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Impact of temperature increase on performance of *kharif* rice at Kalyani, West Bengal using WOFOST model

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ABSTRACT

WOFOST model (version 7.1.2) was used to study the impacts of elevated thermal environment on *kharif* rice at Kalyani situated in lower Gangetic region of West Bengal. The model was calibrated and validated with experimental data collected during *kharif* season of 2010 to 2013. The simulated yield data was well matched with actual data. The sensitivity analysis for effect of temperature change on crop maturity showed that if temperature was increased by 1^0C and 2^0C the maturity period was delayed by 3 and 7 days respectively. The range of simulated yield was 3150 kgha^{-1} to 5046 kg ha^{-1} whereas the actual yield in the experimental field ranged from 2907 kg ha^{-1} to 5495 kg ha^{-1}. The model shows 96 per cent accuracy to predict rice yield with R^2 value 0.82 and RMSE value 337.87. It was also observed that the sowing should be done before 15th July to obtain higher yield of *kharif* rice in the study region.

Key words: Crop simulation model, WOFOST, *kharif* rice, yield, temperature

Crop growth is an extremely complex phenomenon with complicated interactions of soil, plant and weather conditions. Climate changes have a great impact on agricultural production. The impact of weather variables on the entire crop growth period can be best represented by crop–weather models which facilitate the relationship between weather, soil, climate and crop yield.

Crop growth simulation model can be used to evaluate key interactions quickly and identify traits with the greatest impact on yield potential and for assessing the relationships between crop productivity and environmental factors (Aggarwal *et al.,* 1997) . Simulation has been used extensively to assess impacts of climate change on yield and to find out the suitable adaptation options at a specific region. The integration of climate and geo-spatial soil databases allows the user a wide range of crop management options for simulation and analysis.

WOFOST (WOrld FOod STudies) is a computer model that simulates the daily growth of a specific crop, given the selected weather and soil data. In WOFOST, only ecological factors are considered under the assumption that optimum management practices are applied. This model has been used by various workers for sensitivity analysis in wheat (Mishra *et al.* 2015), spatial wheat yield prediction (Chaudhari *et al.* 2010) and for comparing with ORYZA 2000 model for rice crop (Mukherjee *et al.* 2011).

Considering the background, the present research work aims at to simulate the *kharif* rice yield through WOFOST model and to study the impact of elevated temperature on performance of rice.

MATERIALS AND METHODS

Model inputs data

As per the input-requirements of WOFOST Model (Boogaard *et al.,* 1998), secondary information on yield and yield attributes were collected from AICRP on Agrometeorology Reports of Mohanpur Centre, BCKV for the period of 2010 to 2013 (AICRPAM, 2010-13). Information on IET4786 (*Shatabdi)* variety of rice was considered which is the most popular variety of the study region. Weather data, namely, maximum temperature, minimum temperature, bright sunshine hours, rainfall, wind speed and relative humidity were collected from Kalyani Meteorological Observatory (Latitude-$22^0$572 North and Longitude $88^0$202 East). Data on soil characteristics were collected from available report of FASAL Project, Kalyani Cenre (FASAL, 2013).

Evaluation of the model

The performance of the model was evaluated through

Table 1: Calculated genetic coefficient for *Shatabdi* variety generated through iteration method

Genetic coefficient	Code used in WOFOST model	Value
Optimum day-length for development	DLO	10.5 hours
Temperature sum from emergence to anthesis	TSUM1	1723 degree cel
Temperature sum from anthesis to maturity	TSUM2	526 degree cel
Initial total crop dry weight	TDWI	50.00 kg ha^{-1}
Efficiency of conversion into leaves	CVL	0.754 kg kg^{-1}
Efficiency of conversion into storage organ	CVO	0.600 kg kg^{-1}
Efficiency of conversion into roots	CVR	0.754 kg kg^{-1}
Efficiency of conversion into stems	CVS	0.754 kg kg^{-1}

some statistical parameters, namely, coefficient of determination (R^2), root mean square error (RMSE) and others (Fox, 1981). The accuracy and bias were calculated as per standard formula (Banerjee *et al.,* 2014).

Impact studies

For the study region the temperature may increase from 1^0C for next decade to 3^0C at the end of the century (Boomiraj *et al.,* 2010). Considering these projections, the impact of 1^0C and 2^0C temperature rise (above average temperature) on production of *kharif* rice has been assessed for Kalyani. The average weather data of Kalyani Observatory for the period of 1980 to 2010 was considered as the normal weather data and the average temperature for the said period is termed as AT in this paper.The crop performance was assessed under normal weather condition as well as elevated temperature. 1^0C and 2^0C were added with both maximum and minimum average temperature (AT) to obtain elevated temperature regime. This regime was used as 'input weather file' of the WOFOST model to assess the impact.

RESULT AND DISCUSSION

Calibration and validation of WOFOST model

The pre-calibrated WOFOST model (version 7.1.2) for '*Shatabdi*' variety was used in the present study. Simple iteration method (i.e. trial and error method) was used to modify the coefficient related to phenological aspect and crop growth parameter. The evaluated genetic coefficients are summarized in Table 1.

For validation of WOFOST model, the grain yield production data were compared with model output. The wide range of date of transplanting was considered to thoroughly evaluate the model to simulate yield.

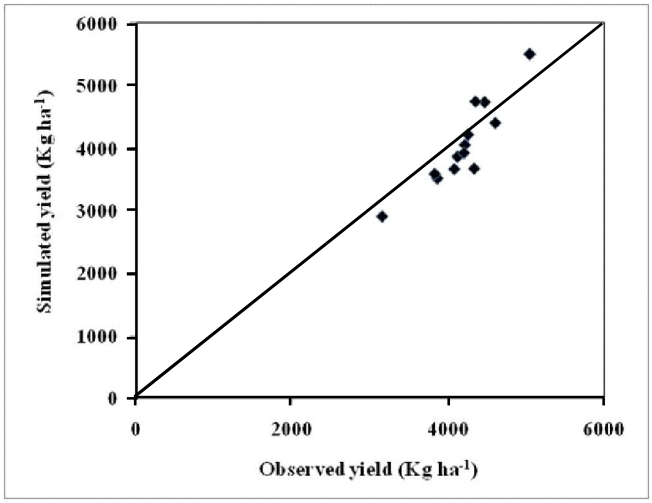

Fig. 1: Relationship between observed and simulated yields of *kharif* rice shown through 1:1 line (Bias= 134.84, R^2 = 0.82, RMSE= 337.87, Accuracy %= 96.67)

Fig.1 shows the relationship of simulated yield against actual ones for *Shatabdi*.It is observed that the data points are very close to 1:1 line, hence the modeled grain yields matched well with actual experimental yields. The model shows 96 per cent accuracy to predict rice yield with R^2 value of 0.82 and RMSE value of 337.87.

Predicting yield under elevated temperature

Crop maturity period is highly dependent on prevailing temperature and crop duration decreases with the temperature enhancement. The effect of increased minimum temperature has pronounced impact on grain yield. Shah *et al.*, (2011) also emphasized on adverse impact of higher temperature on yield of rice.The maturity period of *Shatabdi* variety was reduced by 3 to 7 days due to 1-2^0 C temperature enhancement. The model output also showed the simulated LAI would decrease with increase of temperature. During PI

Table 2: Performance of rice under elevated thermal condition

	AT*	AT+1^{0}C	AT+2^{0}C
LAI at Panicle Initiation stage	6.1	5.5	4.4
LAI at grain filling stage	7.2	6.9	5.8
Days to mature	110	107	103
Reduction in days to maturity (days)		3	7
Yield (kg ha^{-1})	4238.6	4006.5	3784.2
Yield reduction (%)	—	5.5	10.7

*Simulated yield considering average temperature (AT) and normal weather condition

and grain filling stages, the enhanced temperature effect on LAI would be more (Table 2). With the normal DOS (4th week of May) and the common management practices, 5-10 per cent yield reduction would be observed with rise in temperature upto 2^{0}C. Under elevated thermal condition, the yield decrease occurs mainly due to the lower LAI throughout the crop growth stages and shorter crop growth period, which is evident from the study.

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