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Short Communication

Climate resilient wheat production under changing climatic conditions in north western Himalayas of India

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Potato, due to its unique capability of Wheat (*Triticum aestivum* L.) belongs to Poaceae family; is the most staple food crop in the world and second important crop in India only after rice. It occupies around 29.65 million hectare (M ha) area that produced 92.46 million tons (Mt) of wheat with productivity of 3119 kg/ha (Kumar *et al*., 2014). The Northern Hills Zone (NHZ) is one of the six wheat growing zones of the country which includes the major parts of humid Western Himalayan Regions. Area under wheat is around 1.39 M ha in the NHZ of which highest acreage is found in UK followed by HP and J&K (Anonymous, 1995) and produces 1.83 Mt of wheat (Chanda *et al*., 2010). Like any other ecosystem, North West Himalayan hill agriculture also faces challenge due to climate change/climatic variability. The Inter-Governmental Panel on Climate Change (IPCC) of the United Nations has reported that the earth temperature has increased by 0.74 °C between 1906 and 2005 due to increase in anthropogenic emission of green house gases. Several reports have already confirmed that the Himalayan ecosystem is getting warmer at faster rate compared to plains. During the period 1901 – 2003, an increasing trend was already reported in annual minimum temperature in western Himalayas (Sonali and Kumar, 2013).

In western Himalayas, during winter months (December, January, February) from 1975 to 2006 the cold nights are getting warmer and the percentage number of cold nights is decreasing, while percentage number of warm nights is increasing (Dimri and Dash, 2011). They also reported that there are more warm events compared to fewer cold temperature events. Due to the observed and predicted climate change, there is high uncertainty in crop production in near future and adequate attention has to be given to sustain the North West Himalayan agriculture (Bhatt *et al*., 2015). Under these circumstances, an investigation was carried out to identify the trend in long term temperature data of western Himalayas and also to identify the climate resilient wheat genotypes through different date of sowing along with pest dynamics and grain quality.

A field experiment was conducted during 2013-14 at experimental farm, located in the Indian Himalayan region at Hawalbagh (29◦36′N and 79◦40′E and 1250 m above mean sea level) in the state of Uttarakhand, India. Eight wheat varieties *viz*., VL *Gehun* 738, VL *Gehun* 802, VL *Gehun* 804, VL *Gehun* 832, VL *Gehun* 892, VL *Gehun* 907, HS 490 and HS 507 were sown (at one month interval (Nov 15–D I, Dec 15–D II, Jan 15–D III and Feb 15- D IV) in the field and recommended agronomic practices were followed. Physiological parameter like photosynthetic rate (μmol m^{-2} s^{-1}) was determined in late sown plants by using LICOR, - LI- 6400X Portable Photo system, USA. Measurements were taken during cloudless days with photosynthetically active radiation (PAR) more than 1200 μmol m^{-2} s^{-1}. Grain quality (β-carotene) was estimated by the method of AACC (2000) with some modifications. Insect counts *viz*., aphids, syrphids and helicoverpa larva were taken in ten randomly selected plants in the field during heading stage. Aphids were counted as colonies (10-50 individuals/colony) whereas syphids (both grubs and adults) and helicoverpa larva were counted as individuals per ten plants.

Western Himalayan homogeneous regional temperature data (1901-2007) as defined by Indian Institute of Tropical Management (IITM, Pune, source: (http://www.tropmet.res.in) are used in the present investigation. Mann–Kendall (MK) test and sen slope estimation were performed to identify the direction (Z) and magnitude (Q) of the trend. Statistical analysis of the data was done using analysis of variance and the treatment means were compared using least significant differences (LSD) at $P < 0.05$.

The results of long term weather data analysis (1901-2007) indicated a significantly increasing warming trend of both maximum and minimum temperature during February and April month (Mann kendall Z statistic value of maximum and minimum temperature during February and April months showed an increasing positive upward trend). Sen's slope test also revealed the increasing upward trend along with magnitude (Q slope value of maximum temperature during February and April were 0.030 and 0.022 and Q slope value of minimum temperature during February and April 0.014 and 0.007 respectively). Similar results were already been reported (Kothawale *et al*., 2010; Dimri and Dash, 2011; Sonali and Kumar, 2013).

Significant reduction of 15%, 42% and 85% in grain yield was observed at December, January and February condition respectively compared to normal sown (Table 1). Among the varieties VL *Gehun* 892 showed better performance in the form of grain yield at all the four dates of sowing. This shows that this variety is having better climate resilience against late sown heat stress conditions compared to other varieties. Reduction in wheat yields due to delay in sowing beyond the optimum period is also reported (Bassu *et al*., 2009). The mean photosynthetic rate of 8 wheat varieties is only 6.94 μ moles CO_2 $m^{-2}sec^{-1}$ and this less photosynthetic rate is plausibly due to late sown heat stress (40 ^oC) condition at heading stage at hot May month. Significantly better photosynthetic rate (Table 2.) was recorded during heading stage (May month) in VL *Gehun* 907, VL *Gehun* 832 and VL *Gehun* 892 compared to other varieties under late sown heat stress condition (February sown). Inhibition of photosynthesis by heat stress is one of the important factors that adversely affect wheat productivity (Al-Khatib and Paulsen, 1999). Sowing date is one of the most important management factor affecting cereal production and quality (McLeod *et al*., 1992). Significant declining trend (R^2=0.89) in grain β carotene content was observed under late sown condition (Table. 2.) and this may be due to heat stress. Heat stress reduces grain weight and quality and short periods of high temperature (35 - 40 ^oC) during grain development can have a negative effect on grain quality (Calderini *et al*., 1999).

Table 1: Effect of date of sowing on grain yield (Q/ha) in wheat varieties

Variety	November	December	January	February	Mean
VL 738	45.80	34.87	24.65	2.35	**26.92**
VL 802	47.80	42.93	27.38	8.37	**31.62**
VL 804	48.74	40.28	27.93	7.06	**31.00**
VL 832	44.23	38.88	28.25	9.29	**30.16**
VL 892	48.90	42.96	30.61	13.98	**34.11**
VL 907	48.09	39.97	27.91	6.01	**30.50**
HS 490	45.57	36.12	26.68	8.48	**29.21**
HS 507	50.52	46.83	27.29	3.22	**31.96**
Mean	**47.45**	**40.35**	**27.59**	**7.34**	
LSD 5%					
DOS			2.401**		
Variety			3.396**		
DOS x Variety			N.S.		

DOS-Date of sowing, ** indicates statistically significance as $P < 0.01$ *. N.S denotes Non significant
LSD denotes Least significant difference.

Table 2: Effect of date of sowing on βcarotene, photosynthetic rate, insect pests and natural enemies in wheat varieties

Variety	β carotene (ppm)	Photosynthetic rate* (μmol m^{-2} s^{-1})	Aphids* (Count)	Syrphids* (Count)	Helicoverpa* (Count)
VL 738	2.38	6.02	1.75	2.33	2.08

VL 802	3.30	8.41	1.33	1.42	2.00
VL 804	3.34	3.96	1.92	2.42	1.75
VL 832	2.47	9.55	1.63	2.71	2.92
VL 892	2.47	7.54	1.96	2.46	2.25
VL 907	3.01	10.63	1.08	1.83	1.92
HS 490	2.93	3.46	1.42	3.00	2.42
HS 507	2.24	5.93	0.92	2.50	2.50
DOS					
November	3.55	-	1.88	5.00	0.46
December	2.82	-	1.83	1.88	1.83
January	2.39	-	1.38	1.46	3.83
February	2.31	6.94	0.92	1.00	2.79
LSD 5%					
DOS	0.211**	-	0.087**	0.093**	0.078**
Variety	0.298**	2.039**	0.123**	0.132**	N.S.
DOSx Variety	0.597**	-	N.S.	N.S.	N.S.

DOS-Date of sowing, ** indicates statistically significance as $P < 0.01$. N.S denotes Non significant
* Photosynthetic rate was recorded only in February sown wheat at their heading stage. Data shown in this table under variety heading represents varietal means over four date of sowing.

In case of insects, aphid colonies were found to be more in wheat varieties sown at first and second date of sowing *viz*., November and December months (Table. 2). The wheat varieties sown during November harboured more syrphids as high as (7.0/ 10 plants in HS 490) as compared to (2.0/ 10 plants) in wheat sown during December. So, aphids seen in early sown plants are managed by natural enemies very efficiently leading to much lower levels where other control measures are not required. It is evident from the low number of aphids in wheat varieties sown during Dec., Jan. and February month and without syrphids the situation would have bee much devastating as Dec, Jan and Feb are reported as peak season for wheat aphids (Ahamad *et al*., 2006). On the contrary, helicoverpa incidence was very low during first date of sowing (November) and increased gradually and come to peak on January sown crop (Table. 2.). High incidence of helicoverpa was noticed in February sown crop also suggesting a risk of this pest incidence in wheat when sowing is delayed. Helicoverpa is reported as a late season winter pest affecting winter wheat at late stage of crop (Xia *et al*., 1997).

As a conclusion, a significant increasing trend in both maximum and minimum temperature during February and April months of 1901-2007 is evident. And these warming trends might play a major role in wheat crop growth, productivity and grain quality. Heat stress during the grain filling stage has resulted in lesser photosynthetic rate in the late sown condition. VL *Gehun* 907 showed significantly better photosynthetic rate even at heat stress condition. VL *Gehun* 892 also recorded better grain yield in all the date of sowing and thus it proves its resilience capacity against harsh weather. Higher incidence of helicoverpa under late sown condition also suggests a risk of this pest incidence in wheat when sowing is delayed due to late arrival of rains resulting from changes/ variability in climate. In this view, VL *Gehun* 892 can be adopted by NWH farmers for late sown harsh weather condition.

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