Mausam, (1986), **37**, 4, 511-514

551.586:633

Yield-weather relationships of rice crop under different manurial treatments

K. RUPA KUMAR

Indian Institute of Tropical Meteorology, Pune

(Received 20 November 1984)

सार — जब धान की फसल में विभिन्न खादें डाली जाएं तो उस अवस्था में इसकी विभिन्न बढ़वार अवस्थाओं पर अधिकतम एवं न्यूनतम तापमान, सापेक्ष आर्द्रता तथा धूप के चमकने की अवधि जैसे मौसम विज्ञानी तत्वों का जो प्रभाव पड़ता है उसका धान की वास्तविक पैदावार पर पड़ने वाले प्रभाव का, सांख्यिकीय प्रतिउत्तर फलन निदर्श लगा कर अध्ययन किया गया है। इसके लिए प्रयुक्त आंकड़े 17° 38′ उत्तर तथा 83° 01′ पूर्व पर स्थित अनाकापल्ली के क्षेत्रीय कृषि अनुसंधान केन्द्र से प्राप्त किए गए हैं। फसल की पैदावार पर मौसम तत्वों के प्रभाव में सुधार करने के लिए विभिन्न खादों :(क) अमोनियम सल्फेट, (ख) मूंगफली की खल, (ग) खत्ते की देसी खाद, (घ) क तथा ख का नाइट्रोजन के आधार पर 1 : 2 के अनुपात में मिश्रण तथा (ङ) बिना खाद की भूमिका को समझने के लिए 28 वर्ष की अवधि का अर्थात् धान की फसल का विश्लेषण किया गया है। इस लेख में प्रत्येक खाद के अन्तर्गत पैदावार के लिए प्रत्येक परिमापक का प्रति उत्तर वक्र प्रस्तुत किया गया है। ऐसा पाया गया है कि विभिन्न खादों के अन्तर्गत फसल के प्रतिउत्तरों, विशेषकर अधिकतम तापमान व अपराह्न की सापेक्ष आर्द्रता के मामले में अन्तर मात्रा की दृष्टि से आमतौर पर बहुत कम है। बिना खाद की, मूंगफली की खल एवं अमोनियम सल्फेट के मिश्रण वाली फसलों ने न्यूनतम तापमान, वर्षा तथा धूप चमकने की अवधि के विषय में उल्लेखनीय अन्तर दर्शाए हैं।

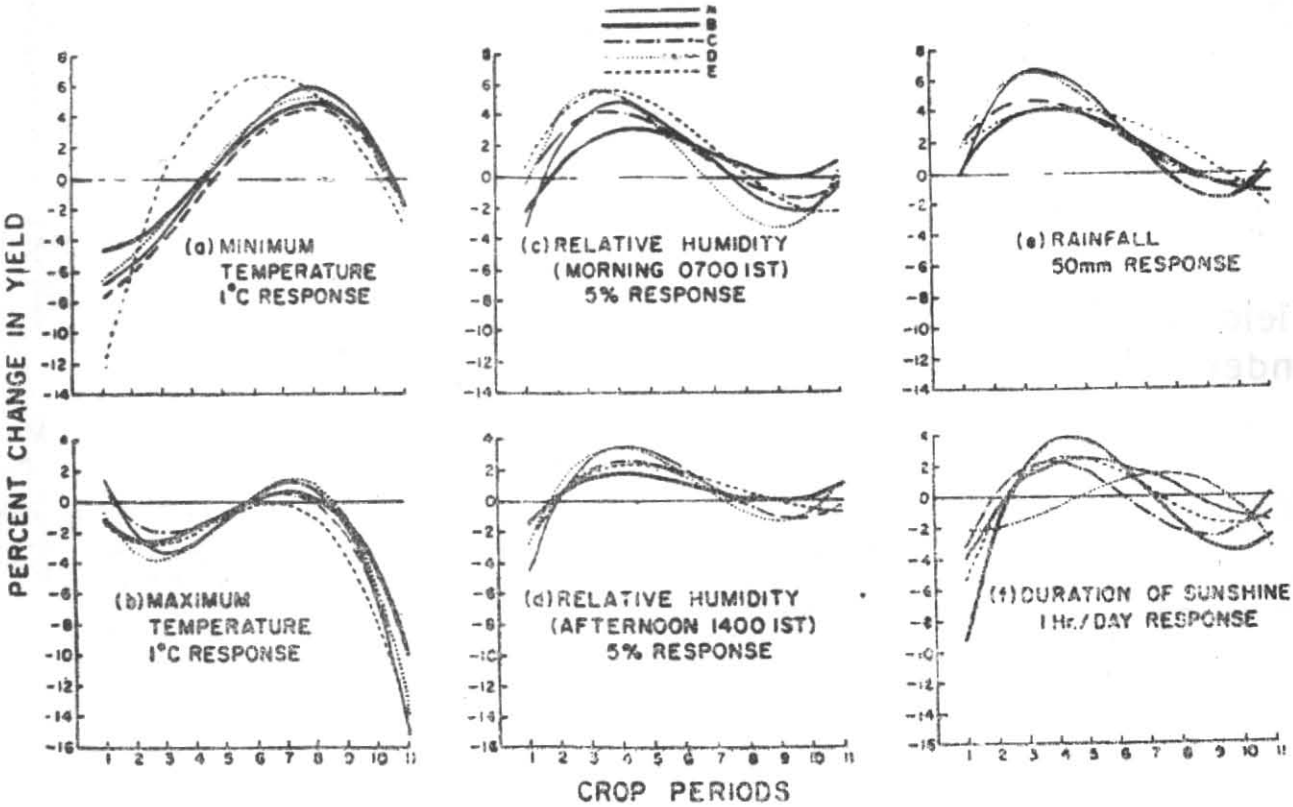
ABSTRACT. The influence of the meteorological factors maximum and minimum temperatures, relative humidity and duration of sunshine at different growth stages of rice crop on the final yield, when it is grown under different manurial treatments, is studied by fitting statistical response function models. The data used for the study have been collected from the Regional Agricultural Research Station at Anakapalle (17°38′N, 83° 01′ E). Rice crops under 5 types of manurial treatments, *viz.*, (A) Ammonium Sulphate, (B) Groundnut Cake, (C) Farm Yard Manure, (D) Mixture of A and B in 1 : 2 ratio on N basis and (E) No Manure, for 28 years are analysed to understand the part played by the manurial treatment in modifying the effects of weather factors on the crop yield. The response curves of each parameter for the yield under each treatment are presented. It is observed that the differences between the responses of crops under different manurial treatments are generally of small magnitudes, particularly in the case of maximum temperature and afternoon relative humidity. The crops under no manure and mixture of groundnut cake and ammonium sulphate show some differences in the case of minimum temperature, rainfall and duration of sunshine.

1. Introduction

For optimum growth the rice plant requires several climatic conditions. It must have high temperatures, a moderately long growing season, sufficient solar radiation, a large volume of water evenly distributed through a major portion of the growing season and a ripening period which is relatively dry (Huke 1976). This ideal rice climate is, of course, somewhat vaguely defined and variations within these conditions do significantly contribute to changes in crop yields.

Some attempts have been made in India to understand the influences of weather factors on the rice crop. Ghosh (1970) noted that high maximum temperature (29°-33° C) and high relative humidity (78-86%) at all stages of growth and bright sunshine at early stages contributed to good yields of rice at Cuttack. Sreenivasan and Banerjee (1973) reported a favourable response of the crop to rainfall during the panicle initiation phase at Karjat, though the integrated influence of rainfall was stated to be not statistically significant. Huda *et al.* (1975) reported that high temperatures and relative humidity were favourable during the establishment phase and high maximum temperature during the ripening period, at Pantnagar. Sreenivasan and Banerjee (1978) found that, at Coimbatore and Aduthurai, additional rainfall was detrimental to the rice crop during sowing, tillering, and flowering periods and bright sunshine throughout the crop season except nursery period were noted to be beneficial. Rupa Kumar and Subbaramayya (1984), using the data at Anakapalle, found that lower maximum temperatures and higher relative humidity during vegetative phase and bright sunshine during panicle initiation, are favourable to the rice crop.

For obtaining increased yields, application of different kinds of manurial treatments, depending on the convenience of the farmers, has been the practice since quite a long time. Though the nutrient contents of the manures may be similar, the form of availability can be different and the plant's ability to draw on the nutrients plays an important role in the yield forming processes. This ability is largely governed by the plant's physiological activity which is again considerably



Figs. 1 (a-f). Weather induced yield response curves for rice crop under different manurial treatments

influenced by the environmental conditions. The objective of the present study is to examine the crop-weather relationships of rice under different manurial treatments and then to attempt to bring out the nature of the general differences if any, in the responses of rice plants to changes in meteorological parameters.

2. Data and analysis

At the Regional Agricultural Research Station at Anakapalle (17°38'N, 83° 01'E), rice crop (GEB-24 cultivar) is grown every year under the permanent manurial experiment. The crop is grown during the kharif season with limited protective irrigation. Four types of manurial treatment, namely, (A) Ammonium Sulphate, (B) Groundnut Cake, (C) Farm Yard Manure and (D) Mixture of A and B in 1 : 2 ratio on N basis, are applied to the crop. There is a check plot with no manure (E). Cultural operations are maintained uniform every year. Under treatments A, B and D, a manure equivalent of 67 kg N/ha is supplied 29 days after transplanting. In the case of treatment C, the same equivalent quantity is supplied before puddling. The crop is sown in the last week of June and harvested in the 2nd week of December.

Rice yield data for 28 years from 1952 to 1979, under all the five treatments each year, have been collected from this station. Daily meteorological data on maximum and minimum temperatures, relative humidity in the morning (0700 IST) as well as afternoon (1400 IST) and rainfall have been collected for the same period. Sunshine observations, however, are available only from 1965.

The method used in the present study, to obtain the response in yield for a unit change in the meteorological factor from its average, is the same as that used by Runge and Odell (1958) who adopted it from Fisher (1924). For the purpose of this analysis, the total crop season is divided into 11 fortnightly periods and the mean values of all the meteorological variables have been evaluated for each period every year. The crop would be in vegetative phase during the first 5 fortnights and reproductive and ripenning phases later. A preliminary examination of the 28-year average values of the meteorological factors shows that a third degree polynomial in time accounts for more than 90% of the variation of all those factors during the crop season. Therefore, it is assumed that a third degree polynomial would adequately describe the distribution of any meteorological factor during the crop season, and the following multiple regression equation has been developed for each of the treatments and weather variables :

$$y = A_0 + \sum_{i=0}^{3} a_i \left[\sum_{t=1}^{11} t^i x_t \right] \qquad (1)$$

where y is the rice yield, A_0 and a_i are the regression coefficients and x_t is the mean value of the meteorological factor during the crop period t. t takes numerical

TABLE 1

Average values of meteorological factors during rice crop season at Anakapalle and multiple correlations of response functions

Crop period No.	Dates	Max. temp. (°C)	Min. temp. (°C)	Relative humidity (Morning) (%)	Relative humidity (Afternoon) (%)	Rainfall total (mm)	Duration of sunshine† (hrs/day)
1	26 Jun-10 Jul	33.1	25.1	84.6	64.7	73.5	4.1
2	11 Jul-25 Jul	32.9	24.9	86.1	66.7	74.6	4.1
3	26 Jul-10 Aug	32.5	24.8	87.2	67.8	73.6	3.9
4	11 Aug-25 Aug	32.9	24.7	86.6	66.8	78.4	4.8
5	26 Aug-10 Sep	32.7	24.5	88.6	68.6	97.8	4.8
6	11 Sep-25 Sep	32.8	24.3	90.5	69.5	97.6	6.0
7	26 Sep-10 Oct	32.2	23.7	91.3	70.8	133.1	6.1
8	11 Oct-25 Oct	31.4	22.8	88.7	67.7	121.1	7.3
9	26 Oct-10 Nov	30.8	21.1	85.9	61.0	57.5	7.7
10	11 Nov-25 Nov	30.0	19.0	82.9	55.3	24.4	7.6
11	26 Nov-10 Dec	29.4	17.8	84.1	51.6	17.4	8.1
Multiple correlation coefficients of response regression functions							
Treatment A		0.67***	0.55*	0.36	0.44	0.50	0.20
Treatment B		0.58**	0.53*	0.26	0.37	0.46	0.46
Treatment C		0 63**	0.58**	0.35	0.36	0.42	0.26
Treatment D		0.66***	0.49	0.40	0.44	0.49	0.22
Treatment E		0.65**	0.47	0.39	0.31	0.43	0·18

†Values for sunshine are based on 15 years data; all the others are based on 28 years data.

*Significant at 10% level;

**Significant at 5% level;

***Significant at 1% level.

values 1, 2,..... upto 11. After estimating the regression coefficients by least squares technique, the required response function is obtained by differentiating y with respect to x in Eqn. (1) at any particular crop period t :

$$\left.\frac{\partial y}{\partial x}\right|_t = \sum_{i=0}^{3} a_i t^i \qquad (2)$$

This equation gives the response ∂y in the yield for a given change ∂x of the meteorological factor during the crop period t. The yield responses thus obtained are converted into percentage proportions of the 28-year mean yield of the corresponding treatment, for convenience of interpretation.

The basic assumptions in this method are, (*i*) the total effect on the yield is directly proportional to the number of units of the meteorological factor above or below average, (*ii*) a unit of meteorological factor affects the yield by the same amount, but in opposite directions, for that factor above or below average, and (*iii*) the effect of each period is independent from that of any other period.

3. Results

The 28-year average values of different meteorological parameters for all the crop-periods are presented in Table 1. The average values of rice yields under the treatments A, B, C, D and E are 2531, 2851, 2948, 2765 and 1929 kg/ha respectively. The multiple correlation coefficients of the regression equations developed for obtaining the response functions are also included in Table 1. It can be seen that the correlations in the case of maximum and minimum temperatures are quite high and some are statistically significant. The response curves are presented in Figs. 1(a) through 1(f) and some important points are noted below :

(*i*) *Minimum temperature* — Rice yield in the case of all treatments except no manure is showing similar response (Fig. 1a) to 1°C increase in minimum temperature above average. Lower minimum temperatures are required during first 4 fortnights and higher afterwards upto the 10th period. Negative response was maximum during the first fortnight (—5 to —8%) and positive in the 8th fortnight (+4 to+6%). For the manureless crop, higher minimum temperatures seem to be favourable from an earlier stage than the others, from the 3rd fortnight. The magnitudes of responses are also higher, being—12% in the 1st fortnight and about +7% in the 6th and 7th periods. In the last fortnight, lower minimum temperatures are better for the crop.

(*ii*) *Maximum temperature* — The response curves are almost similar for maximum temperature (Fig. 1b) with all treatments. During a major part of the crop season, lower maximum temperature is favourable. Only during the 7th and 8th fortnights higher maximum temperature is marginally favourable. The negative response is very large (—10 to —16%) at the end of the crop season.

(*iii*) *Relative humidity* — Rice yield response to above average relative humidity is similar in the morning (Fig. 1c) and afternoon (Fig. 1d). However, the magnitudes of responses are slightly higher for the morning relative humidity. Humid conditions are favourable during most part of the vegetative growth and drier conditions are required during the nursery stage and during ripening and maturity. The crop treated with the mixture of ammonium sulphate and groundnut cake shows particularly larger response than the others.

(*iv*) *Rainfall* — In the case of rainfall, rice crop under all treatments except no manure shows similar yield responses (Fig. 1a). More rainfall is favourable during the first 8 fortnights and unfavourable later. Maximum positive responses of +4 to+7% occur during the 3rd and 4th fortnights. For the manureless crop, however, additional rainfall is favourable right upto the period between the 9th and 10th fortnights.

(*v*) *Duration of bright sunshine* — For above-average duration of sunshine, the crop under all treatments except the mixture of ammonium sulphate and groundnut cake (D) is showing similar responses. Additional duration of sunshine is not favourable during the first

two and last four fortnights. For treatment D, however, it is not favourable during the first four and last two fortnights. The maximum positive response is found near the 4th and 5th fortnights for other treatments (+2 to+4%) while it is at the 7th and 8th fortnights in the case of treatment D (+1%).

4. Discussion and conclusions

(i) General influence of weather factors on rice yield

Rice crop shows significant yield response to variations in maximum and minimum temperatures. Lower maximum temperatures than at the station during most part of the crop season and higher minimum temperatures during late vegetative and early reproductive phases are favourable for good yields. Higher humidity and good rainfall during the vegetative phase is generally favourable. More sunshine during the tillering and elongation periods is good for the crop.

(ii) Role of manurial treatment in modifying rice-weather relationships

The differences between the responses of crops under different manurial treatments are generally of small magnitudes, particularly in the case of maximum temperature and afternoon relative humidity. The crop under no manure differs from the manured crops which show remarkably similar responses among themselves to minimum temperature. The manureless crop requires relatively lower minimum temperature during the establishment phase and higher during the vegetative phase. It appears that the crops under ammonium sulphate as well as the mixture of ammonium sulphate and groundnut cake require relatively more humidity and rainfall during the vegetative growth period and drier conditions during the maturity phase. The crop under groundnut cake shows least responses of all the treatments. The crop without manure requires above normal rainfall during most of the crop season, whereas the manured plots require dry conditions during the ripening and maturity phases. Mixture of ammonium sulphate and groundnut cake differs from the other treatments in the crop's response to the duration of sunshine. It is not much sensitive to sunshine variations and requires more sunshine during the early part of the reproductive growth and less at other times. Other treatments, however, show good and similar responses, *viz.*, low sunshine requirements during the establishment and late reproductive-phases and better sunshine during the tillering and vegetative periods.

Acknowledgements

The author is thankful to the authorities at the Regional Agricultural Research Station at Anakapalle for kindly providing the necessary data, to Prof. I. Subbaramayya, Department of Meteorology and Oceanography, Andhra University, Waltair, for his helpful suggestions, to Dr. Bh. V. Ramana Murty, Director, Indian Institute of Tropical Meteorology (I.I.T.M.), for providing the necessary facilities to carry out the study and to Dr. G.B. Pant, Asst. Director (Climatology), I.I.T.M., for encouragement. Thanks are also due to Miss S.V. Bilay for typing the manuscript.

References

Fisher, R.A., 1924, The influence of rainfall on the yield of wheat at Rothamsted, *Roy. Soc. (London) Phil. Trans.*, **Ser, B,** 213, 89-142.

Ghosh, A.K., 1970, Effect of climatic factors on the growth and production of rice, FAO International Rice Commission Working Party on Rice Production and Protection, 13th Session, Teheran, 9-14 December, Item No. 5.

Huda, A.K.S., Ghildyal, B.P., Tomar, V.S. and Jain, R.C., 1975, Contribution of climatic variables in predicting rice yield, *Agric. Met.*, **15,** 71-86..

Huke, R., 1976., Geography and climate of rice, proceeding of the symposium on climate and rice, International Rice Research Institute, Los Banos, pp. 31-50.

Runge, E.C.A. and Odell, R.T. 1958. The relation be ween precipitation, temperature and the yield of corn on the Agronomy, South Farm, Urbnaa, Illionis, *Agron. J.*, 50, 448 454.

Rupa Kumar, K. and Subbaramayya, I., 1984, Crop- Weather relationships of rice at Anakapalle, *The Andhra Agric. J.*, **31**, 1-8.

Sreenivasan, P. S. and Banerjee, J.P., 1973, The influence of rainfall on the yeild of rainfed rice at Karjat (Colaba District), *Agric. Met.*, 11, 285-292.

Sreenivasan, P.S. and Banerjee, J.R. 1978, Behaviour of the Co-25, variety of unirrigated rice under two environments, *Agric. Met.*, **19**, 189-202.