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Soil moisture regime in crop climate environment of deep black soils of Karnataka

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सार — दैनिक जल आयव्ययक के आधार पर बीजापुर क्षेत्र की गहरी काली मिट्टी की शस्य जल उपलब्धता निकाली गई थी। यद्यपि बीजापुर की वार्षिक वर्षा काफी कम है, मृदा आर्द्रता अभिवृद्धि के लिए जून, जुलाई और अगस्त में प्राप्त हुआ वर्षण पर्याप्त था तथा इसने 75 प्रतिशत सम्भाव्यता पर वर्षा ऋतु के बाद के शस्य विकास के लिए अनुकूल मृदा जल पर्यावरण उपलब्ध करवाया। तत्पश्चात सितम्बर मास से होने वाली वर्षा आर्द्रता की स्थिति में सुधार लाती हैं। सैंतीसवें सप्ताह के अन्त (16 सिम्तबर) में उपलब्ध मृदा आर्द्रता तथा उस अवधि तक संचित वर्षा के मध्य 0.8359 का उच्च सहसंबंध गुणांक प्राप्त किया गया। सैंतीसवें सप्ताह से 41 वें सप्ताह तक बुवाई वर्षा प्राप्त करने की सम्भाव्यता अनुकूल रही। यदि फसलें अक्तूबर मास तक बो दी गई तो ऐसा पाया गया कि पांच में से औसतन तीन वर्षों में रबी की जल की आवश्यकता पूरी करने के लिए मृदा जल पर्यावरण अनुकूलतम रहेगा।

ABSTRACT. Crop water availability was worked out for deep black soil region of Bijapur area based on daily water budgeting. Though Bijapur received low rainfall annually, the precipitation received in the months of June, July and August was sufficient for soil moisture accretion and provided a favourable soil water environment for the crop growth of post rainy season at 75 per cent probability. Further rains from September onwards help in improving the moisture condition. A high correlation coefficient of 0.8359 was obtained between the soil moisture available at the end of 37th week (16 September) and accumulated rainfall upto that period. The probability of receiving sowing rains during 37th to 41st weeks was favourable. If crops could be established by October, it was found that the soil moisture environment will be optimum to meet the water requirements of rabi crops on the average in 3 out of five years.

1. Introduction

The success of post rainy season crop in dry lands depends on its sowing at a time when soil moisture is adequate and on providing sufficiently a long moist period for successful completion of its life cycle. Hence, a complete and quantitative understanding of the natural resources particularly soil moisture and its dependence on rainfall is required for development of suitable crop strategy in these areas. With this in view, an attempt is made to understand the soil moisture availability and its variability due to monsoon rainfall in deep black soils of Bijapur.

Bijapur region is situated in the northwestern part of Karnataka, between 16 deg. 59′ N latitude and 75 deg. 43′ E longitude and at an elevation of 574 mts amsl. This region is characterised by low and uncertain rainfall with high evaporative demand. Soils of this region are derived from Deccan trap. They are black soils of the order of vertisols, with varying depths and moisture holding capacities. In the shallow soil region of this area, crops are grown on the rains received during monsoon season and in deep black soil region, mostly rabi crops are grown. The farmers of this locality generally keep the land fallow during the rainy season and crop it during post rainy season on the residual moisture stored in soil profile, which is believed to be more assuring.

2. Material and methods

The daily rainfall data from 1901 to 1982 and daily data on maximum temperature, minimum temperature, relative humidity of morning and evening hours, wind speed and cloud amount for the period from 1965 to 1982 for Bijapur station were collected from the Indian Meteorological Department. Daily potential evaporation was computed for all the years (1965-82) following Penman's equation (1948). The values 0.33 and 0.41 (Ganesan 1970) were used for the constants a and b in the calculation of incoming radiation as suggested by Doorenbos and Pruitt (1975).

Daily water balance estimates using daily rainfall as input to the soil moisture storage and estimated evapotranspiration as withdrawls, were carried out for the period from 1965 to 1982 to evaluate the soil moisture regime at the end of each day by following

TABLE 1

Mean monthly rainfall, coefficient of variation and potential evapotranspiration at Bijapur (1965-82)

Month	Mean monthly rainfall (mm)	CV (%)	Mean monthly PET (mm)
Jan	0.5	221	115.2
Feb	3.2	331	134.7
Mar	2.9	135	180.1
Apr	24.7	87	196.4
May	40.3	84	219.4
Jun	86.5	74	166.9
Jul	77.7	63	149.2
Aug	83.2	73	144.8
Sep	170.6	49	129.6
Oct	112.8	84	127.3
Nov	35.1	191	107.5
Dec	4.7	159	101.5
Total	642.2		

TABLE 2

Seasonal distribution of rainfall (1965-82)

Period	Mean seasonal rainfall (mm)	CV (%)	% to annual total
		Period 1	
Apr-May	64.9	57	10
		Period 2	
Jun-Aug	247.4	38	38
		Period 3	
Sep-Nov	318.5	49	49

Total annual rainfall : 642.2 mm.
CV among years : 31 per cent.

Thornthwaite and Mather (1955) technique. For this purpose, water available in the soil to plant is generally considered to be that between the field capacity and wilting point and an available water capacity of 250 mm was considered for the black soils of Bijapur as reported by Suryanarayana *et al.* (1984). As per their computation, 225 mm was the value arrived at, as the available water for these soils, but for computational convenience it was considered as 250 mm. From the estimated daily available soil moisture, the moisture availability at the end of each week for all the years was computed.

A linear regression equation model of the form $y = a + bx$ between the soil moisture available at the end of 37th week (16 September) and the accumulated rainfall upto 37th week, was fitted to understand

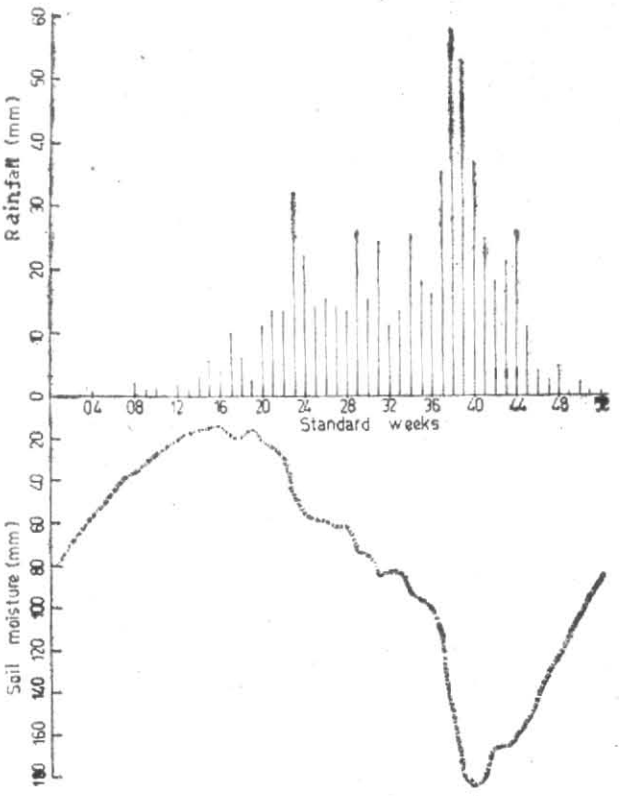

Fig. 1. Crop water availability and rainfall

the dependence of soil moisture accumulation on the rainfall of the prior period.

Based on these estimated available soil moisture at the end of each week the following observations were made and available crop water environment was discussed for developing a suitable crop strategy.

3. Results and discussions

3.1. *Rainfall*

Monthly rainfall (average of 1965-82) during the study period, coefficient of variation (CV) and monthly potential evapotranspiration (PET) are presented is Table 1.

The year to year variation in rainfall in these dry areas was more. A lowest rainfall of 292.0 mm during 1972 and highest amount of 953.0 mm during 1975 was recorded.

The rainfall received during June-November is considered to be important in these location for the soil moisture build-up and hence for crop production. The yearly rainfall is divided into three categories based on the period of its occurrence, to understand the effectiveness of the rainfall of each period in soil moisture accretion. The rainfall during the three periods, respective CV are presented in Table 2.

Though, 49 per cent of total annual rainfall is received during September-November, the rainfall of

TABLE 3

Probability of occurrence of high amount of rainfall in a single day of different months (1930-81)

Month	Amount of rainfall (mm)				Total No. of rainy days (≥2.5 mm)
	15	20	30	40	
May	27	20	10	5	3
Jun	35	24	14	8	5
Jul	23	16	10	8	6
Aug	34	23	13	10	5
Sep	46	35	22	12	8
Oct	41	27	15	10	6

June-August seems to be more reliable and effective in building up the soil moisture for the rabi season. The rainfall during remaining period will be useful to further substantiate the soil moisture availability for better performance of post rainy crops.

3.2. *Soil moisture*

The average weekly soil moisture behaviour in 100 cm soil profile of the black soil region of Bijapur and weekly average rainfall is presented in Fig. 1. It can be observed that during April and May, when the air temperatures are high and evaporative demand is at its highest, the soil moisture reaches as below as 10 mm. Generally moisture accumulation starts from the initial showers as indicated by the increasing trend in the soil moisture curve (Fig. 1).

Preliminary results of land and water management studies which are being conducted under different soils of Bijapur indicate that, runoff was minimal in deep black soils region during the early rainy period as compared to the shallow soils despite their variable slopes (Belgaumi 1984). The deep cracks that develop during summer allow less intense initial showers to enter the soil. Further, the rainfall duration of these dry areas, which are situated in a rain-shadow region for both the monsoon winds, is of short in nature, of low amount and hence of less intensity. The probability of occurrence of high amounts of rainfall (15 to 40 mm) in a single day in different months of the rainy season was worked out (Table 3). In the initial stages of monsoon season (June-August) the probability of receiving a rainfall amount of 15 mm or more in a single day is of the order of 25-35 per cent of the total rainy days during that period. Frequency of high intense storms in the initial period is less and hence a high probability of contribution to soil moisture.

From the Fig. 1, it can be observed that the soil moisture build up is a continuous process right from

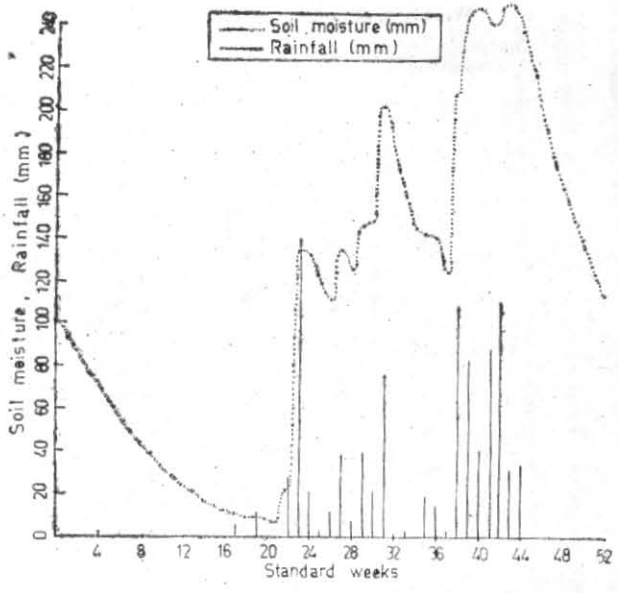

Fig. 2. Soil moisture accumulation and rainfall (1975)

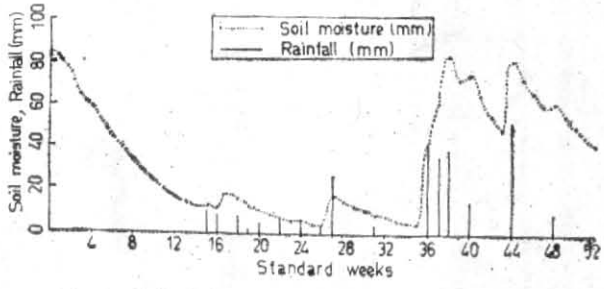

Fig. 3. Soil moisture accumulation and rainfall (1972)

the initial showers of the monsoon rains (23rd week) and by the middle of September (37th week) the soil is recharged to 75 per cent of the maximum available water. Soil water regime of 100 mm and more persists for a substantial part of the season and continues upto the middle of December. A full soil recharge of 250 mm is not uncommon, if individual years are considered. Typical cases of available soil moisture during high rainfall (1975) and low rainfall (1972) situations were presented in Figs. 2 and 3, to have an insight into the variation in soil moisture accumulation in extreme cases. During 1975 (RF 953 mm) the soil moisture build up was observed right from 26th week onwards. The 50 per cent available moisture regime of 125 mm and above, presisted for a period of about 25 weeks, during rabi season (23-49th week). However, in the year 1972, rainfall of only 292 mm was received and the moisture recharge had never reached 50 per cent of maximum storage. In addition, the

TABLE 4

Weekly probabilities of various levels of available soil moisture (AWC 250) in black soils of Bijapur (years 1965-82)

Week	Levels of soil water (mm)								
	50	75	100	125	150	175	200	225	250
23	39	28	6	6	—	—	—	—	—
24	39	22	22	17	6	—	—	—	—
25	44	33	22	11	—	—	—	—	—
26	56	44	17	—	—	—	—	—	—
27	50	39	28	6	—	—	—	—	—
28	67	39	11	6	—	—	—	—	—
29	78	39	17	17	—	—	—	—	—
30	78	39	28	22	—	—	—	—	—
31	78	44	39	22	11	6	6	—	—
32	72	50	44	17	17	6	—	—	—
33	72	50	39	22	11	—	—	—	—
34	78	67	50	33	11	6	—	—	—
35	83	67	44	28	6	6	6	—	—
36	87	78	67	44	11	11	6	6	6
37	100	78	67	44	11	11	6	6	6
38	100	89	83	61	33	33	28	17	11
39	100	94	94	78	67	61	50	33	11
40	100	94	94	72	72	61	61	50	—
41	100	94	72	72	61	61	56	28	6
42	100	94	72	72	67	56	33	22	11
43	94	78	72	72	72	50	33	28	11
44	100	78	72	72	67	44	33	17	6
45	100	72	72	72	61	44	22	11	—
46	100	78	72	67	56	28	11	—	—
47	94	72	72	61	39	22	6	6	—
48	89	72	67	56	39	11	6	6	—
49	83	72	61	44	28	6	6	—	—
50	89	72	56	39	6	6	—	—	—
51	83	72	44	28	6	6	—	—	—
52	78	61	39	11	6	—	—	—	—
01	76	53	29	6	—	—	—	—	—
02	71	47	12	6	—	—	—	—	—
03	71	41	6	—	—	—	—	—	—
04	59	29	6	—	—	—	—	—	—
05	53	12	—	—	—	—	—	—	—
06	41	6	—	—	—	—	—	—	—
07	29	—	—	—	—	—	—	—	—
08	18	—	—	—	—	—	—	—	—
09	18	—	—	—	—	—	—	—	—

TABLE 5

Occurrence of sowing rains for rabi cropping around Bijapur (1930-80) region

Standard week No.	Dates	Amount of rainfall (mm)		
		5	10	15
37	10-16 Sep	62.7	56.9	43.1
38	17-23 Sep	70.6	64.7	58.8
39	24-30 Sep	82.3	78.7	70.6
40	1-7 Oct	70.6	66.7	56.9
41	8-14 Oct	62.7	54.9	51.0

superimposition of rainfall in the crop season over the available soil moisture indicated no occasion of sowing rains for post rainy crops was recorded during 1972. However, occurrence of such situation (<500 mm) of low rains and hence of low available water, during post rainy period were only 28 per cent in these tracts.

In order to assess the persistency of the occurrence of satisfactory soil moisture regime, probability of occurrence of different amounts of available water in each week was worked out (Table 4). By the end of 39th week the possibility of moisture recharge to 175-200 mm was of 61 per cent and during 40th week, 50 per cent probability of soil being fully recharged to field capacity was observed.

To assess the degree of dependence of soil moisture accumulation by 37th standard week (16 September) on the rainfall the moisture accumulated at the end of 37th week was correlated to the accumulated rainfall of 23-37 weeks; using a linear regression model. The results of the regression equation was as follows :

$$y = -20.7476 + 0.4679\,x$$

where, y = available soil moisture at the end of 37th week.

x = Accumulated rainfall (in mm) of 23-37 week

A high correlation coefficient (r) of 0.8359 was observed and it was found significant at 1 per cent level. The coefficient of determination (r^2) is 0.6988, indicating 70 per cent of the variation in the available soil moisture could be explained by the variation in the accumulated rainfall during the period earlier to 37th week.

3.3. *Crop strategy*

Hargreaves and Christiansen (1974) and Hargreaves (1975) established that the crop water requirements during initial stages would be as low as 0.25 of available water and increase to about 0.8 at pre-flowering stage, and finally drop to 0.3 at maturity. On this basis, Virmani (1975) estimated total water requirement as 210 mm of ET for post rainy season crops for Hyderabad region. The results of water balance of Bijapur black soils show that in about 60 per cent of the years there would be adequate water in the soil by the end of 40th week. Though the probability of adequate soil moisture environment after 37th week onwards was high, the surface layer (upto 15 cm) of the soil may be void of moisture due to its proximity to atmosphere. So the sowings can be planned soon after the first good shower of 10-15 mm during the month of September, which can soak the top soil. Planting at the start of rains or even before the receipt of rains (in anticipation) and thereby providing better soil moisture environment for the development of root system in later stages of the crop growth was reported to produce high yields (Gwynne 1964). This demands at least a good probability of favourable rainfall situation to take up sowings at the earliest opportunity. To assess this, percentage probability of occurrence of different amounts of rainfall (as crop sowing rains) during 37 to 41 weeks was worked out and presented in Table 5.

The probability of occurrence of favourable sowing rains for early rabi cropping is high under Bijapur rainfall conditions. Ramana Rao *et al.* (1979) reported 92 per cent probability of sowing rainfall in Bijapur region before 30 September. Once a crop was established by October first half, the crop is well supplied with soil moisture for subsequent crop growth and to meet its moisture demands during crictical periods.

Grain yields of Sorghum trial (Mugathi variety) collected from Dryland Agriculture Project (Anonymous 1980), in relation to moisture stress was analysed to examine the availability of favourable crop soil environment at different stages of the crop growth. It was observed that among all the stages of the crop, final yield was strongly correlated with favourable soil moisture situation at boot leaf stage and flowering period as indicated by their respective high correlation coefficients of 0.9352 and 0.9971. This was well supported by the observation of Nix and Fitzpatrik (1969).

From the above results, it can be concluded that a crop sown at the first favourable opportunity during September, would be well supported by favourable crop water availability environment during its further growth. Given a 75 per cent of favourable soil water environment, productivity of the black soil areas of Bijapur region would be entirely dependent on the crop management alone.

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References

Anonymous, 1980, 'Ten years of Dryland Agricultural Research in Black Soils of Bijapur', AICRP for dry Agriculture, **31**.

Belgaumi, M.I., 1984, 'Studies on the evaluation of different soil and water conservation structures in medium and black soils (*Personal communication*).

Doorenbos, J. and Pruitt, W., O., 1975, Guide lines for predicting crop-water requirements. Irrigation and Drainage paper 24. Food and Agriculture Organization, U.N., Rome, p. 179.

Ganesan, H.R., 1970, 'Estimates of solar radiation over India *Indian J. Met. Geophys.*, **21** 4, 629-636.

Gwynne, M.D., 1964, 'Plant Characteristics that make them suited to areas of low and erratic rainfall' specialist meeting on crops of low and erratic rainfall. East African Agricultural and Forestry Research Organisation, Muguga, Kenya.

Hargreaves, G.H., 1975, '*Water requirements manual*' for irrigated crops and rainfed agriculture, Bull. Utah State Univ., 40.

Hargreaves, G.H. and Christiansen, J.E., 1974, 'Production as function of moisture availability, ITCC review Assoc. Engg. and Architats Israel **3**, **1** (9), 179-189.

Michale, A.M., Hukkeri, S.B. and Singh, N.P., 1977, 'Estimating water requirement of crops, water requirement and irrigation management of crops in India, IARI monograph No. 4, Water Technology Centre, IARI, New Delhi, pp. 91-162.

Penman, H.L., 1948, 'Natural evaporation from open water, bare soil and grasses, *Proc. Roy. Soc. London* (Series A), **193**, 120-145.

Ramana Rao, B.V., Biradar, B.R. Surpur, S.S., and Gopinath Rao, M., 1979, 'A study on the possibility of advancement of sowing Rabi Jowar in Black Soil at Bijapur, Food Farming and Agriculture X, 12, 371-2.

Suryanarayana, G., Hegde, B.R. and Kulkarni, K.R., 1984, Climatological approach to crop pattern in Karnataka', *Mausam*, **35**, 1, 75-80.

Thornthwaite, C.W. and Mather, J.R., 1955, 'Water balance' Publication of climatology, Drexel Institute of Tech. 8.1.

Virmani, S.M., 1975, 'The Agricultural Climate of the Hyderabad region in relation to crop planning (A sample analysis) ICRISAT, p. 50.