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Research Article

Productivity, yield attributes and phenology of wheat *(Triticum aestivum L.)* under different sowing environments under central Punjab

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Abstract

The field experiment was conducted at the Punjab Agricultural University, Ludhiana during the *rabi* 2011-12 and 2012-13. The experiment was conducted in split plot design keeping two dates of sowing, *viz.,* 12 December and 5 January in main plots and five varieties, *viz.,* HD 3059, WH 1021, DBW 71, PBW 590 and PBW 373 as sub-plots with three replications. Under late sown conditions, yield attributes, days to earing and physiological maturity, biological as well as grain yield and pheno-thermal index were significantly higher than under very late sown conditions. PBW 373 accumulated higher GDD, HTU and PTU than other varieties on pooled basis at earing and maturity. Wheat variety HD 3059 recorded the highest grain yield which was statistically at par with DBW 71. The grain yield recorded in variety HD 3059 in 2012-13 under late sown conditions was only statistically at par with PBW 373 and DBW 71 but significantly better than all the varieties sown at two different times during both years. The lowest grain yield was recorded in PBW 373.

Keywords: Grain yield, phenology, sowing time, wheat varieties

1. Introduction

Wheat (*Triticum aestivum* L.) is an important *rabi* crop of Punjab second to rice. Its wide adaptability has been possible due to the complex nature of its genome, which provides a fantastic plasticity to the crop. Wheat is grown under diverse agro-climatic conditions on 31.34 million hectares area in India with a production of 95.91 million tonnes during the season 2013-14 (Anonymous, 2014). Sowing time of wheat is one of the most important factors that governs the crop phenology. 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 (Ram *et al.,* 2012). There are some areas where the sowing of wheat crop is delayed due to some crop rotations like Basmati Rice-Wheat, Maize/Rice/Groundnut-Potato-Wheat, *ratoon* Sugarcane-Wheat and Rice/Maize-Vegetable Peas-Wheat. Development of suitable variety under late sowing is essential for ensuring optimum productivity. Being a thermo-sensitive crop, choice of suitable variety for different seeding times further gets prime importance. Therefore, an experiment was planned to determine the performance of wheat varieties under different crop growing environments of Punjab.

2. Materials and methods

The present field investigations were conducted at the experimental farm of Punjab Agricultural University, Ludhiana during the *rabi* seasons of 2011-12 and 2012-13. The experiment was conducted in split-plot design with two dates of sowing, *viz.,* 12 December and 5 January in main plots and five varieties, *viz.*, HD 3059, WH 1021, DBW 71, PBW 590 and PBW 373 in sub-plots with three replications. The gross plot size was 1.62 m × 8 m whereas the net plot was 1.26 m× 7 m. The crop was sown with the row spacing of 18 cm as per treatments. Four irrigations (75 mm water in each irrigation) were applied at four critical phenological stages (crown root initiation, tillering, boot leaf and milk stages). 100 kg N, 60 kg P_2O_5 and 40 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 first and second irrigation. To control broad leaf weeds, 2, 4-D sodium salt @ 625g ha^{-1} and to control grass weeds, Total 75 WG (sulfosulfuran + metsulfuron) herbicide @ 40 g ha^{-1} were applied after 35 days of sowing.

The data on emergence count, total tillers and earheads recorded from one metre row length were 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 was weighed and presented as gram. 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. The crop was threshed and grains were weighed and presented as quintal per hectare Various agro-meteorological indices such as growing degree days (GDD), helio-thermal unit (HTU), photo-thermal unit (PTU) and pheno-thermal index (PTI) were measured in each replica from the daily meteorological data at respective earing and maturity stage of wheat (Monteith, 1984).

$$\text{GDD (°C day)} = \sum \frac{T_{max} + T_{min}}{2} - 4.5$$

$$\text{HTU (°C day hour)} = \sum (\text{GDD} \times \text{SS})$$

$$\text{PTU (°C day hour)} = \sum (\text{GDD} \times \text{D})$$

$$\text{PTI} = \frac{\text{Growing degree days consumed between two phenological stages}}{\text{Number of days between two phenological stages}}$$

Where T_{max} and T_{min} represent daily maximum and minimum temperature, respectively, SS and D refer to sunshine hours and day length, respectively. The data were analysed using pooled analysis of variance (ANOVA) of split-plot design by using cpcs 1. The comparison of treatment means was made by critical difference (CD) at $p \leq 0.05$.

3. Results and discussion

3.1 Emergence count, yield attributes and grain yield: The emergence count and grains per ear were the highest in 2011-12, however, test weight, days to physiological maturity and grain yield was the highest in 2012-13 (Table 1). It might be due to epidemic form of the yellow rust disease that appeared in first year. However, total tillers and earheads, biological yield and days to earing were not significantly influenced by the year.

Table 1. Emergence, yield characteristics, phenology and yield of wheat varieties under different sowing dates (Pooled for two seasons)

Treatment	Emergence count /sq.m.	Tillers/m^2	Ear head/ m^2	Grain/ear	1000 grain weight (g)	Biological yield (q/ ha)	Days to earing	Days to physiological maturity
Year (Y)								
2011-12	194.8	326	303	39.5	30.01	84.44	81	124
2012-13	148.5	327	303	31.0	40.07	85.07	81	130
CD (0.05)	9.1	NS	NS	2.2	1.04	NS	NS	0.3
Sowing time (T)								
Late	183.9	369	336	37.3	38.14	101.49	89	136
Very Late	159.4	284	270	33.2	31.95	68.02	73	118
CD (0.05)	9.1	12.6	9	2.2	1.04	2.80	0.4	0.3
Varieties (V)								
HD 3059	182.0	316	308	37.5	35.10	96.11	82	127
WH 1021	152.7	310	283	37.5	33.69	77.04	80	127
DBW 71	180.6	338	315	35.6	37.26	91.34	79	127
PBW 590	180.5	335	304	33.7	35.36	81.39	80	127
PBW 373	162.5	334	307	31.8	33.81	77.90	83	127
CD (0.05)	14.4	20	15	3.5	1.64	4.43	0.6	0.5

In late sown conditions, the emergence, yield attributes, days to earing and physiological maturity, biological as well as grain yield were significantly higher than very late sown conditions (Table 1 and 2). The higher grain yield in late sown conditions might be due to more number of days to phenological stages leading to the more dry matter of the wheat crop. On the basis of pooled analysis, the grain yield reduction in very late sown conditions was 44.8%. The very late sown crop completed its life cycle at an accelerated pace, leading to shortening of days taken to earing and maturity. It has been reported that 3-4% decrease in grain yield for each 1°C rise in ambient temperature above 15°C during grain filling (Wardlaw and Wringley, 1994).

Table 2. Effect of sowing date and wheat varieties on grain yield (q/ha) (Pooled for two seasons)

Varieties	Sowing date						Mean
	Late (12 December)			Very Late (5 January)			
	2011-12	2012-13	Pooled mean	2011-12	2012-13	Pooled mean	
HD 3059	45.19	51.55	48.37	37.78	30.89	34.34	41.35
WH 1021	38.40	44.89	41.65	28.27	22.00	25.14	33.39
DBW 71	41.73	47.56	44.65	32.72	35.11	33.92	39.28
PBW 590	42.10	43.22	42.66	29.14	30.00	29.57	36.11
PBW 373	29.63	47.55	38.59	25.43	26.89	26.16	32.38
Mean	39.41	46.96	43.19	30.67	28.98	29.83	

CD (0.05)	2011-12	2012-13	Pooled
Years (Y)	-	-	1.36
Sowing date (T)	6.10	4.40	1.36
Varieties (V)	3.59	2.40	2.14
Y × T	-	-	1.92
Y × V	-	-	3.03
T × V	-	3.39	NS
Y × T × V	-	-	4.29

The wheat variety HD 3059, recorded the highest emergence, grains per earhead, biological yield and grain yield. The emergence count recorded in HD 3059 was statistically on par with the varieties PBW 590, and DBW 71. The highest tillers and earheads recorded in DBW 71 was statistically on par with PBW 590 and PBW 373 except for earheads in which HD 3059 was also statistically at par with this variety. The variety HD 3059 recorded the highest grains per earhead which was statistically on par with the variety DBW 71 and WH 1021. It might be due to their lower tillering habit which is compensated with increased grains per earhead. The 1000 grain weight in DBW 71 and biological yield in HD 3059 were the highest which were significantly higher than all other varieties. DBW 71 was found to slightly early by 3-4 days than all other varieties. In late sown conditions, the emergence, yield attributes, days to earing and physiological maturity, biological and grain yield were significantly higher than very late sown conditions.

In year 2012-13, the grain yield under late sown conditions was significantly better than first year but under very late sown conditions the effects were non-significant. The grain yield recorded in variety HD 3059 in 2012-13 under late sown conditions was only statistically at par with PBW 373 and DBW 71 but significantly better than all the varieties in both years at both sowing time. The lowest grain yield was recorded in PBW 373.

3.2 Agrometeorological indices: The differences observed were significant for various agrometeorological indices *viz.,* GDD, HTU, PTU and PTI across wheat genotypes under late and very late sown conditions (Table 3 and 4). Based on the pooled analysis, significantly higher growing degree days (GDD) and photo-thermal units (PTU) in late sown crop as compared to very late sown. In contrast, heliothermal units (HTU) and phenothermal index (PTI) were significantly higher in very late sown conditions. This trend was noticed at both earing and maturity stage across the varieties. During 2011-12, late sown wheat was characterized by significantly higher GDD, HTU and PTU than very late sown at earing stage which was responsible for higher grain yields. But contrary to this, in 2012-13 very late sown crop possessed significant consumption of HTU and PTU than late sown. PTI was significantly higher under very late sown condition during both years.

Table 3. Effect of sowing time and varieties on growing degree days (GDD), helio-thermal unit (HTU), photo-thermal unit (PTU) and pheno-thermal index (PTI) of wheat at earing stage (Pooled for two seasons)

Treatment	GDD (°C day)			HTU (°C day hour)			PTU (°C day hour)			PTI (°C days day^{-1})		
	2011-12	2012-13	Pooled mean	2011-12	2012-13	Pooled mean	2011-12	2012-13	Pooled mean	2011-12	2012-13	Pooled mean
Sowing time												
Late	763	788	776	4961	4958	4960	8284	8512	8398	8.3	9.0	8.7
Very late	614	795	704	4198	6031	5115	6816	8939	7877	8.8	10.5	9.7
CD (5%)	33	NS	13	320	233	128	391	287	157	0.2	0.1	0.1
Varieties												
HD 3059	694	818	756	4643	5744	5193	7617	9045	8331	8.6	9.9	9.3
WH 1021	674	784	729	4448	5442	4945	7381	8633	8007	8.5	9.7	9.1
DBW 71	669	753	711	4399	5124	4762	7321	8270	7795	8.5	9.6	9
PBW 590	685	775	730	4555	5350	4952	7510	8527	8018	8.5	9.7	9.1
PBW 373	720	827	773	4855	5814	5334	7921	9151	8536	8.7	10	9.3
CD (5%)	10	12	7	94	125	75	114	143	88	0.05	0.06	0.04

Table 4. Effect of sowing time and varieties on growing degree days (GDD), helio-thermal unit (HTU), photo-thermal unit (PTU) and pheno-thermal index (PTI) of wheat at maturity stage (Pooled for two years).

Treatment	GDD (°C day)			HTU (°C day hour)			PTU (°C day hour)			PTI (°C days day^{-1})		
	2011-12	2012-13	Pooled mean	2011-12	2012-13	Pooled mean	2011-12	2012-13	Pooled mean	2011-12	2012-13	Pooled mean
Sowing time												
Late	1502	1855	1678	10767	14562	12665	17533	22029	19781	11.5	13.1	12.3
Very late	1566	1679	1622	11894	14017	12955	18941	20287	19614	13.2	14.2	13.7
CD (5%)	2	32	10	51	357	115	96	398	135	0.1	0.1	0.01
Varieties												
HD 3059	1543	1767	1655	11387	14294	12840	18354	21161	19758	12.4	13.7	13.0
WH 1021	1539	1770	1655	11345	14332	12839	18309	21210	19760	12.4	13.7	13.0
DBW 71	1535	1755	1645	11378	14155	12767	18248	21003	19625	12.4	13.6	13.0
PBW 590	1513	1766	1640	11198	14289	12743	17964	21157	19560	12.3	13.7	13.0
PBW 373	1539	1774	1657	11345	14379	12862	18309	21262	19786	12.4	13.7	13.0
CD (5%)	11	NS	10	124	NS	NS	153	NS	139	0.01	NS	NS

Despite more consumption of thermal units (PTU and HTU) in very late sown crop during 2012-13 at earing, significant reduction occurred in grain yields which suggested that accumulation of heat units might enhance thermo-sensitivity of crop. This would cause ovary/kernel abortion, accelerated senescence in addition to reduced availability of current photo-assimilates for developing grain. Higher values of PTI further confirmed acceleration in phenological stages during crop growth. However at maturity, significantly higher GDD, HTU and PTU were observed in late sown crop during 2012-13. In contrast, GDD, HTU and PTU were significantly lower in late sown crop during 2011-12. Hussain *et al.* (2012) found that delayed sowing of wheat (*i.e.,* 25th Nov and 10th Dec) accumulated more HTU from flowering to complete grain formation. Although the days taken to complete

grain formation was high in early planted crop but short days and foggy weather resulted in extreme short possible sunshine hours (SS) leading to reduced HTU; as it started flowering during 2nd fortnight of Jan compared with 25th Nov and 10th Dec planted wheat which switch into flowering phase during last week of Feb to 1st fortnight of March. Sikder (2009) also reported higher accumulation of HTU only at maturity stage of wheat even having higher GDD at maturity compared with other phenophases in late planted wheat than normal sowing.

The variety DBW 71 accumulated significantly lowest GDD, HTU and PTU than other varieties on pooled basis and during both years at earing. However, it was statistically at par WH 1021 during 2011-12. The variety PBW 373 accumulated significantly more GDD, HTU and PTU in comparison to other genotypes at earing. HD 3059 ranked second in GDD and consumption of heat units (HTU and PTU) than PBW 590 and WH 1021. However, the later varieties were statistically at par to each other in terms of agrometeorological indices. Non significant differences were observed among varieties for HTU and PTI at maturity on pooled basis and during 2012-13. Variety PBW 590 had significantly lower GDD, HTU, PTU and PTI at maturity during 2011-12 across the genotypes. With exception of PBW 590, other varieties were statistically on par to each other for their GDD and PTI at maturity. The present study confirmed that different wheat cultivars had undergone different accretion of GDD, PTU and HTU to switch into different phenophases due to their divergent genetic makeup. Several earlier reports available in literature stressed that different wheat cultivars had different requirement of GDD and PTU buildup at different growth stages both under normal and late sowing conditions (Prabhakar *et al.*, 2007; Nahar *et al.*, 2010).

It can be concluded that under late sown pheno-thermal index and grain yield was significantly higher than under very late sown conditions. Wheat variety HD 3059 recorded the highest grain yield which was similar to DBW 71. The variety PBW 373 accumulated higher GDD, HTU and PTU than other varieties on pooled basis at earing and maturity. The grain yield recorded in variety HD 3059 in 2012-13 under late sown conditions was statistically at par with PBW 373 and DBW 71 but significantly better than all the varieties (PBW 590 and WH 1021).

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