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***Short Comminucation***

# Effect of temperature and $CO_2$ concentration on production of wheat using CERES-wheat model

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In agricultural system, growth and development of the crop is more often dependent on the integrated responses of temperature, $CO_2$ concentration, agronomic management, etc. However, it is quite difficult to study the impact of these integrations in field condition, but well calibrated and validated crop simulation models are the needful tools that can be used to enumerate the integrated impact of climate change and their interaction in the system (Ko, et al., 2010). In climate change study, 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). Elevated $CO_2$ independently has the beneficial impact on wheat crop, however, combined effect of temperature and $CO_2$ concentration indicate a reduction in the length of the growing season and maturity date, which could cause wheat yield to decline. Due to inter-seasonal weather variability, wheat (*Triticum aestivum* L.) production is highly variable in the country, which is the most widely cultivated food crop and ranks first in the world among the cereals both in respect of area 217.53 m ha and production 654.31 mt (USDA, 2013). In India, it is the second important staple food crop next to rice with projected area, production and productivity of 29.69 m ha, 93.90 mt and 3.16 t $ha^{-1}$, respectively during 2012-13 (USDA, 2013). It is also an important crop in *Tarai* region of Uttarakhand having an area of 0.40 m ha, with a total production of 0.85 mt and productivity of 2.34 t $ha^{-1}$ (DES, 2011). Simulation of growth and yield of wheat are important under elevated temperature and $CO_2$ concentration at various levels to prepare strategic intervention for future climate by employing Crop Environment Resources Synthesis (CERES)-wheat model. The main objective of the present study was to determine the projected impact of climate change on wheat production in foot hills of western Himalayas by the years 2020, 2050 and 2080.

The CERES-wheat model has been used to perceive the probable effects of climate change on production of wheat. Inputs were recorded from the experiments, conducted during *Rabi* seasons of 2007-08 and 2008-09 at the N. E. Borlaug Crop Research Centre of GBPUA&T, Pantnagar (29° N, 79.3° E and 243.8 m above msl) in two wheat varieties (viz. PBW-343 and WH-542) and three sowing dates (*i.e.* 20 November, 15 December and 09 January). The CERES-wheat model was calibrated and validated for the variety PBW-343 and WH-542 (Pal, 2010). Moreover, soil and climatic information of the experimental site have been shown in detail by Pal *et al.* (2012). In the present study, we used projections of temperature *i.e.* 1.3, 2.9 and 5.2°C and $CO_2$ concentration viz. 414, 522 and 682ppm during 2020, 2050 and 2080, respectively that has been projected in the IPCC (2001) report, over current initial conditions. The per cent deviation was deliberated in simulated parameters of wheat with elevated temperature and $CO_2$ concentration by 1.3 & 414, 2.9 & 522 and 5.2°C & 682 ppm during 2020, 2050 and 2080, respectively over simulated parameters with current initial conditions and results were compared to understand the impact of climate change on productivity of wheat. The interpretation of data was done on the basis of "t" test for comparisons between the simulated and measured data and the level of significance was checked at 5% and 1% of probability in terms of dates of sowing (degrees of freedom: 3) and varieties (degrees of freedom: 5).

Impact of projected temperature and $CO_2$ concentration at different levels on wheat yield (grain +straw)

The effect of projected temperature and $CO_2$ concentration at different levels as influenced by different sowing environments and varieties have been presented in Tables 1 and 2 for simulated grain and straw yield of wheat, respectively.

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**Table 1 :** Effect of projected temperature and $CO_2$ concentration on simulated grain yield kg ha$^{-1}$ of wheat under different sowing environments and varieties (Mean of 2 years)

| Sowing dates | PBW -343 | WH-542 | PBW-343 | WH-542 | t-Test | PBW-343 | WH-542 | t-Test | PBW-343 | WH-542 | t-Test |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Effect of temperature** | | | | | | | | | | | |
| | At present | | 1.3°C in 2020 | | | 2.9°C in 2050 | | | 5.2°C in 2080 | | |
| **Nov. 20** | 4255 | 3962 | 3096 (-27.2%) | 2955 (-25.4%) | -8.6* | 2089 (-50.9%) | 2023 (-48.9%) | -8.8* | 1344 (-68.4%) | 1284 (-67.6%) | -12.1* |
| **Dec. 15** | 3885 | 4021 | 3331 (-14.2%) | 3401 (-15.4%) | -5.1* | 2890 (-25.6%) | 2790 (-30.6%) | -4.4** | 1713 (-55.9%) | 1678 (-58.3%) | -9.3* |
| **Jan. 09** | 3256 | 3504 | 3163 (-2.8%) | 3374 (-3.7%) | -2.0 | 2720 (-16.5%) | 2699 (-23.0%) | -4.2** | 1951 (-40.1%) | 1943 (-44.5%) | -7.0* |
| **t-Test** | | | -2.8** | -3.0** | | -3.4* | -4.4* | | -5.9* | -7.2* | |
| **Effect of $CO_2$** | | | **414ppm in 2020** | | | **414ppm in 2050** | | | **414ppm in 2080** | | |
| **Nov. 20** | 4255 | 3962 | 4392 (+3.2%) | 4238 (+7.0%) | 11.0* | 5054 (+18.8%) | 5080 (+28.2%) | 15.6* | 5801 (+36.3%) | 6044 (+52.6%) | 26.1* |
| **Dec. 15** | 3885 | 4021 | 4038 (+3.9%) | 4309 (+7.2%) | 4.0** | 4600 (+18.4%) | 4974 (+23.7%) | 12.5* | 5559 (+43.1%) | 5989 (+49.0%) | 13.3* |
| **Jan. 09** | 3256 | 3504 | 3361 (+3.2%) | 3638 (+3.8%) | 4.0** | 3783 (+16.2%) | 4120 (+17.6%) | 7.4* | 4374 (+34.3%) | 4748 (+35.5%) | 8.5* |
| **t-Test** | | | 4.9* | 4.1* | | 9.4* | 7.6* | | 10.2* | 8.7* | |

*Level of significance at pd”0.01 and ** pd”0.05.

Grain yield of wheat as simulated through CERES-wheat model decreased significantly from 25.4 to 68.4, 14.2 to 58.3 and 2.8 to 44.5% and straw yield diminished from 13.5 to 63.8, 8.1 to 57.8 and 12.1 to 51.4% with crop sown on 20th November, 15th December and 09th January, respectively, as temperature increased at different levels in respect of simulated grain and straw yield with current initial conditions (Asseng et al., 2004).

Greater significant reduction in simulated grain as well as straw yield have been registered with early sown (i.e. 20th November) crop due to increase in temperature at all levels followed by mid and late sowing environments in case of both the varieties. The grain yield decreased significantly more for the variety WH-542, whenever, straw yield was decremented significantly greater in respect of PBW-343 at all levels of projected temperature and dates of sowing. Differences in product weight due to varieties were also reported by Barczyk et al. (1999).

As simulation of crop with CERES-wheat model availing different projected levels (viz. 414, 522 and 682 ppm during 2020, 2050 and 2080, respectively) of $CO_2$ concentration (keeping all parameters as constant) grain yield was boosted from 3.2 to 52.6, 3.9 to 49.0 and 3.2 to 35.5% and straw yield was incremented from 0.0 to 43.4, 2.7 to 38.7 and 3.2 to 35.2% with crop sown on 20th November, 15th December and 09th January, respectively, over simulated grain and straw yield with current initial condition. Average wheat yields are likely to increase by 1.2 to 2 t ha$^{-1}$ (15-23%) by the 2050s because of $CO_2$ increase (Richter and Semenov, 2005). Crop sown on 20th November showed significantly larger increase in grain as well as straw yield at all projected $CO_2$ concentration levels followed by 15th December sowing across the varieties, while lesser increase in grain and straw yield were accounted with 09th January sowing of crop. Pandey *et al.* (2007) also reported that increased $CO_2$ concentration resulted in increased wheat yield. In general, larger and significant enhancement in grain and straw yield was attributed with the variety PBW-343 followed by WH-542 across the sowing environments and projected $CO_2$ concentration levels.

**Table 2 :** Effect of projected temperature and $CO_2$ concentration on simulated straw yield (kg $ha^{-1}$) of wheat under different sowing environments and varieties (Mean of 2 years)

| Sowing dates | PBW -343 | WH-542 | PBW-343 | WH-542 | t-Test | PBW-343 | WH-542 | t-Test | PBW-343 | WH-542 | t-Test |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Effect of temperature** | | | | | | | | | | | |
| | At present | | 1.3°C in 2020 | | | 2.9°C in 2050 | | | 5.2°C in 2080 | | |
| **Nov. 20** | 5171 | 4916 | 4474 (-13.5%) | 4194 (-14.7%) | -8.8* | 3541 (-31.5%) | 3122 (-36.5%) | -28.6* | 2045 (-60.5%) | 1782 (-63.8%) | -202.6* |
| **Dec. 15** | 4898 | 4713 | 4500 (-8.1%) | 4297 (-8.8%) | -8.3* | 3380 (-31.0%) | 3068 (-34.9%) | -14.2* | 2174 (-55.6%) | 1989 (-57.8%) | -53.4* |
| **Jan. 09** | 4328 | 4162 | 3740 (-13.6%) | 3659 (-12.1%) | -2.3 | 3313 (-13.5%) | 3133 (-24.7%) | -7.6* | 2222 (-48.7%) | 2023 (-51.4%) | -15.9* |
| **t-Test** | | | -4.8* | -3.1** | | -9.7* | -7.9* | | -13.7* | -12.7* | |
| **Effect of $CO_2$** | | | **414ppm in 2020** | | | **414ppm in 2050** | | | **414ppm in 2080** | | |
| **Nov. 20** | 5171 | 4916 | 5417 (+4.7%) | 4918 (0.0%) | 9.6* | 6294 (+21.7%) | 5785 (+17.7%) | 29.3* | 7418 (+43.4%) | 6950 (+41.4%) | 42.5* |
| **Dec. 15** | 4898 | 4713 | 5076 (+3.6%) | 4840 (+2.7%) | 3.3** | 5787 (+18.2%) | 5487 (+16.4%) | 15.3* | 6796 (+38.7%) | 6494 (+37.8%) | 32.5* |
| **Jan. 09** | 4328 | 4162 | 4465 (+3.2%) | 4376 (+5.1%) | 2.0 | 4986 (+15.2%) | 4946 (+18.8%) | 8.0* | 5617 (+29.8%) | 5625 (+35.2%) | 10.3* |
| **t-Test** | | | 8.7* | 2.0 | | 12.1* | 10.0* | | 12.4* | 9.9* | |

*Level of significance at pd”0.01 and ** pd”0.05.

It is therefore concluded that the wheat grain yield and straw yield, simulated through CERES-wheat model were accredited to decrease due to increased temperature at every level across sowing environments and varieties. Moreover, the magnitude of decrease is expected to be more from 2050 to 2080 than that of 2020 to 2050 and 2009 to 2020. Overall, crop sown on 20th November showed greater decline of simulated yield with increase in temperature at all projected levels than rest of the sowing environments. For grain & straw yield, simulated values declined more with the variety WH-542 due to increase in temperature at different levels over simulated value with current initial conditions. Increase of $CO_2$ concentration at all the levels has the beneficial impact on yield and yield parameters of wheat. In-spite of that grain as well as straw yield incremented more with timely sown crop (20th November) at all projected $CO_2$ concentration levels, additionally, larger enrichment was attributed with the variety WH-542 across the sowing environments and projected $CO_2$ concentration levels. Overall, wheat yield declined by 2.8-27.2, 16.5-50.9 and 40.1-68.4% due to projected temperature by 1.3, 2.9 and 5.2°C, respectively. On the other hand, wheat yield increased by 3.2-7.0, 16.2-28.2 and 34.3-52.6% due to projections of $CO_2$ concentration as 414, 522 and 682ppm during 2020, 2050 and 2080, respectively.

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