International Journal of Agriculture and Food Science Technology.
ISSN 2249-3050, Volume 4, Number 9 (2013), pp. 867-872

http://www.ripublication.com/ ijafst.htm

Simulation of Impact of Projected Climate Change and Strategic Intervention to Minimize their Adverse Effect on Wheat

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Abstract

In order to minimize adverse effect of climate change on wheat, crop as well as management based strategies were applied by employing CERES-wheat model with future projection of temperature and CO_2 concentration with the help of experimental data conducted at the Norman E. Borlaug Crop Research Centre of GBPUAT, Pantnagar (29°N latitude, 79.29°E longitude and at an altitude of 243.80 m above msl) during 2007-08 and 2008-09. All the crop growth and yield attributes as simulated by the CERES-wheat model, in terms of anthesis, physiological maturity, grain yield and vegetative weight were decreased with 20th November sowing environments at all levels of projected temperature and CO_2 concentration by IPCC (i.e. 1.3+414, 2.9+552 and 5.2^{0}C+682ppm in 2020, 2050 & 2080, respectively). Package of practices were adjusted as optimized package of practices for optimization of yield and its parameters that may be suitable for climate change scenario of 2.9^{0}C+552ppm during 2050. As the first step the sowing date and seed rate were adjusted, it was found that if the sowing of crop is advanced by 7 days and seed rate was reduced by 35 kg/ha, the genotype will produce optimum yield with future temperature and CO_2 concentration projection during 2050. After suitable adjustment of sowing time and seed rate, time of irrigation and fertilizer application were adjusted (approximately advanced by seven to ten days) in order to get maximum yield of wheat with projected climatic scenario of 2050. By applying current initial conditions with elevated temperature and CO_2 concentration level, crop duration was found shortened as a result decline in yield and its attributes, while, with the enforcing optimized initial conditions for projected future climate change, wheat yield were incremented due to enhanced crop duration for both the genotypes.

Keywords: CERES-wheat; temperature; CO_2 concentration; strategy; wheat genotypes; sowing dates.

1. Introduction

In India, wheat (Triticum aestivum L.) productions are highly variable due to sensitiveness of climate and weather conditions, which specify a need for adaptation strategies including agronomic as well as resource management practices, drought-tolerant crops, crop diversification and early warning systems. Wheat crop is very sensitive to high temperature but magnitude of damage depends on the variations of ambient temperature, stages of the crop and varieties. In the country, wheat is the second important staple food crop next to rice with an area, production and productivity of 29.4 m ha, 85.9 mt and 3.0 t ha^{-1}, respectively (USDA, 2011). It is also an important crop in Tarai region of Uttarakhand having an area of 0.4 m ha, with a total production of 0.8 mt and productivity of 2.0 t ha^{-1} (DES, 2010).

Because of the rise in temperature and CO_2 concentration level, adaptation which consists of scheme and events to shrink the vulnerability of natural and human system is a necessary strategy to praise climate change mitigation efforts due to its uncertainty. The most important components of climate are temperature, precipitation and CO_2 concentration, which influence the crop growth and productivity independently or in combination (Holden et al., 2003). The crop yields and its phenology can be predicted by Crop Simulation Models (CSMs), which provide an excellent tool to study the effects of climate change on crop production. Simulation of growth and yield attributes of wheat are important under increased temperature and CO_2 concentration level to prepare strategic intervention for future climate change by employing Crop Environment Resources Synthesis (CERES)-wheat model. The intention of the present study was to simulate the impact of projected climate change with optimized agronomic and management practices on irrigated wheat production in foot hills of western Himalayas.

2. Materials and Methods

2.1 Experimental and soil details

Probable effects of climate change on plant growth and development were estimated and assessed using the CERES-wheat model availing combined effect of temperature and CO_2 concentration. The experiments were conducted during Rabi season of 2007-08 and 2008-09 at the Norman E. Borlaug Crop Research Centre (CRC) of G.B. Pant University of Agriculture & Technology, Pantnagar (29° N, 79.3° E and 243.8 m above msl) with two wheat genotypes (viz. PBW-343 and WH-542) and three sowing environments (i.e. 20 November, 15 December and 09 January). The soil of the experimental site is Patharchatta sandy loam having moderately dark colored, well drained and developed from calcareous medium to moderately coarse textured material under the predominant influence of tall grasses in moderately well drained conditions.

2.2 Projected climate change scenarios

Three levels of combined projections of CO_2 concentration (viz. 414, 522 and 682 ppm for 2020, 2050 and 2080, respectively) and temperature (as 1.3, 2.9 and 5.2^{0}C in the years 2020, 2050, and 2080, respectively) were applied for climate change study (IPCC, 2001) over current temperature (23.2°C) and CO_2 concentration Level (385ppm). However, elevated temperature and CO_2 concentration by 2.9°C & 522ppm, respectively, were used for crop, management and weather based strategies.

2.3 Model used for simulation of wheat yield and its attributes

We used the crop simulation model (CERES-wheat) and run in two conditions; i) with elevated temperature and CO_2 concentration by 2.9°C & 522ppm, respectively, alongwith current initial condition, and 2) applying elevated temperature and CO_2 concentration by 2.9°C & 522ppm, respectively, in conjunction with optimized initial conditions (Table 3). The model outputs in terms of anthesis & physiological maturity date, product weight, tops weight and product harvest index were generated and the outcomes were compared to understand the impacts of climate change on wheat crop production. Genotypic coefficients used for calibration and validation of CERES-wheat model and soil and climatic information of the experimental site have been described in Pal et al. 2012.

3. Results and Discussions

3.1 Combined effect of temperature (^{0}C) and CO_2 concentration (ppm) simulated anthesis and physiological maturity

Days to attain simulated anthesis was accounted to decrease from 9.1–29.2, 4.5–21.1 and 5.2–19.7%, while, days to attain physiological maturity was decreased from 4.2–21.0, 3.2–17.3 and 3.6–18.0% with crop sown on 20th November, 15th December and 09th January, respectively as temperature and CO_2 concentration were increased at all the levels used in study in comparison to current temperature and CO_2 concentration. Greater decrement in anthesis as well as physiological maturity was accounted with the genotype PBW-343 than WH-542 at all the levels of projected temperature and CO_2 conc. among sowing dates (Table 1).

Table 1: Effect of increase in temperature (^{0}C) and CO_2 concentration (ppm) on anthesis and physiological maturity (DAS) under different treatments (Mean of 2 years)

Dates of sowing	Genotypes	At present	In year 2020	In year 2050	In year 2080
			1.3^{0}C+414ppm	2.9^{0}C+522ppm	5.2^{0}C+682ppm
Days to attain anthesis (DAS)					
Nov. 20	PBW-343	84	76 (-9.5%)*	69 (-18.5%)	60 (-29.2%)
	WH-542	82	75 (-9.1%)	67 (-18.3%)	59 (-28.7%)
Dec. 15	PBW-343	81	76 (-6.2%)	71 (-11.8%)	64 (-21.1%)
	WH-542	79	75 (-4.5%)	70 (-10.8%)	63 (-19.7%)
Jan. 09	PBW-343	69	64 (-7.3%)	61 (-11.7%)	55 (-19.7%)
	WH-542	67	64 (-5.2%)	60 (-11.2%)	55 (-18.7%)
Days to attain physiological maturity (DAS)					

Nov. 20	PBW-343	122	115 (-5.8%)	106 (-12.8%)	96 (-21.0%)
	WH-542	118	113 (-4.2%)	106 (-10.6%)	95 (-19.5%)
Dec. 15	PBW-343	113	107 (-4.9%)	101 (-10.2%)	93 (-17.3%)
	WH-542	110	107 (-3.2%)	101 (-8.6%)	92 (-16.4%)
Jan. 09	PBW-343	100	93 (-7.0%)	89 (-11.0%)	82 (-18.0%)
	WH-542	97	93 (-3.6%)	88 (-8.8%)	82 (-15.5%)

*****Percent deviation in simulated data over observed.

3.2 Combined effect of temperature (^{0}C) and CO_2 concentration (ppm) simulated vegetative weight and product weight

Simulated vegetative weight was turned down from 4.0–23.5, 4.7–17.9 and 8.6–17.8%, however, product weight was diminished from 20.4–39.9, 1.9–17.5 and 1.0–2.4% with crop sown on 20th November, 15th December and 09th January, respectively, due to increased temperature and CO_2 concentration, among genotypes. Moreover, crop sown on 20th November and genotype PBW-343 registered maximum reduce in simulated vegetative weight and product weight at all the levels of projected temperature and CO_2 concentration. Results revealed that the simulated product weight (grain yield) was declined by 10.1–22.6, 1.0–32.3 and 2.4–39.9% due to elevated temperature and CO_2 concentration by 1.3+414, 2.9+552 and 5.2^{0}C+682ppm in 2020, 2050 & 2080, respectively (Timsina and Humphreys, 2006) [Table 2].

Table 2: Effect of increase in temperature (^{0}C) and CO_2 conc. (ppm) on vegetative weight and product weight (kg ha^{-1}) under different treatments (Mean of 2 years).

Dates of sowing	**Genotypes**	**At present**	**In year 2020 1.3^{0}C+414ppm**	**In year 2050 2.9^{0}C+522ppm**	**In year 2080 5.2^{0}C+682ppm**
Vegetative weight (kg ha^{-1})					
Nov. 20	PBW-343	5171	4717 (-8.8%)*	4962 (-4.0%)	4141 (-19.9%)
	WH-542	4916	4465 (-9.2%)	4460 (-9.3%)	3762 (-23.5%)
Dec. 15	PBW-343	4898	4659 (-4.9%)	4438 (-9.4%)	4104 (-16.2%)
	WH-542	4713	4489 (-4.7%)	4039 (-14.3%)	3869 (-17.9%)
Jan. 09	PBW-343	4328	3898 (-9.9%)	3882 (-10.3%)	3556 (-17.8%)
	WH-542	4162	3803 (-8.6%)	3777 (-9.3%)	3466 (-16.7%)
Product weight (kg ha^{-1})					
Nov. 20	PBW-343	4255	3294 (-22.6%)	2881 (-32.3%)	2559 (-39.9%)
	WH-542	3962	3155 (-20.4%)	2832 (-28.5%)	2545 (-35.8%)
Dec. 15	PBW-343	3885	3491 (-10.1%)	3811 (-1.9%)	3281 (-15.5%)
	WH-542	4021	3571 (-11.2%)	3781 (-6.0%)	3318 (-17.5%)
Jan. 09	PBW-343	3256	3291 (+1.1%)	3422 (+5.1%)	3283 (+0.8%)
	WH-542	3504	3539 (+1.0%)	3471 (-1.0%)	3420 (-2.4%)

*****Percent deviation in simulated data over observed.

3.3 Strategies to minimize adverse upshot of temperature and CO_2 concentration on wheat

Package of practices were adjusted for optimized package of practices that may be suitable for climate change scenario of elevated temperature and CO_2 concentration by 2.9°C & 522ppm, respectively during 2050 with 15^{th} December sowing for the genotype WH-542 due to having highest observed yield (Table 3). Due to advancement in sowing date by almost one week alongwith projected temperature and CO_2 concentration during 2050, days attain to simulated anthesis and physiological maturity will be increased by six to seven days, over current initial conditions. After suitable adjustment of sowing time, the irrigation and fertilizer application time were adjusted in order to get the maximum yield of wheat in changed climatic scenario of 2050 (Table 4). With optimized package of practices in climate change scenario during 2050, results revealed that the product weight and tops weight may accredited to increase by 1088 and 403 kg ha^{-1}, respectively (Table 4) in respect of current package of practices [Asseng et al., 2004]. However, simulated harvest index will be decreased by 0.04 with applying optimized initial conditions and elevated temperature and CO_2 concentration during 2050.

Table 3: Optimization of inputs with rise in temperature by 2.9°C and CO_2 concentration by 522ppm during 2050s using CERES-wheat model (Mean of two years data)

Inputs	Current initial conditions	Optimized initial conditions during 2050s
Sowing dates	15 December	08 December
Seed Rate (kg ha^{-1})	120	85
Irrigation dates (amount 50 mm for each irrigation)	06 January	31 December
	02 February	24 January
	03 March	16 February
	25 March	14 March
Fertilizers application dates (NPK-150:60:40)	15 December	08 December
	09 January	03 January
	05 February	27 January

Table 4: Outputs of 15^{th} December sown crop with current and optimized initial conditions using CERES-wheat model (Mean of two years data)

Output Parameters	Simulated data with elevated temperature of 2.9°C and CO_2 concentration by 522ppm during 2050s	
	Current initial conditions	Optimized initial conditions
Anthesis (DAS)	73	80
Physiological maturity (DAS)	104	110
Product weight (kg ha^{-1})	3965	5053
Tops weight (Kg ha^{-1})	4531	4934
Product harvest index	0.53	0.49

4. Conclusion

From the results of the present study, it may possibly seen that the projection of temperature and CO2 concentration for future climate change with current initial conditions indicate shortened of anthesis & physiological maturity dates as well as duration of the crop, while, due to adaptation of optimized initial conditions for future climate change, crop duration will be enhanced and yields will be improved. Simulated wheat yield and its contributing characters tested in present study were found under-predicted with future climate change projection and current initial conditions in respect of simulated parameters with current initial conditions. Whenever, with the use of optimized initial conditions alongwith elevated temperature and CO2 concentration by 2.9°C & 522ppm, respectively, during 2050, all simulated wheat parameters were found over-predicted in comparison of simulated parameters with current initial conditions. Reduction in yield as well as yield attributing parameters were accredited due to elevated temperature and CO2 concentration with current initial conditions, while, with the applying of optimized initial conditions for future climate change, wheat yield and its contributes were incremented.

References

[1] Directorate of Economics and Statistics (DES), Department of Agriculture and Cooperation (2010), eands.dacnet.nic.in/At_A_Glance-2011/4.7(b).xls.

[2] IPCC (2001), IPCC 3rd Assessment Report-Climate Change 2001: Working Group II: Impacts, Adaptation and Vulnerability.

[3] J Timsina and E Humphreys (2006), Performance of CERES-Rice and CERES-Wheat models in rice–wheat systems: A review, *Agr. Syst.*, 90: 5-31.

[4] N M Holden, A J Brereton, R Fealy and J Sweeney (2003), Possible change in Irish climate and its impact on barley and potato yields, *Agr. Forest Meteorol.*, 116:181–196.

[5] R K Pal, N S Murty and M M N Rao (2012), The response of wheat to temperatures as simulated with CERES-wheat model in Tarai region, *J. Agrometeorol.*, 14 (2): 163-166.

[6] S Asseng, P D Jamieson, B Kimball, P Pinter, K Sayre, J W Bowden and S M Howden (2004), Simulated wheat growth affected by rising temperature, increased water deficit and elevated atmospheric CO_2, *Field Crop Res.*, 85: 85-102.

[7] U S Department of Agriculture (2011), Production, Supply, & Distribution, electronic database, at www.fas.usda.gov/psdonline, updated 9 December 2011.