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Effects of change in temperature and CO_2 concentration on summer groundnut in middle Gujarat- A simulation study

B. M. MOTE, VYAS PANDEY and D. D. PATIL

Dept. of Agricultural Meteorology, Anand Agricultural University, Anand, Gujarat

Email:amarmote4141@gmail.com

ABSTRACT

The present investigation was carried out to study the impact of climate change on summer groundnut in middle Gujarat using calibrated CROPGRO-peanut model by changing maximum and minimum temperatures by -2 to +3^{0}C and increasing concentration of CO_2 upto 550 ppm. Results revealed that with increase in maximum temperature by 3 ^{0}C, the pod yield was decreased by 39 to 48 per cent in different cultivars. The effect of minimum temperature on pod yield was less as compared to maximum temperature. The simulated pod yield increased upto 41 per cent with elevated CO_2 concentration of 550 ppm. However, if the maximum temperature was increased alongwith increase in CO_2 concentration the pod yield could be compensated upto 2 ^{0}C with CO_2 of 500 ppm, but further increasing of the maximum temperature and carbon dioxide caused decrease in the pod yield.

Key words : CROPGRO-peanut model, climate change, groundnut cultivars

In India, 80 per cent of the groundnut area and 84 per cent of its production is confined to the states of Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka and Maharashtra. Among these, Gujarat ranks first both in area and production (Anonymous, 2012a). In Gujarat, the average productivity of groundnut is 1603 kg ha^{-1} in *kharif* and 1903 kg ha^{-1} in summer season (Anonymous, 2012b).

The climate change is now a reality as it is evident from the observed trends in climatic parameters due to enhancement of greenhouse gases. Globally, the mean temperature has increased by 0.74 ^{0}C and it is projected to increase by 1.8 to 4 ^{0}C by 2100 (IPCC, 2014). In addition to increase in temperature, the increase in frequency of weather extremes events *viz*., heat waves, floods, cyclones and droughts projected to aggravate the situation further. These parameters are bound to affect the agricultural production. The increase in temperature by 1 to 3 ^{0}C may cause reduction in wheat yield in Gujarat by 8 to 31 per cent (Pandey *et al.,* 2007). Similarly, the reduction of production in *kharif* maize (47 %), paddy (32 %), groundnut (24 %) and pearl millet (14 %), *rabi* maize (10 %) and summer pearl millet (8%) have been reported with increase in temperature by 2.8 to 7.7 ^{0}C (Patel *et al.,* 2008). The crop growth models are helpful to assess the impact of climate change on the stability of crop production under different management options and is used across the world. Different workers have evaluated the CROPGRO model (Suriharan *et al.,* 2008; Patel *et al.,* 2013) for groundnut crops grown in *kharif* season. In the present investigation, an attempt has been made to study the impact of change in temperature and CO_2concentration on summer groundnut using CROPGRO-peanut model.

MATERIALS AND METHODS

The field experiment on groundnut was carried during the summer season of 2015 and 2016 at Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand (Latitude of 22^{0}35'N and longitude of 72^0 55'E and at an elevation of 45.1m above mean sea level). The experimental site located near to the agrometeorological observatory and falls in the middle Gujarat Agro-Climatic Zone-III.The experiment was laid out in split plot design with four replications and the details of treatments are as follow. The four varieties of groundnut *viz.,* GG-2, GG-20, GJG-31 and TG-26 were sown on three different dates *viz.*, D_1early date (31th January),D_2normal date (15th February) and D_3late date (2ndMarch).

The data on plant growth and development, soil characteristics, weather and crop management for 2015 were used for calibration of the CROPGRO-peanut model as required for determining the genetic coefficients of GG-2, GG-20, GJG-26 and TG-26 cultivars using GLUE program. The calibrated genetic coefficients of groundnut cultivars (Table 1) were validated with data set of 2016.

After validation of model, the sensitivity analysis was done with input parameters which include maximum and

Table1: Genetic coefficients for different cultivars of groundnut

Parameter	GG2	GG 20	GJG 31	TG 26
CSDL	11.84	11.84	11.84	11.84
PPSEN	0.00	0.00	0.00	0.00
EM-FL	19.5	19.5	18.5	18.5
FL-SH	11.0	10.0	8.0	11.0
Fl-SD	20.0	19.0	18.0	18.0
SD-PM	40.0	39.0	35.0	36.0
FL-LF	89.0	87.0	80.0	80.0
LFMAX	1.50	1.50	1.48	1.40
SLAVR	270	260	240	240
SIZLF	16.0	16.0	16.0	16.0
XFRT	0.84	0.84	0.84	0.80
WTPSD	0.155	0.200	0.200	0.200
SFDUR	24.0	22.0	24.0	22.0
SDPDV	1.46	1.65	1.46	1.55
PODUR	3.0	4.0	4.0	4.0
THRSH	76.0	74.0	74.0	80.0
SDPRO	.270	.270	.270	.270
SDLIP	.510	.510	.510	.510

minimum temperatures and CO_2 concentration by increasing and decreasing maximum and minimum temperatures by -2 to +3^{0}C and increasing CO_2 level of 450,500, 550 ppm in input file of the model and pod yield were simulated for each variety under normal sowing period (February 15) and per cent change in yield were calculated.

RESULTS AND DISCUSSION

Impact of maximum temperature on pod yield

The effects of incremental change in maximum temperature (-2 to +3^{0}C) on simulated pod yield of groundnut cultivars of under normal date of sowing D_2 (15th February) were compared with base yield (simulated by model under daily normal weather data set) and its per cent change from base yield are presented in Table 2. Increasing maximum temperature was found to have negative effect while decreasing maximum temperature had positive effect on the pod yield of groundnut cultivars. With a change of ±1 ^{0}C of maximum temperature, yield was found to change between 10 to 20 per cent in different cultivars. With 3 ^{0}C increase in maximum temperature, the pod yield decreased between -39 and -48 per cent, the highest effect being in cultivar TG 26 and lowest in GG 2. With decrease in temperature by 2 ^{0}C variety GG 20 is benefited most (+ 34%) and variety GG 2 is benefited least (21%). Patel *et al*. (2013) reported that due to climate change the pod yield of groundnut would decrease by 20 to 36 per cent by end of the century (2071-2100), mainly due to increase in temperature. Mishra *et al*. (2015) also reported that the elevated maximum temperature decreased yield of wheat significantly.

Impact of minimum temperature

Impact on pod yield of groundnut cultivars due to change in minimum temperature was lower as compared to the maximum temperature but the trend was similar (Table 2). An increase of minimum temperature by 3^0 C the highest reduction in yield (-16 %) was observed in *cv.* GJG 31 and lowest reduction (10 %) in *cv.* TG 26. However the decrease of minimum temperature upto -2^{0}C increased the yield of different cultivars, between 5 to 11 per cent. This type of behaviour shown by the crops might be due to dual effects of higher rate of respiration during night time resulted in to comparatively higher loss of photosynthates than that was occurred during day time due to increased maximum temperature. Paradoxically, the lower minimum temperature increased the pod yield in the all cultivars, but not in the same magnitude. Similar effects of increased and decreased temperature on groundnut yield have been reported by Rao *et al.* (2011).

Impact of carbon dioxide

Elevated concentration of carbon dioxide had a significant and positive impact on the pod yield of different groundnut cultivars (Table 2). Increase in the concentration of carbon dioxide from base value 400 ppm by 50, 100 and 150 ppm the change in yield were between 13 to 41per cent in different cultivars. Cultivar GJG 31 was found to be more responsive to CO_2 concentration. In commonly grown cultivar GG 2, the pod yield increased by 14 to 24 per cent. Yadav *et al*. (2016) also reported that the productivity of different pulse, oilseed and vegetable crops increased under expected enhanced CO_2 concentrations.

Combined effects of maximum temperature and carbon dioxide

The sensitivity results showed that the increase in maximum temperature by 1^{0}C, combined with increase in CO_2 concentration upto 450ppm, increased the pod yield in different cultivars, the highest increase (25%) was in GG 20 followed by GG 2 (20%) and GJG 31 (Table 2). Borjigidai *et al.,*(2006) reported that a positive interaction between elevated CO_2 and high temperature on photosynthesis of C_3

Table 2: Effect of maximum temperature, minimum temperature, CO_2 concentration on pod yield of groundnut cultivars

Change in parameter	V_1- GG 2 (2160 kg ha^{-1})		V_2- GG 20 (2164 kg ha^{-1})		V_3-GJG 31 (2513 kg ha^{-1})		V_4-TG 26 (2086 kg ha^{-1})	
	Simulated pod yield (kg ha^{-1})	% change over base yield	Simulated pod yield (kg ha^{-1})	% change over base yield	Simulated pod yield (kg ha^{-1})	% change over base yield	Simulated pod yield (kg ha^{-1})	% change over base yield
Maximum temperature (°C)								
-2	2606	21	2890	34	3301	31	2617	25
-1	2518	17	2385	10	2975	18	2344	12
+1	1818	-16	1787	-17	2007	-20	1755	-16
+2	1543	-29	1326	-39	1630	-35	1364	-35
+3	1317	-39	1173	-46	1423	-43	1088	-48
Minimum temperature (°C)								
-2	2289	6	2328	8	2798	11	2194	5
-1	2267	5	2294	6	2598	3	2148	3
+1	2336	-6	1968	-9	2261	-10	1851	-11
+2	1982	-8	1897	-12	2178	-13	1782	-15
+3	1908	-12	1848	-15	2115	-16	1878	-10
CO_2 concentration levels (Base value 400 ppm)								
450	2495	16	2581	19	2856	14	2365	13
500	2687	24	2786	29	2942	17	2653	27
550	2935	37	2994	38	3112	24	2948	41
Maximum temperature (°C) + CO_2 concentration (Base value 400 ppm)								
1 + 450	2655	23	2709	25	3033	20	2469	18
2 + 500	2269	5	2183	1	2481	-1	2143	3
3 + 550	2061	-4	1845	-15	2108	-16	1738	-17

plants. However, the increase of maximum temperature by 2^{0}C and corresponding increase in level of CO_2 at 500 ppm, the adverse effect of maximum temperature was compensated with positive effect of CO_2 concentration as a result the net effects were very marginal (-1 to 5 %) across the cultivars. Further increase of temperature by (+3^{0}C) with corresponding increase of CO_2 at 550ppm, resulted in adverse effect on groundnut. The per cent reduction of yield was maximum in cultivar TG 26 (-17%) followed by *cv.* GJG 31 (-16 %) and *cv.* GG 20 (-15 %). Attri and Rathore (2003) also observed that an increase of 1.0 ^{0}C temperature and a doubling of the atmospheric CO_2 concentration could increase wheat yields by 29 – 37 per cent. However, further increases in temperature beyond 3 ^{0}C would negate the beneficial impacts of enhanced CO_2 and decrease yield by 20 per cent.

CONCLUSIONS

It is concluded that increase in temperature reduced the pod yield of summer groundnut and vice versa. The effect of minimum temperature on pod yield was less than that of maximum temperature. Among different cultivars GG 20 and GJG 31 was more vulnerable to increase in maximum temperature. The yield reduction due to the increase in maximum temperature upto 2 ^{0}C would be compensated by increase in CO_2 concentration upto 500 ppm, thereafter yield of groundnut will decrease.

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