Bangladesh J. Bot. **52**(3): 701-707, 2023 (September) DOI: https://doi.org/10.3329/bjb.v52i3.68878

GRAIN YIELD, HEAT AND WATER USE EFFICIENCY OF WHEAT CULTIVARS IN RELATION TO DIFFERENT SOWING ENVIRONMENTS

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Keywords: Canopy temperature, Cultivars, Grain yield, Sowing date, Water use efficiency

Abstract

Grain yield and water use efficiency of wheat cultivars in relation to different sowing environments were evaluated where seven dates of sowing *viz.* October 22, 29, November 5, 12, 19, 26 and December 3 in the main plots and three varieties namely PBW 725, HD 3086 and HD 2967 in sub-plots for three consecutive years were considered. Results revealed that crop sown from October 22 to November 5 had better agrometeorological indices, yield attributes, normalized difference vegetative index and higher water use efficiency resulting in higher grain yield than delayed sowing. Wheat varieties PBW 725 and HD 3086 resulted the lower canopy temperature, and higher grain yield along with all the yield attributing characters and agrometeorological indices under Northwestern conditions of India.

Introduction

In the world's wheat production, India ranks second following China. India is able to produce 107.18 million tonnes of wheat from an area of 30.55 million hectares (2019-20) withanaverage productivity of 3.51t/ha (ICAR-IIWBR 2020). Due to urbanization, the possibility to increase area is impracticable while the food grain requirement is increasing at a faster pace. For exploiting the yield potential of a crop under a particular agro-climatic zone, genotype-environmental interaction plays a pivotal role. Zia–ul–Hassan *et al.*(2014) recorded that wheat yield is far-flung from its actual potential due to many factors in which time of sowing is most important. Several researchers reported that temperatures below 10°C or above 25°C will reduce the grain yield of wheat varieties by amending their phenology, growth and development. Delayed sowing results in low temperature at the germination stage, and higher canopy temperature at the reproductive stage (Basu*et al.* 2014), resulting in a short-grain filling period (Farooq *et al.* 2011) and altering the reproductive mechanisms (Innes *et al.* 2015) leading to forced maturity with less yield (Ram *et al.* 2012). Early planting helps to shun terminal heat stress by facilitating the grain filling at a lower temperature but short-duration varieties like PBW 550 face frost injury at the earing stage (Ram *et al.* 2012).

Under the declining groundwater level of North India, there is a need to improve water use efficiency. The field study was conducted to find the variety and different sowing environment interactions for realizing the yield potential water and heat use efficiency of wheat.

Materials and Methods

The field experiment was conducted in a split-plot design with three replications during the winter season at the research farm of the Punjab Agricultural University, Ludhiana, India for three consecutive years i.e. 2016-17, 2017-18and 2018-19. The treatments comprised October 22, 29, November 5, 12, 19, 26 and December 3 sowing dates and three varieties PBW 725, HD 3086 and HD 2967. The data about growth and yield attributes were recorded at maturity of the cropby selecting five random plants from each plot. To reduce the border row effect, an area of 0.40 m

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around the plot was left to record the seed yield per plot which was then extrapolated to calculate per ha grain yield. The harvest index was then calculated by dividing the per-plot grain yield by biological yield.

To measure crop health and plant dynamism normalized difference vegetative index (NDVI) (GreenSeeker)and canopy temperature (Infra-red thermometer) at 90 DAS was observed. The Agrometeorological parameters used in the study were recorded from the Agrometeorological Observatory at the Department of Climate Change and Agrometeorology, Punjab Agricultural University, Ludhiana. The heat use and heliothermal use efficiencies for the three consecutive years were calculated. The WU was calculated by summation of soil water contribution, irrigation water applied and rainfall. The water use efficiency (WUE) was then calculated by the given formula by dividing grain yield by water use. The year-wise replicated data for all the parameters were recorded and analysed in split-plot design as described by Gomez and Gomez (1984).

Results and Discussion

The maximum temperature across three years of study was 0.9-1.3^{o}C which is less than the normal temperature in October and thus facilitated to sow the crop on time (Fig. 1). Results presented in Table 1 showed that days to earing was the highest in November 12 sown crop followed by November 5 and 19, respectively(Table 1). The days to earing were similar in PBW 725 variety sown on October 29 to November 19 (Table 2).

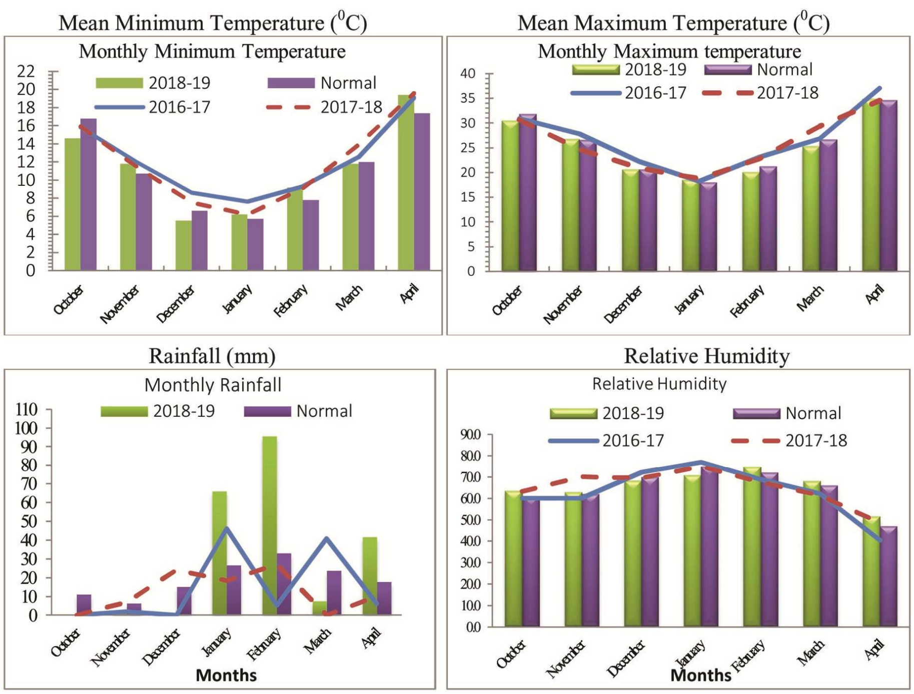

Fig. 1.Weather parameters during the study period (2016-17 to 2018-19).

Among varieties, PBW 725 required 109 days to earing which was similar to HD 2967 but 8 days more than HD 3086 (Table 1). A progressive decrease of days to maturity was recorded from October 22 to December 3 sowing date. It plays an important role in yielding ability of the wheat varieties. Chakrabati *et al.* (2013) also reported that an elevated temperature of 1.8- 2.9°C from optimum reduced the days to flag leaf initiation and 50% flowering by 3-8 days. Thus in spring wheat, the days to physiological maturity were inversely proportional to temperature.

Chakrabati *et al.* (2013) reported that with every 1°C rise in temperature, days to physiological maturity reduced between 1.1 and 1.6 days. Heat use efficiency (HUE) and heliothermal use efficiency (HTUE) describe the ability of a plant to relocate the accumulated heat to the economical product *i.e.* grain yield (Pal and Murty 2010).

Table 1. Effect of dates of sowing and varieties on phenology, agrometeorological indices and normalized difference vegetative index of wheat(pooled mean of three years).

Treatment	Days to earing	Days to maturity	HUE (kg/ha/^{o}C)	HTUE (kg/ha/^{o}C/day)	Canopy temp. (^{o}C)	NDVI
Sowing date						
22Oct	101	166	3.08	0.49	10.53	0.80
29Oct	105	160	3.25	0.51	10.73	0.79
05Nov	107	156	3.11	0.46	10.91	0.77
12Nov	109	151	2.96	0.43	11.10	0.77
19Nov	107	149	2.74	0.38	11.16	0.72
26Nov	106	146	2.24	0.31	11.41	0.69
03Dec	100	137	2.1	0.29	11.86	0.67
C.D. (p=0.05)	0.7	4.4	0.12	0.02	1.34	0.02
Variety						
PBW 725	109	151	2.87	0.42	11.15	0.74
HD 3086	101	151	2.97	0.44	10.78	0.76
HD 2967	108	153	2.50	0.37	11.37	0.73
C.D. (p=0.05)	0.5	NS	0.07	0.01	0.76	0.01
Interaction	1.4	NS	0.19	0.03	NS	NS

At the different date of sowing, the highest HUE and HTUE were recorded on October 29 *i.e* 3.25 and 0.51kg/ha/^{o}C/day and it followed a diminishing trend for delayed sowing. The highest HUE and HTUE were recorded with HD 3086 followed by PBW 725 and HD 2967 (Table 2). To mitigate the stress, plants transpire more which reduces the canopy temperature. The more vigorous the crop, the lower the canopy temperature. The canopy temperature under delayed sowing i.e.; December 03 recorded a significantly higher value of canopy temperature 11.86°C (Table 1). A similar finding under delayed sowing also reported by Jatana*et al.* (2020). Higher canopy temperature of 11.37°Cwas recorded in HD 2967. With the delayed sowing the crop health and vigour decreased resulting in low grain yield (Table 3). The higher NDVI was recorded with October 22 which was 0.80 and was similar to October 29 where the lowest was recorded on December 03 (0.67).

Similarly, varieties also differ significantly in their dynamism. The variety HD 3086 showed higher NDVI and was statistically similar to PBW 725. The November 5 sown crop recorded NDVI of 2.3 and 11.4% higher than the November 20 and December 5 sowing, respectively

(Jatana*et al.*2020). Canopy temperature was inversely correlated with NDVI.A significant effect of sowing dates was observed on all the growth and yield attributes during the study period.

Table 2. Effect of date of sowing and varieties on phenology and agrometeorological indices (pooled mean of three years).

Variety	Dates of sowing						
	22Oct	29Oct	05Nov	12Nov	19Nov	26Nov	03Dec
				Days to earing			
PBW 725	108	109	109	110	109	107	100
HD 3086	89	98	102	106	103	104	98
HD 2967	105	108	112	113	109	107	102
				HUE (kg/ha/^{o}C)			
PBW 725	3.15	3.39	3.35	3.06	2.85	2.27	2.04
HD 3086	3.08	3.37	3.22	3.24	3.03	2.41	2.46
HD 2967	3.01	2.98	2.76	2.57	2.35	2.05	1.81
				HTUE (kg/ha/^{o}C/day)			
PBW 725	0.50	0.53	0.50	0.44	0.39	0.31	0.28
HD 3086	0.49	0.53	0.48	0.47	0.43	0.33	0.34
HD 2967	0.47	0.47	0.41	0.37	0.32	0.28	0.25
CD (5%)		Days to earing		HUE		HTUE	
Interaction		1.4		0.19		0.03	

Table 3. Effect of different dates of sowing and varieties on growth, yield parameters and grain yield of wheat (pooled mean of three years).

Treatment	Plant height (cm)	Effective tillers (no./m^2)	Grains per earhead	1000-grain weight (g)	Grain yield (t/ha)	Harvest index (%)
Sowing date						
22Oct	91.6	407.5	34.6	46.3	6.31	40.9
29Oct	91.2	414.4	34.8	44.6	6.34	40.9
05Nov	89.3	385.3	35.2	44.7	5.91	41.3
12Nov	86.5	364.4	34.7	43.6	5.42	40.4
19Nov	86.3	360.9	34.8	41.1	5.05	39.1
26Nov	83.8	347.2	31.8	38.9	4.15	39.2
03Dec	79.8	309.0	30.4	38.3	3.54	35.1
C.D. (p=0.05)	2.1	15.1	2.7	2.38	0.203	1.66
Variety						
PBW 725	87.1	377.9	34.7	41.98	5.48	40.2
HD 3086	85.7	379.5	33.4	43.38	5.44	40.4
HD 2967	87.9	352.1	33.2	42.12	4.82	38.1
C.D. (p=0.05)	1.2	8.1	NS	NS	0.14	1.12
Interaction	NS	21.4	NS	NS	0.36	NS

The crop sown on October 22 and 29 performed better with respect to all the recorded growth and yield parameters. The highest plant height of 91.6 cm was observed in the October 22 sown crop which was statistically at par with October 29 (91.2 cm) and November 5 (89.3 cm) sown crop, followed by a diminishing trend at later sowing dates till December 3(79.8 cm).

Table 4. Interactive effect of different dates of sowing and varieties on growth and yield parameters of wheat(pooled mean of three years).

Varieties	Dates of sowing						
	22Oct	29Oct	05Nov	12Nov	19Nov	26Nov	03Dec
	Effective tillers (no./m^2)						
PBW 725	412.3	424.3	392.1	378.3	371.5	353.6	313.4
HD 3086	409.8	427.2	379.9	388.0	372.1	357.8	321.8
HD 2967	400.4	391.7	384.0	326.9	339.3	330.4	291.8
	Grain yield (t/ha)						
PBW 725	6.50	6.64	6.36	5.61	5.31	4.22	3.71
HD 3086	6.18	6.44	6.06	5.88	5.42	4.41	3.66
HD 2967	6.24	5.92	5.30	4.77	4.43	3.83	3.26

CD ($p = 0.05$) Effective tillers: 21.4, Grain yield: 0.36 Interaction: NS

In delayed sowing lower temperature at the time of sowing slows the cell expansion and division resulting in a reduction in the vegetative phase and an abrupt increase in temperature at the late vegetative stage forced the crop into the reproductive stage. The present findings is similar to the results reported by Ram *et al.* (2012). The highest plant height (87. 9cm) was recorded in HD 2967 which was statistically at par with PBW 725 (87.1 cm) but significantly higher(85.7 cm) than HD 3086. Plant height is essentially affected by environmental and genetic interaction of the variety (Pal and Murti 2010)

The highest tiller density(414.4m^{-2}) was recorded on October 29 and was similar to the October 22 sowing date while the lowest was obtained on December 3 sowing (309.0/m^2).HD 3086 recorded a higher tillering density (379.5/m^2) similar to PBW 725(377.9/m^2) but significantly higher than HD 2967 (352.1/m^2). It was observed that HD 3086 recorded the highest tiller density when sown on October 29 (427.2/m^2) and the lowest when sown on December 3 (281.8/m^2) (Table 4). From November 12 onward sown crop, variety HD 2967 was a significantly poor performer for tillers than PBW 725 and HD 3086. Mukherjee *et al.* (2012) reported reduced tillering under delayed sowing. The highest grains per spike (35.2) were recorded in November 5 sown crop and were similar upto November 9 sown crop and 13.6% higher than December 3 (30.4) (Table 3). The observation of the progressive decrease in grain number with delayed sowing might be due to the reduced vegetative and reproductive period of the crop. Varieties had a non-significant effect on grains per spike (Ram *et al.* 2012). The variety PBW 725 resulted in higher grains per spike than HD 3086 and HD 2967. The highest 1000-grain weight was recorded in the October 22 sown crop although'similar to October 29 and November 5 sown crop. It might be due to higher heat and heliothermal use efficiencies and all other agroclimatic parameters in the early sown crop which increased the biomass accumulation period and higher reproductive period for translocation of photosynthates to the grains. The highest 1000-grain weight was recorded in HD 3086 (43.38g) which was 3.3 and 3.0% higher than PBW 725 and HD 2967, respectively. The data about the reduction in the number of effective tillers(per m^2), number of grains per spike and 1000-grain weight due to delayed sowing. Mukherjee (2012) observed that during early sowing conducive temperature prevails resulting in a higher number of effective tillers which results in higher photosynthate accumulation resulting in higher grain yield contributing parameters.

The highest grain yield (6.34t/ha) was obtained in October 29 sown which was statistically at par with October 22 sown (6.31t/ha) wheat crop while the lowest-performing date of sowing was December 3 which yielded 44.1% (3.82t/ha) less grain yieldthanOctober 29 sowing.The higher grain yield recorded in early sowing was due to more days to earing and maturity and higher yield attributing characters. In the case of varieties, the highest grain yield was obtained with PBW 725 (5.48t/ha) which was statistically similar to HD 3086 (5.44t/ha) but 13.6% significantly higher than the HD 2967 the poorest yielder (4.82t/ha) variety.

Significantly higher water was consumed when the wheat crop was sown on November 5 (734.1 mm) to exploit the higher yield potential (Table 5). Contrary to the October 22 sowing, the November 05 sown crop consumed 12.15 per cent less water. The minimum water (643.4 mm) was used in the December 3 sown crop. Linear crop yield relationships with seasonal evapotranspiration was also reported by Musick*et al.*(1994). The highest amount of water (688.26 mm) was used by HD 2967 to mitigate the stress and was 0.14 and 0.32 per cent higher than PBW 725 and HD 3086, respectively. The highest WUE was found in the October 22 sown crop which was similar to the October 29 sowing date but significantly better than all other sowing dates. It might be due to higher wheat productivity recorded in the early sown crop. The data revealed that the highest WUE was achieved with HD 3086 (8.12 kg/ha-mm) followed by PBW 725 (8.03 kg/ha-mm) and HD 2967 (7.05 kg/ha-mm). The highest WUE was recorded in PBW 725 (10.20 kg/ha-mm) sown on October 29 which was similar to October 22 (PBW 725 and HD 3086) and October 29 (HD 3086) sowing. Higher water use efficiency in these dates and varieties was due to higher grain yield under these treatments.

Table 5.Water use efficiency of wheat varieties at different sowing dates (Pooled mean of three years 2016-19).

Varieties	Dates of sowing							
	22-Oct	29-Oct	05-Nov	12-Nov	19-Nov	26-Nov	03-Dec	Mean
				Water use (mm)				
PBW 725	654.6	654.4	733.8	711.3	719.9	693.6	643.3	687.3
HD 3086	655.4	654.9	733.9	710.3	710.9	693.6	643.3	686.1
HD 2967	653.6	652.1	734.6	719.7	720.8	693.4	643.6	688.1
Mean	654.6	653.8	734.1	713.8	717.2	693.5	643.4	
				Water use efficiency (kg/ha-mm)				
PBW 725	10.12	10.2	8.70	7.89	7.39	6.08	5.80	8.03
HD 3086	9.49	9.9	8.28	8.28	7.63	6.34	6.93	8.12
HD 2967	9.61	9.03	7.25	6.65	6.16	5.52	5.17	7.05
Mean	9.74	9.71	8.08	7.61	7.06d	5.98e	5.97	

CD	Water use	Water use efficiency
Date of sowing	1.44	0.44
Varieties	0.35	0.26
Interaction	0.92	0.69

Based on the findings of three years, it may be concluded that wheat varieties PBW 725 and HD 3086 contribute better yield attributes performing better under timely sown conditions i.e. from October 22 to November 5. Beyond November 5, a significant decrease in yield was observed in all the cultivars.

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(Manuscript received on 25 December, 2021; revised on 14 November, 2022)