

Water requirement and growth of sorghum over semi-arid region in Deccan Plateau

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सारांश — वर्षा के उपरत फसल के समय 1978 से 1986 तक सोलापुर में किए गए एक प्रयोग के परिणाम के आधार पर ज्वार की फसल की बढ़ोतरी की विभिन्न अवस्थाओं में फसल गुणांक का पता लगाया गया है। जलवायु प्रभाव की विभिन्न अवस्थाओं में जल के उपभोगात्मक प्रयोग का जलवायवी प्राचरों तथा फसल की जल आवश्यकताओं के साथ संबंध का पता लगाने के लिए एक मॉडल विकसित किया गया है। फसल की मांग के अनुरूप की गई जल आपूर्ति की सीमा तथा जल उपयोग की क्षमता के बारे में बताया गया है।

ज्वार की फसल में कलियां खाने/फूल खाने की अवस्थाओं में जल की सर्वाधिक आवश्यकता होती है। सोलापुर के पर्यावरण के अनुसार इस समय फसल को प्रति दिन चार मि०मी० जल की आवश्यकता पड़ती है। वर्षा ऋतु के उपरत मौसमी वर्षा का फसल की पैदावार में कोई विशेष योगदान नहीं है।

ABSTRACT. Based on the result of an experiment conducted from 1978-86 during post-rainy crop season at Solapur, crop coefficients for sorghum during different stages of growth were determined. A model has been developed for relating consumptive use of water at different phenological stages in relation to climatic parameters and crop water needs. The extent to which water requirements of the crop are met and water use efficiency have been discussed.

The water requirement appears to be maximum at tasseling/flowering phases of sorghum growth. It works out at 4 mm per day under Solapur environment. The seasonal rainfall in post-rainy season does not appear to furnish a reliable estimate of the yield.

Key words — Crop coefficient, Consumptive use, Tasseling, Agroclimatic need, Water use efficiency (WUE).

1. Introduction

Sorghum (*Sorghum bicolor* L) is one of the important cereal crops of the world on account of its wide adaptability to diverse agro-climatic conditions and soil types. It is a dual purpose crop, grown for fodder as well as for grain. It is an important food grain in many of the Afro-Asian countries. In India, it is grown both during rainy and post-rainy cropping seasons. The ability of sorghum to produce good yields under conditions of low soil moisture and high temperature, that are unsuitable for other cereal crops, make it the 'Camel' of the plant world. Complete failure due to limited rainfall are much less frequent for sorghum than other crops (e.g. maize). It is well adapted to semi-arid tropics with an average precipitation of 400-450 mm. It is a productive crop under irrigated agriculture.

A vital part of any irrigation management programme is based on reliable estimates of crop water

needs. Because of difficulty in obtaining accurate field measurements, predictive methods for crop water requirements are normally used. The amount of evapotranspiration (ET) from a crop depends on climatic parameters such as radiation, temperature, wind speed, vapour pressure deficit and related factors like type of soil, growth stage of crop etc. Actual water loss from the plant surface is strongly influenced by the supply of moisture in the root zone (Denmead and Shaw 1962).

The objective of the present study is to compute crop coefficient in different stages of growth and development to estimate plant water use in relation to potential evapotranspiration (PET).

Crop evapotranspiration has been determined by various workers by indirect and direct methods, e.g., lysimetric techniques, profile soil water depletion or field water balance etc. (Lal and Sharma 1976, Kumar *et al.* 1977, Hundal *et al.* 1989, Biswas and Khambete 1988).

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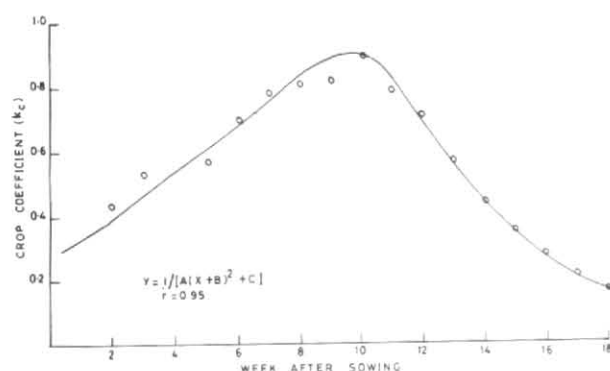


Fig. 1. Weekly distribution of crop coefficients

2. Materials and methods

The study was conducted at the experimental area of Agriculture Research Station, Mulegaon Farm, Solapur (17°04'N, 75°54'E 477m asl) during post-rainy season, from 1978-79 to 1985-86, *i.e.*, for a period of 9 years.

Sorghum variety, M-35-1 (also called *Maldandi*), was cultivated in all years under study. This sorghum variety is a long duration one. It is usually planted in October and matures in 18 weeks in February. Sorghum reaches maturity in 19 weeks in Nigeria (Goldsworthy 1970). In the present study sorghum reached phenological maturity in 14 weeks after sowing.

The evapotranspirative loss was determined daily by using a weighing lysimeter. Weekly totals were computed. The daily weather data on temperature, relative humidity, wind speed, duration of bright sunshine and rainfall was collected from the adjacent observatory. These data were used to compute PET by Penman's modified equation.

The crop coefficient (K_c) is defined as the ratio of actual evapotranspiration (ET) to PET. Crop water requirement was computed as follows:

$$ET = K_c (PET)$$

3. Results and discussion

3.1. Crop coefficients

It was assumed that adequate soil water was available in the lysimeter accumulated through residual moisture or rainfall. Weekly water use data was collected by using the lysimeter.

TABLE 1

Crop yield and distribution of agroclimatic factor (1978-86)

Year	Yield (kg/ha)	Rainfall (mm)	ET (mm)	WUE (kg/ha-mm)	Seasonal water deficit/excess (%)
1978-79	730	200	431	1.69	43.9
1979-80	755	384	395	1.91	45.8
1980-81	737	73	302	2.44	-11.7
1981-82	712	228	269	2.66	-25.6
1982-83	830	79	255	3.26	-14.7
1983-84	633	77	255	2.48	-1.6
1984-85	823	249	233	2.47	-22.8
1985-86	497	116	270	1.84	-19.3

The mean values of K_c (Fig. 1) show that during early stages, the values of crop coefficient were low, ranging from 0.10 to 0.60. During this period of growth, greater part of water is lost by evaporation from bare soil. Gradually, the evaporation rate is reduced due to drying of surface. This leads to lower K_c values. The highest value was 0.90 observed 70 days after sowing (DAS). In different years the K_c values obtained 70-77 DAS exceeded 1.0. The high K_c values during this period coincide with flowering and soft dough stages. This may be due to advection of energy through 'clothesline' effect (Tanner 1957). The values fall substantially (*e.g.* to 0.16) at the time of maturity due to senescence which reduced transpiration. The K_c value ranged from 0.11 in the initial stage to 1.09 in development stage. Biswas and Khambete (1988), however reported this range between 0.49 to 0.71. Subramaniam and Rao (1985) found K_c as 1.00 in crop development stage and 1.15 in the mid-season. Abdulmumin and Misari (1990) found K_c as 0.3 during the beginning of crop season, and a peak of 1.0 about 20 days before maturity in Samaru, Nigeria. The values of K_c obtained in the study, thus, generally agree with those observed by other workers.

For normalizing K_c , the crop season was divided into initial growth stage (*i.e.*, 20 DAS), development stage (20-40 DAS), mid-season (40-80 DAS) and late season (80 DAS to harvest maturity). The mean values obtained during these phases were, 0.48, 0.65, 0.80 and 0.29 respectively.

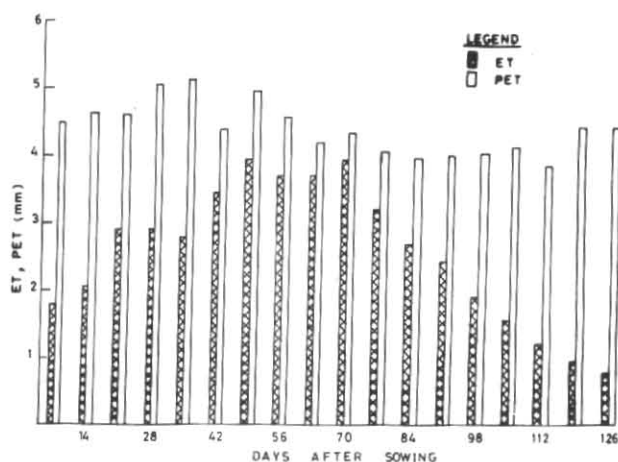


Fig. 2. Mean daily water use (ET) and climatic demand (PET)

When the weekly values of K_c were fitted to time, the equation obtained was,

$$Y = \frac{1}{0.047 (X - 8.117)^2 + 0.960} \quad (1)$$

where, X = week number after sowing, and
 $Y = K_c$

The correlation coefficient obtained was 0.95 which indicates that the above curve represents K_c data reasonably well. Thus, from value of PET, which can be computed from the meteorological factors and the average value of K_c obtained in the study, it is possible to estimate water use for any crop growth stage from empirical Eqns. (1) & (4). Making use of these values and the lysimetric actual consumptive use values, it is possible to estimate water need of crops.

3.2. Consumptive use of water

Statistics on the seasonal rainfall, yield, consumptive use, water use efficiency etc., are given in Table 1.

Being a dry land crop, the consumptive use of sorghum should be less than that for other crops, particularly those grown in rainy cropping season. The consumptive use of water was seen to fluctuate from year-to-year. The mean consumptive use was found as 314 mm and ranged from 255 mm in 1982-83 to 425 mm in 1978-79. Subramaniam and Rao (1985) found consumptive use of rainy cropping season sorghum in Maharashtra to range from 373 to 447 mm with a mean of 336 mm. The value of consumptive use found in the present study agrees well with their data.

The mean yield of sorghum at Solapur was low, i.e., 715 kg/ha and did not exceed 830 kg (Table 1). It

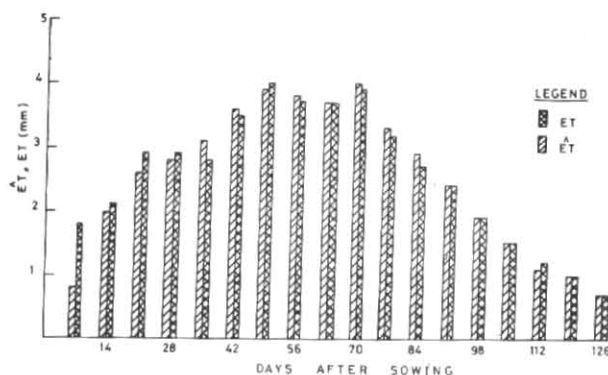


Fig. 3. Estimated daily agroclimatic water demand (ET) for different weeks and actual water use (ET)

is also seen that seasonal rainfall does not bear much relationship with the yield. In the year 1979-80, when the rainfall was highest, the yield was moderate. On the other hand, in 1982-83 though rainfall was low, the yield realised was highest. Thus, it is obvious that it is not the total quantum of rainfall but its distribution which plays vital role in determining the yield.

The water use efficiency (WUE) is also shown in Table 1. As in case of consumptive use, the WUE also showed wide variations. The lowest value of 1.69 kg/ha-mm was observed in 1978-79, while highest value of 3.26 kg/ha-mm was recorded in 1982-83. It is obvious that variations in WUE were entirely due to the rainfall and its distribution that occurred in different years during the post-rainy cropping season at Solapur. The crop appears to have used water most efficiently in 1982-83, when, inspite of low seasonal rainfall of 79 mm, highest WUE was registered. On the contrary though rainfall was quite high in 1979-80, the WUE was one of the lowest.

3.3. Climatic water requirement

The climatic water requirement (CWR) of the plant was computed as

$$CWR = \frac{(PET - ET)}{PET} \times 100 \quad (2)$$

It was noted in the years 1980-86 that slightly less than 50% of the seasonal needs could be satisfied. In the years 1978-80, the available moisture could meet plant water demands favourably.

PET as we know is the potential demand of the crop canopy. It is based on prevailing weather conditions. However, when applied to crop plants, the growth of the crop has a major control of PET.

Therefore, a true and more representative estimate of water demand can emerge only when crop stage is also considered, as revealed by K_c . The estimate of ET works out as

$$\widehat{ET} = K_c \cdot PET \quad (3)$$

The water deficit (WD) can now be computed from the equation

$$WD = \frac{(\widehat{ET} - ET)}{\widehat{ET}} \times 100 \quad (4)$$

For season as a whole the values of WD are given in Table 1. In studying the results it must be borne in mind that the crop at Solapur was raised purely on residual moisture in the post-rainy season. The climatic water demand of the sorghum is very unlikely to be met completely. Assuming a threshold of -25%, deficit may not drastically affect the crop, it is seen that only in 1981-82 crop season, the WD exceeded the limit marginally. In the remaining years the departures were within the tolerance limit. In fact, in 1978-79 and 1979-80 the water use far exceeded the crop water requirement.

The mean values of consumptive use *vis-a-vis* climatic demand during crop growth period is shown in Fig. 2. In the initial stages, the crop requirement is limited. However, as the plant develops, there is a gradual increase in the moisture requirement of the crop, so much so that during the flowering/soft dough stage the requirement nearly matches the demand.

When the crop factor is introduced to determine water need, the pattern is altogether different (Fig. 3). In the initial stages of the crop development, K_c is low and water demand is less. This phase also occurs immediately after the monsoon season where the top soil has substantial moisture. As such it is seen that the demand is much less than the supply with the progress of the crop season, the soil moisture gets gradually depleted, the moisture supply in these cases lags behind the demand and the crop may experience stress. This is noticed from 35 to 84 DAS, *i.e.*, from tillering to tasseling/flowering phases. After soft dough stage, the demand tapers off consequent to the setting up of senescence conditions and moisture supply nearly matches the demand. Assuming that a crop maintained at 10% deficiency of estimated ET will suffer no detrimental water stress, the sorghum crop of Solapur

appeared well watered up to maturity at low levels of productivity. The magnitude of this stress is, however, within the accepted limits for this purpose and hardly exceeds 10%.

4. Conclusions

(i) Crop co-efficient during tasseling/flowering is found to be maximum as compared to other phases.

(ii) The consumptive use of water increases gradually as the vegetative cover develops. On an average about 375 mm of water is consumed by sorghum.

(iii) Water requirement attains a maximum value of nearly 4 mm per day between tasseling and flowering.

(iv) Water use efficiency reveals year-to-year wide variations.

(v) The crop coefficient and estimated evapotranspirative loss values can be utilized suitably to schedule irrigation and also to determine quantum of water to be provided to the plant to avoid stress.

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