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Some agroclimatic aspects of sorghum and millet production in India

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सार — भारत के जिलों में सोरघम और बाजरे के विस्तार व उत्पादन क्षमता को जल संतुलन के सान्निध्य में रखने पर पता चला है कि सोरघम और बाजरे की खेती अर्धशुष्क क्षेत्रों में सघनता से की जाती है। जिनमें औसत वास्तविक जल संतुलन 1–3 महीने का होता है या उसमें वर्ष में 400 से 1000 मि० मी० औसत वर्षा होती है।

भारत के अर्धशुष्क क्षेत्रों में, सोरघम की बढ़वार के समय सूखा उसकी पैदावार में मुख्य बाधक होता है। लेकिन रबी के मौसम (अक्तूबर-मार्च) में कम तापमान भी विशेष रूप से उत्तरी क्षेत्रों में एक समस्या है। उत्तरी भारत में सोरघम तथा बाजरे के उत्पादन की तुलना जनवरी के औसत तापमान से करने पर पता चलता है कि सोरघम तथा बाजरे की फसलें उन क्षेत्रों में अच्छी नहीं होती जहां पर जनवरी में माध्य तापमान 15° सें० से कम होता है।

ABSTRACT. Studies of sorghum and millet spread and yield indices in Indian districts juxtaposed with water balance revealed that sorghum and millet are extensively cultivated in semi-arid region having an average positive water balance of 1-3 months or receiving an average annual rainfall of 400 to 1000 mm.

Drought in the growing period is the major constraint to sorghum production in semi-arid region of India, but low temperature in the rabi season (October-March) is also a problem especially in the northern region. A comparison between sorghum and millet production in northern India and the January mean temperature shows that sorghum and millet crops do not do well in areas where the January mean temperature is below 15°C.

1. Introduction

In India, sorghum [*sorghum bicolor* (L) *Moench*] is extensively grown in the kharif (June-October) season. It is also grown in the rabi (October-March) season on the moisture retentive deep black cotton soils (vertisol) of semi-arid region of India that usually benefit from the late post-monsoon rains, whereas millet [*Pennisetum typhoides* (*Burm. F.*) *stapf & C.E. Hubb.*] is grown only in kharif season in the dry farming tracts when the rainfall is considered inadequate for maize and sorghum. The millets are important source of food in many parts of the dry regions of India where they are grown on soils to poor or climate too dry to support any other crop.

This paper will examine the important macroclimatic conditions for sorghum and millet production in India.

2. Materials and methods

The percentage of gross cropped area (G.C.A.) and relative yield index (R.Y.I.) for sorghum and millet growing districts of India were worked out by using the average area and yield for 1979-80 (Directorate of *Economics & Statistics, 1979-80)*, and are presented in Figs. 1 and 2.

$$\text{G.C.A.} = \frac{\text{Cultivated area of sorghum/millet in the district}}{\text{Total cultivated area in the district}} \times 100$$

$$\text{R.Y.I.} = \frac{\text{Mean yield for sorghum/millet in the district}}{\text{Mean all India yield of sorghum/millet}} \times 100$$

On the basis of monthly normal rainfall (P), potential evapotranspiration (PET) computed by Penman's equation (Rao *et al.* 1971) and water holding capacity (S) of different soil types of India, number of months having positive water balance [P or $(P+S)/\text{PET} \geqslant 1.0$] and partial water balance [$1.0 > P$ or $(P + S)/\text{PET} \geqslant 0.5$] which meet the water requirement fully in the early as well as in the maturity stages but meet water requirement partially at other growth stages are calculated and shown in Figs. 3 & 4.

3. Results and discussion

3.1. *Relative yield index of sorghum and millet*— Figs. 1 and 2 show the percentage of gross cropped area and yield indices of sorghum and millet crops for each

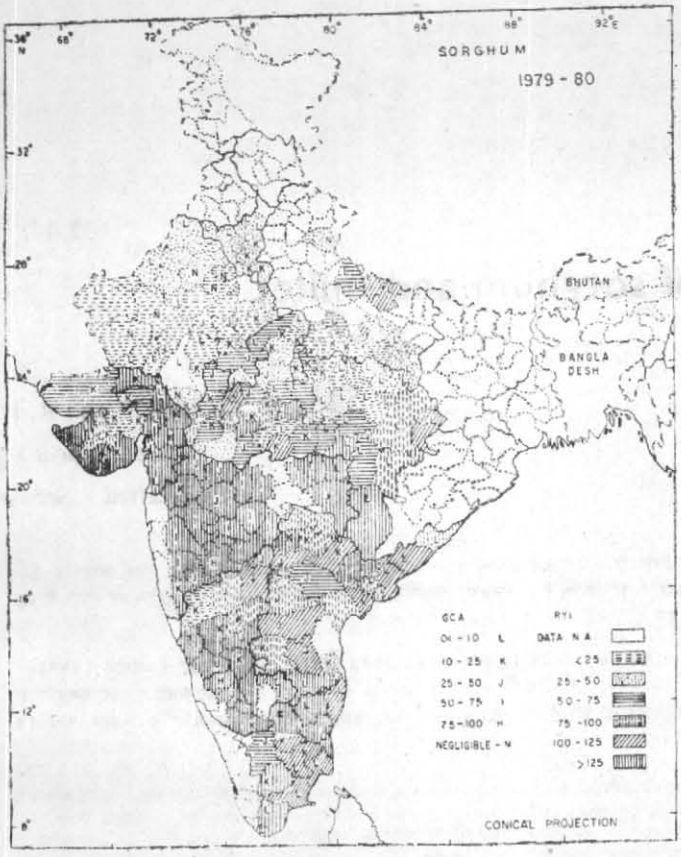

Fig. 1. Districtwise percentage of gross cropped area & relative yield index of sorghum

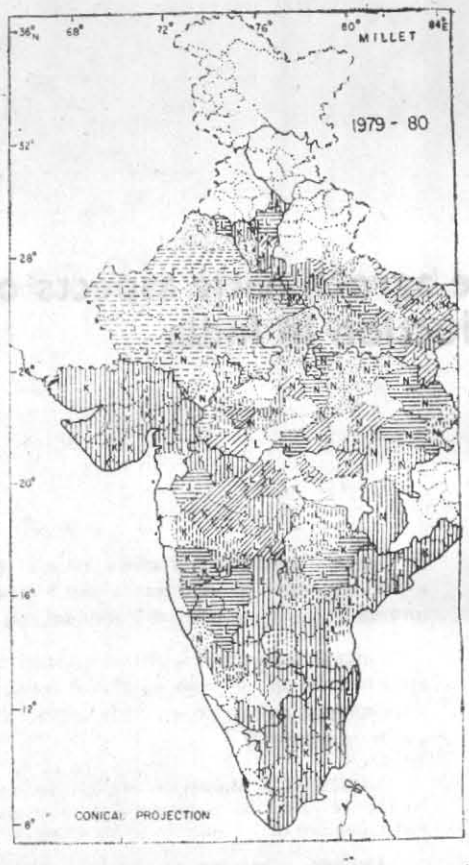

Fig. 2. Districtwise percentage of gross cropped area & relative yield index of millet

district respectively. R.Y.I. values for some districts are not available and are kept unshaded. The relative yield index values of millet are quite high compared to that of sorghum for most of the States. The average millet and sorghum yields in Indian States are 3.8 and 6.9 q/ha respectively (Directorate of Economics and Statistics, 1979-80). Fig. 2 reveals that the percentage of gross cropped area in Indian States is within 20 percent except in Rajasthan where millet is grown extensively.

3.2. *Meteorological aspects of sorghum and millet growing areas of India*

3.2.1. *Water balance* — Sorghum and millet are normally grown in warm areas of semi-arid tract with well distributed annual rainfall of 250-1000 mm.

On the basis of number of months having positive (Fig. 3) and partial water balance (Fig. 4) in the semi-arid and arid regions of India, three distinct zones could be delineated (Fig. 5).

(*i*) Region with 3 months positive water balance and 3 to 4 months partial water balance where both sorghum and millet crops can be taken.

(*ii*) Regions with 2 months positive water balance and 2 to 3 months partial water balance where sorghum or millet and some short-duration pulse crop can be grown.

(*iii*) Region with 1 or less than one month positive water balance and 3 or less than three months partial water balance where only one crop (millet) can be grown with some risk factor.

In a region comprising northeast Karnataka, northwest Andhra Pradesh and parts of Maharashtra and Tamil Nadu having 3 months positive water balance along with 3 to 4 months partial water balance, crops like sorghum and some short duration legume can be taken by adjusting the maximum water requirement of the crops with the peak rainfall periods. The duration of water availability period and dates of onset of monsoon have considerable influence on sowing date and growing period of sorghum and millet crops. The highest acreage of sorghum and millet in Maharashtra and Rajasthan respectively are thus attributable to fulfilment of water and thermal requirements of these crops in respective States.

The warm dry climate of Rajasthan and adjoining Rajasthan along with lesser number of months with positive and partial water balance in these zones are the major constraints for cultivation. The poor soil water retentivity and frequent dry spell in Rajasthan area have compelled farmers to grow millet instead of sorghum in kharif season. In these regions, drought as an eco-physiological phenomenon, is found to occur almost synonymous with dry spell. In winter, water and thermal requirements are not fulfilled in northwest India and consequently millet is not grown and sorghum yield is very low in these regions.

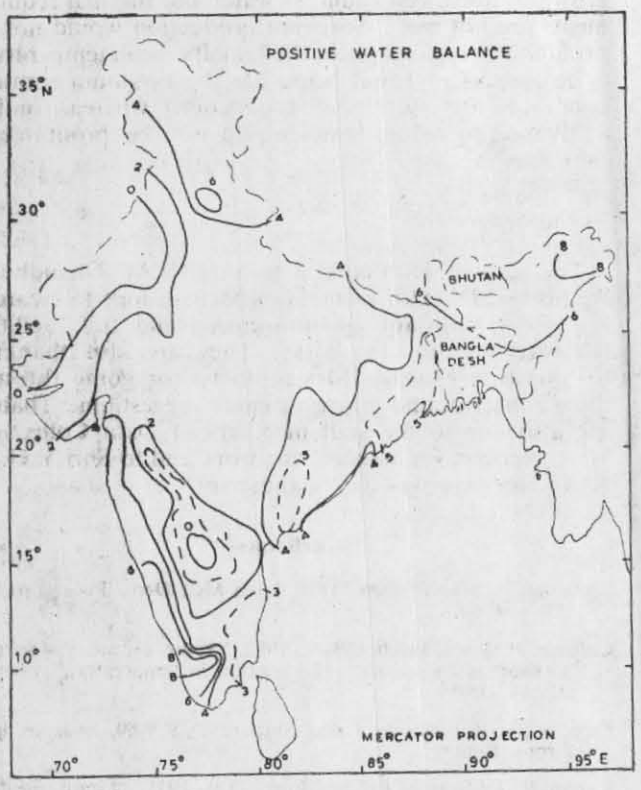

Fig. 3. Number of months with positive water balance [P or $(P+S)$/ PET ≥ 1.0] in India
(P = Precipitation, S = Plant available soil moisture storage)
PET = Potential evapotranspiration (Penman method)

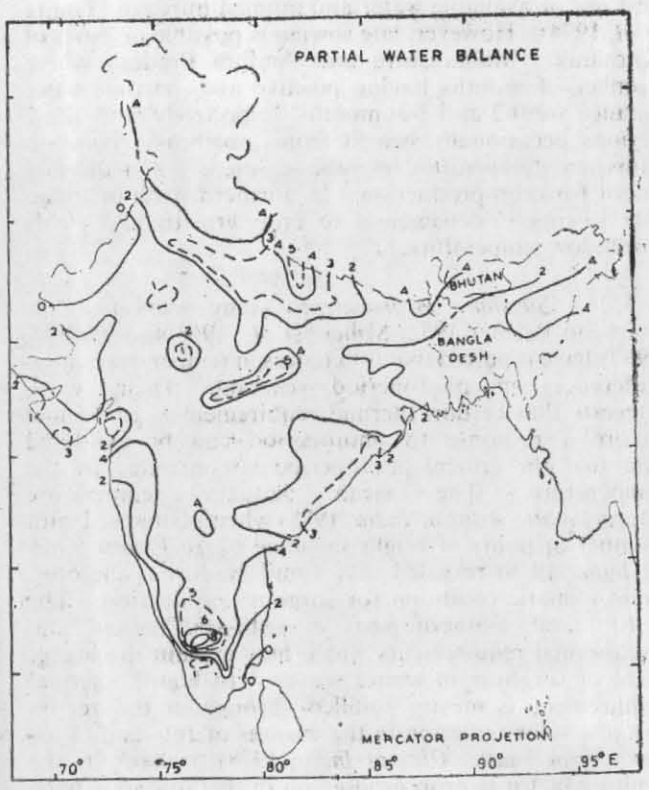

Fig. 4. Number of months with partial water balance [P or $(P+S)/\text{PET} \geq 0.5$ but < 1.0] in India. (legends P, S and PET same as in Fig. 3)

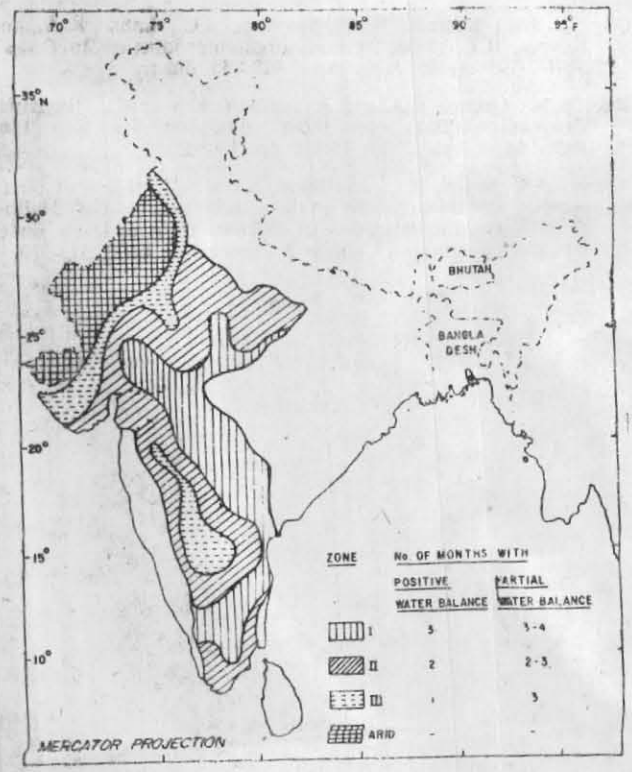

Fig. 5. zones of semi-arid India

3.2.2. *Temperature environment* — Sorghum is seldom produced commercially in areas where average temperatures drop below 15°C. The minimum temperature requirements are 7–10°C for germination and 15°C for growth. Optimum temperatures for growth are 27 - 30°C (Quinby *et al.* 1958). Sorghum is better able than most grain crops to withstand high temperatures but yields are adversely affected when mean temperatures exceed 26° C during the heading period (Karper *et al.* 1931).

A comparison between sorghum production areas in India (Fig. 1) and the mean temperature in January (*Agroclimatic Atlas of India,* 1978) shows no sorghum production in areas where the mean monthly temperatures are below 15°C.

Millets are short-day, warm-weather plants that are even more resistant to drought than sorghum. Due to their high temperature requirements, they are not grown in the winter season. A comparison between millet production areas in Indian States (Fig. 2) and mean daily minimum and mean daily temperatures in January (*Agroclimatic Atlas of India,* 1978) shows that millet production is not possible in winter season.

In the Haryana region, when the crop is sown very late, the yield is depressed because of the prevailing low temperature. Hence, it is necessary to determine a suitable sowing date to get optimum yields and make the

best use of available water and applied nitrogen (Tomer *et al.* 1974). However, late sowing is possible in parts of Karnataka, Maharashtra and Andhra Pradesh where number of months having positive and partial water balance are 0-2 and 2-3 months respectively and these regions occasionally benefit from northeast monsoon rains and temperature in rabi season is not a limiting factor for crop production. In northern parts of India, late sowing is detrimental to crop growth and yields due to low temperature.

3.2.3. *Sunshine environment*—Many workers (Colman and Belcher 1952, Miller *et al.* 1968 and Quinby 1967) have reported that differences in temperature cause differences in photoperiod reaction. Their work suggests that certain thermal requirement is to be met before a response to photoperiod can be exhibited and that the critical photoperiod is controlled by the temperature. The mean January temperature (*Agroclimatic Atlas of India,* 1978) when juxtaposed with number of hours of bright sunshine (*Agroclimatic Atlas of India,* 1978) revealed that Tamil Nadu has the optimum climatic condition for sorghum production. The central and southern parts of semi-arid region fulfil the thermal requirements which may explain the higher yield of sorghum in winter season. In kharif, thermal requirement is mostly fulfilled throughout the region but low solar radiation in the months of July and October (*Agroclimatic Atlas of India,* 1978) probably is the limiting factor in crop production in the southern part. Northern region comprising Gujarat, Haryana and Rajasthan has higher crop potentiality in normal rainfall years. However, this region is mostly affected by dry spells and poor soil condition enhances the crop failure.

4. Conclusion

Using water balance as a criterion three distinct zones have been delineated. The zone comprising northeast Karnataka, northwest Andhra Pradesh and parts of Maharashtra and Tamil Nadu having 3 months positive and 3 to 4 months partial water balance, fulfils the water requirement of sorghum. Sorghum cultivation in Rajasthan would not be encouraging. However, millet production can be stabilized with suitable water management practices. In winter, sorghum and millet cannot be grown in northwest India as water and thermal requirements are not met. Sorghum production would not be profitable in regions where the January mean temperature is below 15°C. Tamil Nadu has the optimum climatic condition for sorghum production whereas millet cultivation in Indian States would not be profitable in rabi season.

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