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ANALYSING THE EFFECT OF TEMPERATURE VARIATION ON RICE YIELD AND CROP CHARACTERISTICS USING ORYZA MODEL IN TARAI REGION OF UTTARAKHAND

1. Rice (*Oryza sativa L.)* is the most important cereal food crop of India and also of Uttarakhand. Rice being climatically the most adaptable cereal, it is grown over a large spatial domain. Climate change is one of the important environmental aspects which increase the pressure on Indian agriculture. Long-term climate variability influences sowing date, crop duration, crop yield, and other management practices adapted in rice production. Short-term weather episodes can also affect yield by inducing changes in temperature, potential evapotranspiration, and moisture availability. Temperature influences both growth duration and growth pattern of the rice plant. Depending on growth stage, injury to the rice plant may occur when the mean daily temperature drops below 20 °C. Crop simulation models are simulation models that help to estimate crop yield as a function of weather conditions, soil conditions, and choice of crop management practices. These models explain much of the interaction between the environment and the crops. They also provide a means to quantify the effects of climate, soil and management on crop growth and sustainability of agriculture production (Kumar and Sharma, 2004; Timsina *et al*., 2004). ORYZA2000 is an updated and integration of the models ORYZA1 for potential production, ORYZA_W for water-limited situations, and ORYZA-N for nitrogen-limited production. It simulates the growth and development of a rice crop in situations of potential production, water limitations, and nitrogen limitations (de Wit and Penning, 1982). ORYZA2000 contains new features that allow a more explicit simulation of crop management options, such as irrigation and nitrogen fertilizer management. ORYZA2000 is suitable for predicting the change of rice production in response to future climate change in further studies.

2. A field experiment was conducted on “Analysing the effect of climate change on rice yield using ORYZA model in *tarai* region of Uttarakhand” was conducted during *kharif* seasons of 2013. The field experiments were conducted at the Norman E. Borlaug Crop Research Centre of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, U.S Nagar (Uttarakhand) during *kharif* seasons of 2013. Pantnagar is situated in the *Tarai* belt, at latitude of 29.2° N, 79° E longitude and at an altitude of 243.80 m above the mean sea level.

The variety of rice selected for the experiment was *Sarju 52*. The maturity period of the selected cultivar is 130-133 days. ORYZA2000 contains new features that allow a more explicit simulation of crop management options, such as irrigation and nitrogen fertilizer management. The model was calibrated with data collected during 2013 against the treatment that showed best performance in the field trials. Cultivar coefficients were determined successively. In ORYZA2000, the rice crop has four phenological phases, *viz*., juvenile phase from emergence (development stage [DVS] = 0) to start of photoperiod-sensitive phase (DVS = 0.4), photoperiod-sensitive phase until panicle initiation (DVS = 0.65), panicle development phase until 50% of flowering (DVS = 1.0), and grain-fill phase from DVS = 1.0 until physiological maturity (DVS = 2.0). Each of these four phases has variety-specific development rate constants (DRC).

Model calibration is the adjustment of parameters or coefficients in a functional relationship so that the model behaviour matches with one set of the real world data and simulated values are comparable with observed data. Model validation in its simplest form is a comparison between simulated and observed values. If the simulated values lie within the predicted confluence level band, model can be considered as valid. Thus validation is used as evaluation of the model for its usefulness. The ORYZA2000 model was calibrated using the field trial data of 2013 and validated with the corresponding data of different treatments in the same year for the rice cultivar *Sarju 52*. To assess the accuracy of the ORYZA2000 Rice model, results were validated with the data generated from all the treatments. Prediction capability of the model was tested by judging the capacity of the crop in terms of Leaf area index, total above ground dry weight and grain weight (kg/ha). Performance evaluation of the model was done using RMSE and linear regression analysis.

Sensitivity analysis is used to determine how "sensitive" a model is to the changes in the values of the parameters used in the model and to changes in the structure of the model. Sensitivity analysis helps to build confidence in the model by studying the uncertainties that are often associated with parameters. Many parameters in the system dynamics of the model represent quantities that are very difficult or even impossible to measure to a great deal of accuracy in the real world. Sensitivity analysis allows determination of level of accuracy for a parameter to make the model sufficiently useful and valid. If the tests reveal that the model is insensitive, then it may be possible to use an estimate rather than a value with greater precision. Sensitivity analysis can also indicate, which parameter values are reasonable to use in the model. If the model behaves as expected from the real world observations, it gives indications that the parameter values reflect, at least in part, the "real world" (Breierova and Choudhari, 1996).

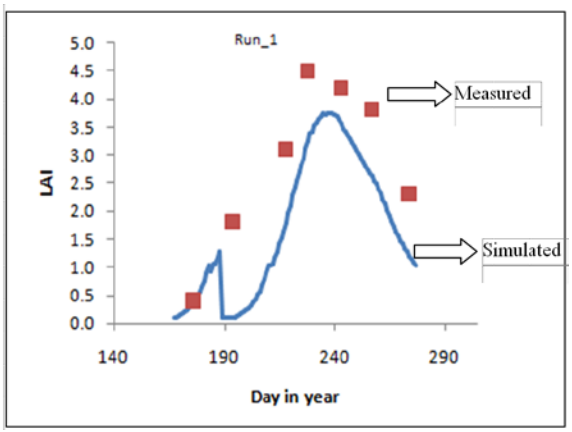

Fig 1. Graph of measured and simulated values as given by the model

In this study, the ORYZA2000 model was applied to a growing period of 2013 in order to determine the model sensitivity on the changes in several meteorological parameters such as minimum temperature (°C), maximum temperature (°C). In the model, the temperature variations were applied from ±1 °C to ±3 °C.

3. Fig. 1 depicts that there were large differences between the simulated and observed values of LAI. So it was concluded that the model could not well estimate the values of LAI during the experimental year 2013. Table 1 shows the differences between the simulated and observed values of LAI. RMSE was found to be 1.19 (40.18%) in the year 2013.

Similar results have also been reported by Kaur *et al*. (2007). But the model performed well in estimating the total above ground dry weight and grain yield.

In this study, the ORYZA2000 model was applied to a growing period of 2013 in order to determine the model sensitivity on the changes in several meteorological parameters such as minimum temperature (°C), maximum temperature (°C). In the model, the temperature variations were applied from ±1 °C to ±3 °C. It was found that with increasing temperatures the leaf area index, total above ground dry weight and grain yield decreased simultaneously while with the decreasing temperatures, these factors had an increasing trend.

As shown in Fig. 2. among the dates of transplanting the leaf area index decreased as the temperature increased

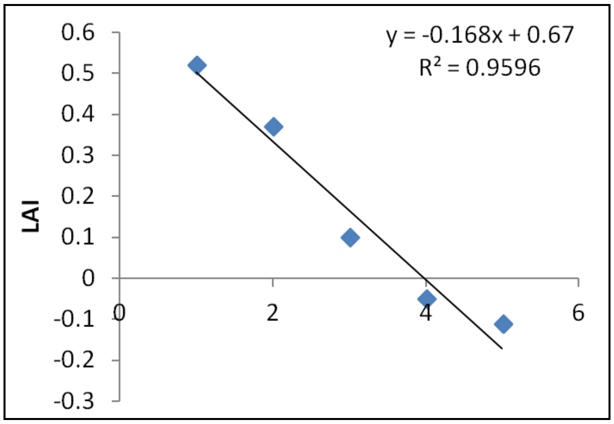

Fig. 2. Relationship between LAI and temperature

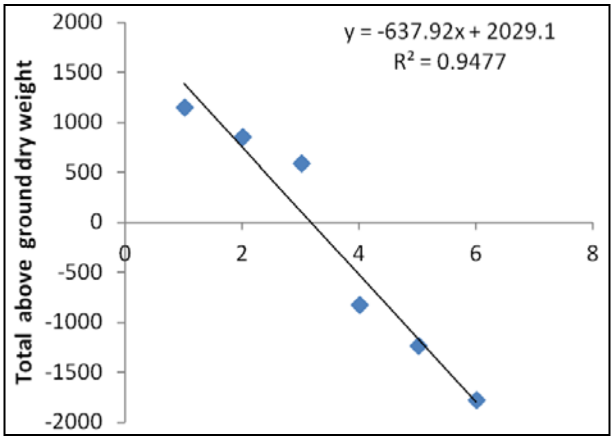

Fig. 3. Relationship between temperature and total above ground dry weight

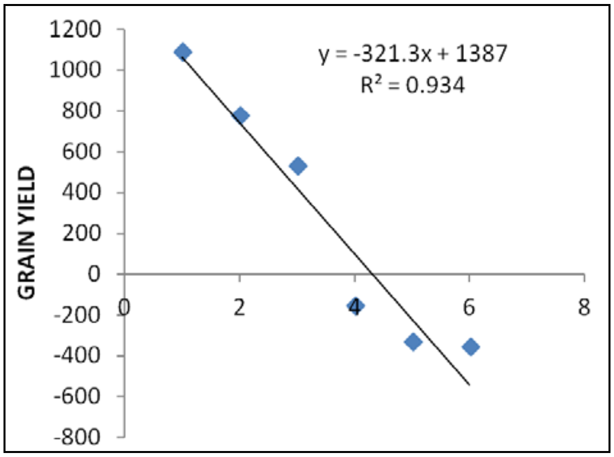

Fig. 4. Relationship between Grain yield and temperature

TABLE 1

Simulated and observed values for Leaf Area Index

Date of transplanting	2013	
	Observed	Simulated
26 June	3.8	1.97
2 July	2.3	1.82
11 July	2.3	1.78
RMSE	1.19	
% RMSE	40.18	
R^2	0.70	

TABLE 2

Simulated and observed values for total above ground dry weight (kg/ha)

Date of transplanting	2013	
	Observed	Simulated
26 June	17201	14170
2 July	15632	12936
11 July	15174	11068
RMSE	2296	
% RMSE	41.52	
R^2	0.99	

TABLE 3

Simulated and observed values for grain yield (kg/ha)

Date of transplanting	2013	
	Observed	Simulated
26 June	4939	5021.6
2 July	4673.8	4834
11 July	3450	4294.8
RMSE	479.7	
% RMSE	13.2	
R^2	0.87	

and *vice-versa*. Crop transplanted on 11th July recorded decreased leaf area index with increased minimum and maximum temperatures at all levels. Table 4 clearly shows that Leaf area index increased more with decreased minimum and maximum temperature of 3 °C during dates of transplanting.

The effect of increasing and decreasing temperatures on total above ground dry weight has been shown in Fig.3.

TABLE 4

leaf area index values as influenced by temperatures variations

Dates of transplanting	At normal Tmean (°C)	Simulated leaf area index values					
		Average change in temperature by					
		+1 °C	+2 °C	+3 °C	-1 °C	-2 °C	-3 °C
26th June	1.97	1.88	1.80	1.78	2.04	2.45	2.55
2nd July	1.82	1.80	1.76	1.68	1.97	2.25	2.32
11th July	1.78	1.74	1.68	1.59	1.87	1.99	2.28

TABLE 5

Effect of temperature on above ground dry weight (kg/ha)

Dates of transplanting	At normal Tmean (°C)	Simulated total above ground dry weight values (kg/ha)					
		Average change in temperature by					
		+1 °C	+2 °C	+3 °C	-1 °C	-2 °C	-3 °C
26th June	14170	13545	12986	11945	14733	14884	14998
2nd July	12936	11368	10945	10687	13263	13487	13879
11th July	11068	10786	10547	10225	11965	12367	12768

TABLE 6

Simulated grain yield values (kg/ha) at increased and decreased temperatures

Dates of transplanting	At normal Tmean (°C)	Simulated yield values (kg/ha)					
		Average change in temperature by					
		+1 °C	+2 °C	+3 °C	-1 °C	-2 °C	-3 °C
26th June	5021.6	4987	4872	4643	5500.4	5927.4	6464.2
2nd July	4834	4672	4423	4272.3	5376.5	5573.4	5879
11th July	4294.8	4033	3872	4178.4	4872	4988.5	5093

Table 5 showed that among the dates of transplanting, the total above ground dry weight decreased with increased temperature from 1 to 3 °C and *vice-versa*. Crop transplanted on 11th July recorded lowest above ground dry weight with increased minimum and maximum temperature at all levels.

As shown in Fig. 4., the grain yield decreased in the crop transplanted on 26th June, 2nd July and 11th July with increased minimum and maximum temperature from 1 to 3 °C. Reduction in yield might be due to reduction in days to attain heading and physiological maturity by rise in temperature. The results are supported by Mathauda and Mavi (1994). 11th June transplanted crop recorded the maximum decrease in grain yield with increased minimum and maximum temperature.

Table 6 shows that the grain yield increased when the temperature was decreased from 1 to 3 °C and *vice versa*. Reduction in yield might be due to reduction in days to attain heading and physiological maturity by rise in temperature.

4. (*i*) Maximum leaf area index ranged between 2.3 to 3.8 and 1.78 to 1.97 for observed and simulated data, respectively (Table 1). LAI decreased with delayed transplanting in the experimental year. The RMSE was found to be 1.19 (40.18%).

(*ii*) In case of total above ground dry weight accuracy percent of simulated values over observed were found to be more with 2nd July transplanting during the year 2013. RMSE was found to be (41.52%) in the year 2013.The R^2 value was found to be 0.99 (Table 2).

(*iii*) The grain yield ranged between 3450 to 4939 kg/ha and 4294.8 to 5021.6 kg/ha with observed and simulated data, respectively (Table 3). Across different dates of transplanting RMSE was found to be 479.7 kg/ha which is 13.2%.

5. Sensitivity analysis of the model

5.1. Effect of mean temperature

(*i*) The Leaf Area Index for each date of transplanting decreased as the temperature was increased from 1 to 3 °C and *vice-versa* (Table 4).

(*ii*) Among the dates of transplanting, total above ground dry weight decreased as the temperature increased over temperature level of 2013 by 1 °C to 3 °C from 13545 to 11945 (kg/ha), 11368 to 10687 (kg/ha) and 10786 to 10225 (kg/ha) with crop transplanted on 26th June, 2nd July and 11th July, respectively (Table 5).

(*iii*) Grain yield decreased more with increasing mean temperature by 3 °C and *vice versa* across all transplanting dates (Table 6).

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