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Sensitivity analysis of InfoCrop model for Indian-mustard varieties in western Haryana

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Abstract

An InfoCrop model was validated with data sets generated on three varieties of *Brassica juncea viz.* Kranti, RH 406 and RH 0749 through field experiment laid in split plot design with three sowing dates of *Rabi* 2014-15 *viz*. 25th October, 5th November and 15th November, respectively. In sensitivity analysis, different combinations of maximum and minimum temperature, seasonal rainfall and elevated CO_2 concentration were simulated which reflected a substantial change in seed yield. A change of ± 1^0C in daily maximum and minimum temperatures led to increase in seed yield over base yield. The simulation results also supported the increase in seed yield in all three varieties due increase in the seasonal rainfall by 10 to 20%. Further, elevation in CO_2 concentration up to 490 ppm at constant temperature resulted in 13–32% also showed increment in seed yield of mustard; however, further increase in CO_2 concentration beyond 490 ppm adversely affected the seed yield all three varieties.

Key words: *Brassica juncea, climate change, InfoCrop model, simulation*

Introduction

Indian mustard [*Brassica juncea* (L.) Czern & Coss.] is much sensitive to climatic conditions and climate change could have substantial effects on its production. Global production of the annual crops is expected to reduce significantly due to climate change by the end of the 21st century. IPCC global studies indicate considerable probability of loss in crop production in India with increases in temperature (IPCC, 2014). According to fourth IPCC assessment report (AR_4), global average temperature has increased by 0.74 ^{0}C over the last hundred years and projected temperature increase is about 1.8 to 4 ^{0}C by 2100 A.D. Global losses may account from 1 to 5 % of GDP but, developing countries with tropical and sub-tropical climate are likely to suffer more (Parry *et al*., 2007).

Studies on impact of climate change on crops need simulation models as they provide to quantify the effects of climate, soil and management on crop growth, productivity and sustainability of agricultural production. These tools may reduce the expensive and time consuming field experimentations as they can be used to extrapolate the results of research conducted in one season or location to other season, location, or management (Boomiraj *et al*., 2007). InfoCrop growth simulation model, developed under Indian condition, is one of the user friendly dynamic crop growth models. This model has the capability to estimate the potential yield and yield gaps, and also to assess the impacts of climate variability and climate change. This model simulates the crop growth processes *viz*. phenology, interaction among genotypes, environment, management and pests, yield forecast, yield loss assessment due to pests and greenhouse gas emissions (Aggarwal *et al*., 2006). InfoCrop model can successfully simulate growth and yield of mustard crop across different locations in India. Simulated yield of mustard has been found to be sensitive to change in atmospheric CO_2 and temperature (Boomiraj *et al*., 2010). An elevated level of CO_2 concentration and temperature shows negative impact on mustard yield (Singh *et al*., 2013). Till now the scientific information on simulation of growth and yield of mustard crop using modeling in Haryana state is very limited; therefore, keeping in view the importance of the role of crop simulation model in agriculture, the present investigation was carried out to validate and carry out sensitivity analysis of InfoCrop model for Indian-mustard crop under western Haryana conditions.

Materials and Methods

An experiment was designed to simulate the impact of change in maximum temperature (T_{max}) & minimum temperature (T_{min}), seasonal rainfall and elevated CO_2 concentration within a range of ±5ºC, ±10 % and 415 to 640 ppm, respectively, on the seed yield of three varieties of Indian mustard (*Brassica juncea*) *viz.* Kranti, RH 406, and RH 0749. An InfoCrop model (Aggarwal *et al.*, 2009) was used for the simulation study. The experiment was laid in split plot design in four replication at Research farms of Agril. Meteorology, CCSHAU, Hisar (Haryana) during *Rabi* 2014-15. The study material was sown at three different dates *viz.* 25th October, 5th November and 15th November, 2014. The meteorological data used in the present

Table 1: Simulated effect of change in daily (a) maximum and (b) minimum temperature on yield of mustard varieties

Change in maximum temperature	Variety					
	Kranti	RH 406	RH 0749	Kranti	RH 406	RH 0749
	Change in yield over base value (Kg ha^{-1})			% change		
5	1041.7	1213.0	1426.3	-21	-18	-16
4	1120.8	1272.1	1460.2	-15	-14	-14
3	1397.7	1612.3	1884.7	6	9	11
2	1503.2	1686.3	1969.6	14	14	16
1	1582.3	1878.6	2173.4	20	27	28
-1	1661.4	1908.2	2190.3	26	29	29
-2	1542.7	1715.9	2020.5	17	16	19
-3	1199.9	1346.1	1562.1	-9	-9	-8
-4	1041.8	1183.4	1409.3	-21	-20	-17
-5	988.9	1153.8	1341.4	-25	-22	-21
Base yield (kg/ha)*	1318.6	1479.2	1697.9	1318.6	1479.2	1697.9

Change in minimum temperature	Variety					
	Kranti	RH 406	RH 0749	Kranti	RH 406	RH 0749
	Change in yield over base value (Kg ha^{-1})			% change		
5	1041.7	1213.0	1426.3	-21	-18	-16
4	1120.8	1272.1	1460.2	-15	-14	-14
3	1397.7	1612.3	1884.7	6	9	11
2	1503.2	1686.3	1969.6	14	14	16
1	1582.3	1878.6	2173.4	20	27	28
-1	1595.5	1819.4	2088.5	21	23	23
-2	1503.2	1701.1	1986.6	14	15	17
-3	1226.3	1405.3	1646.9	-7	-5	-3
-4	1147.2	1316.5	1545.1	-13	-11	-9
-5	1081.2	1242.5	1443.2	-18	-16	-15
Base yield (kg/ha)*	1318.6*	1479.2*	1697.9*	1318.6*	1479.2*	1697.9*

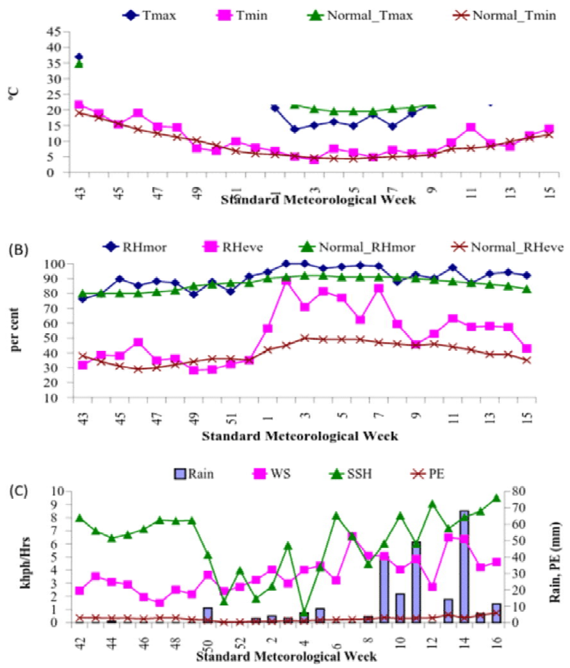

Figure 1: Weekly weather parameter a) Temperature; b) Relative humidity; c) Rain, wind speed, SSH and PE during the crop season 2014-15 at Hisar

investigation was recorded at meteorological observatory of Department of Agricultural Meteorology during the standard weeks (SMW) from week 43rd to 15th and has presented in fig 1.

Results and Discussion

Temperature

Maximum temperature: Simulated effect of varying levels of daily T_{max} on yield of mustard varieties has been detailed in table 1a and figure 2. The effect of both gradual increase and as well as decrease in the daily T_{max} (-5 to 5 ºC) during the experimental period was studied in mustard. As a result, we recorded a change in mean yield, in a particular fashion, with respect to change in daily T_{max} (Figure 2). The yield was found to be increased when the temperature variation was kept between -2 to 3ºC, however, the maximum yield was obtained at the T_{max} -1. Further, when the T_{max} was lowered and increase by -5 to -3 and 4 to 5, respectively, the yield loss was high. Substantial results were obtained with variation in between ± 1ºC. The effect of percent change in yield was higher in RH 0749 followed by RH 406 and Kranti.

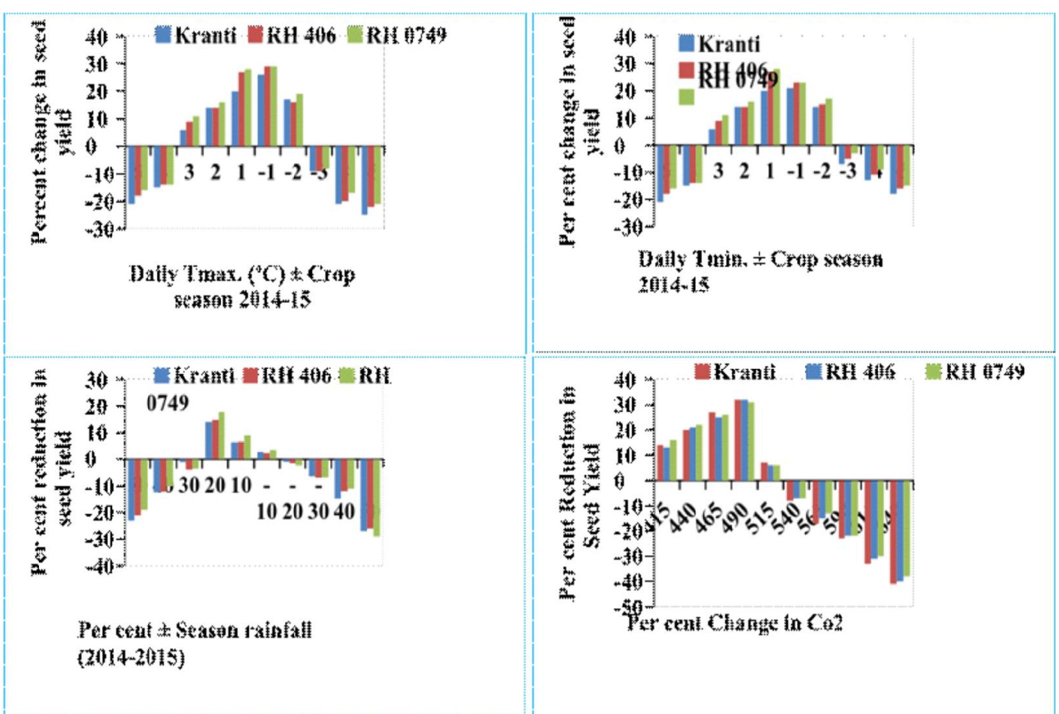

Figure 2: Depicting the InfoCrop simulation results of impact of change in (a) maximum temperature (T_{max}) (b) minimum temperature (T_{min}) (c) seasonal rainfall and (d) elevation in CO_2 concentration on the seed yield of all three varieties of mustard during the *Rabi*- 2014-2015

Table 2: Simulated effect of varying levels of rainfall on yield of mustard varieties

Per cent change in rainfall	Variety					
	Kranti	RH 406	RH 0749	Kranti	RH 406	RH 0749
	Change in yield over the base value (Kg ha^{-1})			% change		
50	1015.30	1668.58	1375.32	-23	-21	-19
40	1155.07	1298.75	1528.14	-12.4	-12.2	-10
30	1304.07	1421.52	1638.50	-1.1	-3.9	-3.5
20	1503.17	1698.13	2000.16	14	14.8	17.8
10	1402.96	1576.84	1850.74	6.4	6.6	9
-10	1354.17	1511.75	1755.66	2.7	2.2	3.4
-20	1305.38	1455.54	1657.18	-1	-1.6	-2.4
-30	1235.50	1377.15	1582.47	-6.3	-6.9	-6.8
-40	1124.74	1301.71	1511.16	-14.7	-12	-11
-50	962.56	1094.62.5	1205.53	-27	-26	-29
Base yield (kg/ha)*	1318.57*	1479.21*	1697.93*	1318.57*	1479.21*	1697.93*

Table 3: Simulated effect of varying levels of CO_2 on yield of mustard varieties

Change in CO_2 concentration (ppm)	Variety					
	Kranti	RH 406	RH 0749	Kranti	RH 406	RH 0749
	Change in yield over base value (Kg ha^{-1})			% change		
415	1503.2	1671.5	1969.6	14	13	16
440	1582.3	1789.8	2071.5	20	21	22
465	1674.6	1849.0	2139.4	27	25	26
490	1740.5	1952.6	2224.3	32	32	31
515	1410.9	1568.0	1799.8	7	6	6
540	1213.1	1375.7	1579.1	-8	-7	-7
565	1094.4	1257.3	1477.2	-17	-15	-13
590	1015.3	1153.8	1324.4	-23	-22	-22
615	883.4	1020.7	1188.6	-33	-31	-30
640	777.9	887.5	1052.7	-41	-40	-38
Base yield (kg/ha)*	1318.6*	1479.2*	1697.9*	1318.6*	1479.2*	1697.9*

The simulated results indicates that decrease in T_{max} is more beneficial as compare to increase since elevated temperature lowers the days to flowering and days to maturity, which in turn lowers the total crop duration. An increase in daily T_{max} resulted in increased mustard yield which may be due to the pre proposed fact, that, in plants, warmer temperature accelerates growth and development leading to less time for carbon fixation and biomass accumulation before seed set resulting in poor yield (Rawson, 1992; Morison, 1996). Similar results were supported by earlier studies of same aspect (Singh *et al.*, 2008; Kumar *et al.*, 2010; Aggarwal *et al.*, 2006).

Minimum temperature: The effect of change in daily T_{min} between -5 and 5ºC was also studied for its impact on mustard yield (table 1b and figure 3). Interestingly, the impact on mustard yield, of change in T_{min} was quite similar to the impact of T_{max}. However, unlike T_{max}, here the highest benefits on yield was obtained on increasing the daily T_{min} by 1. The effect of percent change in the base yield was increased by 1ºC. Our results are in support with Singh *et al*. (2008) and Kumar *et al*. (2010).

Rainfall

In the present investigation substantial impact of change in seasonal rainfall in a range of ±10 % on the seed yield of mustard was recorded. The details of simulated effect of varying levels of rainfall on seed yield of mustard are given in table 2 and figure 2(c). An acceptable degree of agreement was simulated by the InfoCrop simulation model under the elevated seasonal rainfall by 10 to 20%. Further, the pursuance of table 2 reveals that elevation in seasonal rainfall by 20% simulate the base yield at maximum level (RH 0749 > RH 406 > Kranti); However, under decreasing amount of seasonal rainfall varying from -10 to -50% model was under performed and gave the highest seed yield reduction in case of RH 0749 variety followed by Kranti and RH 406. Similar results were reported by earlier workers Pidgeon *et al*. (2001) and Singh *et al*. (2008).

CO_2 concentration

Simulated effect of varying levels of CO_2 on yield of mustard varieties are detailed in table 2 and figure 2(d). The InfoCrop also helped in simulating the effect of elevated CO_2 level (415 to 640 ppm) on the seed yield in the crop under study. The simulation showed positive impact on seed yield when CO_2 concentration was elevated up to 490 ppm. The further elevation in CO_2 concentration left negative impact on seed yield might be due to warming effect over the mean positive seed yield response for the mustard crop. Model also simulated the acceptable limit of elevated CO_2 which may be due to increased photosynthetic activity during the growth period and resulted in quit increasing trend with the specific plant geometric parameters such as leaf area, leaf weight, biomass production and numbers of grain. Our findings are supported by earlier workers Mishra *et al*. (1999), Uperty *et al*. (2003), Rotter and Van de Geijn (1999)

Conclusion

In the present investigation this model helped us in simulating the impact of varying levels of maximum and minimum temperature, seasonal rainfall and CO_2 on three varieties of mustard *viz*. Kranti, RH 406 and RH 0749. Change in T_{max} and T_{min} by -1 to 1ºC, rainfall by 10 to 20% and CO_2 between 415 to 490 ppm showed beneficial impact on the crop and increased the seed yield considerably. The InfoCrop model was found useful tool in simulating the effect of various meteorological parameters on mustard and may help us in increasing the overall yield of mustard under continuously changing climatic conditions to fight for the issue of future food security at both national and international level.

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