having low water-holding capacity. The problem is further aggravated by variability in quantity and distribution of rainfall and by high evaporative demand. Based on the experiments conducted at ICRISAT Center, we have developed a program for N fertilizer application for cereals. Split application of N fertilizer is useful for both Vertisols and Alfisols. In Vertisols, water does not become a limiting factor for N response because of their high water-holding capacity, whereas in Alfisols, water is the main factor dictating crop response to N. Based on an analysis of long-term (1901-87) rainfall received during the crop growing season, the probability of fertilizer N required to optimize sorghum production has been estimated. These data can be used to assess risks to fertilizer N application and differences in fertilizer N needs from year to year in a semiarid tropical environment.

Introduction

In many parts of the semiarid tropics (SAT), great advances in agricultural productivity along with the introduction of modern agronomic practices have been witnessed in the last few decades. These advances have been possible mainly because of a remarkable fusion of the introduction of high-yielding varieties (HYVs) and improved agrotechnology. In particular, controlled use of irrigation and application of balanced amounts of fertilizers have contributed significantly to increased agricultural production. However, this impressive growth has not taken place across all of the semiarid tropics. Unirrigated, dryland areas, which are characterized by uncertain rainfall and a poor resource base, have largely remained neglected. The adoption of improved practices such as the use of HYVs, application of balanced doses of fertilizers, and crop protection measures is fairly low across the SAT. This paper attempts to examine the climatic constraints of some typical SAT locations in relation to their current and potential fertilizer use practices.

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Climatic Characteristics of SAT

Seasonality of Rainfall

The SAT regions are characterized by a seasonal rainfall. The rainy season varies from 2 to 4.5 months in the dry SAT and from 4.5 to 7 months in the wet-dry SAT. The distribution of rainfall is generally unimodal in areas lying >15° north and >15° south of the equator; it is bimodal in equatorial regions. The SAT exhibits a wet rainy season followed by a distinct dry season. About 90% of the total annual rainfall is received during the rainy season (Figure 1).

Variability of Rainfall

The amount of annual rainfall received in SAT areas varies greatly from year to year; its coefficient of variability (CV) is 20%-30%. For example, the mean annual rainfall at Hyderabad based on 1901 to 1987 rainfall records is 781 mm with a standard deviation of ±212 mm and a CV of 27%. At Hisar, the mean annual rainfall is 456 mm (1930-70) with a standard deviation of ±149 mm

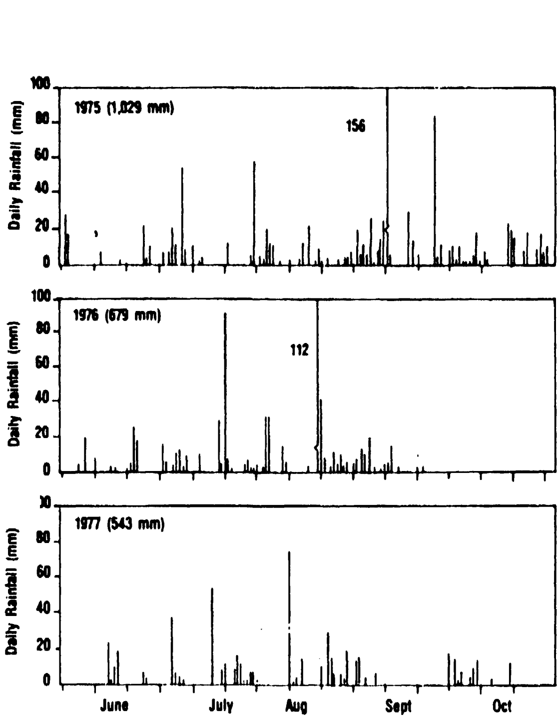

Figure 1. Rainfall Distribution at ICRISAT Center, 1975 to 1977.

and a CV of 33%. Thus, large variations in interannual rainfall are observed. The range of annual rainfall observed at Hyderabad is 950 mm for the period 1901-87. The annual rainfall may be as low as 450 mm or as high as 1,400 mm – about 90% of which is received during the 4-month rainy season.

Another characteristic of tropical rainfall is that the bulk of the seasonal rainfall is received during a few (generally 5-10) rainy days. The 24-hour total rainfall on each of such torrential rainy days may exceed 100 or 150 mm (Figure 1). At ICRISAT Center, it has been observed that in 43% of the rainy days, the rainfall storm intensity exceeded 20 mm hour^{-1}. In Niamey, this characteristic was observed in 72% of the rainy days. In about 10% of the days, rainstorm intensities as high as 120-160 mm hour^{-1} are not uncommon (Hoogmoed, 1981). Hence there is a considerable loss of water due to surface runoff and soil erosion. Miranda et al. (1982) observed that at the ICRISAT Center in traditionally managed Vertisols, 28% of the total seasonal rainfall was lost as surface runoff. This runoff carried away 7 tonnes of surface soil per hectare.

The convective nature of rain-producing storms in the tropics means that the rainy periods are interspersed with dry periods. During the rainy periods, when the soil profile is fully charged, a portion of the soil water is lost as deep drainage. The proportion of total seasonal rainfall lost by this pathway ranges from about 20% in light-textured soils to 10% in heavier soils. Thus the amount of effective seasonal rainfall in the tropics is about 50%-60% of the total annual precipitation.

Evaporation

The SAT areas are characterized by a high water demand due to intense radiation and uniformly high temperatures throughout the year. Sivakumar and Virmani (1987) calculated potential evapotranspiration (PE) statistics for 169 locations in rainfed India and found that the total annual PE was about 1,550 mm with a standard deviation of 196 mm and a CV of 13%. The PE in the months just prior to the rainy season is relatively high – about 200 mm month^{-1}; sometimes the PE exceeds 15 mm day^{-1}. The climatic data for the SAT regions show that the variability in PE is much lower than the rainfall variability and that the atmospheric demand for water is consistently high.

Length and Characteristics of the Growing Season in the SAT

Length of the growing season is defined as the period during which the availability of moisture in the root zone of the crop is adequate to meet the crop's water needs. Because the soil is practically dry prior to the onset of the rainy season, almost all activities related to land preparation for seeding are undertaken when the surface soil is moist enough for ploughing. As a rule of thumb, sowing is done within a week of the onset of the main rainy season in sandy soils and within 2-4 weeks in heavier soils.

The moisture in the soil is enough to sustain crop growth for about 4 weeks after the cessation of rains in lighter soils and about 8-12 weeks in the heavier soils. Thus the length of the growing season in SAT areas receiving rainfall for 2 months will be of the order of 80 days in light-textured soils and about 100 days in soils with clay or clay loam textures. Similarly, in areas with 5 rainy months, the growing season varies between 180 days in light-textured soils and 210 days in clayey soils. Because the amount and distribution of rainfall vary considerably from year to year, the length of the growing season also varies. This variability is higher in the dry SAT than in the wet-dry SAT. The risk to dependable crop production is least for short-duration crops like pearl millet, mung beans in lighter textured soils, and sorghum