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Effect of rainfall on growth and yield of rice in Konkan coast

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सार — इस शोध-पत्र में महाराष्ट्र के रत्नागिरि और थाणे जिलों में, 37 वर्षों (1951-1987) के आंकड़ों का प्रयोग करते हुए वर्षा और चावल की उपज के संबंधों की जांच की गई है । उपज सूचकांक विकसित करने के लिए साप्ताहिक जल संतुलन तैयार किए गए और उपज के साथ-इसकी सहसंबंध का परीक्षण किया गया । 450 और 500 मि० मी० के वानुभविक वर्षा संचयनों की दो परिकल्पित कोटियों के आधार पर रोपण की तारीखें आकलित की गई । पैदावार के परिकल्पित चरणों, कुल वर्षा उपज सूचकांक और तकनीकी प्रवृत्ति के साथ-साथ उपज वर्षा के साथ सह सहसंबंधित थी । उपज पर मानसून के देर से आने या पहले प्रारम्भ होने के प्रभावों का भी परीक्षण किया गया ।

यह देखा गया है कि 1 जून से 450 मि. मी. वर्षा के संचयन कोंकण क्षेत्र में धान के रोपण के लिए सही संकेत देते हैं । धान की उपज पर इस तकनीक का अधिक प्रभाव दिखाई देता है । परिणामों से पता चलता है कि उपज के प्रथम चरणों के दौरान वर्षा फसल के साथ उल्लेखनीय रूप से संबंधित है । रोपण की तारीख का उपज पर कोई निर्णायक प्रभाव नहीं पाया गया ।

ABSTRACT. In this study, relationship between rainfall and rice yield has been investigated in Ratnagiri and Thane districts of Maharashtra using 37 year's (1951-1987) data. Weekly water balance has been worked out in developing a yield index and its association with yield examined. Planting dates have been calculated assuming two categories of empirical rainfall accumulations of 450 and 500 mm. The yields were correlated with rainfall during selected growth phases, total rainfall, the yield index and the technological trend. Effects of late or early onset on yield has also been examined.

It appears that 450 mm rainfall accumulation from 1st June gives a reasonably accurate indication of transplanting paddy in Konkan. Technology seems to have much influence on the paddy yield. Results also reveal that rainfall during early growth phases is significantly related to the yield. The date of planting was not found to have a determining influence on the yield.

Key words — Water-balance, Yield index, Transplanting.

1. Introduction

Rice (*Oryza Sativa L*) is the staple diet of the people in the coastal districts of Maharashtra State. The two districts in the Konkan *viz.*, Ratnagiri and Thane, between them have about 2.90 lakh hectare under paddy cultivation, with a production of nearly 4.10 lakh tons and a mean yield of about 1440 kg/hec. Rice is grown mostly as wetland crop with different varieties. Nearly whole of the paddy production comes from the kharif season. With limited irrigation, the crop is mostly affected by the vagaries of monsoon and thus there is large year to year fluctuations in the level of yield.

There had been not much contribution to the crop weather relationship in the developing countries like India. Wheat data was analysed by Gangopadhyaya and Sarker (1965), sugarcane by Gangopadhyaya and Sarker (1964), Roopakumar (1984), and rice by Srinivasan (1973) Huda *et al.* (1975), Chowdhury and Gore (1991) etc. In the present study relationship between rainfall and rice yield has been investigated for Ratnagiri and Thane districts of Maharashtra.

2. Soil and crop growth phases

The coastal strip in Ratnagiri district have alluvial and saline soils but inland, laterite derived from basalt, predominates. The soils in Thane district are mostly red to dark brown loamy. According to Alexandar (1972) the soils in these districts are rather acidic, particularly the laterite soils of Ratnagiri district which have pH values ranging from 5.0 to 6.5. This soil need liming to improve productivity.

Paddy transplantation commences early in Ratnagiri district, *i.e.*, 3rd/4th week of June while in Thane district it is slightly delayed. In both districts the vegetative phase of the plant lasts about 50-55 days, the reproductive stage 10-15 days and the grain setting and ripening last another 10-15 days. On the basis of above, the active growth period of the crop at the two districts comes out around 90 days. This general observation agrees well with the results obtained in the analysis, and discussed in a later section. It may be mentioned that the growth period determined here does not take into account the yield harvest which is carried out after a few days after the physiological maturity is attained in early October.

3. Basic data and the scope

The study is based on data from 1951 to 1987. Daily rainfall data from first June to first week of October were analysed. The weekly potential evapotranspiration values used in the study were interpolated from the monthly values given by Rao

TABLE 1

Frequency distribution (%) of planting dates

Criteria	Dates 16-22 May	23-29 May	31 May-5 Jun	6-12 Jun	13-19 Jun	20-26 Jun	27 Jun-3 Jul
			Ratnagiri district				
I	8.0	21.5	19.0	32.5	19.0		
II	5.5	13.5	24.3	29.7	24.3	2.7	
			Thane district				
I	2.7	8.0	19.0	27.2	27.2	16.0	
II		10.8	16.0	24.3	27.2	19.0	2.7

et al. (1971). Rice acreage and production figures were collected from state Department of Agriculture and supplemented by data from Economic and Statistical Advisor, Govt. of India, New Delhi. Ratnagiri district was bifurcated, administratively, in 1981 into Ratnagiri and Sindhudurg districts. For the sake of homogeneity in the data series, the part carved out (*i.e.*, Sindhudurg) from its 'mother' district (Ratnagiri) was considered as a part of the 'mother' district in the analysis.

In view of importance of planting dates, crop growth cycle, planting dates have been calculated assuming daily rainfall accummulation from 1st June onwards.

4. Analysis and discussion

4.1. *Time of transplanting and rice yields*

The time of transplanting determines the length of the growing season. This is because, the kharif crops are mostly dependent on southwest monsoon rainfall. Ideal dates of sowing from rainfall distribution has been attempted earlier in India (Raman 1974, Virmani 1975, India Met. Dep. 1984, 1986, 1989 etc). Some studies have also been reported from other countries, (*e.g.*, Stern and Coe 1982).

We know that farmers will plant the crop if adequate rainfall has already occurred. This 'adequate' rainfall should be such that it must be able to infilterate atleast a few centimetres of the soil surface and should be available to the seeds for initiating germination. It is rather difficult to quantify this 'adequate' rainfall. This is particularly so for water-loving plant like paddy. After examining various threshold amounts and keeping in view the rainfall amounts in the west coast, two threshold totals, *viz.*, 450 mm and 500 mm were separately selected for the sake of accumulation. 1st June was chosen as the starting day for both the criteria in this computation. Using these thresholds, an attempt was made to calculate the planting dates (*cf.* Morris and Zandstra 1978) and study its characteristics.

Frequency distribution of the dates of transplanting for both criteria is given in Table 1. Considerable variations in such dates can be seen from the empirical selection of the criteria. The median dates of transplanting were observed as 25th and 26th June for Ratnagiri district for both criteria with Semi-Interquartile Range (SIQR) of 6.5 and 6.7 days respectively. The mean actual dates have been worked out on the basis of actual transplanting over at least 25% of the cropped area for paddy, as reported by the State Government was 25th June. At 60% probability level the computed dates of transplanting in this district comes out as 27th and 28th June respectively for the two criteria.

The median date of transplanting for 450 mm threshold at Thane district was 30th June and for 500 mm, 2 days later. The actual dates in case of Thane comes out as 4th July which is 4 days later than those computed for 450 mm and 2 days later than that for 500 mm. The SIQR observed was 6.5 days in case of first criteria and 8 days in case of second criteria, for this district. It is obvious from the above analysis that the threshold amounts assumed are quite reasonable and in agreement with the actual transplanting dates in general for both thresholds though 450 mm criteria appear more representative of the actual conditions than 500 mm.

In view of large variability in the planting dates the rhythm of the crop growth may change. Early planting may lengthen the crop season, producing more vegetative growth, make plants tender and taller and so liable for lodging and pest and disease infestation. Delay in planting in turn may make the plant susceptible to moisture stress at same critical phases. In either case, yields should reveal some relationship, *albeit* negative in relation to transplanting. This has been confirmed when the dates of planting (reckoned as numbers starting from 1st June) for the two criteria were separately correlated with the de-trended yield. For this purpose a 3-year moving average was fitted to the yield. The deviation of trend yield from actual yield in a year as a fraction of trend yield was correlated with planting dates for both criteria separately. The correlation observed was — 0.32, for both the thresholds at Ratnagiri district. For Thane district, the corresponding correlations were even less, *i.e.*, —0.08 and —0.14. Thus the paddy yields do not appear to be sensitive to the dates of transplanting in Konkan coast.

Absence of association between sowing dates and yield was further corroborated from Table 2. The yields computed in previous paragraph were subjected to χ^2 analysis. The values obtained were 33.68 and 18.04 for Ratnagiri and 37.24 and 24.78 for Thane districts. In each of the cases χ^2 values were insignificant. Thus we accept the null hypothesis that yield of paddy in Konkan does not depend on the date of its transplanting.

4.2. *Yield-rainfall relationships*

The growing period considered in this study consists of the period when water storage in the soil (contributed mainly by rain water) is freely available to paddy. The entire growth cycle was divided into four periods *viz.*, transplanting, tillering, vegetative and reproductive called 1st, 2nd, 3rd and 4th stages respectively in the text. These four periods characterise the rainy season in relation to crop growth. In order to understand the influence of rainfall during the growth phases on

TABLE 2

Contingency table showing transplanting dates and yield deviations from trend

Planting dates	Trend Dep. (%) <—20	—11 to —20	0 to —10	1 to 10	11 to 20	>20	Total
Ratnagiri district							
Before 1 Jun		1	2	1	3		4
1-5 Jun		1	1	1	3		6
6-10 Jun			1	1	3		5
11-15 Jun			5	1	1		7
16-20 Jun	1	1		3	1	1	7
After 20 Jun	1	1		3	1		6
Total	2	4	9	10	9	1	35
Thane district							
Before 1 Jun		1	4	3	1		9
1-5 Jun			3	4			7
6-10 Jun	1	2	4	1			8
11-15 Jun	1	1	1	1			4
16-20 Jun	3		2			1	6
After 20 Jun							
Total	5	4	14	9	1	1	34

the yield, linear correlation were worked out between yield and rainfall for each of the four phases. Response of yield to total crop season rainfall were also examined through correlation.

During the first, *i.e.,* transplanting phase, rainfall appears mostly adequate to meet the evaporative demand in both Ratnagiri and Thane districts with correlations of 0.36 and 0.30 respectively. Tillering seems to be highly dependent on rainfall. In Ratnagiri district rainfall bears a correlation of 0.51 with yield while in Thane district it is 0.42 during the phase. Thus prolonged dry spell may force a farmer to replant.

During the third and fourth growth phases, the effect of rainfall in Ratnagiri appears marginal; presumably the water stored in the soil provide the requisite moisture to meet plant evaporative requirements. Similarly in Thane district rainfall during the vegetative growth stage does not have much influence, though the crop seems to have significant relationship with rainfall during the reproductive phase with correlation equal to 0.41.

When the seasonal rainfall was correlated with yield, it is seen that at Thane rainfall bears a correlation of 0.42, at Ratnagiri the correlation is comparatively large, *i.e.,* 0.50.

No large change in the correlations are observed when square term in each of the above parameters are introduced in the analysis. Absence of significant correlation in the square term implies absence of any optimal rainfall for yield in Konkan.

TABLE 3

Analysis of variance

	Sum of squares	Degrees of freedom	Mean sum of squares	*F* value
Ratnagiri district				
Regression	1849919.75	5	369983.94	8.30*
Residual	936650.81	21	44602.42	
Total	2786570.50	26		
Thane district				
Regression	2717844.50	4	679461.12	12.85*
Residual	1639544.38	31	52888.53	
Total	4357389.00	35		

* Significant at 1%

Agricultural technology is increasingly being used in Konkan during past few years. Use of dummy time scale variables is often recommended to take care of the increase in yield due to such factors in crop yield-weather relationship (Das *et al.* 1971, Chowdhury and Sarwade 1984, etc.). Introduction of this time scale dummy linear parameter showed that yield bears correlations of 0.76 and 0.77 in Ratnagiri and Thane districts respectively with the trend. In both cases the presumption that high doses of agro-technological inputs are being used in Konkan thus stands vindicated.

An attempt was also made to find out how combination of significant rainfall parameters in the four stages, yield index and the trend modify total variance. The analysis of variance is given in Table 3. The multiple correlation was large in Thane, *i.e.,* 0.81 and was slightly less, *i.e.,* 0.79 in Ratnagiri.

The high correlation (inclusive of rainfall parameters and trend) suggest that the model, with perhaps further refinement has a forecasting potential.

4.3. *Water balance approach : The yield index*

Frere and Popov (1979) have devised an index based on cumulative water balance over the whole growing season, by dividing it into suitable time intervals. The method takes into account water retained in the soil after considering water received by crops and water lost by crops and the soil.

The time interval taken in the study is a week. It is presumed that at the start of the growing seasons water is amply available, which is generally true for transplanted paddy. Ratnagiri and Thane get heavy rainfall at the start of monsoon and hence the above presumption is fulfilled. According to the methodology with 30 cm of rainfall during the first week of transplanting the index takes a value as 100. During the succeeding weeks the index remain 100 till either a surplus of more than 100 mm or a deficit in the water balance occurs. For surplus, for any amount of weekly rainfall of more than 100 mm the index is reduced by 3 to 97 and remains so till a deficit commence in any succeeding week. If in such a week, a deficit occurs, the ratio of deficit to water requirement for the

week (expressed as percentage) is further substracted from the value of the index in the immediately preceding week. This procees is repeated till the end of crop season.

The final yield index thus obtained was correlated with the yield in both the districts. In this case the linear correlation was found 0.47 in case of Thane but only 0.39 for Ratnagiri. Inclusion of square terms was not found to increase the correlation for the two districts.

The method provides thus a qualitative assessments. It may be pointed that for establishing a precise qualitative relation between yield and the index mentioned above, accurate agricultural statistics is needed. The low though statistically significant correlations obtained above may be due to lack of accurate farm records including dozes of technology like irrigation, fertilizers etc. Other factors which have not been considered and which do affect the yield are floods causing water logging, biological factors like locust, birds, fungi or insects.

As such for establishing an accurate relationship between index and yield, water status in the plant also should be taken. The index can then be used for monitoring crop development and forecasting yields.

5. Conclusions

The following conclusions could be drawn from the analysis :

(*i*) Daily rainfall accumulation of 450 mm from 1st June onwards furnishes a reasonably accurate and objective date of transplanting of paddy in Konkan.

(*ii*) Paddy yield does not seem to be much dependent on the date or transplanting.

(*iii*) Index developed from water balance bears significantly large correlation with paddy yield.

(*iv*) Rainfall during tillering phase appears essential for healthy crop growth and high yield.

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