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Simulating impact of climate change on mustard (*Brassica juncea*) production in Himachal Pradesh

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ABSTRACT

The study examines the impact of climate change on mustard crop using. Info Crop simulation model after calibration and validation for Sub temperate and sub humid conditions. The IPCC-2004 seasonal climatic scenarios for temperature (0.74ºC for 2020 and 1.71ºC for 2050) for Himachal Pradesh were used to simulate impact of climate change scenarios. The days to flowering, days to physiological maturity and yield indicated the best fit. Under climate change scenarios, days to flowering and days to maturity showed reduction of 1 to 4 and 4 to 19 days for 2020 and 5 to 13 and 10 to 23 days for 2050 respectively due to elevated temperature and decreasing rainfall. The seed yield also showed decreasing trend ranging between 4 to 16% and 9 to 25% for the crop sown on October 10, October 20 and October 30 during 2020 and 2050 respectively. Late sown crop (November 9) showed an increase in seed yield to the tune of 1 to 12% and 12 to 17% for 2020 and 2050 respectively. Under present climatic scenario (2008-09), October 10 is the best planting window while advantage of increase in yield under late sown (November) conditions was observed during climate change scenarios 2020 and 2050. Hence, delayed sowing windows under elevated temperature proved beneficial under sub-humid and sub temperate climate of Himachal Pradesh.

Key words: Mustard, simulation, climate change, impact, assessment and adaptation

Oilseeds contribute approximately 8% to the agriculture GDP of the country. The per capita consumption of vegetable oil has increased to 12.6 kg $year^{-1}$ and projected demand for the year 2020 is expected to reach 16.38 kg $year^{-1}$ (Anonymous 2010). In Himachal Pradesh, the rapeseed and mustard crop occupies first position with an area of 9.3 thousand hectare, production 4.3 thousand metric ton and average yield of 4.7 quintals per hectare (Anonymous, 2007).

As per fourth assessment report of IPCC, global average temperature has increased by 0.7ºC over the last 100 years and projected temperature increase is about 1.8 to 4ºC by 2100. Global losses may account for 1 to 5% of GDP but developing countries with tropical and subtropical climate are likely to suffer more (IPCC, 2007).

Crop growth models can be used for determining the production potential of a location, for matching agro-technology with the farmers' resources, analyzing yield gaps, forecasting yields, and assessing the impact of climatic variability and climate changes on agriculture (Aggarwal, 2003). INFOCROP growth model is one of the user friendly dynamic crop growth models developed under Indian condition to address the issues like global climate change impacts, emission of green house gasses and soil carbon and nitrogen dynamics (Aggarwal *et al.,* 2004).

The paper presents the effect of projected climate change (temperature and rainfall) on performance of mustard under sub temperate and sub humid climatic conditions of Himachal Pradesh using Info Crop, a crop simulation model developed by Aggarwal *et al*., (2006) considering the coefficients worked under Indian conditions.

MATERIALS AND METHODS

Calibration and validation of model

The two field experiments comprising three varieties and four dates of sowing were conducted to generate data for calibration and validation of Info Crop model. The filed experiments were conducted during *rabi* 2007-2008 and 2008-2009 at the research farm of the Department of Agronomy, Forage and Grassland Management, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur (32 6' N, 76 3'E and 1290.8 m amsl). The soil was silty clay loam in texture with pH 5.7 and available N, P and K were 326, 16.2 and 290 kg/ha respectively. The experiment was laid out in randomized block design with three replications. The treatment combination comprised of four sowing dates 10 October (D1), 20 October (D2) and 30 October (D3) and 9 November (D4)) and three varieties (RCC-4 (V1), Kranti (V2) and Varuna (V3). The crop was grown with all recommended package and practice for the experimental stations. One pre sowing irrigation and two subsequent irrigations as per requirement of the crop were applied during both the year

Table 1: RMSE of observed and simulated / periodical and dry biomass as influenced by treatments

Treatments	Leaf area index	Dry biomass (kg ha^{-1})
$D_1 V_1$	0.5	128.9
$D_1 V_2$	0.1	142.8
$D_1 V_3$	0.3	113.2
$D_2 V_1$	0.2	62.1
$D_2 V_2$	0.1	53.1
$D_2 V_3$	0.1	80.7
$D_3 V_1$	0.2	114.0
$D_3 V_2$	0.1	94.7
$D_3 V_3$	0.2	73.3
$D_4 V_1$	0.4	94.7
$D_4 V_2$	0.2	81.6
$D_4 V_3$	0.2	79.0

of field experimentation. Crop coefficients for mustard were calculated by using information from field experiments and a wide literature survey. Further calibration of these coefficients was done by the observations recorded from the field experiment conducted. These coefficients were used in the subsequent validation and application. Model performance using the coefficients developed was evaluated by calculating residual mean square error (RMSE). The RMSE describes mean absolute deviation between simulated and observed and accuracy of simulation is characterized by lower RMSE.

Impact assessment

The impact of projected climate change scenarios were assessed by IPCC (Inter-governmental Panel on Climate Change- 2004) for Himachal Pradesh. The seasonal climate scenarios were calculated and used in the model to assess the impact of maximum and minimum temperature and rainfall. The temperature increase was predicted to the tune of 0.74°C for 2020 and 1.71°C for 2050 for Himachal Pradesh Grid. The grid size was 3.75 degree in longitude and 2.5 degree in latitude for extraction of climate scenarios. In the scenarios, the base data was used from 1961-1990. The rainfall scenarios for Himachal Pradesh were taken as decreasing (-10%) trends of rainfall.

RESULTS AND DISCUSSION

Calibration of model

The thermal units (GDD) for different varieties and dates of sowing were calculated and averaged value of eight sowing environments was computed. The base temperature was taken as 5 ^{0}C. GDD for sowing to germination, Germination to 50 % flowering and from 50 % flowering to maturity were 103 to 124, 547 to 700 days ^{0}C and 699 to 861 respectively for different varieties under varying sowing environment. The radiation use efficiency was 3.0 and relative growth rate was 0.008 ^{0}C/d. The other inbuilt parameters in Info Crop-mustard were calibrated satisfactorily by specific crop growth parameters. Results showed that Info Crop model was in general able to simulate the temporal change of leaf area and dry matter production satisfactorily in all treatments. The model also satisfactorily simulated mustard phenology and yield.

Validation of Info Crop model

The Info crop model simulated the days to flower initiation varied between -3 to +3 days of the observed days (Fig.. 1). The root mean square error (RMSE) value for days taken to flower initiation was 2.0 days as compared to the mean value of 58.6 days, this means good fit of model for this parameter. The simulated days to maturity were estimated between -5 to +4 days of the observed field data for different varieties (Fig. 2). The root mean square error (RMSE) values for days taken to maturity were 7.8 days as compared to the mean value of 150 days.

Info Crop model was evaluated for leaf area index (LAI) of mustard measured at different crop growth stages (Table 1). The root mean square error (RMSE) values for leaf area index ranged from 0.5 to 0.2 in RCC-4, 0.2 to 0.1 in Kranti and 0.1 to 0.3 in Varuna sown under four sowing environments from October to November. The average lowest RMSE value (0.12) was recorded in genotype Kranti. Amongst sowing dates, the lowest average RMSE value (0.13) was recorded in October 20 sown crop. The differences were higher in early and late sown crop. The results are in conformity with Neog *et al.,* (2006).

The root mean square error (RMSE) values for dry matter accumulation ranged from 62.1 to 128.9 kg ha^{-1} in RCC-4, 53.1 to 142.8 kg ha^{-1} in Kranti and 73.3 to 113.2 kg ha^{-1} in Varuna sown under four sowing environments from October to November (Table 1). Lower value of RMSE indicated good fit of model for this parameter.

Info crop model was validated for simulating mustard yield for Palampur location using wide range of yield data for dates of sowing and varieties. The economic yield simulated by model corresponded well with that actually observed in the field (Fig. 3). The root mean square error (RMSE) value for yield was 74.8 kg ha^{-1} as compared to mean value of 1127.1 kg ha^{-1} in different crop varieties sown under four sowing environments from October to November.

Climate change impact assessment

Effect of increasing temperature

The observed and predicted days taken to flower initiation, maturity and yield are given in Fig. 4, 5 and 6,

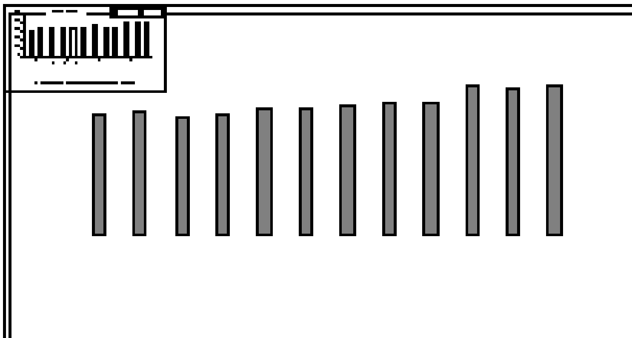

Fig. 1: Observed and simulated days to flower initiation

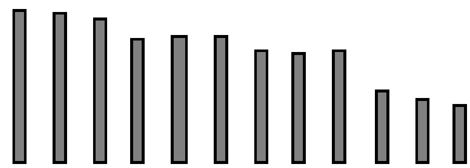

Fig. 2: Observed and simulated days to physiological maturity

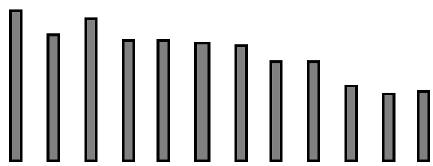

Fig. 3: Observed and simulated yield of India mustard

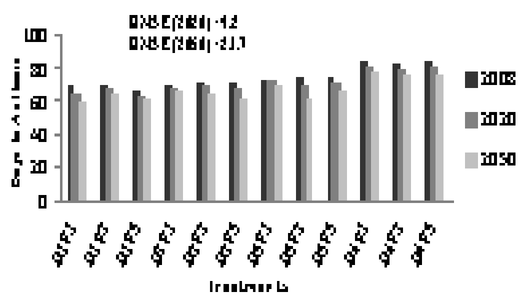

Fig. 4: Observed and predicted days to flower initiation of India mustard for 2020 and 2050

respectively. The decreasing trends for days to flower initiation and maturity were observed at all sowing environments in all three varieties. The days to flower initiation ranged from 0 to -4 days and -3 to -13 days while the days to maturity ranged from -5 to -18 days and -10 to -20 days for 2020 and 2050, respectively reflecting early maturity of crops. The decreasing grain yield for October 10, October 20, and October 30 was ranged between -3.8 to -14 % and -8 to -25 % for 2020 and 2050, respectively. The increasing trend of grain yield for November 9 sown crop ranged from 0 to +17 % and +13 to +15 % for 2020 and 2050, respectively. The maximum decrease in days to flower initiation and maturity was simulated for 2050 and lesser for 2020 scenario. This decrease in days to flower initiation and maturity is due to the projected increase in temperature by 1.71^{0}C and 0.74^{0}C for the years 2050 and 2020, respectively. Increasing temperature lowered days to flowering and days to maturity, which in turn lowered total crop duration. 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 (Boomiraj *et. al.,* 2010).

Effect of decreasing rainfall

The effects of decreasing rainfall on days taken to flower initiation, maturity and yield are given in Fig. 7, 8 and 9, respectively. The slight decrease for days to flower initiation, maturity and yield was observed at -10 per cent reduction in rainfall throughout the crop season as compared to 523 mm of normal seasonal rainfall in all treatments. The reduction in days to flower initiation and maturity due to decreasing rainfall ranged between -1 to -8 and 0 to -10 days, respectively. Similarly, the reduction in grain yield of Indian mustard due to decreasing rainfall (-10 %) ranged from 0 to -16 % compared to 2008 yield. Simulation study conducted by Singh *et al.,* (2008) also revealed that with rise in temperature, rain becomes the deciding factor in regulating crop production. It is envisaged that the increase in temperature, if any, may be compensated by increase in rainfall.

Effect of increasing temperature and decreasing rainfall

The predicted effects of increasing temperature and decreasing rainfall on days taken to flower initiation, maturity and yield are given in Fig. 10, 11 and 12 respectively. The decreasing trend for days to flower initiation, maturity and yield was observed at increasing temperature and 10 per cent reduction in rainfall in all treatments for the year 2020 and 2050. The magnitude of reduction was observed more for 2050 due to maximum rise in temperature (1.71^{0}C). The reduction in days to flower initiation due to increasing

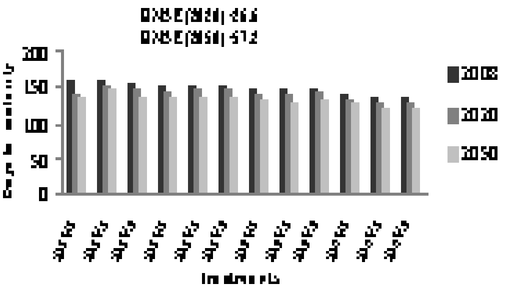

Fig. 5: Observed and predicted days to physiological maturity of Indian mustard for 2020 and 2050

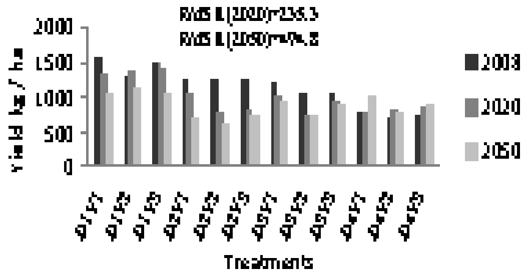

Fig. 6: Observed and predicted yield of Indian mustard for 2020 and 2050

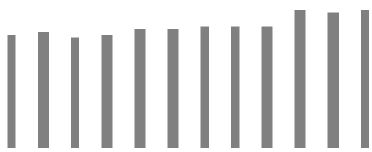

Fig. 7: Effect of decreasing rainfall (-10%) on flower initiation of Indian mustard

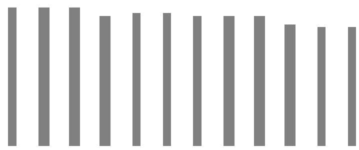

Fig. 8: Effect of decreasing rainfall (-10%) on maturity of Indian mustard

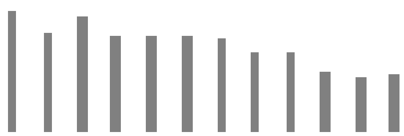

Fig. 9: Effect of decreasing rainfall (-10%) on yield of Indian mustard

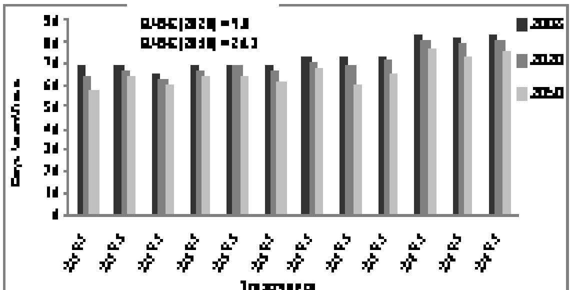

Fig. 10: Effect of increasing temperature and decresing rainfall (-10%) on flower initiation of Indian mustard for 2020 and 2050

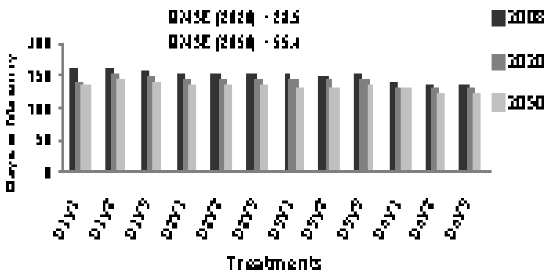

Fig. 11: Effect of increasing temperature and decresing rainfall (-10%) on maturity of Indian mustard for 2020 and 2050

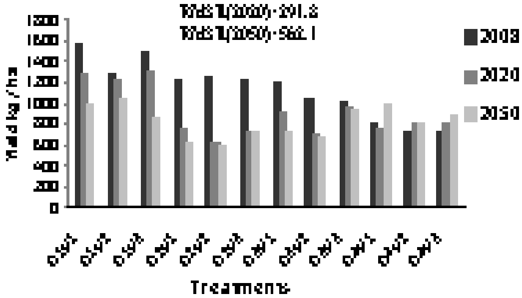

Fig. 12: Effect of increasing temperature and decresing rainfall (-10%) on yield of Indian mustard for 2020 and 2050

temperature and decreasing rainfall ranged between -1 to -4 and -5 to -13 days for 2020 and 2050, respectively. The days to maturity also showed decreasing trend for the years 2020 and 2050 and ranged between -4 to -19 and -10 to -23 days, respectively. For all sowing dates (October 10, October 20 and October 30) grain yield showed reduction except for November 9 sown crop. The decrease in grain yield ranged from -4 to -16 percent and -9 to -25 percent, for 2020 and 2050, respectively. The increasing grain yield for November 9 sown crop ranged from +1 to +12 % and +12 to +17 % for 2020 and 2050, respectively. Similar findings indicating beneficial impact of delayed sowing of mustard during November under elevated temperature conditions at Delhi were also reported by Kumar *et.al.* (2010). Increasing temperature lowered the days to flowering and days to maturity thus shortening the seed formation period. A higher temperature leads to higher respiration rates, lower biomass production, smaller and lighter grains, and therefore lower crop yields. Bhagat *et al.,* (2007) also reported that increase in temperature caused shortening of days to flower initiation in linseed crop by 2 to 13 days under Palampur condition.

CONCLUSION

Crop simulation model can be used in climate change impact assessment and adaptation strategy. Results from simulation study revealed that Info Crop model satisfactorily calibrated and validated for sub-temperate and sub humid conditions of Palampur, Himachal Pradesh for Indian mustard crop. The simulated and observed days to flower initiation and maturity, LAI, dry matter accumulation and yield matched closely. Due to increased temperature (0.74^{o}C for 2020 and 1.71^{o}C for 2050) and decreased rainfall (-10%) there is reduction in days to flower initiation and days to maturity. The crop sown on October 10, October 20, and October 30 showed the decreasing trend of grain yield while the late sown crop (November 9) showed increase in simulated grain yield for 2020 and 2050. Under present climatic conditions, October 10 is the best planting window for the mustard crop under mid hill sub-humid region of Himachal Pradesh. Under elevated level of temperature delay of sowing by one month proved beneficial.

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