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Accumulated heat unit requirement and yield of irrigated wheat (*Triticum aestivum* L.) varieties under different crop growing environment in central Punjab

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ABSTRACT

Field experiment was conducted during *rabi* seasons of 2009-10 and 2010-11 to study the phenology, accumulation of growing degree days (GDD), helio-thermal unit (HTU), photo-thermal unit (PTU), pheno-thermal index (PTI) and performance of wheat (*Triticum aestivum* L.) varieties grown under different sowing dates. The crop sown on October 25 took maximum calendar days, growing degree days, photo-thermal unit and helio-thermal unit for 75% earing and maturity which got reduced significantly with subsequent delay in sowing time. The grain yield recorded in October 25 was statistically at par with November 5. The significant reduction in grain yield of timely sown varieties was recorded when sowing was delayed beyond November 15. Among the varieties 'PBW 621' recorded the highest grain yield which was statistically on par with 'PBW 550'. The timely sown wheat varieties like 'PBW 621', 'PBW 343', 'DBW 17' and 'WH 542' took highest calendar days, GDD, HTU, PTU and PTI for earing and maturity. However, in medium duration varieties like 'PBW 550' the significant reduction was noticed when sowing was delayed beyond November 25. The variety 'PBW 550" recorded the highest grain yield at November 15 sowing as compared to all other sowing dates.

Key words: Wheat, GDD, PTU, HTU, PTI, Grain yield

Wheat (*Triticum aestivum* L.) is an important *rabi* crop of North-western plains of India. It is the second most important cereal crop after rice. Wheat is a widely adapted crop it is grown from temperate irrigated to dry and high rainfall areas, and from warm humid to dry cold environments. Undoubtedly this wide adaptation has been possible due to the complex nature of its genome, which provides a fantastic plasticity to the crop. Wheat is a C_3 plant and as such it thrives in cool environments. It is grown under diverse agro-climatic conditions on 29.2 million hectares area in India with a production of 85.9 million tonnes during the season 2010-11 (Anonymous, 2011).

Sowing time of wheat is one of the most important factors that governs the crop phonological development and efficient conversion of biomass into economic yield. Normal sowing has longer growth duration which consequently provides an opportunity to accumulate more biomass as compared to late sowing and henceforth manifested in higher grain and biological yield (Singh and Pal, 2003). Whereas in case of delayed sowing, the wheat crop is exposed to sub-optimal temperatures at establishment and supra-optimal temperature at reproductive phases that leads to forced maturity and reduction in grain yield (Sardana *et al*., 1999). Growing of suitable variety at an appropriate time is essential for ensuring optimum productivity. Being a thermo-sensitive crop, choice of suitable variety for different seeding time further gets prime importance. Temperature is an important environmental factor influencing the growth and development of crop plants. Influence of temperature on phenology and yield of crop plants can be studied under field condition through accumulated heat units system (Bishnoi *et al.,* 1995). Plants have a definite temperature requirement before they attain certain phenological stages. Though accumulation of degree-days for each development stage is relatively constant and independent of sowing date, crop variety may modify it considerably. Under North Indian condition, the maturity of wheat hastened due to gradual rise in ambient temperature under delayed planting. Hence, it becomes imperative to have knowledge of exact duration of phenological stages in a particular crop-growing environment and their impact on yield of crop. Therefore, an experiment was planned to determine the phenology and heat unit requirement of promising wheat varieties under different crop growing environment of central Punjab.

Table 1: Normal as well as actual weather data during crop growth period

Parameter	Months						
	October	November	December	January	February	March	April
Total Rainfall (mm)							
2009-10	26.2	5.1	00	18.4	25.0	2.0	4.4
2010-11	8.8	00	17.6	5.4	44.2	6.5	26.5
Normal	6.0	9.4	16.9	25.4	29.9	26.1	18.3
Mean maximum air temperature (°C)							
2009-10	31.8	25.1	21.1	15.7	22.5	31.0	38.7
2010-11	31.6	27.1	20.5	16.0	21.2	27.9	33.8
Normal	31.9	26.7	20.4	18.9	21.6	26.6	34.2
Mean minimum air temperature (°C)							
2009-10	16.4	10.6	6.5	6.6	9.0	14.8	20.1
2010-11	18.9	11.4	5.6	5.2	9.4	13.4	17.6
Normal	16.1	10.1	6.1	5.3	7.2	11.3	16.9
Mean relative humidity (%)							
2009-10	67	67	71	86	72	65	45
2010-11	71	67	76	82	81	72	49
Normal	59	61	68	71	69	63	47
Mean Sunshine (hours day^{-1})							
2009-10	8.7	4.7	5.5	2.8	7.3	9.4	8.8
2010-11	5.5	7.2	5.5	4.4	5.6	8.5	9.2
Normal	11.4	10.6	10.1	10.2	11.1	11.6	12.6

MATERIALS AND METHODS

The present field investigations were conducted at the experimental farm of Punjab Agricultural University, Ludhiana (30^0 542 north latitude and 75^0 482 east longitude at a height of 247 m above the mean sea level) during the *rabi* seasons of 2009-10 and 2010-11. The experiment was conducted in split plot design with seven dates of sowing, viz. 25 October, 5 November, 15 November, 25 November, 5 December, 15 December and 25 December in main plots and six varieties of wheat, viz. 'PBW 621', 'PBW 550', 'PBW 590', 'PBW 343', 'DBW 17' and 'WH 542', in sub-plots with three replications. Wheat crop was sown with the row spacing of 22.5 cm as per treatments. Four irrigations (75 mm water in each irrigation) were applied at four critical phenological stages. In regards to fertilizer application of the crop, 150 kg N, 62.5 kg P_2O_5 and 30 kg K_2O were applied. Out of which, 1/3rd N and full dose of P_2O_5 and K_2O were applied as basal dose at the time of sowing by broadcasting method. The remaining 2/3rd dose of N was applied in two splits at CRI and late tillering stages. Total tillers and ears recorded from one metre row length and presented as per square metre. Five ears were randomly selected and threshed manually, grains counted and data presented as grains per ear. The sample of 1000-grains collected from each plot, weighed and presented as gram. Total bundle weight was recorded from each plot at the time of harvesting. The crop was threshed and grain were weighed and presented as quintal per hectare.

Table 2: Effect of sowing time and varieties on plant characters, yield attributes and biomass of wheat (pooled data of two years)

Treatment	Total tillers m^{-2}	Ears m^{-2}	Grains ear^{-1}	1000-grain weight (g)	Biological yield (q ha^{-1})
Sowing date					
October 25	351.9	321.4	50.8	36.1	119.6
November 5	354.4	319.9	54.7	34.2	107.8
November 15	342.3	310.5	52.3	33.6	100.6
November 25	309.8	277.7	51.3	32.8	94.7
December 5	292.1	260.1	49.5	32.4	92.6
December 15	284.0	252.9	45.6	30.8	81.7
December 25	274.3	248.8	43.0	30.5	76.2
CD (5%)	19.7	18.2	4.1	1.3	3.2
Varieties					
PBW 621	316.6	284.8	51.3	33.4	102.1
PBW 550	305.7	278.5	50.3	35.0	95.8
PBW 590	312.0	274.4	50.1	34.1	97.4
PBW 343	321.3	290.6	45.6	32.3	89.6
DBW 17	317.9	288.9	47.4	32.7	96.7
WH 542	319.9	289.5	53.0	30.1	95.4
CD (5%)	8.7	10.4	2.8	0.8	2.1

Table 3: Effect of sowing time on grain yield (q ha^{-1}) of wheat varieties (pooled data of two years)

Varieties	Sowing date							
	Oct. 25	Nov. 5	Nov. 15	Nov. 25	Dec. 5	Dec. 15	Dec. 25	Mean
PBW 621	59.22	57.74	50.70	47.57	44.19	41.18	36.37	48.14
PBW 550	49.33	52.36	59.14	49.17	45.25	39.58	37.15	47.42
PBW 590	42.48	44.22	45.07	48.64	46.76	43.13	40.63	44.42
PBW 343	50.09	51.09	50.70	41.92	38.07	35.06	36.60	43.36
DBW 17	57.24	55.32	50.48	44.57	40.60	39.57	34.23	46.00
WH 542	54.13	49.26	48.52	45.61	43.43	34.40	34.98	44.33
Mean	52.08	51.66	50.77	46.25	43.05	38.82	36.66	

CD (5 %) : Sowing date 0.99: Varieties 0.84: Interaction 2.23

Table 4: Effect of sowing time and varieties on days taken to earing, growing degree days (GDD), helio-thermal unit (HTU), photo-thermal unit (PTU) and pheno-thermal index (PTI) (pooled data of two years)

Treatment days day^{-1})	Days taken to		GDD (°C day)		PTU (°C day hour)		HTU (°C day hour)		PTI (°C	
	Earing	Maturity	Earing	Maturity	Earing	Maturity	Earing	Maturity	Earing	Maturity
Sowing dates										
October 25	106.6	168.0	1119.1	2163.7	11823.6	24358.2	6286.6	16033.8	10.52	12.88
November 5	109.0	160.9	1077.4	2081.7	11343.5	23650.9	5984.5	15724.4	9.88	12.93
November 15	104.5	152.8	997.8	1980.6	10563.7	22675.3	5749.0	15255.2	9.54	12.96
November 25	99.7	145.3	945.3	1920.7	10090.4	22217.5	5575.0	15024.9	9.48	13.22
December 5	93.9	137.0	891.2	1848.2	9618.1	21591.3	5443.9	14632.4	9.49	13.48
December 15	86.9	129.2	839.9	1802.3	9174.3	21284.4	5330.3	14456.0	9.65	13.94
December 25	79.3	121.0	796.2	1771.8	8803.7	21137.0	5203.2	14321.0	10.04	14.63
CD (5%)	1.23	2.22	20.1	58.8	239.6	765.1	192.9	437.3	0.10	0.21
Varieties										
PBW 621	100.4	146.4	992.6	1979.1	10662.1	22944.9	5967.0	15392.6	9.87	13.57
PBW 550	91.2	142.2	881.8	1867.9	9408.7	21497.4	5117.7	14518.5	9.69	13.19
PBW 590	91.5	142.2	881.5	1868.4	9402.6	21504.9	5101.1	14525.0	9.65	13.19
PBW 343	100.4	146.2	993.7	1971.9	10677.2	22851.6	5979.3	15319.3	9.89	13.55
DBW 17	99.5	146.1	979.4	1971.4	10507.7	22845.5	5845.4	15302.4	9.84	13.55
WH 542	99.8	146.2	985.6	1972.1	10556.5	22854.1	5908.8	15325.9	9.87	13.55
CD (5%)	0.65	0.69	10.5	18.0	124.5	235.5	96.5	135.1	0.05	0.07

Meteorological data, viz., rainfall, relative humidity, maximum and minimum temperature, bright sunshine hours, day length etc. were recorded from Agro-meteorological observatory, Punjab Agricultural University, Ludhiana.

The agro-meteorological indices were computed using the daily meteorological data. The dates of occurrences of different phenological events, viz. earing and maturity were recorded when 75 per cent of the plants in each replication reached the respective stages.

Photo-thermal unit (PTU)

Photo - thermal unit (PTU)

helio thermal unit (HTU)

and pheno-thermal index (PTP)

were celerlated using following termvlai

$$\text{GDD } (^\circ\text{C day}) = \Sigma \frac{(T_{max} + T_{min})}{2} - 4.5 \text{ (base temperature)}$$

$$\text{PTU } (^\circ\text{C day hour}) = \Sigma \text{ (GDD} \times \text{D)}$$

$$\text{HTU } (^\circ\text{C day hour}) = \Sigma \text{ (GDD} \times \text{SS)}$$

RESULTS AND DISCUSSION

Yield attributes

The total tillers m^{-2}, ears m^{-2}, grains ear^{-1}, 1000 grain weight and biological yield were significantly influenced by sowing dates and varieties (Table 2). The highest total tillers m^{-2} were recorded in crop sown on November 5 which was statistically on par with that of October 25 and November 5 date of sowing and were significantly more than later four dates of sowing. Among different varieties, the total tillers m^{-2} recorded in ''PBW 621', 'PBW 343', 'DBW 17' and 'WH 542' were significantly more than 'PBW 550' and 'PBW 590' (short duration varieties). October 25 sown crop gave significantly higher ears m^{-2} which was statistically on par with November 5 and November 15 date of sowing. Among different varieties, ears m^{-2} of varieties 'PBW 621', 'PBW 343', 'DBW 17' and 'WH 542' were significantly more than 'PBW 550' and 'PBW 590'. Numbers of grains ear^{-1} being statistically at par among earlier four dates of sowing were significantly more than December 5, December 15 and December 25 sown crop. Regarding different varieties, number of grains ear^{-1} was significantly more in 'WH 542'. However, it was at par with variety 'PBW 621' and 'PBW 550'. October 25 sowing date recorded significantly higher 1000-grain weight as compared to all other later dates of sowing. Wheat variety 'PBW 550' produced significantly higher 1000-grain weight than all other varieties. The biological yield was significantly higher in crop sown on October 25. The wheat variety 'PBW 621' recorded significantly higher biological yield as compared to other 5 varieties. It might be due to its higher tiller density. The higher value of yield attributing parameters and yield in case of early sowing over delayed ones could be attributed to availability of optimum environmental conditions for growth and development of crop which might enhance accumulation of photosynthates from source to sink.

Grain yield

The crop sown on October 25 recorded the highest grain yield which was statistically on par with November 5 sowing but significantly higher than recorded in later sowing dates (Table 3). It might be due to higher yield attributes, GDD, HTU and PTU in this sowing date (Table 2 & 4). The detrimental effect of heat at later stage of crop development and earing in delayed sowing had adverse effect on grain yield. Wardlaw and Wringley (1994) reported 3-4 per cent decrease in grain yield for each 1°C rise in ambient temperature above 15°C during grain filling. The variety 'PBW 621' recorded the highest grain yield which was statistically on par with 'PBW 550' but was significantly higher than other varieties. It might be due to potential of different varieties. The interaction effect between dates of sowing and wheat varieties was also found to be significant (Table 3). The variety 'PBW 621' sown on October 25 being at par with 'PBW 621' sown on November 5, 'PBW 550' sown on November 15 and 'DBW 17' sown on October 25. A significant decline in yield with delay in sowing was obtained in all the varieties, except 'PBW 550' and 'PBW 590' in which the highest yield was recorded in November 15 and November 25 dates of sowing, respectively. The significant reduction in grain yield of timely sown varieties was recorded when sowing was delayed beyond November 15. However, in late sown variety (PBW 590) the significant reduction was noticed when sowing was delayed beyond November 25. The greater reduction in yield of long season wheat varieties under delayed sowing situations was attributed to decrease in season length might have an effect by reduction in their potential yield. Delayed sowing hastened the crop phenological development, thereby causing significant reduction in wheat yields (Singh and Pal, 2003). Kaur *et al*. (2010) and Pandey *et al*. (2010) also reported the similar observation under delayed sowing. The higher grain yield in timely sown variety 'PBW 621' was due to better expression of yield attributing characters which led towards an increase in grain yield.

Days taken to earing and maturity

Date of sowing and different varieties had significant difference in days taken to earing and maturity (Table 4). The crop sown on November 5 took significantly higher number of days to earing than one earlier and later five dates of sowing. However, October 25 date of sowing took significantly more days for maturity than later dates of sowing. In different varieties, 'PBW 550' and 'PBW 590' being statistically at par took significantly fewer numbers of days to earing and maturity than ''PBW 621', 'PBW 343', 'WH 542' and 'DBW 17'. The late sown crop completed its life cycle at an accelerated pace, leading to shortening of days taken to earing and maturity.

Growing degree days (GDD)

Growing degree days were found to be significant both at earing and maturity of different dates of sowing (Table 4). Significantly higher GDD from sowing to earing were recorded in October 25 date of sowing. GDD required for earing and maturity reduced with delayed sowing. Pandey *et al*. (2010) also reported lower consumption of heat units under delayed sowing. The requirement of GDD was higher for normal growing condition than the late growing condition. This was due to longer period for all the phenological stages in the normal growing condition. Late sowing decreased the duration of phenology as compared to normal sowing due to fluctuated un-favourable high temperature during the growing period. So, the requirement of heat units decreased for different phenological stages with late sowing. Masoni *et al.* (1990), Bishnoi *et al.* (1995) and Tripathi *et al*. (2004) also opined alike.

GDD statistically on par among 'PBW 550' and 'PBW 590' was significantly lower than varieties ''PBW 621', 'PBW 343', 'WH 542' and 'DBW 17' both at earing and maturity. The varieties 'PBW 550' and 'PBW 590' (short duration varieties) took significantly lower GDD for earing and maturity. Early development of phenological stages might be the reason for less consumption of heat units in late sown wheat varieties.

Photo-thermal unit (PTU)

The variation in photo-thermal units (PTU) in different treatments at earing and maturity has been presented in Table 4. Accumulation of photo-thermal units (PTU) at earing found significantly higher in October 25 sown crop. However, at maturity accumulation of PTU among October 25 and November 5 sown crop were significantly more than November 15, November 25, December 5, December 15 and December 25 sown crop. Among genotypes, 'PBW 550' and 'PBW 590' accumulated significantly lower PTU than 'PBW 621', 'PBW 343', 'DBW 17' and 'WH 542' both at earing and maturity stages.

Helio-thermal unit (HTU)

The early sown wheat crop showed higher consumption of HTU as compared to late sown wheat crop (Table 4). This might be due to delayed maturity in early sown as compared to late sown wheat crop. At earing, October 25 sown crop accumulated significantly higher HTU as compared to all other later dates of sowing. Similarly at maturity, significantly higher HTU were accumulated in October 25 sown crop, however, it was statistically on par with November 5 date of sowing. It was reported that HTU for different phenological stages decreased with delay in sowing as reported by Masoni *et al.* (1990). Among different varieties accumulated HTU in 'PBW 550' and 'PBW 590' were significantly less than 'PBW 621', 'PBW 343', 'DBW 17' and 'WH 542' both at earing and maturity. It might be due to their shorter life cycle than other varieties.

Pheno-thermal index (PTI)

Pheno-thermal index was more at maturity than at earing (Table 4). Significantly higher value of PTI was found in October 25 sown crop at earing. However, at maturity December 25 sown crop resulted in significantly higher PTI values. Among different varieties, PTI values in 'PBW 621', 'PBW 343', 'DBW 17' and 'WH 542' were significantly higher than 'PBW 550' and 'PBW 590'. It might be due to long duration of these varieties.

CONCLUSION

The crop sown on October 25 took maximum calendar days, growing degree days, photo-thermal units and helio-thermal units for earing and maturity which got reduced significantly with subsequent delay in sowing time and recorded lowest value on December 25 sown crop. October 25 recorded the highest grain yield which was statistically on par with November 5. Among the varieties the timely sown wheat varieties ('PBW 621', 'PBW 343', 'DBW 17' and 'WH 542') took the highest calendar days, growing degree days, photo-thermal unit, helio-thermal unit and pheno-thermal index for earing and maturity. Variety 'PBW 621' recorded the highest grain yield which was statistically on par with 'PBW 550'. The variety 'PBW 550' recorded the highest grain yield at November 15 sowing as compared to all other sowing dates.

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