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Study on growing degree days, heat use efficiency and weather indices of timely sown wheat (*Triticum aestivum* L.) varieties

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Abstract
The field experiment was conducted during *Rabi* season of 2017-18 at Students' Instructional Farm of Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, UP (India) to assess the performance of timely sown wheat varieties in relation to climate change situation and to assess impact of maximum temperature, minimum temperature and growing degree days on wheat cultivars. The treatments consisted 10 wheat varieties viz., K307, K 402, K 607, K 1006, HD-2733, DBW-17, HD-2967, PBW-343, PBW-502 and PBW-550, laid out in Randomized Block Design replicated three times. The varieties were sown on 17th November, 2017 and harvested at physiological maturity ranged 130 days to 142 days after sowing. The inputs were given time to time at recommended rates. The meteorological data viz. minimum temperature maximum temperature at standard meterological weeks (SMW) were collected from meteorological observatory and growing degree days were calculated. The results exhibited that temperature (maximum and minimum) and growing degree days established positive correlation with growth characters, yield attributes and grain yield wheat varieties. Comparatively more duration (140 days) varieties viz. HD 2967 and PBW 343, recorded maximum growing degree days (1909.9), yielded maximum grain yield (5590.0 kg and 5277.00 Kg ha^{-1}), better harvest index (42.23% and 39.90%), respectively. The minimum grain yield (4601.00 kg ha^{-1}) and harvest index (35.67%) was recorded under PBW 502. The heat use efficiency of K402, HD 2967 and PBW-343 was found higher (3.05, 2.93 and 2.76 kg °C day^{-1}, respectively) while, K307 recorded minimum (2.62 Kg °C day^{-1}) HUE.

Keywords: Growing degree days, heat use efficiency, minimum & maximum temperature, wheat varieties

Introduction
Wheat is one of the most important food crop of whole world. Globally it is grown in 122 countries and occupies an area of 218.5 m.ha, producing nearly 771.7 mtonnes, with a productively of 3.53 t ha^{-1}. It is the third most produced cereal after maize (1134.7 million tonnes) and rice (769.66 million tonnes). (FAO, statistical data, 2017).

In India, wheat is grown mainly in northern states, with Uttar Pradesh being the highest contributor at 34% of the total production followed by Punjab, Haryana and Madhya Pradesh. The average productively of wheat in Uttar Pradesh (28.76 q ha^{-1}) is lower than Punjab (42.67 q ha^{-1}) Haryana (39.67 q ha^{-1}) and even the national average (32 q ha^{-1}).

Currently agriculture is facing multi-dimensional challenges including climate change. Projected increase in temperature and frequency of weather extremes could significantly constrain wheat production in future climate. Average global temperature have increased over the last decades and are predicted to continue rising, along with a greater frequency of extremely hot days. Surprisingly, observed variation of ± 2 °C in average growing season in the main wheat growing regions can cause reduction in grain production of up to 50%. Most of this can be attributed to increased leaf senescence as a result of temperature > 34 °C. (Assang *et al* 2011) [2]. Wheat varieties vary for their duration as well as tolerance to temperature stress. A shorter duration cultivars is likely to yield less, while the longer duration variety may be exposed to more climatic stress. Hence farmer's always are in dilemma regarding the choice a variety. The majority of previous studies showed that increase in temperature shortened crop growing period, leading to reduced crop productivity (Wang *et al* 2012) [9]. This study was aimed to quantity the response of long duration and medium duration varieties to high temperature and is expected to provide scientific basis for the choice of a variety in changing climate Conditions.

Material and Methods

The field experiment was conducted during rabi season of 2017-18 at Student's Instructional Farm of Chandra Shekhar Azad University of AGricultrue & Technology, Kanpur Uttar Pradesh, India, situated at 125.9 meter altitude, 26.4148 North latitude, and 80.2321 East longitude. Treatments involved 10 wheat varieties viz. K307, K402, K607, K1006, HD2733, BDW-17, HD2967, PBW343, PBW502 and PBW 550 matures in 135 to 145 days after sowing. The tretments were laidout in Randomized Block Design replicated three times. The soil of experimental field was sandy loam with 55% sand, 25.50% silt and 19.50% clay with pH of 7.95. It was moderately fertile being low in organic carbon (0.42%) available N (179.0 kg ha^{-1}), and Potash (156.0 kg Kro ha^{-1}).

The meterological observations recorded during the study period revealed that at the time of germination (November 2017) the temperature ranges 7.6 °C to 26.7 °C. The temperature during growth period i.e. December 2017, January 2018, February 2018 was ranged 5.3 °C to 14.6 °C (minimum temperature) and 17.1 °C to 30.3 °C (maximum temperature). During maturity in the month of March and April 2018, the minimum temperature varies 13.9 °C to 22.3 °C and maximum temperature varies 30.7 °C to 36.1 °C. The relative humidity ranged between 45.9% to 83.8% and cumulative rainfall limited to only 15.8 mm, which reveals that almost dry *Rabi* season was notified in 2017-18.

Results and Discussion

Growth Variables

The data summarised in Table-1 revealed that plant height of different varieties showed positive but non-significant correlation with maximum temperature, while minimum temperature established significantly positive correlation with plant height. Similarly growing degree days express significantly positive correlation with plant height of different varieties. Fresh weight of different varieties exhibited significantly negative correlation with maximum & minimum temperature and growing degree days. Dry weight of plant in different varieties exhibited significantly positive correlation with minimum temperature, maximum temperature and growing degree days. Tillers per meter square established positive but non-significant correlation with minimum and maximum temperature, while growing degree days exhibited significantly positive correlation with tiller's per meter square. It may be concluded that maximum temperature, minimum temperature and growing degree days observed positive correlation with growth variables of different varieties of wheat at different stages. The above findings are corroborated with the findings of Chapman *et al*. 2012 [3] and He *et al* 2015 [4].

Table 1: Correlation coefficient of growth characters of wheat varieties

Treatments	Correlation coefficients of different growth characters											
	Plant Height (cm)			Fresh Weight (g)			Dry Weight (g)			Tillers m^{-2}		
	T_{max} (^{0}C)	T_{min} (^{0}C)	GDD	T_{max} (^{0}C)	T_{min} (^{0}C)	GDD	T_{max} (^{0}C)	T_{min} (^{0}C)	GDD	T_{max} (^{0}C)	T_{min} (^{0}C)	GDD
K307	0.384	0.404*	0.763*	-0.682*	-0.705*	-0.266	0.599*	0.594*	0.835*	0.107	0.143	0.569*
K402	0.379	0.400*	0.800*	-0.688*	-0.716*	-0.240	0.600*	0.596*	0.877*	0.098	0.134	0.605*
K607	0.382	0.401*	0.791*	-0.683*	-0.711*	-0.244	0.600*	0.596*	0.866*	0.104	0.137	0.598*
K1006	0.387	0.406*	0.764*	-0.680*	-0.703*	-0.264	0.600*	0.595*	0.836*	0.108	0.144	0.570*
HD2733	0.389	0.410*	0.746*	-0.680*	-0.699*	-0.280	0.600*	0.593*	0.816*	0.091	0.133	0.539*
DBW17	0.387	0.406*	0.764*	-0.682*	-0.705*	-0.266	0.601*	0.595*	0.836*	0.128	0.164	0.585*
HD2967	0.388	0.409*	0.754*	-0.681*	-0.701*	-0.274	0.600*	0.594*	0.825*	0.117	0.156	0.567*
PBW343	0.388	0.409*	0.754*	-0.681*	-0.701*	-0.273	0.600*	0.594*	0.825*	0.110	0.149	0.561*
PBW502	0.388	0.407*	0.759*	-0.681*	-0.704*	-0.270	0.592*	0.586*	0.822*	0.110	0.146	0.567*
PBW550	0.384	0.403*	0.809*	-0.680*	-0.704*	-0.224	0.600*	0.596*	0.888*	0.107	0.143	0.614*

$T_{max}{}^0$C= Maximum temperature degree centigrade
$T_{min}{}^0$C= Minimum temperature degree centigrade
GDD= Growing Degree Days

Yield Attributes

The data pertaining to yield attributes (Table 2) exhibited that among different varieties tested HD 2967 and PBW 343 recorded maximum ears (m^{-2}), ear length (cm), grains ear^{-1}, grain weight $plant^{-1}$ and test weight (g). All the above expressed yield attributing characters showed positive correlation with maximum temperature and growing degree days, while minimum temperature observed significantly positive correlation with grains ear^{-1}, grain weight $plant^{-1}$ and test weight of different varieties, Sandhu *et al* 2016 [7], expressed that wheat varieties are sensitive to high temperature, particularly when it occurs during reproductive and grain tilling phases.

Yield

The data expressed in Table-2, exhibited that among different varieties tested HD2967 recorded maximum grain yield (5590.00 kg ha^{-1}) and harvest index (42.23%) with 140 days maturity time, followed by PBW 342 which recorded grain yield (5277.00 kg ha^{-1}) and harvest index (39.90%) during similar maturity time. In terms of maximum straw yield (8397 kg ha^{-1}), variety K607 grassped better rank among different varieties. The biological yield and straw yield of different varieties observed negative correlation with maximum temperature, minimum temperature and growing degree days. While, grain yield and harvest index established positive correlation with maximum temperature, minimum temperature and growing degree days. The temperature (maximum and minimum) and cumulative heat unit plays important role in dry matter production and translocation of food material from source to sink which ultimately increase grain yield of wheat varieties and higher harvest index.

Growing degree days and heat use efficiency

The data presented in Table-2 revealed that increase in growing degree days or cumulative heat unit of different varieties is directly correlated with increase in maturity time. The growing degree days found maximum (1954.5) under HD 2733 followed by HD-2967 (1907.9) and PBW 343 (1907.9) and minimum GDD was recorded under K402 (1678.0) with

minimum maturity time. The heat use efficiency of biological yield was recorded maximum (7.88 kg °C day^{-1}) under variety K402 and minimum (6.64kg °C day^{-1}) under K307. While heat use efficiency of grain yield was recorded maximum (3.05 kg °C day^{-1}) under K402 and minimum (2.62 kg °C day^{-1}) under K307. The varieties HD2967 and PBW-343 recorded comparatively better GDD (1907.9) and heat use efficiency of biological yield (6.94 and 6.93 kg °C day^{-1}) and grain yield (2.93 and 2.76 kg °C day^{-1}), respectively. It might be due to these varieties posses better genome characteristics to access more solar radiation for the production of dry matter. The above findings are corroborated with the findings of Dangi and Shrestha (2018) [10], Karambir *et al.* (2003) [5], Sharma *et al.* (2003) [8] and Kaur *et al.* (2004) [6].

Table 2: Correlation coefficient of yield attributes of wheat with maximum temperature, minimum temperature and Growing Degree Days

Treatments	No. of Ear's m^{-2}	Length of Ear(cm)	No. of grain Ear^{-1}	Grain Weight plant(g)$^{-1}$	Test Weight (g)	Biological Yield (kg ha^{-1})	Grain Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	Harvest Index (%)
K307	392.87	8.40	49.42	8.25	37.65	12341.00	4875.00	7466.00	39.50
K402	419.42	8.84	51.98	8.67	39.60	13235.00	5128.00	8107.00	38.75
K607	390.32	8.33	49.01	8.18	37.33	13231.00	4834.00	8397.00	36.54
K1006	418.83	8.98	52.83	8.82	40.25	13239.00	5211.00	8028.00	39.36
HD2733	405.70	8.67	50.99	8.52	38.84	13237.00	5030.00	8207.00	38.00
DBW17	414.28	8.84	52.01	8.68	39.62	13228.00	5130.00	8098.00	38.78
HD2967	450.66	9.64	56.67	9.46	43.17	13238.00	5590.00	7648.00	42.23
PBW343	425.53	9.10	53.49	8.93	40.75	13226.00	5277.00	7950.00	39.90
PBW502	386.62	7.90	47.65	7.96	36.30	12900.00	4601.00	8299.00	35.67
PBW550	400.18	8.59	50.51	8.43	38.48	13228.00	4983.00	8245.00	37.67
Correlation(r) $T_{max\ (^0C)}$	0.160	0.172	0.210	0.218	0.210	-0.125	0.177	-0.289	0.253
Correlation(r) $T_{min\ (^0C)}$	0.326	0.321	0.358*	0.366*	0.358*	-0.018	0.326	-0.321	0.370*
Correlation(r) GDD	0.269	0.221	0.267	0.275	0.267	-0.161	0.228	-0.373*	0.327

Table 3: Growing Degree Days and Heat Use Efficiency of different varieties on the basis of biological yield and grain yield

Treatments	Days to Maturity	GDD	HUE (kg ^{0}Cday-1) of Biological Yield	HUE (kg ^{0}Cday-1) of Grain Yield
K307	138	1857.4	6.64	2.62
K402	130	1678.0	7.88	3.05
K607	132	1723.9	7.68	2.80
K1006	138	1857.4	7.13	2.80
HD2733	142	1954.5	6.77	2.57
DBW17	138	1857.4	7.12	2.76
HD2967	140	1907.9	6.94	2.93
PBW343	140	1907.9	6.93	2.76
PBW502	139	1882.6	6.85	2.44
PBW550	137	1832.2	7.22	2.71

GDD – Growing Degree Days
HUE – Heat use efficiency

Conclusion

Based on the findings of results it may be concluded that comperatively more duration varieties viz. HD2967 and PBW 343, when sown timely (17th November) recorded more growing degree days (1907.9) was least affected by temperature fluctuations, positively correlated with minimum temperature at growth stages, yielded comparatively better grain yield (5590.0 and 5277.00 kg ha^{-1}), harvest index (42.23% and 39.90%), heat use efficiency of grain yield (2.93 and 2.76 kg °C day^{-1}), respectively.

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