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Short Communication

Sensitivity analysis to study the effects of temperature, carbon dioxide and solar radiation on sunflower under middle Gujarat Agro climatic region

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Sunflower thrives in climates ranging from arid under irrigation to temperate under rainfed conditions, but is susceptible to frost. In the subtropics under irrigation the total growing period is about 130 days. For temperate climates the optimum planting date for early as well as late maturing varieties is between late spring and early summer. Delay in planting results in shortening of the vegetative period and early maturity, causing a decrease in head diameter and seed weight. Sunflower is a short-day plant with a variable response to daylength, but day-neutral varieties exist. The crop requires a low temperature (3.0 – 6.0 °C) during germination and optimum temperature of 20.0 – 26.0 °C later on. Warm weather and non-cloudy sunny days are considered favorable during reproductive phase i.e. flowering to maturity. The crop can be sown in all the season and across the country. Temperature above 40.0 °C would cause desiccation of pollen and drying of stigma attributing to poor seed set and low yield. Deccan plateau, hot semi-arid eco region has largest area under sunflower, whereas, Northern Plains have shown higher productivity of sunflower during summer season with assured irrigation (Source: Annual Report Directorate of oilseeds Research Hyderabad 2014).

The field experiments were conducted at experimental form of Anand Agriculturl University, Anand during two consecutive years (2015 and 2016) with three plant spacing (S_1- 60 x 10 cm, S_2-60 x 20 cm, S_3- (60 x 30 cm) and two cultivars (V_1- LFSH 35 and V_2- LFSH 171. The experiment was laid out in split plot design with four replications. The soil was sandy loam soil having gentle slope and good drainage as well as fair moisture retentive capacity.

OILCROP-SUN is a process-oriented crop mod-el which simulates, with a daily time step, sunflower development and growth (Villalobos *et al*., 1996). Crop development is divided into three phases: (i) sowing to emergence; (ii) emergence to first anthesis; and (iii) first anthesis to physiological maturity. The photoperiod only interferes with the flower bud initiation (e.g. Goyne and Schneiter, 1988). For the calculation of the cumulative thermal time, a base temperature of 4.0 °C is considered (Villalobos and Ritchie, 1992). In OILCROP-SUN, crop development is regulated by three genotype-specific genetic coefficients (P1, P2 and P5) P1 expresses the length of the juvenile phase in °C day. P2 is a photoperiodic coefficient that identifies the number of days by which development is delayed when the crop is grown in a photoperiod shorter than the opti-mum (15 h) and is expressed in days per hour of shorter photoperiod (days h^{-1}). P5 accounts for the duration of the first anthesis to the physiological maturity stage expressed in °C day. Leaf appearance, expansion and senescence are used to estimate leaf area index (LAI) during the growing period and are modelled as a function of temperature as well (Villalobos *et al.,* 1996).

The calibration and validation of DSSAT model (OILCROP-SUN) was done using experimental data of year 2015 and 2016. Sensitivity analysis is an important way of evaluating models. It helps to better understand variation in output to changes in inputs. The input weather parameters which include maximum and minimum temperatures, solar radiation and CO_2 were used for sensitivity analysis. The maximum and minimum temperatures were increased and decreased from 0.5 to 2.0°C at 0.5 increment level, solar radiation increased and decreased from 1.0 to 3.0 at 1.0 MJ day^{-1} increment level and CO_2 increased from 330 to 530 ppm at 50 ppm increment level to assess the climate change impact on seed yield. Similarly row spacing and sowing windows will be altered to assess model sensitivity.

As much as 80% of variability of agricultural production is sensitive mainly due to variability in weather conditions. These include maximum and minimum air temperature, solar radiation, carbon dioxide and rainfall at different levels. Therefore, the results produced by the models during the present investigation can be used to make

Table 1: Sensitivity of OILCROP-SUN model to maximum and minimum temperature.

	Maximum		Minimum	
Change in Temp (^{0}C)	Simulated seed yield(kg ha^{-1})	% change from 1056kg ha^{-1}	Simulated seed yield(kg ha^{-1})	% change from 1056kg ha^{-1}
-2.0	954	-9.7	1140	8.0
-1.5	990	-6.3	1139	7.9
-1.0	1035	-2.0	1110	5.1
-0.5	1070	1.3	1082	2.5
0.5	1100	4.2	1065	0.9
1.0	1130	7.0	1031	-2.4
1.5	1350	27.8	1010	-4.4
2.0	1210	14.6	987	-6.5

Table 2. Sensitivity of OILCROP-SUN model to elevated CO_2

Elevated level of CO_2 (ppm)	CO_2 after elevation (ppm)	Simulated seed yield (kg ha^{-1})	% change from 1056 kg ha^{-1}
50	380	1381	30.8
100	430	1575	49.1
150	480	1568	48.5
200	530	1578	49.4

Table 3. Sensitivity of OILCROP model to solar radiation

Change in Solar radiation (MJ m^{-2})	Simulated seed yield (kg ha^{-1})	% change from 1056 kg ha^{-1}
-3.0	482	-54.4
-2.0	604	-42.8
-1.0	874	-17.2
1.0	1274	20.6
1.5	1485	40.6
2.0	1583	49.9

appropriate management decisions and to provide farmers and farming community with alternative options for their farming systems. In most climate change applications, long term historical data is used as input for the models. But, in the present investigation, the simplest approach by assuming a fixed climate change by modifying the data with a constant number, such as an increase considered as super optimum and decrease as sub optimum for maximum and minimum temperature (± 0.5, 1.0, 1.5 and 2.0 °C) and carbon dioxide concentration (± 380, 430, 480 and 530 ppm) was applied to daily weather data, and the crop simulation models were performed to determine the sensitivity of seed yield levels to varying weather variables and climate change impact for these modified inputs for sunflower crop. The model simulated results with altered weather was compared with base yield (1056 kg ha^{-1}). The base yield was simulated by model having normal weather data and normal packages and practices.

The estimations obtained from the sensitivity analysis represent both current and future climate conditions as well as the expected climate change impact on sunflower production under varying dates of sowing and row spacing which are presented and discussed under following sub headings.

Temperature effect

The data pertaining to the effect of maximum temperature on seed yield of sunflower is presented in Table 1. The sensitivity of OILCROP-SUN model simulated seed yield to super optimum condition with incremental units of maximum temperature 0.5 to 2 ^{0}C showed a gradual increase in yield levels upto 1.5°C level. The decrease in seed yield varied according to the decrease in the maximum temperature. These results were in good confirmation with the findings of Wajid Nasim (2010).

The data pertaining to the effect of minimum temperature on seed yield of sunflower is presented in Table 1. The model simulated seed yield to super optimum condition with incremental units of minimum temperature 0.5 to 2 ^{0}C showed a gradual increase in yield levels. The increase in seed yield varied according to the decrease in the minimum temperature. The decrease was lowest for 1.0 ^{0}C (-2.4%) and was highest at 2 ^{0}C (-6.5%). However, the seed yield increased with increase in the minimum temperature upto 3 ^{0}C. The yield increased by 8.0 to 22.7 from decrease in the minimum temperature by 1 to 3 ^{0}C respectively.

Effect of elevated CO_2

The data pertaining to the effect of elevated CO_2 on seed yield of sunflower is presented in Table 2. The sensitivity of OILCROP-SUN model to elevated level of CO_2 50, 100, 150 and 200 ppm (base level 330) showed increase in seed yield up to 430 ppm level and after that seed yield found stagnated. These results were in confirmation with the findings of Wajid Nasim (2010).

Effect of increased solar radiation

The data pertaining to the effect of solar radiation on seed yield of sunflower is presented in Table 3. The sensitivity of OILCROP-SUN model simulated seed yield to super optimum condition with incremental units of solar radiation 1.0 to 3.0 MJ m^{-2} showed a gradual increase in yield levels. The decrease in seed yield varied according to the decrease in the solar radiation by 1.0 to 3.0 MJ m^{-2}.

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