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Response of wheat to temperatures as simulated with CERES-wheat model in *Tarai* region

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ABSTRACT

The present investigation was carried out to quantify the impact of change in minimum and maximum temperatures on wheat production in Uttarakhand using CERES-wheat model. Grain and biomass yields as simulated by the CERES-wheat (cv. BPW-343) model were found to have increased significantly due to decrease minimum (Tmin) and maximum (Tmax) temperature units from 1 to 3°C and vice-versa. Generally, minimum temperature has more significant effect than maximum temperature.

Key words: CERES-wheat, simulation, T_{min}, T_{max} and sowing dates.

Wheat (*Triticum aestivum* L.) is very important crop in *Tarai* region of Uttarakhand, which is sown during November/December and harvested during March/April. The total area under wheat in Uttarakhand is 0.4 m ha, with a total production of 0.8 mt and productivity of 2.0 t ha^{-1} (DES, 2010). The wheat production in the country is highly variable due to inter-seasonal weather variability. Using HADCM3 model, an analysis made by Tripathi *et al*. (2006) indicated that the projected increase in average temperature will be 3-4^{0}C by 2080 AD for eastern U.P. Hence, winter production will be adversely affected due to high temperature. Wheat is sensitive to high temperature (during early and late stages of the crop) but magnitude of damage depends on the variations of ambient temperature, stage of development and varieties (Asseng *et al*. 2011; Modarresi *et al*. 2010). Extreme temperatures at sensitive developmental stages are especially detrimental.

The Decision Support System for Agro-technology Transfer (DSSAT) (Version 4.0) is an application software program that includes crop simulation models for more than 25 crops to make more reliable predictions (Jones *et al*. 2003). DSSAT and its crop simulation models have been used for a wide range of applications, including on-farm and precision management to regional assessments of the impact due to climate change. Crop simulation models are principal tools that can successfully apply to assess the effect of changes due to temperature on wheat yields (Matthews *et al*., 2002; Nain *et al*., 2002) and also helpful to assess the impact of climate change on the stability of crop production under different management options (Hoogenboom *et al*., 1995). Crop Environment Resources Synthesis (CERES)-wheat model is a process based management-oriented model that can simulate the growth and development of wheat crop (Ritchie *et al.,* 1998). The model can identify gaps between potential and on-station farm yield and yield contributing characters etc. The main goal of this study is to quantify the impact of change in minimum and maximum temperature on the level of wheat production in Uttarakhand.

MATERIALS AND METHODS

The present experiments were conducted in split plot design with three dates of sowing *i.e*. November 20, December 15 and January 09 during *rabi* seasons of 2007-2008 and 2008-2009 at the Norman E. Borlaug Crop Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar (29°N, 79.29°E with 243.80 m above msl). The CERES-wheat model for the genotype PBW-343 was well calibrated (Table 1) based on field experiment data, soil data and the actual weather parameters (i.e. minimum & maximum temperature, rainfall and bright sunshine hours). CERES-wheat model was used to simulate the biomass and grain yield of wheat using changes in temperature (Tmin & Tmax) from +1 to +3°C and -1 to -3°C under different sowing environments and percent change was calculated.

Table 1 : Genotypic coefficients used for simulation modeling (calibration) of wheat (cv. PBW-343) for environmental condition of Uttarakhand

Parameters	Genotype (PBW-343)
Vernalisation coefficient (P1V)	0
Photoperiodism coefficient (P1D)	92
Grain filling duration coefficient (P5)	560
Kernel number coefficient (G1)	22
Kernel weight coefficient (G2)	43
Tiller weight coefficient (G3)	2.3
Phyllochron interval (PHINT)	95

RESULTS AND DISCUSSION

Impact of temperature changes on biomass (kg ha^{-1})

Simulated biomass varied from -3.7 to -23.0% and 0.9 to 16.2% with increment and decrement of Tmin, respectively, from 1 to 3°C, while the variation was observed from -0.3 to -21.6% and 1.6 to 12.6% with increment and decrement of Tmax, respectively, from 1 to 3°C. Data revealed that the simulated biomass has more significant variation over actual biomass with crop sown on 20th November as decreased/increased units of Tmin/ Tmax. Increasing units of temperatures have more significant effect on biomass than decreasing temperatures units for all the dates of sowing. Crop sown on 20th November found more significant variation in simulated biomass due to increment/decrement of Tmin/Tmax, respectively over actual biomass at 3^{0}C. Generally for all the dates of sowing, biomass decreased with increasing temperature units and increased with decreased

Table 2: Effect of change in minimum and maximum temperature on biomass and grain yield using CERES-wheat model

Dates of sowing	Deviation in temperature	Simulated Biomass (kg ha^{-1})				Simulated Grain yield (kg ha^{-1})			
		Tmax		Tmin		Tmax		Tmin	
		Yield	% change	Yield	% change	Yield	% change	Yield	% change
Nov. 20	-3	10610	12.6	10952	16.2	5187	21.9	5072	19.2
	-2	10287	9.1	10404	10.4	4875	14.6	4750	11.6
	-1	9779	3.7	9907	5.1	4645	9.2	4510	6.0
	1	8862	-6.0	8725	-7.4	3814	-10.4	3689	-13.3
	2	8084	-14.2	7951	-15.6	3365	-20.9	3245	-23.7
	3	7393	-21.6	7255	-23.0	2913	-31.5	2788	-34.5
Dec. 15	-3	9752	11.0	9737	10.9	4472	15.1	4387	12.9
	-2	9368	6.7	9328	6.2	4274	10.0	4149	6.8
	-1	9085	3.4	9085	3.4	4137	6.5	4032	3.8
	1	8595	-2.1	8315	-5.3	3790	-2.4	3665	-5.7
	2	8202	-6.6	8043	-8.4	3511	-9.6	3386	-12.8
	3	7896	-10.1	7781	-11.4	3262	-16.0	3137	-19.3
Jan. 09	-3	8002	5.5	8029	5.9	3501	7.5	3476	6.8
	-2	7749	2.2	7832	3.3	3343	2.7	3378	3.7
	-1	7708	1.6	7654	0.9	3316	1.8	3291	1.1
	1	7565	-0.3	7305	-3.7	3244	-0.4	3119	-4.2
	2	7491	-1.2	7266	-4.2	3209	-1.4	3084	-5.3
	3	7390	-2.6	7198	-5.1	3156	-3.1	3036	-6.8

temperature units (Sharma *et al.,* 2010), but the magnitude of variations was found significantly more with crop sown on 20th November. Among sowing dates, minimum temperature has the more significant effect on biomass than maximum temperature for all the levels of increment and decrement (Table 2).

Impact of temperature changes on grain yield (kg ha^{-1})

The results of varying Tmin & Tmax and its effects on wheat grain yield as simulated by CERES-wheat model for different sowings are presented in Table 2. Data revealed that the simulated grain yield decreased from 13.3 to 34.5%, 5.7 to 19.3% and 4.2 to 6.8% by increasing the Tmin and increased from 6.0 to 19.2%, 3.8 to 12.9% and 1.1 to 6.8 % by decreasing Tmin from 1 to 3^{0}C over actual grain yield with crop sown on 20th November, 15th December and 09th January, respectively. Simulated grain yield decreased from 10.4 to 31.5%, 2.4 to 16.0% and 0.4 to 3.1% by increased units of Tmax and increased from 9.2 to 21.9%, 6.5 to 15.1% and 1.8 to 7.5% by decreased unit of Tmax from 1 to 3^{0}C over actual grain yield with crop sown on 20th November, 15th December and 09th January, respectively. Grain yield increased more significantly with decrement of Tmin/Tmax and also decreased more significantly due to increment of Tmin/Tmax form 1 to 3°C with 20th November sowing of the crop. Such behaviour of the model was mainly due to reduction in duration of anthesis and grain filling with rise in Tmin and vice versa (Aggarwal and Sinha, 1993). Pathak *et al*. (2003) and Patel and Shekh (2005) also stated on the basis of sensitivity analysis of CERES-wheat that elevated Tmax decreased wheat yield significantly. Akula (2003) has reported similar findings for WTGROWS and INFOCROP models for wheat (cv. GW- 496). In respect of grain yield, minimum temperature has more significant effect than maximum temperature with almost all the dates of sowing, while the significant level was observed more with 20th November sowing. In addition, grain yield was more influenced by increasing units of temperatures than decreasing units.

CONCLUSION

The CERES-wheat model simulated grain yield and biomass increased more significantly with decrement of Tmin/Tmax and also decreased more significantly due to increment of Tmin/Tmax form 1 to 3°C with 20th November sowing of the crop. Minimum temperature has more significant effect than maximum temperature with almost all the dates of sowing, while the significant level was observed more with 20th November sowing.

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