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Effect of temperature and sunshine on the productivity of rice crop

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सार — धान की खेती पर धूप एवं तापमान के प्रभाव का आठ विभिन्न तापीय एवं प्रकाशीय परिस्थितियों के प्रयोग के आधार पर अध्ययन किया गया। यह पाया गया है कि शीत/ग्रीष्म ऋतु के दौरान तैयार होने वाली धान की फसल की पौध लगाने के समय तथा पौधों की बढ़ोत्तरी की अवस्था में सबसे न्यूनतम तापमान की तथा पौधे में दाना आने के समय और फसल के पकने के समय सबसे अधिकतम तापमान की आवश्यकता पड़ती है। फसल पैदावार और अधिकतम एवं न्यूनतम तापमान, पौधों की बढ़ोत्तरी के दिनों और फसल तैयार होने की प्रत्येक अवस्था में, जैसे, पौध लगाने, बढ़ोत्तरी, दाना पड़ने और फसल पकने की अवस्थाओं के मध्य सहसंबंध गुणांकों का पता लगाया गया है।

धान की पैदावार के पूर्वानुमानों हेतु फसल की बढ़ोत्तरी की अवस्था तक पांच प्राचलों सहित बहुगुण समाश्रयण समीकरण तैयार किया गया है।

ABSTRACT. Based on the experimental work with 8 different thermal and light environments, the effect of temperature and sunshine on rice crop (var : IR-36) was studied. It was found that the rice crop grown during winter/summer season experiences extremes of minimum temperature at seedling and vegetative stages and extemes of maximum temperature at reproductive and maturity stages. Correlation coefficients between the grain yield and maximum and minimum temperatures, growing degree days and total number of sunshine hours at each of the growth stages, *viz.*, seedling, vegetative, reproductive and maturity stages were worked out.

Multiple regression equation was worked out with 5 parameters upto vegetative stage to predict the grain yield of rice.

Key words — Rice crop, Temperature, Sunshine, Regression equations, Degree days.

1. Introduction

For better crop growth, development and finally for grain yield, three important climatic regimes, *viz.*, moisture, thermal and light regimes, need to be in optimum conditions. Doorenbos and Pruitt (1977) expressed that the productivity of a crop is dependent on the extent to which certain optimum conditions of solar radiation, temperature and growing degree days are satisfied during different stages of crop growth. Each growth phase of rice crop, according to Yosihda (1978) has critical low and high temperature limits, normally above 20°C and below 30°C. Phenology models are used based on Growing Degree Days (GDD) for evaluating the length of growing season and thereby productivity (Major *et al.* 1975 and Neild & Seeley 1977).

In Chhattisgarh region of Central India (Fig. 1) rice is grown in about 3.7 million hectares during monsoon season. The sowing time of the crop depends upon the onset of monsoon while the harvest time is around mid-November as the winter conditions (night temperature below 12-15°C) set in afterwards. In years of late onset of monsoon, the rice crop suffers from cool weather conditions at reproductive and maturity stages and in case of early onset of monsoon, sunshine during the reproductive stage limits the productivity of early maturing varieties like IR-36. Therefore, in this paper, an attempt has been made to examine the effect of thermal and light regimes at different growth stages on crop productivity for this particular variety.

2. Material and methods

Experiments were conducted at the Research Farm of Indira Gandhi Agriculture University,

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Fig. 1. Location map of Chhattisgarh region and different agroclimati zones

Raipur to examine the influence of temperature and sunshine on productivity of rice crop (var : IR-36) during the monsoon and winter seasons of 1992-93 and monsoon season of 1993.

There were, altogether, 8 sowing dates, *viz.*, 20 June, 5 July, during kharif 1992, 9 December, 2 January, 25 January during rabi 1992-93 and 25 June, 10 July, 4 August in kharif 1993. The meteorological data required for the analysis were collected from the adjacent agro-meteorological observatory. The GDD under each of the sowing dates were computed using the formula (Major *et al.* 1975) :

$$GDD = \sum_{i=1}^{n} \frac{(T_{max} + T_{min})}{2} - T_t \qquad (1)$$

where,

T_{max} = Daily maximum temperature (°C)
T_{min} = Daily minimum temperature (°C)
T_t = Basal temperature

The Basal temperature, in this case, is taken as 10°C as the minimum of cardinal temperatures for rice is 10°C (Mavi 1986). Correlation coefficients and multiple regression equations were worked out between the grain yield (Y) and mean maximum and minimum temperatures, bright hours of sunshine and growing degree days at each of the growth stages, *viz.*, seedling, vegetative, reproductive and maturity stages.

3. Results and discussion

The average maximum and minimum temperatures, total growing degree days and total number of sunshine hours from sowing to harvest of the crop on 8 different dates of sowing during the study period are shown in Table 1. As the crop grown during winter/summer period flowers and matures during peak summer season, the total number of degree days was much higher during winter period than during monsoon season. Similarly, crop grown during the winter/summer period received 2 to 2.5 times more number of sunshine hours than the crop grown during monsoon season. With higher temperatures, growing degree days and total number of sunshine hours, the productivity of rice is always higher in this area during winter/summer season as compared to monsoon season.

With 8 different thermal and light environments during the growing season of the crop in the study

TABLE 1

Average maximum and minimum temperatures, growing degree days and total bright sunshine hours during the growing period for different dates of sowing of rice crop (var : IR-36) and corresponding grain yield

Date of sowing	Maximum temp. (°C)	Minimum temp. (°C)	Growing degree days	Total bright sunshine hours	Yield (kg/ha)
20 Jun 1992	31.4	22.5	2035.6	544.0	3650.0
5 Jul 1992	31.0	22.1	1977.6	641.8	2050.0
9 Dec 1992	32.3	17.4	2431.8	1372.8	5485.0
2 Jan 1993	36.1	18.4	2834.8	1540.6	4800.0
25 Jan 1993	37.1	19.7	2716.6	1351.2	6514.0
25 Jun 1993	30.8	24.7	2026.9	557.8	4416.0
10 Jul 1993	30.5	23.9	1960.6	642.1	3417.0
4 Aug 1993	30.1	19.7	1789.2	774.0	2200.0
Average	32.4	21.1	2221.7	928.0	4066.5

period, the effects of temperatures, growing degree days and total number of sunshine hours were worked out for each of the growing seasons and for each of the sowing dates.

The range of temperatures, growing degree-days and total number of sunshine hours in each growth period are given in Table 2. It can be seen that the range of the mean maximum temperature averaged for each date of sowing was 28.3 to 34.7, 29.4 to 36.9, 29.5 to 43 and 29.5 to 43.6°C during seedling, vegetative reproductive and maturity stages respectively. Thus, the range of maximum temperatures was higher during reproductive and maturity stages in kharif and rabi crop. For the minimum temperature, the lower limits of the range are detrimental for the growth and development of rice crop. For example, during the seedling stage the range of minimum temperature was 9.8 to 23.6°C while at reproductive stage the range was 19.1 to 23.4°C. The maximum temperatues during reproductive and maturity stages and minimum temperatures during seedling and vegetative stages are in the extreme limits for the winter/summer crop. The range of growing degree days varied from 1789 to 2835 with the mean value of 2222.

Similarly, the range of the mean total number of sunshine hours was 69.5 to 486.5 hours, 79.4 to 378.4, 103.4 to 408.0 and 215.1 to 357.3 hours during seedling, vegetative, reproductive and maturity stages respectively. The higher values of total number of sunshine hours during the seedling stage were due to longer duration of seedling stage (30-40 days) during winter season.

Based on the data of 8 different crop-growing environments for rice, correlation coefficients between the grain yield and each of maximum and minimum temperatures, growing degree days and total number of sunshine hours were worked out and are shown in Table 3.

It can be seen that the sunshine hours during the seedling and vegetative stages are significantly correlated with crop yield, as during these stages, sunshine becomes a limiting factor for the crop grown during kharif seaon while the maximum temperature is significantly correlated with grain yield in all stages of crop growth except in seedling stage.

Interestingly, the minimum temperature during seedling stage was negatively and significantly correlated with grain yield while it is positively correlated during maturity stage. As the rice crop is exposed to lower night temperatures at maturity stage for the crop grown during monsoon season, higher minimum temperatures are favourable for higher productivity. But the negative correlation of minimum temperatures during seedling stage needs some more thorough investigation.

Multiple regression equations between the four parameters averaged for the season and grain yield

TABLE 2

Range of temperatures, growing degree days and total number of sunshine hours averaged for each growth stage of rice crop

Stage of crop	Max. temp. (°C)	Min. temp. (°C)	Growing degree days (GDD)	Total bright sunshine (hrs)	Yield (kg/ha)
Initial Seedling stage					
(*i*) Highest*	34.7	23.6	546.3	486.5	—
(*ii*) Lowest**	28.3	9.8	410.0	69.5	—
(*iii*) Mean	31.1	18.7	464.6	227.1	—
Vegetative stage					
(*i*) Highest	36.9	23.4	574.0	378.4	—
(*ii*) Lowest	29.4	12.5	467.4	79.4	—
(*iii*) Mean	31.4	20.0	510.2	194.0	—
Reproductive stage					
(*i*) Highest	43.0	23.4	914.7	408.0	—
(*ii*) Lowest	29.5	19.1	557.5	103.4	—
(*iii*) Mean	34.3	22.5	675.3	267.4	—
Maturity stage					
(*i*) Highest	43.6	26.7	862.3	357.3	—
(*ii*) Lowest	29.5	12.2	324.7	215.1	—
(*iii*) Mean	34.7	21.9	600.6	261.7	—
Whole crop growth period					
(*i*) Highest	37.1	24.7	2834.8	1540.6	6514.0
(*ii*) Lowest	30.1	17.4	1789.2	543.9	2050.0
(*iii*) Mean	32.4	21.1	2221.6	928.0	4066.5

* Highest of the averages of 8 thermal environments.
** Lowest of the averages of 8 thermal environments.

TABLE 3

Correlation coefficients between grain yield of rice (IR-36) and maximum and minimum temperatures, growing degree days and total number of sunshine hours at each growth stage

Stage	Correlation coefficients with			
	Max. temp. (°C)	Min. temp. (°C)	Growing degree days	Total sunshine hours
Seedling	−0.36	−0.78*	0.80*	0.82*
Vegetative	0.75*	−0.62	0.61	0.78*
Reproductive	0.77*	0.23	0.76*	0.53
Maturity	0.80*	0.79*	0.80*	−0.06

* Significant at 5% level.

at each of the crop growth stages were also worked out. The coefficients of determination are significant at reproductive and maturity stages only. The partial regression coefficient of maximum temperature and GDD during the reproductive stage has great influence and accounted for 84% of yield variation. Similarly, in maturity stage, all the three partial regression coefficients are significant except sunshine hours and accounted for 91% of yield variation. As all the parameters are not significantly correlated with grain yield at all the stages, multiple regression equation between the grain yield and the 10 significant parameters at dfferent growth stages (as per Table 3) has been worked out and found as follows :

$$
\begin{aligned}
Y = & -1163.8 - 5.3X_1 - 25.4X_2 \\
& + 16.4X_3 + 600.3X_4 - 9.5X_5 \\
& + 63.3X_6 - 9.5X_7 - 126.0X_8 \\
& + 298.2X_9 - 2.6X_{10} \qquad (2) \\
& (R^2 = 1.00^{**})
\end{aligned}
$$

where,

- X_1 – Minimum temperature during seedling stage (°C)
- X_2 — Growing degree days during seedling stage (°C)
- X_3 — Total number of sunshine hours during seedling stage
- X_4 — Maximum temperature during vegetative stage (°C)
- X_5 — Total number of sunshine hours during vegetative stage
- X_6 — Maximum temperature during reproductive stage (°C)
- X_7 — Growing degree days during reproductive stage
- X_8 — Maximum temperature during maturity stage (°C)
- X_9 — Minimum temperature during maturity stage (°C)
- X_{10} — Growing degree days during maturity stage.

Thus, it can be seen that the regression equation with 10 variables can estimate the grain yield with $R^2 = 1.0$, though it is too idealistic. Regression equations with less number of parameters, with 10, 9, 8, ... upto 2 parameters, were worked out and it was found that in regression equation with first 5 variables, R^2 value was 0.91. Thus, a regression equation, with these initial 5 variables till vegetative stage, could explain the yield variability upto 91% which is fairly high and significant at 1% level. The parameters used are upto vegetative stage only and hence can be used for prediction of the productivity of rice (var : IR-36) at least 2 months before the crop harvest. The regression equation with these 5 variables is given below :

$$
\begin{aligned}
Y = & 2794.9 - 9.0X_1 - 5.4X_2 \\
& + 20.4X_3 + 134.6X_4 - 24.2X_5 \qquad (3) \\
& (R^2 = 0.91^{**})
\end{aligned}
$$

(The variables X_1 to X_5 denote same meaning as above)

With the above equation based on temperatures and their derived parameter GDD and also sunshine hours upto vegetative stage, the productivity of rice crop variety IR-36 can be predicted by the end of vegetative stage. This is tested against rabi 1993-94 and the estimated yield was 4368 kg/ha, whereas the actual yield obtained was 4409 kg/ha. Thus, the equation estimates the productivity fairly well if temperatures and sunshine hours are considered upto vegetative stage only.

4. Conclusions

Experimental work on the effect of temperature and sunshine on the productivity of rice (var : IR-36) revealed that the maximum and minimum temperatures and their derived factor, growing degree days and sunshine hours at different growth stages have influence on productivity of rice. Multiple regression equation for estimating the yield of rice with 10 significant parameters at different growth stage was worked out. Multiple regression equation with the first 5 parameters which are considered till the end of vegetative stage of crop growth has R^2 value of 0.91 which is highly significant. This equation, as it has parameters till vegetative stage, can well be used as a yield prediction equation about 2 months before the crop harvest. This equation was used for estimating the rabi 1993-94 crop yield and the estimate was found fairly good.

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