RESEARCH ARTICLE Indian Journal of Agricultural Research, Volume 58 Issue 1: 77-82 (February 2024)

Grain Yield, Heat use Efficiency and Water use Efficiency of Diverse Wheat (*Tritcum aetivum* L.) Varieties under Different Sowing Environments in North-Western India

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10.18805/IJARe.A-5655

ABSTRACT

Background: Wheat is an important food crop of world. This crop has the wider adaptability due to its genetic makeup. The sowing environment and varieties interaction plays important role to enhance its productivity and optimum utilization of the resources. As this crop has wider adaptability so we planned our experiment to study the grain yield, heat use and water use efficiency of diverse wheat varieties which have been recommended in different wheat growing zones, sown at different environment in North-western India, to increase the varietal spectrum.

Methods: The field experiment was conducted in 2017-18 and 2018-19 at the research farm of the Punjab Agricultural University, Ludhiana, India. The experiment was conducted with four sowing dates (November 5, November 25, December 15 and January 5) in main plot and six wheat varieties (HS 562, HD 2967, HD 3086, HI 1544, MACS 6222 and WR 544) in sub-plot of split plot design with three replications.

Result: The wheat crop sown on November 5 recorded the highest emergence count, plant height, heat use efficiency, normalized difference vegetative index, yield attributes, grain yield and water use efficiency than later sowing dates. Among the wheat varieties, HS 562 recommended for northern hill zone recorded heat use efficiency, helio-thermal use efficiency, at leaf value, effective tillers, grains per earhead, grain yield and water use efficiency similar to HD 3086 recommended for North-western zone. The varieties recommended for other zones like HI 1544, MACS 6222 and WR 544 could not perform similar to the HD 3086.

Key words: Canopy temperature, Grain yield, North-western zone, Sowing date, Varieties.

INTRODUCTION

Among the staple crops, wheat (*Triticum aestivum* L.) is one of the most copious sources of energy as it all alone provides about 20 per cent of total food calories required for human beings. Because of its complex genomics, it has wider adaptability to the sowing environment. It can be grown over a temperate irrigated to dry and high rainfall areas and from warm humid to dry cold regions (Monteith, 1984). For sustainable food security its increased production is essential. The total production of wheat in India is 101.20 million tonnes from 31.0 million hectares (Anonymous, 2019) Due to increasing population pressure, land under cultivation is going to be negligible and thus it necessitates in thriving low cost technologies without altering the natural resource balance. Changing climate is an imperative factor accountable for yield reduction in all the crops especially wheat because being a C_3 plant it thrives superlative in cool environment.

Among the different climatic parameters *viz*; atmospheric temperature, rainfall, susnshine hours or light hours are of utmost importance to exploit the potentiality of the crops (Kaur *et al.,* 2017). In plants, before attaining a definite phenophase a particular temperature is required. Change in optimum temperature during the vegetative and reproductive phase adversely affected the growth and development finally lowering the yield of the wheat crop (Ray and Ahmed, 2015). Among the agronomic practices, optimum time of establishment and selection of suitable variety is of great importance to exploit the potential yield of wheat crop. It had already been observed that delayed sowing of wheat got exposed to low temperature at the time of emergence and higher temperature during the grain filling period or milking stage finally results in forced maturity that ultimately lowers wheat grain yield (Ram *et al*., 2017). Selection of variety as per environment of particular region is of utmost importance. The varieties are being developed in different zones in India and are being recommended where they are developed. Our objective was to explore the possibility of evaluating the performance, micro-environment and water use efficiency of diverse varieties recommended

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How to cite this article: Ram, H. and Kaur, M. (2024). Grain Yield, Heat use Efficiency and Water use Efficiency of Diverse Wheat (*Tritcum aetivum* L.) Varieties under Different Sowing Environments in North-Western India. Indian Journal of Agricultural Research. 58(1): 77-82. doi: 10.18805/IJARe.A-5655.

Submitted: 21-07-2020 **Accepted:** 28-12-2020 **Online:** 26-02-2021

in other zones under North-western plain zone (NWPZ) for enhancing the productivity.

MATERIALS AND METHODS

The present investigations were carried out at the research area of the Punjab Agricultural University, Ludhiana, Punjab, India. The soil of the experimental field was loamy sand in texture and has low N (180.9 kg/ha), high P (32.6 kg/ha) and medium K (175.8 kg/ha) content and 7.3 soil pH. The experiment was carried out with four dates of sowing in main plots (November 5, November 25, December 15 and January 5) and six varieties in sub plots [HS 562 (Northern Hill zone), HD 2967 (Northwestern plain zone-NWPZ), HD 3086 (NWPZ), HI 1544 (Central zone-CZ), MACS 6222 (Peninsular zone) and WR 544 (Late sown-National Capital region-Delhi) in split plot design with three replications during Rabi 2017-18 and 2018-19. The meteorological data indicated that rainfall received during the cropping season was 86.4 and 206.8 mm in first and second year of study. The mean maximum air temperature ranged from 15.5 to 34.8°C in 2017-18 and 14.8 to 38.0°C, respectively (Fig 1). The mean minimum air temperature varied from 5.3 to 20.3°C in 2017-18 and 0.6 to 21.8°C in 2018-19. The crop was raised by giving pre-sowing irrigation of 100 mm. The full dose of P_2O_5 (60 kg/ha) and half dose of N (60 kg/ha) was applied at the time of sowing and remaining ¼ was applied at first irrigation and ¼ at second irrigation. The crop was kept weed free by hoeing. The number of irrigations (75 mm of each) applied was 6, 6, 5 and 5 in 2017-18 and 6, 5, 5 and 4 in first, second, third and fourth sowing dates respectively. The data pertaining to growth and yield attributes *viz*; emergence count, plant height, effective tillers, grains per earhead, 1000-grain weight was recorded at maturity of the crop. Microclimatic parameters *viz*; NDVI (normalized difference vegetative index), canopy temperature, at Leaf value was recorded at 100 days after sowing. Observations on yield attributes were recorded by selecting five random plants from each plot. Grain yield and biological yield were recorded from 9.8 square metres net plot area.

NDVI was measured with handheld green seeker (Crumble) whereas canopy air temperature difference (CATD) was measured with infrared thermometer. Heat use efficiency and helio-thermal use efficiency were calculated as given by Montaith (1984). Water use (WU) was calculated from the initial soil water content (at sowing), final soil water content (at harvest), rainfall (P) and irrigation (I). The runoff, drainage and capillary rise were nil for this site. The water use was calculated as given in equation 1.

$$WU = P + I + \Delta W \quad ...(1)$$

Where:

ΔW is the change in soil moisture between sowing minus harvesting. The soil moisture at sowing and at harvest were determined gravimetrically upto 150 cm soil depth.

Water use efficiency (WUE) was computed by using the equation 2.

$$\text{Water use efficiency (WUE)} = \frac{\text{Grain yield (kg ha}^{-1})}{\text{Water use (mm)}} \quad ...(2)$$

The data obtained for all growth and yield attributes and micro-environment parameters were pooled for two years and analysis of variance was performed by using OPSTAT software.

RESULTS AND DISCUSSION

Emergence, growth parameters and heat use efficiencies

The highest emergence count was recorded in November 25 which was statistically similar to November 5 *i.e.* timely sowing date but significantly higher than other sowing dates (Table 1). The lower emergence count in very late sowing date (January 5) was due to less temperature which hinders the germination. The highest emergence count recorded in HD 2967 was statistically at par with other varieties. The tallest plant recorded in November 5 sowing were significantly taller than other sowing dates The taller plant in early sowing and lesser height in later sowing was due

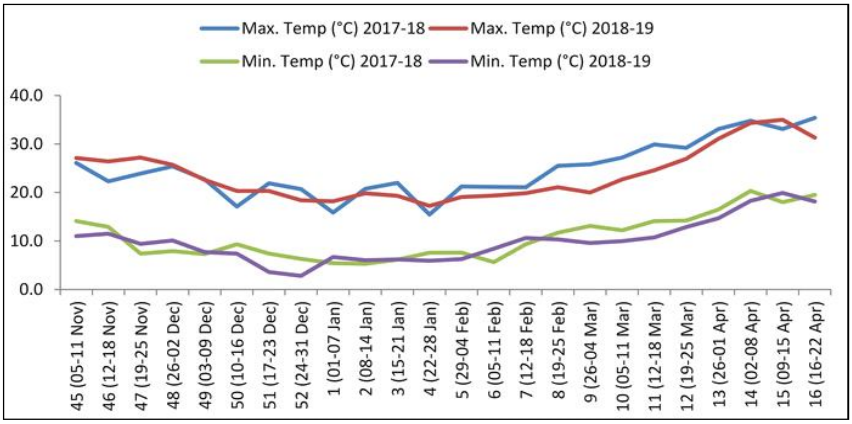


Fig 1: Maximum and minimum temperature prevailed during the study period.

Table 1: Effect of sowing date and varieties on growth and micrometeorological parameters of wheat (Pooled mean).

Treatment	Emergence count (no./m²)	Plant height (cm)	Heat use efficiency (kg per °C day)	Helio-thermal use efficiency (kg per °C day hour)	Days to maturity	NDVI (100 DAS)	Canopy temperature ℃ (100 DAS)	atLeaf value
Sowing date								
November 5	139.5	87.9	2.65	3.08	156.0	0.79	14.5	50.3
November 25	140.6	84.1	2.43	2.75	139.8	0.72	14.4	51.0
December 15	108.5	79.7	2.20	1.48	131.8	0.63	17.2	54.5
January 5	90.3	75.6	1.89	1.22	107.1	0.54	18.5	55.4
SEM±	1.31	1.20	0.05	0.07	0.1	0.07	0.3	0.6
CD(P≤0.05)	3.98	3.6	0.19	0.23	0.3	0.02	0.8	1.8
Varieties								
HS 562	121.2	82.8	2.32	2.48	134.6	0.73	16.3	55.9
HD 2967	123.2	82.4	2.11	1.92	136.0	0.66	16.6	55.0
HD 3086	118.7	80.6	2.59	2.42	133.0	0.69	15.8	55.3
HI1544	116.6	80.5	2.35	1.98	132.4	0.63	16.3	46.6
MACS 6222	118.7	82.3	2.09	2.06	136.1	0.70	16.0	54.0
WR 544	121.4	82.6	2.29	1.92	130.1	0.61	16.7	50.1
SEM±	1.67	1.40	0.06	0.07	0.10	0.01	0.30	0.60
CD(P≤0.05)	NS	NS	0.16	0.21	0.3	0.01	NS	1.7
Interaction	NS	NS	0.34	NS	0.7	0.03	NS	NS

to less days were given to the crop to complete its growth and development. The wheat variety HS 562 recorded the plants. Fayad *et al.* (2015), Ram *et al.* (2017) and Jat *et al.* (2018) also reported higher emergence count and plant height under optimum sowing period.

Heat use efficiency (HUE) and helio-thermal use efficiency (HUTE) recorded in early sowing (November 5) was the highest and was 40.2 and 152.4% higher than recorded in January 5 sowing. It was due to fewer days taken to mature in late sowing dates. Among the varieties, HUE recorded in HD 3086 was the highest. It was due to higher grain yield and more days taken to maturity in this variety. HUTE recorded in HS 562 was the highest which was statistically at par with HD 3086. Our results are in confirmation with reports of Ram *et al.* (2016) on *durum* wheat who reported that heat use efficiency decreased under late sowing. Reyonald *et al.* (2000) reported that improved radiation use efficiency will be partly a function of variety's ability to buffer itself against changes in its optimum environment to match the demand imposed by its development.

Phenology, normalized difference vegetative index (NDVI), canopy temperature and at leaf value

The earlier sowing date of November 5 sowing recorded 48.9 more days to mature than January 5 sowing (Table 1). The early sowing resulted in proper development of the grains due to longer congenial growing environment. The highest NDVI was recorded in November 5 sowing date which was similar to November 25 but significantly higher than rest of the sowing dates. The highest NDVI value recorded in HS 562 was higher than rest of the varieties. The highest canopy temperature recorded in January 5 sowing date was statistically at par with December 15 sowing date. The November 5 sowing date recorded the lowest canopy temperature. Among the varieties, minimum canopy temperature was recorded in HS 562. It was due to better growth as depicted in NDVI values. Ray and Ahmed (2015) also recorded cooler canopy in early sowing and varieties which cover the soil surface early. They found higher canopy temperature depression (CTD) in genotypes BARI gom 26 and BARI gom 25 under heat stressed condition in comparison to other genotypes. The atLeaf value (chlorophyll index) was the highest in January 5 sowing which was statistically similar to December 15 sowing but significantly higher than recorded in November 25 and November 5 sowings. It was due to early ground cover by the early sown crop which also increased the crop health as depicted from NDVI and canopy temperature. The atleaf value was found to be higher in January 5, which was due to less dilution effect of nutrients as low grain yield was recorded in later sowing. Ahmed and Hassan (2015) also reported significant improvement in chlorophyll content with delayed sowing date due to less grain yield.

Yield attributes and grain yield

The highest effective tillers in November 5 were siginificantly higher than November 25, December 15 and January 5 (Table 2). The higher effective tillers in early sowing might be due to availability of low temperature at tillering stage. Among the wheat varieties, HS 562 recorded the highest effective tillers which were significantly higher

than other varieties but statistically at par with HD 3086. The tillering of variety HS 562 in November 5 sowing was similar to all other varieties except HD 3086 and WR 544 (Fig 2). In November 25 sowing any other variety could not surpass HS 562 in tillering. But at January 5 sowing all varieties were similar for tillering capacity. Tillering habit is the specific character of the variety which sometime varies with sowing environment. The variety HS 562 recorded highest grains per earhead which was significantly higher than other varieties but statistically at par with HD 2967 and HD 3086. All the varieties were similar in producing grains per ear head at November 5 sowing except WR 544. But at January 5 sowing date only HD 2967 and HI 1544 were statistically similar to HS 562 (Fig 3). Thousand grain weight recorded in November 5 sowing was significantly higher than other sowing dates. Earlier sowing recorded the highest thousand grain weight due to more days taken to maturity which increase the duration of transportation of photosynthates to developing grains. On pooled mean basis, the highest thousand grain weight was recorded in variety WR 544 which was statistically similar to HD 3086. It might be due to poor tillering of this variety.

The grain yield recorded in November 5 sowing was 10.5, 22.6 and 30.9 q/ha higher than November 25, December 15 and January 5 sowing date respectively (Table 2). The higher grain yield in earlier sowing date was due more days to maturity, higher growth parameters and yield attributes. The early planting of wheat helped to skip the terminal heat stress and increase the crop duration, NDVI and lowered canopy temperature. Early the crop maturity due to early sowing helps the crop to mature under mild temperature conditions (Fig 1). At November 5 sowing date, HD 2967, HD 3086 and MACS 6222 were able to produce

Table 2: Effect of sowing date and varieties yield attributes, grain yield, biomass yield, water use and water use efficiency (Pooled mean).

Treatment	Effective tillers (/m^2)	Grains per earhead	1000-grain weight (g)	Grain yield (q/ha)	Biomass yield (q/ha)	Water use (mm)	Water use efficiency (kg/ha-mm)
Sowing date							
November 5	350.3	36.4	42.6	53.8	133.8	677.87	7.92
November 25	309.2	36.2	39.5	43.3	105.1	637.03	6.79
December 15	281.4	32.3	34.8	31.2	73.2	584.66	5.47
January 5	249.2	30.0	31.0	22.9	59.9	542.63	4.31
SEM±	7.7	1.0	0.7	1.0	3.3	0.18	0.16
CD (P≤0.05)	23.4	3.1	2.1	3.0	10.1	0.66	0.49
Varieties							
HS 562	319.4	36.9	35.0	41.7	105.2	611.24	6.71
HD 2967	288.5	34.3	34.9	35.5	91.3	611.38	5.76
HD 3086	309.0	35.2	38.7	42.5	100.9	611.00	6.90
HI1544	296.0	33.2	36.3	36.2	88.0	610.98	5.86
MACS 6222	284.6	33.4	37.6	36.8	93.0	610.06	5.95
WR 544	287.5	29.5	39.4	34.0	79.6	608.62	5.56
SEM±	5.10	1.20	0.70	0.80	1.40	0.25	0.13
CD (P≤0.05)	14.4	3.4	1.8	2.3	3.9	1.07	0.35
Interaction	28.7	6.7	NS	4.5	7.8	NS	0.71

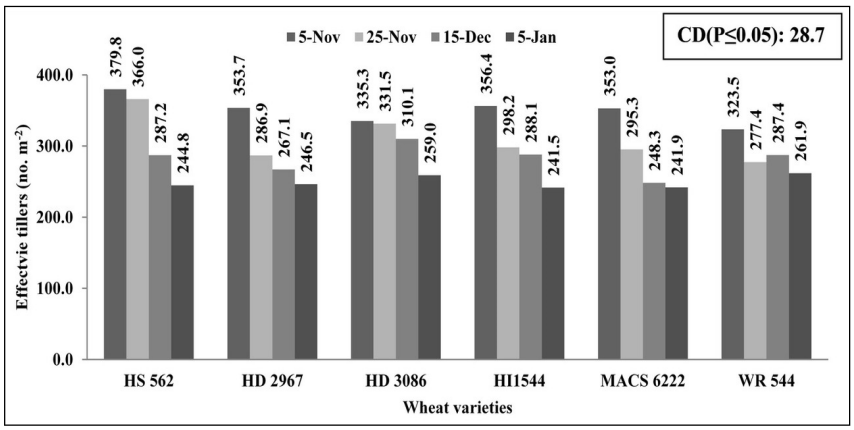


Fig 2: Pooled interactive effect of sowing dates and varieties on effective tillers.

same grain yield as recorded in HS 562. However in November 25 sowing only HD 3086 and HI 1544 produced statistically similar grain yield to HS 562 (Fig 4). Fayad *et al.* (2015) and Kaur *et al*. (2017) also reported higher grain yield under optimum sowing time. The lower grain yield in varieties might be due to less crop duration, less yield attributes and poor adaptation. Variation in wheat cultivars grain yield under different sowing dates was also reported by Ram *et al.* (2016). Jat *et al.* (2018) indicated differential grain yield according to sowing time and maturity time under different temperature conditions.

Biomass yield, w**ater use and water use efficiency**

The highest biomass yield recorded in November 5 sowing was significantly higher than delayed sowing. The highest biomass yield recorded in HS 562 followed by HD 3086.

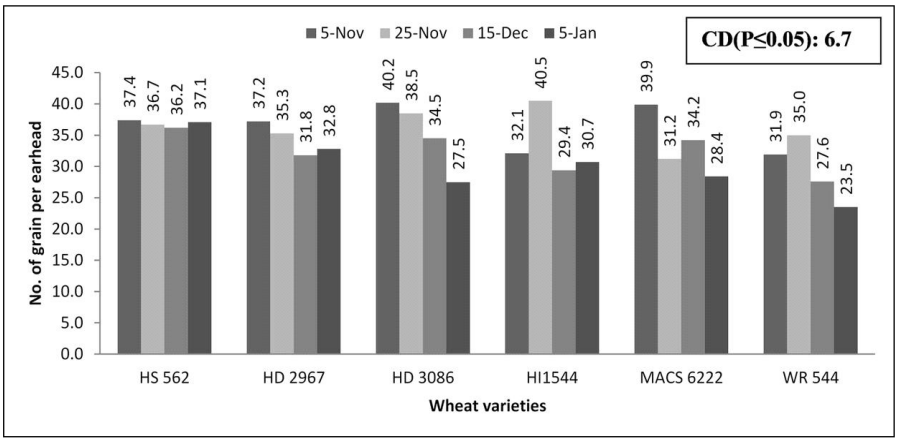


Fig 3: Pooled interactive effect of sowing dates and varieties on number of grains per earhead.

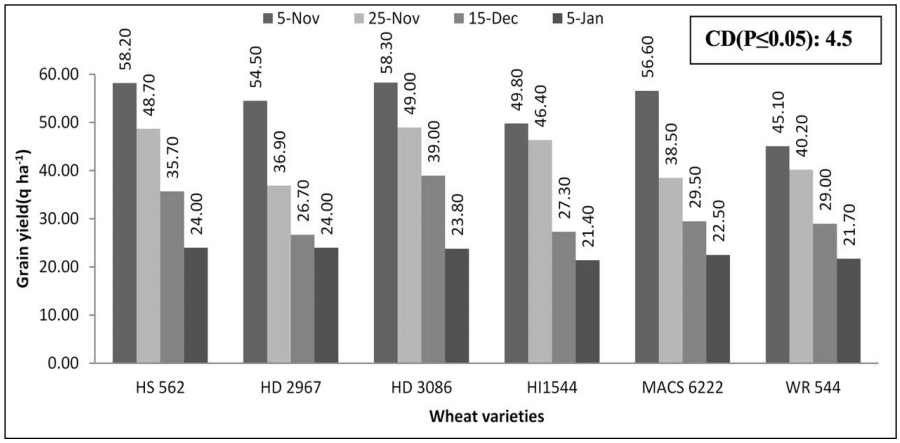


Fig 4: Pooled interaction effect of sowing dates and varieties on grain yield.

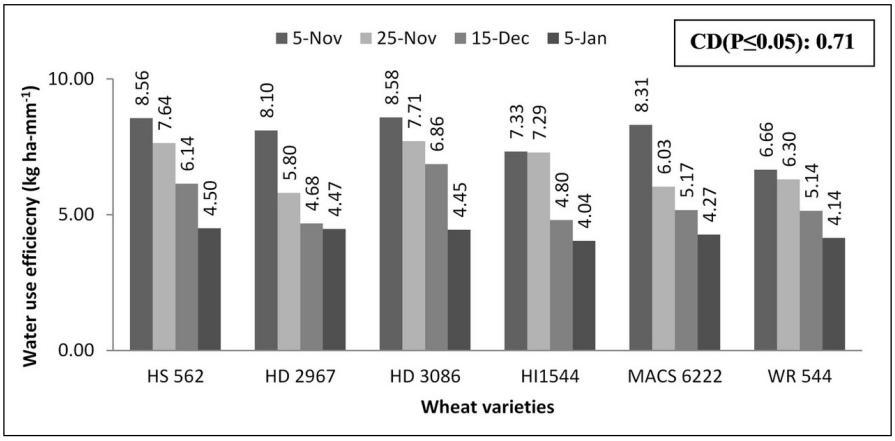


Fig 5: Water use efficiency of wheat varieties under different sowing dates (Pooled).

November 5 recorded 6.4, 15.9 and 24.9% higher water use than November 25, December 15 and January 5 sowing, respectively. It was due to more number of days the crop remains in the field and more irrigations applied. Similarly, the water use efficiency recorded in early sowing (November 5) was the highest which was 16.6, 44.8 and 83.8% higher than recorded in November 25, December 15 and January 5 sowing dates respectively. The higher water use efficiency in early sowing might be due to higher grain yield recorded. On pooled mean basis, HD 2967 recorded the highest water use which was statistically similar to HS 562 and HD 3086. The higher water use efficiency in these varieties might be due to higher grain yield. The interaction effect was similar in water use efficiency as recorded in grain yield except for December 15 sowing where HD 3086 surpassed all varieties (Fig 5).

CONCLUSION

November 5 sowing recorded the highest yield attributes, grain yield and water use efficacy than other sowing dates. The varieties HS 562 and HD 3086 gave similar grain yield and water use efficiency. So the hill zone cultivar HS 562 can be grown under timely sown conditions in North-western plains zone for higher productivity and improving the varietal spectrum.

Conflict of interest

All authors declare that they have no conflict of interest.

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