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Assessment of climate change and its impact on growth and yield of wheat under temperate and sub-tropical conditions*

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ABSTRACT

Field experiments were conducted at research farm of SKUAST-K, Shalimar campus, Srinagar for 2 years (2003-04 and 2004-05) on silt clay loam soil and at research farm of Integrated Farming System, SKUAST-J, Chatha, Jammu for 7 years (2003-04 to 2009-10) at sandy loam soil in order to find out the impact of climate change on wheat crop under temperate and sub tropical condition by using crop simulation model (DSSAT-v4.0). The results showed that under temperate condition the phenology of wheat is more affected compared to sub tropical condition if temperature increased and decreased. Simulated grain yield of wheat increased up to 18.31 per cent by elevated CO_2 to 350 ppm from the base value 330 ppm in temperate condition.

Key words: Climate change, wheat, CO_2 concentration, DSSAT4.0 model, sub tropical, temperate condition.

Climate of Jammu and Kashmir varies from sub tropical to temperate conditions. Wheat is grown in an area of about 2.66 lakh ha with annual production of 4983 thousand quintals with productivity of 19 q ha^{-1} (Anonymous, 2008-09). Temperature has profound effect on the yield mainly through phenological development processes. Increase in air temperature may be more important than the expected rise in atmospheric CO_2 concentrations as there are no evidences that elevated CO_2 concentrations may directly induce changes in development (Lawlor and Mitchell 1991). In temperate region, temperature drop below freezing point for couple of weeks. According to IPCC, 2007 the CO_2 level will rise to 605-755 ppm by 2070 and warming of 1.5^{o}C by 2015-2050 and 3^{o}C by 2050 to 2100. The data revealed that the day temperature in Jammu has decreased by 0.7° C from last two decades while night temperature has gone up by 0.6° C. On the other hand in Srinagar, both maximum and minimum temperatures have gone up by 1.0 and 0.4° C, respectively. Similarly the rainfall in these places has increasing trend of 2.0 mm $year^{-1}$ in Jammu and decreasing trend of 8.0 mm $year^{-1}$ in Srinagar. The rates of most biophysical processes are highly dependent on climate variables such as radiation, temperature in addition to moisture. For example, rates of plant photosynthesis depend on the amount of photosynthetically active radiation and levels CO_2. Temperate crops may benefit more from increasing CO_2 than tropical. The C_3 pathway characteristic of non-tropical plant (eg. wheat, soybean, cotton) will be affected adversely more with increasing CO_2 concentration and increase in temperature. Various studies showed that increase in temperature by 2.5°C to 4.9°C, the rice yield will decrease by 15 % to 49 % and wheat yield will decrease by 25 % to 42 % without carbon dioxide fertilization. Mall, (2008) reported that the yield of rice and wheat increased by 26.6% and 18.4% due to double CO_2 and 17.1% and 8.6% due to increase in temperature respectively. To find the possibility of wheat cultivation in rice based system by manipulating agronomic practices specially dates of sowing and varieties and find the effect of climate change on crop growth and grain yield of wheat using dynamic crop growth simulation model CERES-wheat is useful. This model takes into account climate variables, soil variables and the

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influence of higher atmospheric concentration of CO_2.

MATERIALS AND METHODS

The crop, weather and soil data required for the present study were taken from research farms at SKUAST-K Research farm Shalimar campus, Srinagar (34^{o}52 N, 74^{o}522 E and 1587 m above sea level) and Research Farm of Integrated Farming System Research, SKUAST-J, Chatha, Jammu (32^o 392 N, 74^o 582 E and 332 m above sea level). Two field experiments at temperate condition in Kashmir, during 2003-04, 2004-05 and five under low altitude sub tropical during 2005-06, 2006-07, 2007-08, 2008-09 and 2009-10 were conducted. Under temperate condition three dates of sowing *viz*. D_1 (1st October), D_2 (15th October) and D_3 (30th October) with six cultivars of wheat *viz.* HS 240, HS 295, HS 365, SKW 191 SKW 193 and Shalimar wheat-1 were selected. The treatments were same during both the years. The treatments were replicated thrice in split plot design with dates of sowing in main plots and genotypes of wheat in subplots. The crop was sown in second fortnight of November with variety PBW 343 under sub tropical condition. At both locations, crop was raised using normal package of practices.

The important phenophases of wheat were recorded by tagging five plants in each treatment. Observations on different phenological stages such as emergence, tillering, jointing, booting, heading, anthesis, milk, dough and maturity were recorded for every treatment. Out of these five, three plants have attained the particular phenophases or Anthesis was determined when more than 50 % of spikes were visible in the center of the plot. The crop reached physiological maturity when 95 % of the ear head has turned from green to yellow.

Daily data on temperature, rainfall and duration of bright sun shine were collected from India Meteorological Department, Srinagar for Sub tropical region (Jammu) and temperate (Kashmir). The DSSAT4.0 was calibrated and validated with the experimental data.

Sensitivity analysis

After validation of model the sensitivity analysis were carried out by changing in input weather parameters (Pathak *et al.*, 2003). Detailed treatment combinations of different climate scenario are given Table 1

Table 1: Treatment combinations of different climate scenario :

Treatment	Max. Temperature (ºC)	Min. Temperature (ºC)	Carbon dioxide Concentration (ppm)
C1	Normal (Ambient)	Normal (Ambient)	Normal (330 ppm)
C2	+2	+2	Normal
C3	+4	+4	Normal
C4	Normal	Normal	350
C5	Normal	Normal	450
C6	Normal	Normal	700
C7	+2	+2	450
C8	+2	+2	700
C9	+4	+4	450
C10	+4	+4	700
C11	-2	-2	Normal
C12	-4	-4	Normal

RESULTS AND DISCUSSION

Effect on maturity of wheat crop

The simulation results showed that the wheat crop sown under normal temperature and carbon dioxide took 263 days to mature under temperate condition, while under subtropical condition wheat crop mature in about 164 days. The increase in maximum and minimum temperature by 2^{o}C and 4^{o}C without change in CO_2 concentration during the crop growing period the wheat maturity observed earlier by 17 and 30 days under temperate condition, while 10 and 18 days under subtropical condition, respectively. Hundal and Prabjyot Kour (2007) revealed that increase in temperature by 4^{o}C decreased days to maturity by 17 days for wheat in Punjab. However increase in carbon dioxide levels to 350, 450 and 750 ppm under normal temperature did not affect maturity of wheat crop under temperate condition of Jammu and Kashmir, but it enhances the wheat maturity by 3-5 day under sub tropical condition (Table 2). Wheat crop matured in advance by 6 to 18 days under sub tropical condition, while 17-30 days in temperate condition. But when the temperature decreased to 2^{o}C and 4^{o}C the ripeness of wheat crop was delayed by 20 to 38 days and 10 to 17 days under

Table 2: Effect on yield and maturity of wheat as function of change in temperature and CO_2 levels under temperate and sub tropical condition

Climate change	Maturity date		Days to maturity		Deviation in maturity days	
	Temperate	Sub tropical	Temperate	Sub tropical	Temperate	Sub tropical
C_1	24 June	25 April	263	164	-	-
C_2	7 June	15 April	246	154	-17	-10
C_3	25 May	07 April	233	146	-30	-18
C_4	24 June	25 April	263	164	0	0
C_5	24 June	28 April	263	167	0	+3
C_6	24 June	30 April	263	169	0	+5
C_7	7 June	15 April	246	154	-17	-10
C_8	7 June	19 April	246	158	-17	-6
C_9	25 May	07 April	233	146	-30	-18
C_{10}	25 May	09 April	233	148	-30	-16
C_{11}	14 July	05 May	283	174	+20	+10
C_{12}	1 August	12 May	301	181	+38	+17

Table 3 : Effect on Leaf Area Index of wheat as function of change in temperature and CO_2 levels at different days after sowing under temperate and sub tropical condition

Climate change	50 DAS		100 DAS		150 DAS		200 DAS	250 DAS
	Temperate	Sub tropical	Temperate	Sub tropical	Temperate	Sub tropical	Temperate	Temperate
C_1	0.96	1.17	1.44	2.40	1.68	0.55	1.52	1.18
C_2	1.62	1.80	1.24	1.98	1.08	0.20	0.94	-
C_3	1.48	2.02	0.74	0.88	0.98	-	0.72	-
C_4	0.86	1.34	1.40	2.65	1.58	0.80	1.45	1.12
C_5	0.90	1.52	1.41	3.01	1.50	0.95	1.48	1.20
C_6	0.92	2.20	1.39	3.85	1.50	1.18	1.42	-
C_7	1.53	1.97	1.13	3.48	0.90	0.72	0.56	-
C_8	0.57	1.88	0.60	3.03	0.63	0.41	1.22	1.10
C_9	1.57	2.20	0.62	1.81	0.75	-	0.58	-
C_{10}	1.40	2.01	0.63	1.75	0.65	-	0.56	-
C_{11}	1.58	1.14	1.12	3.10	0.84	1.15	0.60	0.67
C_{12}	0.22	0.78	0.26	2.02	0.28	2.86	1.04	1.40

Table 4 : Effect on leaf dry weight kg/ha^{-1} of wheat as function of change in temperature and CO_2 levels at different days after sowing under temperate and sub tropical condition

Climate change	50 DAS Temperate	100 DAS Sub tropical	150 DAS Temperate	Sub tropical	Temperate	Sub tropical	200 DAS Temperate	250 DAS Temperate
C_1	507	680	790	938	990	377	1010	900
C_2	838	1032	800	902	790	205	730	-
C_3	890	1128	530	640	650	-	600	-
C_4	305	536	790	892	970	401	1180	980
C_5	505	637	810	1089	1005	466	1230	980
C_6	310	674	840	1176	380	516	640	-
C_7	610	615	495	715	680	185	660	-
C_8	490	589	850	695	710	108	660	970
C_9	600	700	505	566	700	-	600	-
C_{10}	620	642	485	560	620	-	595	-
C_{11}	210	517	300	630	320	345	1200	390
C_{12}	195	328	205	488	210	454	810	1190

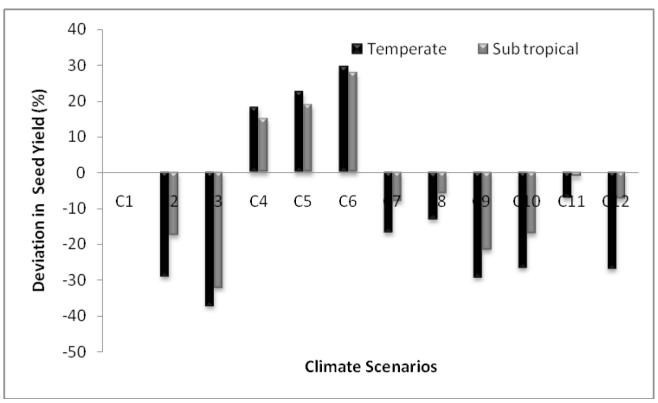

Fig. 1: Effect of deviation in Seed yield (Per cent) as function of climate change in wheat crop under temperate and sub tropical condition

temperate and sub tropical condition, respectively and the results confirmed with findings of Kalra *et al.*, (2008).

Effect on growth parameters

Simulation study was carried out to describe the effects of climate change on leaf area index in wheat (Table 3). The leaf area index of normal sown wheat crop increased with advancement of the crop and it was found maximum at about 100 days after sowing, thereafter it declined up to the physiological maturity of crop, but with the increase in temperature by 4^{o}C, shorten the vegetative phase of wheat crop and the maximum leaf area index stage observed around 50 days after sowing in sub tropical areas. While leaf area index increased with increase in CO_2 concentration and observed maximum of 3.85 at 700 ppm CO_2 concentration at normal temperature. In temperate region, leaf area index increased with the increased in temperature in combination with increased concentration of CO_2 and vice versa. Increase in temperature by 2^{o}C enhanced leaf area index by 12 per cent in this region.

The leaf dry weight was found maximum (1230 kg ha^{-1}) at CO_2 concentration of 700 ppm under temperate condition. But when temperature decreased by 2 and 4^{o}C coupled with normal CO_2 concentration, the leaf dry weight slowly increased up to 150 DAS and then abruptly increased at 200 and 220 DAS under temperate condition (Table 4). Under sub tropical condition the effect of climate change on leaf dry weight substantiate the analogous outline as in case of leaf area index, but it was found maximum at 100 days after sowing, when concentration of CO_2 increases up to 700 ppm with no change in temperature. Amir and Sinclair (1991) from Israel highlighted that the influence of cool conditions were clearly advantageous for increasing leaf area duration and accumulated biomass development of wheat crop in Asia. It was shown that the effect of climate change on total biomass production in wheat crop had been found more under subtropical condition compared to temperate condition.

Effect on grain yield of wheat

Simulated effect of increase in maximum and minimum temperature by 2^{o}C and 4^{o}C throughout the crop growing periods reduced the crop yield by 29.09 and 37.29 per cent, respectively under temperate condition and 17.52 and 32.18 percent, respectively under subtropical condition as compared to normal temperature (Fig. 1) and results confirmed by Rosenzweig (1991). Increase in maximum and minimum temperature by 2^{o}C under elevated CO_2 concentration 450 ppm abruptly decreased wheat yield by 16.82 per cent, while increase in temperature by 2 ^{o}C with CO_2 concentration of 700 ppm enhanced grain yield by 13.14 per cent in temperate condition and similar type of results reported by Tubiello *et al.*, (1995). Decrease in maximum and minimum temperature by 2 and 4^{o}C with normal concentration of CO_2 decreased wheat yield by 7.07 and 26.96 per cent in temperate condition and such type of results reported by Miyata et *al.*, (2004).

CONCLUSION

In temperate condition increase in temperature (4^{o}C) shortened the wheat crop duration about one month, which declined the wheat yield up to 37.29 percent, but in subtropical condition seed yield reduced by 32.18 per cent. The seed yield fluctuation was found more in temperate condition compared to sub tropical condition.

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