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Phenology, photo-thermal units requirement and productivity of wheat varieties as influenced by sowing dates under irrigated conditions in Punjab

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ABSTRACT

Studies were conducted at the research farm of the Punjab Agricultural University, Ludhiana from 2009-10 to 2012-13. The experiment was conducted in split plot design with two sowing dates, viz. normal (November 5-11) and late (December 10-16) sowing as main plot treatment and wheat varieties (PBW 621, PBW 343, DBW 17, PBW 550 and HD 2967 in 2009-10, PBW 621, PBW 343, DBW 17, PBW 550 and WH 1105 in 2011-12 and PBW 621, DBW 17, PBW 550 and HD 2967 in 2012-13) as sub plot treatments with three replications. Delayed sowing of wheat recorded significantly lower emergence count. Timely sown wheat crop recorded significantly higher GDD (growing degree days), HTU (helio-thermal units), PTU (photo-thermal units), PTI (pheno-thermal index) and grain yield than late sown. The highest agrometeorological indices were recorded in PBW 343, HD 2967 and DBW 17 in different years. Timely sowing recorded 14.1-37.3 per cent higher grain yield than late sown conditions. Similarly, on mean basis of respective years it is concluded that wheat variety WH 1105 performed better than other varieties.

Keywords : GDD, grain yield, HTU, PTI, PTU, sowing dates, wheat

Wheat (*Triticum aestivum* L.) is an important cereal crop of North-western plains of India next to rice and is consumed in different forms. Wheat has wider adaptability; it is being grown from temperate humid to dry cold environments which provide a fantastic plasticity to the crop. It is being grown under different agro-climatic conditions on 30.2 million hectares area in India with a production of 93.5 million tonnes during the season 2015-16 (Anon., 2016). Wheat sowing time governs the duration of different phenological stages and conversion efficiency of biomass into the sink *i.e*. grain yield. Timely sown crop has longer growth duration which consequently provides an opportunity to accumulate higher biomass as compared to late sown crop. Under delayed sowing, the wheat crop is exposed to sub-optimal temperatures at grain development stages, which leads to forced maturity and reduction in grain yield (Ram *et al*., 2012). Raising an appropriate variety at optimum time is essential for ensuring optimum wheat productivity. As wheat crop is thermo-sensitive crop, so selection of suitable variety for different seeding time is very much important. The effect of temperature on phenological stages and wheat productivity can be studied under field condition through photothermal and heat units system (Bishnoi *et al.,* 1995). Under Northwestern Indian conditions, early earing and maturity of wheat observed due to gradual rise in temperature under delayed planting. Hence, it is very much important to have knowledge of duration of all phenological stages in a particular crop-growing environment and their effect on wheat productivity. Therefore, an experiment was planned to determine the phenology, photothermal heat unit requirement of some wheat varieties under different sowing dates.

MATERIALS AND METHODS

The present investigations were conducted at the experimental farm of the 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 winter seasons of 2009-10, 2011-12 and 2012-13. The experiment was conducted in split plot design with two dates of sowing, *viz*. normal (November 5-11) and late (December, 10-16) sowing in main plot and wheat varieties (PBW 621, PBW 343, DBW 17, PBW 550 and HD 2967 in 2009-10, PBW 621, PBW 343, DBW 17, PBW 550 and WH 1105 in 201-12 and PBW 621, DBW 17, PBW 550 and HD 2967 in 2012-13) in sub plots with three replications. The soil was low in available N (192.4 kg ha^{-1}), medium in available P (15.3 kg ha^{-1}) and K (217.8 kg ha^{-1}). Wheat varieties were sown with the row spacing of 20 cm. Four to five irrigations (75 mm water in each irrigation) were applied at different critical phenological stages. With respect to fertilizer application of the crop, the nitrogen dose of 150 kg N and phosphorus dose of 62.5 kg P_2O_5 per hectare were applied. Full dose of P_2O_5 and $1/3^{rd}$ N were applied as basal dose at the time of sowing by broadcasting method. The remaining $2/3^{rd}$ dose of N was applied in two splits at CRI and late tillering stages. Total tiller density and effective tiller density were recorded from one metre row length and presented as per area square metre. Five ears from the net plot were randomly selected and threshed manually, grains counted and data presented as grains per ear. The sample of 1000-grains collected from each plot after threshing, weighed and presented in gram. Total biomass was recorded from each plot at the time of harvesting. The crop was threshed and grain were weighed and presented as quintal per hectare.

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The agro-meteorological indices were computed using the daily meteorological data collected form Punjab Agricultural University Agrometeorological observatory. Various agro-meteorological indices GDD (growing degree days), HTU (helio-thermal units), PTU (photo-thermal units), PTI (pheno-thermal index) were calculated as explained in our earlier studies (Ram *et al.*, 2012). 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. Data collected for different parameters were analysed using analysis of variance (ANOVA) of split-plot design. The comparison of treatment means was made by least significant difference (LSD) at *p* d" 0.05.

RESULTS AND DISCUSSION

Effect of sowing time

The delayed sowing of wheat crop recorded significantly lower emergence count as compared to timely sowing during three years of study (Table 1). The delayed sowing recorded 14.5 to 34.5 per cent lower emergence count as compared to the timely sown wheat crop. The lower germination under late sown condition was due to low temperature prevailed during this period. The total and effective tillers recorded in timely sown conditions were significantly higher than late sown conditions except total tillers in 2012-13 where it was non-significant. The total tillers density was 19.4-21.6 per cent and effective tiller density 15.5-20.5 per cent lower under delayed sown conditions. It might be due to lower GDD, HTU, PTU and PTI at earing and physiological maturity stages which ultimately helped in accumulation of higher biomass and its translocation to the developing sink. The grains per earhead of 3.5 to 12.6 per cent recorded in 2009-10 and 2011-12 were higher in timely sown conditions than late sown conditions but the reverse was true in 2012-13, however the results were non-significant during three years of study. Thousand grain weight recorded in timely sown conditions was 5.5, 8.4 and 1.2 g higher in 2009-10, 2011-12 and 2012-13 respectively than that recorded under late sown conditions. Lower thousand grain weight recorded in late sown condition might be due to less number of days in earing and maturity of the crop during three years of study. The biological yield (Table 2) recorded in timely sown condition was significantly higher than that recorded under late sown conditions. The biological yield was 18.2-40.5 per cent higher than late sown conditions in different years of study. The higher biomass accumulation under timely sown conditions can be ascribed to higher total and effective tillers and more number of days to earing and maturity, leading to higher values of all meteorological indices. Earing under late sown conditions was 10 to 20 days later whereas physiological maturity was 21-25 days later than timely sown condition.

Effect of varieties

The emergence of all the varieties was not significantly influenced as all the varieties recorded the similar emergence count. The emergence count was 148.8-189.8 plants/m^2 in different years (Table 1). The highest tillers were recorded in variety PBW 343 in 2009-10 and 2011-12, however tillers were the highest in DBW 17 in 2012-13. During 2009-10, the highest tillers recorded in PBW 343 was statistically similar with DBW 17 but significantly higher than all other varieties. The lowers tillers were recorded in PBW 550 in 2009-10 and 2011-12 which was statistically *at par* with all the varieties in 2009-10 except PBW 343 but at par with WH 1105 in 2011-12. During 2012-13, the highest tillers recorded in DBW 17 were statistically similar to HD 2967 and PBW 621 but significantly higher than PBW 550 and WH 1105. It might be due higher tillering ability of these varieties. The highest effective tillers were recorded in DBW 17 in 2009-10 and 2012-13 but in 2011-12, the highest tillers were recorded in PBW 343. The lowest tillers were recorded in PBW 550 in first two years and in WH 1105 in the last year of study. The differential tillering ability was also reviewed and reported in other studies like Andrew *et al*. (2015). The grains per earhead recorded in 2009-10 were non-significant. However, in 2011-12 and 2012-13, the highest grains per earhead was recorded in WH 1105 which was significantly higher than all other varieties in 2011-12 and 2012-13. The lowest grains per earhead were recorded in DBW 17 in 2009-10 and in PBW 550 in 2012-13. This is the most important character which is also varied with different varieties. The thousand grain weight recorded in PBW 550 during three years of study was the highest among all the wheat varieties however the results were non-significant during 2009-10. During 2011-12, the 1000-grain weight of PBW 550 was significantly higher than all other varieties but it was statistically similar to HD 2967 and PBW 621. The similar character of bold grain of the variety PBW 550 was also reported by Ram *et al*. (2012). The biological yield (Table 2) recorded in different years is different for all the varieties. In 2009-10, the highest biological yield was recorded in HD 2967 which was significantly higher than all other varieties. The lowest biomass was recorded in PBW 343 in 2009-10 and 2011-12. In 2011-12, the highest biomass was recorded in WH 1105 which was statistically similar to PBW 621 but significantly higher than rest of the varieties. In 2012-13, the biomass recorded in PBW 621 was statistically similar to WH 1105 but significantly superior than all other varieties.

During 2009-10, days to earing recorded in PBW 621, PBW 343 and HD 2967 were similar and significantly higher than other varieties. In 2011-12, the variety PBW 343 took maximum days whereas in 2012-13, the variety HD 2967, DBW 17 and PBW 621 recorded similar days to earing. The wheat variety PBW

Table 1: Effect of sowing date and varieties on emergence count and yield attributes of wheat

Treatment	Emergence count m^{-2}			Total tillers m^{-2}			Effective tillers m^{-2}			Grain ear^{-1}			Test weight (g)		
	2009-10	11-12	12-13	09-10	11-12	12-13	09-10	11-12	12-13	09-10	11-12	12-13	09-10	11-12	12-13
Sowing date															
Timely	172	192	205	434	453	418	396	420	389	48.3	51.1	41.8	38.6	38.6	38.7
Late	147	126	139	340	365	332	315	355	315	42.2	49.3	45.2	33.0	30.1	37.5
LSD (0.05)	**16**	**32**	**29**	**29**	**27**	**NS**	**29**	**43**	**72.57**	**NS**	**NS**	**NS**	**3.7**	**2.40**	**NS**
Variety															
PBW 621	166	158	190	380	417	387	355	392	368	47.6	53.5	41.0	35.9	34.2	39.5
PBW343	168	159	-	408	449	-	359	434	-	41.9	45.3	-	35.0	32.7	-
DBW 17	159	158	166	391	419	395	372	396	369	42.0	43.6	43.7	34.8	33.4	35.5
PBW 550	149	149	179	373	371	361	339	345	338	47.1	48.8	41.4	37.2	38.2	39.6
HD 2967	155	-	159	385	-	384	352	-	357	47.8	-	41.9	36.0	-	39.3
WH 1105	-	171	167	-	387	350	-	371	330	-	59.7	49.5	-	33.2	36.5
LSD (0.05)	**NS**	**NS**	**NS**	**19**	**22**	**24**	**16**	**24**	**19**	**NS**	**4.38**	**4.26**	**NS**	**2.70**	**2.1**
Interaction	**NS**	**NS**	**NS**	**NS**	**32**	**34**	**NS**	**34**	**27**	**NS**	**NS**	**6.02**	**NS**	**NS**	**2.9**

Table 2: Effect of sowing date and varieties on biological yield and phenology of wheat

Treatment	Biological yield (q ha^{-1})			Days taken to earing			Days taken to physiological maturity		
	2009-10	2011-12	2012-13	2009-10	2011-12	2012-13	2009-10	2011-12	2012-13
Sowing date									
Timely	152.38	153.86	150.89	107	106	109	156	157	153
Late	108.80	91.58	123.44	87	96	91	131	133	132
LSD (0.05)	**2.23**	**28.59**	**16.97**	**0.6**	**0.8**	**1.3**	**0.2**	**0.2**	**1.0**
Variety									
PBW 621	131.84	133.43	146.67	99	103	102	145	146	144
PBW343	124.04	108.89	-	99	106	-	144	146	-
DBW 17	128.07	117.37	133.06	98	104	102	144	145	143
PBW 550	126.31	118.72	127.78	91	92	95	141	143	141
HD 2967	142.66	-	136.67	99		102	144	-	144
WH 1105	-	135.20	141.67	-	100	99	-	145	142
LSD (0.05)	**4.29**	**10.40**	**7.64**	**0.7**	**0.5**	**0.7**	**0.5**	**0.2**	**0.7**
Interaction	**6.06**	**14.70**	**10.80**	**1.0**	**0.7**	**1.0**	**0.6**	**0.3**	**0.9**

621, recorded the highest days to physiological maturity which was significantly higher than all other varieties except it was statistically *at par* with HD 2967 in 2012-13.

Agro-meteorological indices

Effect of sowing date

Timely sowing recorded significantly higher agrometeorological indices *i.e* GDD, HTU, PTU, PTI at earing and physiological maturity (Table 3 and 4) during all the years of study. The GDD was 21.9-26 per cent, PTT 4.9-12.1, PTTT 17.8-24.2 and PTI 1.9-13.9 per cent higher under timely sown conditions as compared to late sown condition. Similarly at physiological maturity, The GDD was 6.7-10.5 per cent and PTU 6.8-12.1higher under timely sown conditions. The PTU accumulated under timely sown conditions in 2009-10 and 2011-12 was significantly less as compared to late sown conditions. The PTI accumulated in all the three years was significantly low under late sown conditions. Bishnoi et al. (1995) and Ram *et al.* (2012) reported similar findings of reduced heat units in wheat under late sown conditions.

Effect of varieties

At earing stage, the highest GDD in 2009-10 and 2011-12, was recorded in PBW 343 which was statistically similar to PBW 621 and HD 2967 in 2009-10 and to WH 1105 in 2011-12 (Table 3 and 4). However, the highest GDD was recorded in DBW 17. The HTU recorded at earing during 2009-10 was in HD 2967 which was statistically similar to PBW 343 and PBW 621. The

Table 3: Effect of sowing time and varieties on growing degree days, helio-thermal unit, photo-thermal unit and pheno-thermal index of wheat at earing stage

Treatment	GDD (°C day)			HTU (°C day hour)			PTU (°C day hour)			PTI (°C days day^{-1})		
	2009-10	2011-12	2012-13	2009-10	2011-12	2012-13	2009-10	2011-12	2012-13	2009-10	2011-12	2012-13
Sowing date												
Timely	1010	1034	1030	5170	5736	6230	10629	10856	10875	9.44	9.76	9.47
Late	794	820	845	4775	5468	5557	8556	8963	9231	9.17	8.57	9.29
LSD (0.05)	**5**	**4**	**6**	**50**	**34**	**59**	**63**	**53**	**74**	**0.02**	**0.02**	**0.02**
Variety												
PBW 621	923	946	960	5148	5704	6025	9831	10120	10304	9.36	9.16	9.45
PBW 343	923	980	-	5138	6037	-	9829	10525	-	9.35	9.21	-
DBW 17	912	954	971	5043	5790	6146	9699	10213	10439	9.32	9.15	9.49
PBW 550	828	844	871	4368	5032	5450	8748	8975	9284	9.13	9.23	9.21
HD 2967	925	-	966	5167	-	6098	9856	-	10383	9.36	-	9.47
WH 1105	-	911	921	-	5449	5748	-	9714	9852	-	9.07	9.29
LSD (0.05)	**9**	**7**	**10**	**80**	**54**	**93**	**100**	**83**	**117**	**0.03**	**0.03**	**0.04**
Interaction	**12**	**10**	**14**	**113**	**77**	**131**	**141**	**118**	**166**	**0.04**	**0.04**	**0.05**

Table 4: Effect of sowing time and varieties on growing degree days, helio-thermal unit, photo-thermal unit and pheno-thermal index of wheat at maturity stage

Treatment	GDD (°C day)			HTU (°C day hour)			PTU (°C day hour)			PTI (°C days day^{-1})		
	2009-10	2011-12	2012-13	2009-10	2011-12	2012-13	2009-10	2011-12	2012-13	2009-10	2011-12	2012-13
Sowing date												
Timely	1926	1828	1755	14022	12036	13005	21746	20512	19675	12.34	11.67	11.48
Late	1742	1560	1643	14103	11214	13161	20353	18293	19288	13.31	11.70	12.42
LSD (0.05)	**7**	**3**	**9**	**51**	**35**	**86**	**89**	**41**	**121**	**0.03**	**0.01**	**0.03**
Variety												
PBW 621	1866	1715	1719	14300	11801	13251	21467	19676	19738	12.94	11.74	12.01
PBW343	1848	1715	-	14188	11801	-	21235	19676	-	12.88	11.74	-
DBW 17	1835	1695	1697	14101	11613	13063	21065	19420	19451	12.83	11.69	11.94
PBW 550	1772	1641	1667	13555	11213	12821	20252	18732	19076	12.59	11.52	11.85
HD 2967	1848	-	1719	14168	-	13251	21226	-	19738	12.87	-	12.01
WH 1105	-	1702	1693	-	11696	13028	-	19510	19403	-	11.71	11.93
LSD (0.05)	**11**	**4**	**15**	**81**	**55**	**136**	**141**	**65**	**191**	**0.04**	**0.01**	**0.05**
Interaction	**15**	**6**	**21**	**115**	**78**	**NS**	**200**	**92**	**270**	**0.06**	**0.02**	**NS**

Table 5: Grain yield (q ha^{-1}) of wheat varieties under different sowing dates

Variety	Sowing time								Overall mean
	Timely				Late				
	2009-10	2011-12	2012-13	Mean	2009-10	2011-12	2012-13	Mean	
PBW 621	62.30	65.45	60.67	62.81	49.42	44.77	58.00	50.73	56.77
PBW343	62.91	45.88	-	54.40	40.96	34.07	-	37.52	45.96
DBW 17	65.62	61.78	60.00	62.47	46.50	34.78	52.44	44.57	53.52
PBW 550	64.11	70.23	62.00	65.45	45.99	38.36	49.11	44.49	54.97
HD 2967	64.11	-	61.55	62.83	49.11	-	52.66	50.89	56.86
WH 1105	-	70.32	65.11	67.72	-	44.57	53.44	49.01	58.36
Mean	**63.81**	**62.73**	**61.87**	**62.80**	**46.40**	**39.31**	**53.13**	**46.28**	**54.54**
LSD (0.05)	**2009-10**	**2011-12**	**2012-13**						
Sowing date	**2.98**	**2.03**	**2.73**						
Varieties	**2.06**	**3.31**	**NS**						
Interaction	**2.92**	**4.68**	**NS**						

wheat variety PBW 343 recorded the highest HTU in 2011-12. In 2012-13, the highest HTU was recorded in DBW 17 which was statistically similar to HD 2967. The PTU recorded in HD 2967 (2009-10), PBW 343 (2011-12) and in DBW 17 (2012-13) was the highest in the respective years. The PTI recorded in 2009-10 in HD 2967 was statistically similar to DBW 17 but significantly higher than rest of the varieties. In 2011-12, the PTU recorded in HD 2967 and PBW 343 was statistically similar but significantly higher than rest of the treatments. The DBW 17 recorded the highest PTI which was statistically similar to HD 2967. At maturity stage, the highest GDD, HTU, PTU and PTI were recorded in PBW 621 across all the years of the study. However, the highest agrometeorological indices recorded in PBW 621 during 2011-12 were statistically at par with PBW 343 during 2012-13 were statistically at par with HD 2967. It might be due to higher days taken by this variety for maturity.

Grain yield

Effect of sowing date

The grain yield recorded in timely sown conditions was 27.3, 37.3 and 14.1% higher than that recorded under late sown condition in 2009-10, 2011-12 and 2012-13 respectively (Table 5). The grain yield reduction recorded under 2012-13 might be due to lower grains/earhead and reduction in 1000-grain weight, loer days to earing/maturity, lower GDD, HTU, PTU and PTI. Our results are in line with the findings of Silva *et al*. (2014) who reported better grain yield under timely sown conditions as compared to late sown conditions due to higher yield attributes.

Effect of varieties

The grain yield recorded during 2009-10 in timely sown conditions was the highest in variety DBW 17 which was significantly higher than PBW 343 but statistically at par with rest of the varieties. In 2011-12, the variety WH 1105 recorded the highest grain yield which was statistically similar to variety PBW 550 but significantly superior to the all other varieties. In 2012-13, the variety WH 1105 recorded 3.11 to 4.44 q ha^{-1} higher grain yield than rest of the varieties. The varied varietal potential of wheat for grain yield was also reported in earlier studies of Ram *et al*. (2015) and Andrew *et al*. (2015).

Under late sown, PBW 621 recorded the highest grain yield in all the years of study which was statistically similar to HD 2967 in 2009-10 and to WH 1105 in 2011-12. In 2012-13, this variety recorded 4.56 to 8.89 q ha^{-1} higher grain yield than other varieties.

Based on the mean, it can be concluded that WH 1105 recorded 1.50 to 12.41 q ha^{-1} higher grain yield than other varieties. The lowest was recorded in the variety PBW 343.

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