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Short Communication

Effect of weather on yield, heat and water use efficiency of wheat crop in a semi-arid environment

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Wheat (*Tritium aestivum* L.) is the major food crop of India contributing 12 per cent of the total food grain production, covering an area of 31.5 Mha with production and productivity of 86.5 Mt and 2.8 tha^{-1} respectively (http://eands.dacnet.nic.in/). In India, wheat is grown during November to March, as it requires cool and moist weather during the vegetative phase, and warm and dry weather during reproductive phase. Cardinal (minimum, maximum and optimum) temperature is one of the most critical parameter that decides fate of crop productivity in wheat. However, wheat sowing after rice is delayed because of late harvesting of rice, large turn around time and poor soil tilth of seed bed which forces delaying of wheat sowing to varying degrees. Wheat yield under such circumstances is mainly affected by terminal heat and water stress.Reproductive phase is the ultimate determinant of yield, if faces high temperature stress shows a significant impact on yield (Mitra and Bhatia, 2008). Different wheat cultivars take different time from germination to maturity under varied agro-climatic condition. Therefore, crop development phases alone cannot be considered as a good predictor for measuring abiotic stress. The more scientific way of characterizing abiotic stressis through meteorological indices like growing degree-days, heat use efficiency, etc. Considering all these, a study was undertaken to investigate the impact of sowing date on yield, heat and water use efficiency of three wheat cultivars in Indo-Gangetic Plains of India.

A field experiment was conducted during the *rabi* season of 2011-12 and 2012-13 at the experimental farm of Indian Agricultural Research Institute (IARI), New Delhi. Soil of the experimental site was sandy loam (*TypicUstochrept*) with alkaline nature (pH 8.3) having electrical conductivity of 0.16 dS m^{-1}. Soil was low in organic carbon and available nitrogen and medium in available phosphorous and potassium. Bulk density in 0-30 cm of the soil varied between 1.55-1.61 Mg m^{-3}. Experiment was laid out in split plot design with three replications. The treatment consisted of three wheat varieties (V1: HD2932, V2: WR544 and V3: HD2967) with three sowing dates [D1: Normal sowing (15 November in 2012-13); D2: Late sowing (30 November) and D3: Very late sowing (15 December). The seeds were sown at a depth of 5cm with the recommended spacing of 22.5 cm. Nitrogen was applied @120 kg ha^{-1} in the form of urea in three splits; 50 per cent at sowing, 25 per cent at CRI stage and rest 25 per cent at maximum tillering stage. Phosphorous (60 kg P_2O_5ha^{-1} as SSP) and potassium (60 kg K_2O ha^{-1} as MOP) were applied at sowing. Desired meteorological observations were collected from the meteorological observatory of IARI which is located 500 m away from the present experimental site (Table 1). Leaf area index (LAI) was measured by a leaf area meter (Model LI-3100, LI-COR, Inc., USA) in which individual green leaf was measured at flowering stage. Growing degree days (GDD) and heat use efficiency were computed from daily weather data. Base temperature for wheat was taken as 5°C (Gill *et al.,* 2014). Heat use efficiency (HUE)was calculated as yield (kg ha^{-1}) per unit of accumulated heat units (°C day)(Kingra and Kaur, 2012) and water use efficiency (WUE) as grain yield per unit of evapotranspiration (mm) (Pradhan *et al.,* 2018). Crop was harvested manually and biomass and grain yield were expressed in kgha^{-1}. Statistical analysis of the data was performed using SPSS where means were compared at $P \leq 0.05$ level of probability.

The mean monthly temperature, relative humidity, total rainfall and pan evaporation are given in Table 1. Mean monthly temperatures were almost similar in both the years of study except for the month of November. The November month of 2011-12 experienced 2.1°C higher temperature than the year 2012-13. The cropping season of 2011-12 received a total 43 mm of rainfall in four rainy days, whereas 2012-13 received 176 mm of rainfall in 10 rainy days, which coincided with flowering and milking stage of wheat crop.

Table 1:Weather data of the year of experiment period

Month	Mean temperature (°C)		Relative humidity (%)		Total rainfall(mm)		Pan evaporation (mm day^{-1})	
	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13	2011-12	2012-13
November	20.7	18.6	61	76	0.0	0.0	2.9	2.4
December	14.2	14.6	67	49	0.0	8.6	2.2	2.6
January	12.1	11.4	73	79	14.8	40.8	2.2	2.8
February	15.3	15.8	54	72	0.0	109.4	4.2	2.7
March	21.3	21.8	50	61	19.2	12.6	5.5	4.7
April	27.4	27.7	40	47	9.0	11.6	7.1	7.1

Table 2: Effect of date of sowing and variety on biomass yield, grain yield, heat and water use efficiency in wheat crop (pooled analysis over two season)

Treatments	Biomass yield (t ha^{-1})	Grain yield (t ha^{-1})	Heat use efficiency (kg $ha^{-1o}C^{-1}$ day^{-1})	Water use efficiency (kg $ha^{-1}mm^{-1}$)
Year				
2011-12	12.62	5.10	3.68	12.24
2012-13	13.14	5.35	3.66	10.59
CD	0.38	0.57	0.14	0.51
Date of sowing (DOS)				
D1	14.31	5.93	4.21	12.58
D2	12.94	5.32	3.63	11.66
D3	11.39	4.43	3.18	10
CD	0.47	0.70	0.17	0.62
Variety				
HD 2932	13.06	4.91	3.71	11.51
WR 544	13.23	5.54	3.74	11.81
HD 2967	12.36	5.02	3.55	10.92
CD	0.36	0.48	0.14	0.72

The mean monthly relative humidity was 6-18 per cent higher in 2012-13 compared to 2011-12, except in December, where it was 18 per cent lower. The higher mean monthly relative humidity can be attributed to the higher rainfall of the year.The dailypan evaporation rate of February 2011-12 was 1.5 mm day^{-1} lower than the year 2012-13 which can be attributed to the higher rainfall, higher relative humidity and lower solar radiation

Yield parameters

Biomass and grain yield of wheat cultivars were significantly higher in normal date of sowing (Nov. 15) than late (Nov. 30) and very late sowing (Dec. 15). Mean biomass yield in normal sown wheat was 14.31 tha^{-1} which was 9.6 per cent and 22.7 per cent higher than late and very late sown wheat respectively (Table 2). Similarly, grain yield was highest in Nov. 15 sown wheat (5.93 tha^{-1}) and declined with successive delay of sowing.The reduction in grain and biomass yield can be attributed to heat stress at reproductive stages under late and very late sowing which resulted in overall decrease grain weight and hence yield. Sial *et al.* (2005) have also reported that late sowing in wheat resulted in yield reduction by 55-70 per cent among the cultivars. Amongst varieties, although biomass yield was found higher in WR 544 compared to HD 2932 and HD 2967, but they were statistically non-significant, which implies that till most of the vegetative growth phase of wheat crop temperature did not played crucial role compared to its role in reproductive phase. Variety WR 544 showed higher grain yield (5.54 tha^{-1}) which was statistically significant as

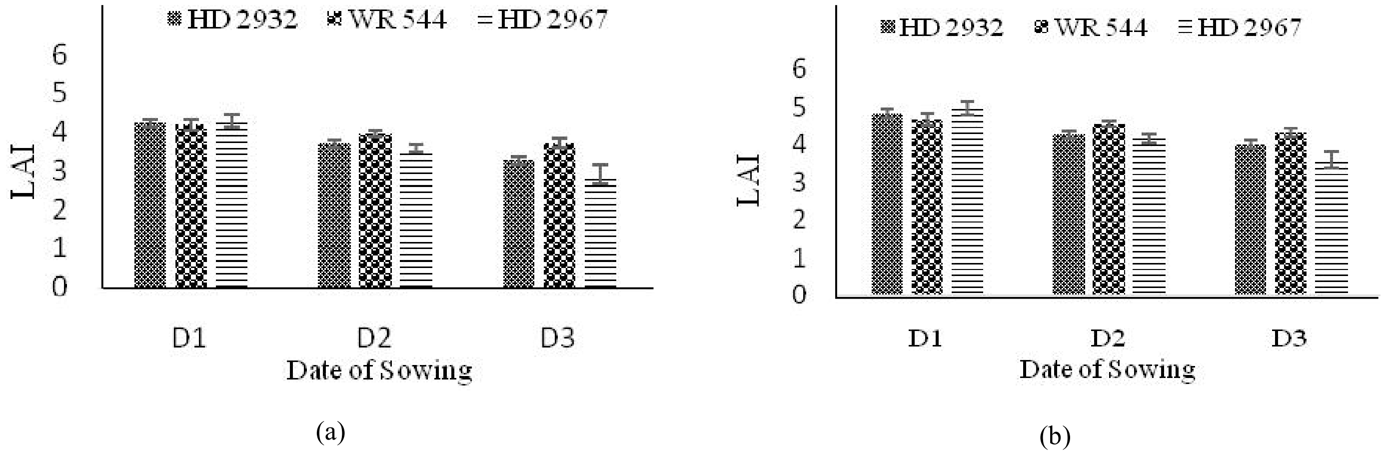

Fig.1: Leaf area index of wheat cultivars at flowering stage under different sowing dates (a) 2011-12 and (b) 2012-13. (Footnotes)

compared to HD 2932 (4.91tha^{-1}) and HD 2967 (5.02 tha^{-1}) (Table 2).For both grain and biomass yield, performance of WR 544 was better especially with delay in sowing which signifies its thermo-tolerance characteristics among the three wheat cultivars (Table 2).

Leaf area index (LAI)

Leaf area was measured at flowering stage and depicted in Fig. 1. Mean LAI in normal sown wheat was higher than that of late and very late D2 LAI sown crop. It shows that with delay in sowing the leaf area gets reduced which may be due to decline in photosynthetic rate and poor leaf development (Gupta *et al.,* 2017) leading to lower LAI. Among the three cultivars, the cultivar WR 544 registered highest LAI (3.3 to 6.1%) followed by HD 2967 and HD 2932. Gupta *et al.* (2017) has also observed decrease in LAI delay in sowing.

Heat use efficiency (HUE)

The HUE of wheat crop decreased with delay in sowing (Table 2). HUE in Nov. 15 sown wheat was 13.8 and 24.5 per cent higher than Nov. 30 and Dec. 15 sown wheat respectively. Adak and Chakravarty (2010) also showed that with each day delay in sowing, grain matures early resulting in lower heat accumulation in grains and hence lower yield. Dar *et al.* (2018) also reported decrease in HUE with delay in sowing of wheat from the normal (Nov-10) date at Ludhiana. Among the varieties, HD 2967 showed lowest HUE compared to WR 544 and HD 2932 (Table 2).While variety WR 544 has significant higher HUE($P=0.05$) again indicating towards its thermo-tolerance characteristics. Prakash *et al.* (2017) also reported that the HUE of sorghum was found to vary significantly with dates of sowing and cultivars.

Water use efficiency (WUE)

WUE decreased significantly ($P<0.05$) with delay in sowing (Table 2). Normal sown wheat registered 7.3 and 20.5 per cent higher WUE compared to late and very late sown crop. Pradhan *et al.* (2018) has also observed significantly lower WUE of mustard crop due to delay in sowing which they attributed to decrease in grain yield with delay in sowing.Among the cultivars,WR 544 showed significantly higher WUE compared to HD 2932 and HD 2967. However, the WUE of the cultivars HD 2932 (11.51 kg ha^{-1} mm^{-1}) and WR 544 (11.81 kg ha^{-1}mm^{-1}) were statistically at par and significantly higher than HD 2967 (10.92 kg ha^{-1}mm^{-1}). WR 544 registered 2.5 and 7.5 per cent higher WUE compared to HD 2932 and HD 2967 respectively.

This is study revealed that timely sown wheat crop showed highest yield, LAI, HUE and WUE compared to late and very late sown crop. Among the cultivars, WR 544 performed better in terms of biomass, grain yield, LAI, HUE and WUE especially under delayed sowing condition. Hence, from the above study it may be concluded that under normal sown condition any cultivar i.e., HD 2932, WR 544 or HD 2967 can be recommended. However, under late sown condition WR 544 can be recommended for higher yield, HUE and WUE.

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