632.11 : 631.559

ESTIMATION OF PADDY YIELD ON THE BASIS OF CLIMATIC ELEMENTS AT RAIPUR

1. Rice (*Oryza sativa* L.) is the second staple food of human beings. In Chattisgarh region of Madhya Pradesh, it is the main crop which is grown under rainfed conditions. Therefore, weather plays an important role in different phenological growth phases of the crop. There are three separate approaches in studying the impact of weather on the crop yield. In the first, an empirical statistical ralationship is established between crop yield and the crop growth parameters (Gangopadhyaya and Sarkar 1964 a, b). In the second case a relationship between climatic element and crop yield is developed (Sreenivasan 1972, Shanker and Gupta 1987, Chowdhury and Sarkar 1981, Baier 1977); the third approach is based on simulation models which involves a mathematical representation of the basic physiological processes governing growth and development (Penning de vries 1983). The aim and objective of this paper is to develop a multiple linear regression equation to estimate paddy yield from the combined effect of different climatic elements and technological trend.

2. Paddy yield data were collected from the "Agricultural Statistics" published by the Directorate of Agriculture, Govt. of Madhya Pradesh. Weekly climatic data of maximum and minimum temperatures, relative humidity (RH) at 0700 IST and 1400 IST, bright sunshine hours (BSH), total rainfall and number of rainy days (NRD) have been collected for the period of 41 years (*i.e.* from 1951-1991) from the Department of Physics & Agro-meteorology, Raipur situated at (21°16'N, 81°36'E, 289 m asl). The crop period of paddy at Raipur spans 19 weeks from 26th (25 June-1 July) to the 44th (29 October-4 November) standard week. This study uses two different methods, *i.e.*, method based on crop growth phases and maximum correlation method, for developing regression equations and estimating paddy yield.

2.1. In this method crop period is split into following four phenological phases :

(a) Seedling (establishment) phase	26th to 30th Standard week (25 June to 29 July)
(b) Vegetative phase	31st to 35th Standard week (30 July to 2 September)
(c) Reproductive phase	36th to 40th Standard week (3 September to 7 October)
(d) Maturity phase	41st to 44th Standard week (8 October to 4 November)

2.2. Multiple linear regression equation for each phase was developed to predict the crop yield using predictor variables as the averages of each of seven climatic elements over different weeks in the given phase. Maturity phase has not been considered for forecast purpose, because after this phase, the prediction equation loses its utility. In fact, forecast is useful only before harvest.

2.3. In this method correlation coefficients (CC) between paddy yield and all the individual climatic elements except rainfall and NRD have been calculated for different weeks ranging from 26th to 37th standard weeks (*i.e.* from 25 June to 10 September). Similarly, the correlation coefficients were calculated for 2, 3, ..., 12 point moving averages taken over the 12 consecutive weeks (*i.e.* 26th-37th standard weeks). Next, the correlations obtained from weekly as well as moving average basis were pooled together. Out of these, the significant maximum correlation coefficients (MCC) were selected corresponding to each of the climatic element. The week(s) corresponding to MCC is termed as sensitive period (Gupta and Singh 1988) of the given climatic element. For the climatic elements rainfall and NRD, the moving cumulation of data was done instead of taking moving averages. Finally, sensitive periods obtained for each of 41 years corresponding to different climatic elements and the technological trend variable were together regressed on paddy yield.

2.4. The technological trend variable (say T_t) was introduced to explain away the effects of technologies (*i.e.* use of fertilisers, high yielding varieties, insecticides, improved agronomic practices etc.). The values of T_t were considered following the method of Chowdhury and Sarwade (1983). On plotting the yield over time, the time trend was observed only from 1980 onwards. Therefore, T_t were given values equal to 1 for each of the years from 1951 to 1980. Thereafter, the values 2, 3, ... 12 were assigned to each of the years from 1981 to 1991. Because of the multi-collinearity existing between different climatic elements, the stepwise regression procedure (Draper and Smith 1981) was followed to obtain the multiple linear regression equation.

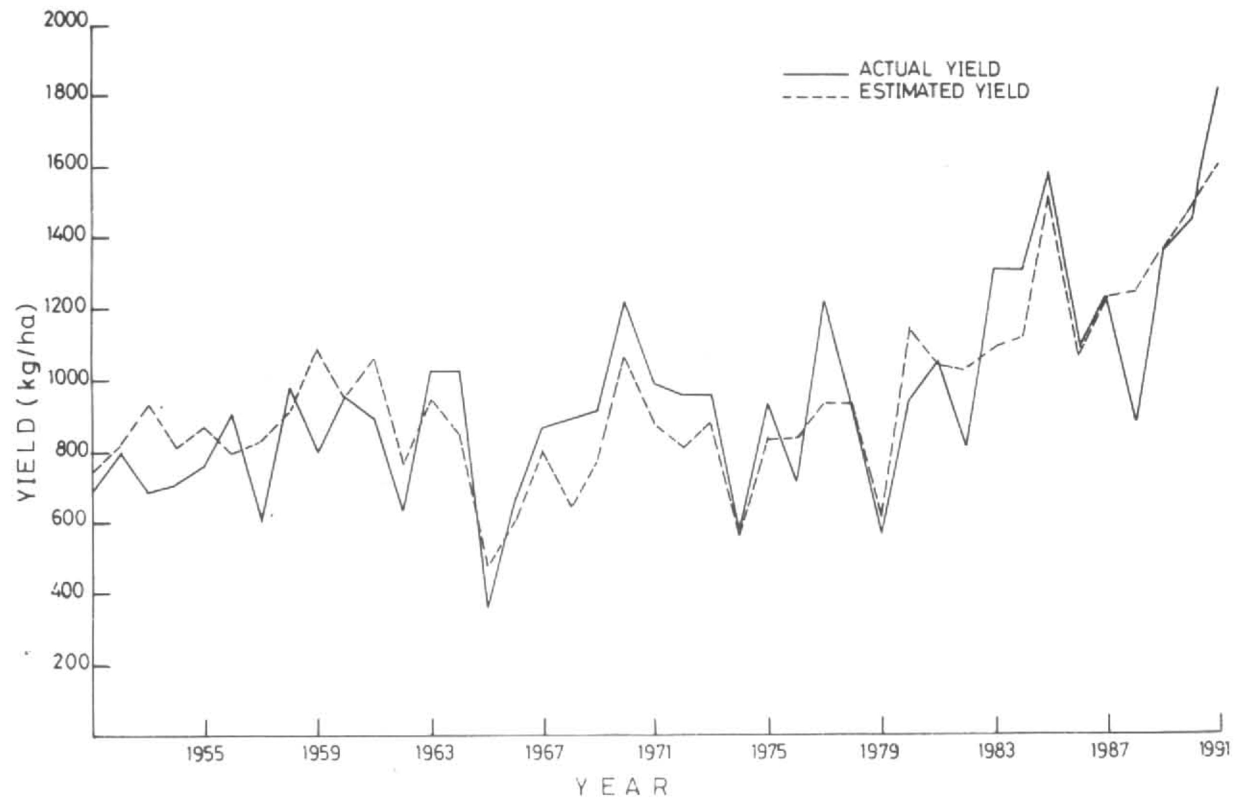

Fig. 1. Actual and estimated paddy yield at Raipur

3. From the regression equations developed for respective phases it was seen that coefficients of determination (R^2) in the seedling, vegetative and reproductive phases were significant at 5% level. The variation in yield accounted for by these phases were 34%, 32% & 41% respectively. However, none of the partial regression coefficient were found significant.

3.1. Phase wise — correlation study was also done to determine relationship between the paddy yield and different climatic elements. Maximum temperature showed significant (at 5% level) negative correlation with paddy yield in all the phases (-0.3134 to -0.3773) which may be because the maximum temperature was above the optimum condition as given by Nishiyama (1976), *i.e.*, 30-33°C. High maximum temperature is thus not favourable for rice crop at Raipur. BSH is significant (at 1%) and negatively correlated with seedling phase (-0.4456). It means lower amount of sun shine helps better establishment of the seedlings (Rupa Kumar and Subbaramayya 1984). Rainfall showed positive correlation in seedling (0.3324) and reproductive phase (0.3731) of the crop (both significant at 5% level). The PET requirements of paddy during these phases are therefore suitably met by the rainfall giving a favourable indication for a good paddy yield. The RH morning and afternoon also showed positive significant correlations during seedling (0.3614 and 0.4693) and reproductive phase (0.4308 and 0.5886). Thus high relative humidities during these phases are favourable for crop growth and development and in turn for higher yield.

3.2. The climatic elements, period of sensitive standard weeks and the corresponding maximum correlation coefficients are shown in Table 1. Using the maximum correlation method as described above, the following multiple regression equation was obtained. All the partial regression coefficients were found significant.

$$Y = -3334.5 - \underset{(2.9)^{**}}{37.5\,X_3} + \underset{(2.63)^{**}}{0.68\,X_4} + \underset{(3.83)^{**}}{18.8\,X_7} + \underset{(7.86)^{**}}{36.6\;T_t} \qquad (1)$$

$$(R^2 = 0.74^{**})$$

where Y is the estimated yield; X_3, X_4, X_7 have the same meaning as in Table 1 and T_t is the technological trend variable.

TABLE 1

Climatic elements and values of the maximum correlation coefficient during sensitive periods

Weather elements	Variable defined as	Period of sensitive standard weeks	Max. Corr. Coefficient
Maximum temp. (°C)	X_1	34-35	−0.4670**
Minimum temp. (°C)	X_2	—	—
Bright hours of sunshine	X_3	27-28	−0.5101**
Rainfall (mm)	X_4	35-37	0.4527**
Number of rainy days	X_5	33-37	0.4415**
Rel. humidity (%) (Morning)	X_6	28-36	0.4646**
Rel. humidity (%) (Afternoon)	X_7	32-35	0.6050**

** Significant at 1% level of significance.

3.3. The actual and estimated yields are shown in Fig. 1. This shows a very good fit between estimated and the actual yield. It was discovered that in 44% of cases the deviations of the estimated yields were within ±10% of the actual yields, in 39% cases the deviations ranged between ±11-20% and in remaining 17% cases the same lied between ±21-40% of actual yield. For the sake of further validation the predicted yields were calculated for 1992, 1993 and 1994. The departures of the predicted yield from the actual yield were found to be between ±7-13%. Thus, our model therefore tends to forecast within the tolerable limits. From the economic point of view, this regression equation can be used as a predictive model which can estimate paddy yield during the second week of reproductive phase, *i.e.,* two and half months before harvest.

4. The salient features of the present study are summarised below :

(*i*) It is seen that rainfall, number of rainy days, morning or afternoon relative humidities during seedling to reproductive phases, help increase paddy yield.

(*ii*) Maximum temperature from seedling to maturity phases causes decline in the yield.

(*iii*) The multiple regression method gave 74% coefficient of determination and showed a very good agreement between actual and estimated yield.

(*iv*) The paddy yield at Raipur can be predicted during the second week of reproductive phase, *i.e.,* two and half months before harvest.

References

Baier. W., 1977, W.M.O. Tech. Note No. 151, Geneva.

Byrne. G. W. and Drummond, J. E., 1980, *Agric. Meteorol.*, **22**, pp. 1-9.

Chowdhury, A. and Sarkar, M. B., 1981, *Mausam*, **32**, 4, pp. 393-396.

Chowdhury, A. and Sarwade, G. S., 1983, *Mausam*, **36**, 2, pp. 209-214.

Draper, N. R. and Smith, H., 1981, John Wiley & Sons, New York, pp. 307-311.

Food and Agricultural Organization of the United Nations (FAO), 1981, Report on the Agro-ecological zones project, Rome, 251 p.

Gangopadhyaya, M. and Sarkar, R. P., 1964 (a), *Indian J. Met. Geophy.*, **15**, 2, 201 p.

Gangopadhyaya, M. and Sarkar, R. P., 1964 (b), *Indian J. Met. Geophy.*, **15**, 2, 215 p.

Gupta, B. R. D. and Singh, K. K., 1988, *Mausam*, **39**, 4, pp. 421-424.

Nishiyama, I., 1976, In Proc. Symp. Climate and rice, pp. 159-185.

Penning de vries, P. W. T., 1983, In : *Physiological Plant Ecology* IV, pp. 118-150.

Rupa Kumar, K. and Subbaramayya, I., 1984, *The Andhra Agri. J.*, **31**, 1, pp. 1-8.

Shanker, U. and Gupta, B. R. D., 1987, *Mausam*, **38**, pp. 415-418.

Sreenivasan, P. S., 1972, *Indian J. Met. Geophys.*, **23**, 3, pp. 385-392.

Stewart, D. W., 1984, *Agric. and For. Meteor.*, **32**, pp. 71-77.

SUCHIT K. RAI
A. KUMAR SINGH
J. L. CHAUDHARY
A.S.R.A.S. SASTRI

Indira Gandhi Agricultural University, Raipur

19 October 1994. Modified 10 April 1996