Vol. 18, No. 1, pp. 99-106 (2018)
Journal of Agricultural Physics
ISSN 0973-032X
http://www.agrophysics.in

Research Article

Effect of Weather Parameter on Growth and Yield of Wheat (*Triticum aestivum* L.) Crop under Semi-Arid Environment

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ABSTRACT

An experiment was conducted during the *rabi* season, 2017-18 at the research farm of ICAR-Indian Agricultural Research Institute, New Delhi to evaluate the effect of weather parameter on growth and yield attributes of wheat crop under conservation agriculture. The crop was sown under different dates mainly timely sown, late sown and very late sown with three wheat cultivars (PBW-723, HD-2967 and PBW-3086). The Results showed that under different dates of sowing conditions, timely sown crops had better growth and yield as compared to late and very late sown crop. The yield and grains m^{-2} were maximized for all cultivars in timely sown as compared to the late sown and very late sown crops. After the optimum sowing date, there were 21.1 to 37.7%, 3.2 to 9.3% and 1.6 to 6.3% yield reduction for cultivars PBW-723, HD-2967and HD-3086 respectively.

Key words: Relative water content, Leaf water potential, Biomass, Yield

Introduction

Wheat is the most important staple food grain crop all over the globe. Among all commercially grown crops, it occupies largest area and also it ranks highest in terms of production. In the period leading up to 2020, demand for wheat for human consumption in developing countries is expected to grow at 1.6% per annum, and for feed at 2.6% per annum. The global average wheat yield will have to increase during the coming 25 years from 2.6 to 3.5 tonnes ha^{-1}. In this 21st century, a major concern of interest to human kind is the global warming. Continuously changing pattern of climate has great influence on the world crop production (Jones and Davis, 2000). Now days changing climate on agricultural production is the main issue and food security has given considerable more attention on future impact (Lobell *et al*., 2011). Some studies showed that adaptations of cultivars in different sowing date, climate change and global warming effect in the past decades have advance wheat phenology and reduced the wheat growth duration increased terminal heat stress, and extreme temperature decline wheat production (Wang *et al*., 2013).The winter wheat is generally exposed to high temperature during post-anthesis stages which are the hottest periods during the crop growth period (Wardlaw and Wrigley, 1994). The effect of high temperature during post-heading stages period reduced the grain filling duration (Zhao *et al*., 2007; Lobell *et al*., 2012). If the crop is exposed to extremely higher temperature conditions, it reduced the leaf photosynthetic activity of wheat which lead to senescence or early forced to maturity (Zhao *et al*., 2007). Global warming, as a result of climate change, may negatively affect wheat grain yields potentially increasing food

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insecurity and poverty, although it should be noted that current effects of climate change in relation to wheat are inconclusive and model dependent (Tubiello *et al.*, 2005). Predicted effects on wheat production include reduced grain yield over most of India with the greatest impacts in the lower potential areas, for example in the eastern plains.

Materials and Methods

The present study was carried out in the experimental field of ICAR-Indian Agricultural Research Institute (IARI), New Delhi, India (28^o35' N, 77^o12' E and 228.16 m altitude above mean sea level). The field had fairly levelled topography. The soil of the experimental site belongs to Indo-Gangetic alluvium soil group. The soil belongs to order Inceptisols having sandy clay loam (fine loamy, illitic, Typic Haplustept) in upper 30 cm layer and loam below with weak to medium angular blocky structure. The soil was neutral in reaction, non-calcareous and poor in available N, and medium in available P and organic carbon. During *rabi* 2017-18 wheat cultivars PBW-723, HD-2967 and PBW-3086 were sown on 14^{th} November, 4^{th} and 22^{nd} December, 2017 in the split plot design (SPD) with three replications. Temperature and relative humidity within canopy were measured by pocket weather tracker at 2.00 PM. Weather condition during crop growing period is shown in Fig. 1. Observation of different crop biophysical parameters such as leaf area index, biomass, chlorophyll content and were recorded at different growth stages. For biomass, five plants were selected randomly from each plot and oven dried at 65ÚC for 48 h and weighed until a constant weight was achieved. Dry biomass produced was expressed in g m^{-2}. Seed yields were measured after harvest. Daily weather parameters were taken from the agromet observatory adjacent to the experimental field. Different heat indices were calculated as given in table 1.

Leaf water potential was measured with the help of pressure bomb (PMS Instruments Co, USA). Relative water content was measured by following formula:

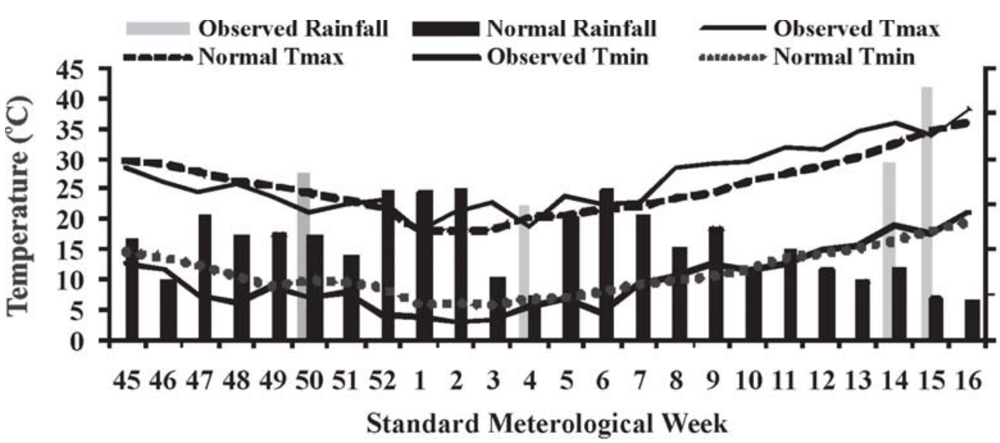

Fig. 1. Weekly weather data during crop growing period

Table 1. Methods for calculation of different heat indices

S. No.	Indices	Computation
1	Growing degree days (GDD)	$= \Sigma\{(T_{max}+T_{min})/2\}-T_b$
2	Helio thermal units (HTD)	$= \Sigma GDD \times SSH$
3	Photo thermal units (PTU)	$= \Sigma GDD \times$ Day length
5	Heat use efficiency (HUE)	=Yield/GDD
6	Photo thermal index (PTI)	GDD/Growing day

$$\text{RWC (Relative water content): } \frac{\text{Fresh wt- Dry wt}}{\text{Turgid wt-Dry wt}} \quad ...(1)$$

Chlorophyll Content was measured by Spectrophotometer Spectronic-20 and calculated using following formula:

$$\text{Total chlorophyll content (mg/g of fresh weight)} = \frac{[20.2 x A_{645} + 8.02 A_{663}]V}{1000W}$$

Where, A_{645} = Absorbance at 645 nm, A_{663} = Absorbance at 663nm, V = Final volume of chlorophyll extract in DMSO, W= Weight of plant sample

Statistical analysis and computation of DMRT test was carried out using SPSS packages (Version 17.0) and Excel. The required graphs were drawn using MS Excel software.

Results and Discussion

Thermal indices in different cultivars of wheat crop under different sowing conditions

Wheat crop required GDD around 1613, 1486 and 1454°C for PBW-723 and 1694, 1595 and 1564°C for both HD-2967 and HD-3086 to reach sowing to harvesting under timely, late and very late sown crop. Cultivars HD-2967 and HD-3086 had more value of total GDD as compared to corresponding value for PBW-723 in all sown conditions. Timely sown had slightly more GDD followed by late and very late sown conditions. This is due to increase in temperature during gain filling to physiological maturity stage in very late sown crop, total number of crop growing days reduced in very late sown crop followed by late and timely sown crop. Heat use efficiency (HUE) was found to be higher value in timely sown crop followed by late and very late sown crop. Cultivar HD-3086 had higher value of heat use efficiency (2.69, 2.54 and 2.50 kg ha^{-1} °C day^{-1}) followed by HD-2967 (2.51, 2.37 and 2.33 kg ha^{-1} °C day^{-1}) and PBW-723 (2.46, 2.09 and 1.70 kg ha^{-1} °C day^{-1}) in timely, late and very late sown conditions. Photothermal index (PTI) was found to be higher in very late sown crop followed by late and timely sown crop. PBW-723 had lower value of PTI (11.95, 12.18 and 12.98 °C day day^{-1}) compared to corresponding value for HD-2967 and HD-3086 (12.10, 12.11 and 13.37 °C day day^{-1}) in timely, late and very late sown conditions. Similar to GDD, PTU was found to be higher value in timely sown followed by late and very late sown crop. Cultivar HD-3086 and HD-2967 had higher value of photo thermal unit (18919, 18128 and 17755 °C day h^{-1}) followed by PBW-723 (17820, 17067 and 16855°C day h^{-1}) in timely, late and very late sown conditions. HTU had similar trend as PTI. HTU was found to be higher in very late sown crop followed by late and timely sown crop. Cultivar HD-3086 and HD-2967 had higher value of photo thermal unit (10643,10740 and 10781°C day h^{-1}) followed by PBW-723 (9910, 9915 and 10123°C day h^{-1}) in timely, late and very late sown conditions (Table 2).

Table 2. Thermal indices for different varieties of wheat under different sowing conditions

Date of sowing	Varieties	GDD (°C)	HUE (kg ha^{-1} °C day^{-1})	PTI (°C day day^{-1})	PTU (°C day) /hour)	HTU (°C day hour)
Timely sown	PBW-723	1613	2.46	11.95	17820	9910
(14.11.2017)	HD-2967	1694	2.51	12.1	18919	10643
	HD3086	1694	2.69	12.1	18919	10643
Late sown	PBW-723	1486	2.09	12.18	17067	9915
(04.12.2017)	HD-2967	1595	2.37	12.11	18128	10741
	HD3086	1595	2.54	12.11	18128	10741
Very late sown	PBW-723	1454	1.7	12.98	16855	10123
(22.12.2017)	HD-2967	1564	2.33	13.37	17755	10781
	HD3086	1564	2.5	13.37	17755	10781

Air temperature within the wheat crop canopy at different phonological stage under different sowing conditions

There was significant difference in air temperature within canopy at different growth stage under different sowing conditions. Air temperature within canopy ranged between 20.1 to 25.5°C at tillering stage, 25.2 to 34.7°C at jointing stage, 29.2 to 39.3°C at flowering stage and 33.7 to 38.7°C at grain filling stage under different sowing conditions. Differences in the temperature within canopy in late sown crop as compared to corresponding value in timely sown crop was less by 2.5 and 0.7°C in PBW-723, 1.6 and 0.4°C in HD-2967, 1.1 and 0.6°C in HD-3086 during tillering and jointing stage. However it was more during flowering and grain filling stage by 2.9 and 3.4°C in PBW-723, 2.7 and 3.3°C in HD-2967, 2.7 and 3.0°C in HD-3086. Differences in the temperature within canopy in very late sown crop as compared to corresponding value in timely sown crop was more by 2.6, 7.5, 9.5 and 4.5°C in PBW-723, 2.5, 8.7, 8.5 and 4.8°C in HD-2967, 2.3, 8.7, 8.3 and 4.2°C in HD-3086 during tillering, jointing, flowering and grain filling stage (Table 3). Air temperature in HD-3086 within canopy was found to be more value during tillering and jointing stage and less value during flowering and grain filling stage followed by HD-2967 and PBW-723 in different sowing conditions.

Relative Humidity Profile within crop canopy under different sowing conditions

Relative humidity (RH) profile showed opposite trend with respect to that of temperature profile i.e., RH measured within the canopy was higher than the value measured above the canopy in different treatments because of shading effect of leaves, lesser transmission of solar radiation, less air movement and accumulation of high water vapour from evapotranspiration. Relative humidity within canopy ranged between 42.1 to 73.5 % at tillering stage, 28.5 to 48.3% at jointing stage, 25.1 to 30.4% at flowering stage and 17.1 to 23.7% at grain-filling stage under different sowing conditions. Differences in the relative humidity within canopy in late sown crop as compared to corresponding value in timely sown crop was more by 11 and 5.6% in PBW-723, 18.2 and 4.5% in HD-2967, 15.4 and 7.1% in HD-3086 during tillering stage and jointing stage. However it was less during flowering and grain filling stage by 0.3 and 1.8% in PBW-723, 1.2 and 3.9% in HD-2967, 2.0 and 3.1% in HD-3086. Differences in the temperature within canopy in very late sown crop as compared to corresponding value in timely sown crop was less by 10.3, 9.3, 1.6 and 4.1% in PBW-723, 14.5, 15.0, 1.7 and 5.3 in HD-2967, 14, 11.9, 5.3 and 5.2% in HD-3086 during tillering, jointing flowering and grain filling stage (Table 4). HD-3086 had higher value of relative humidity in all sowing conditions

Table 3. Temporal variation in air temperature (°C) within wheat crop canopy at different phonological under different sowing conditions

Date of sowing	Varieties	Tillering	Jointing	Flowering	Grain-filling
Timely sown	PBW-723	22.6[h]	25.9[e]	30.1[g]	34.2[i]
	HD-2967	22.8[g]	25.8[f]	29.4[h]	33.8[g]
	HD-3086	23.0[f]	26.0[d]	29.2[i]	33.7[h]
Late sown	PBW-723	20.1[e]	25.2[h]	32.8[d]	37.6[d]
	HD-2967	21.2[d]	25.4[g]	32.2[e]	37.1[e]
	HD-3086	21.9[c]	25.4[g]	31.9[f]	36.7[f]
Very late sown	PBW-723	25.2[a]	33.4[c]	39.3[a]	38.7[a]
	HD-2967	25.3[b]	34.5[b]	38.0[b]	38.6[b]
	HD-3086	25.3[b]	34.7[a]	37.5[c]	37.9[c]
LSD at 5%		0.06	0.05	0.06	0.05

Table 4. Temporal variation in Relative Humidity (%) within the wheat crop canopy at different phonological stage under different sowing conditions

Date of sowing	Varieties	Tillering	Jointing	Flowering	Grain-filling
Timely sown	PBW-723	56.5^{f}	39.4^{f}	27.7^{e}	21.2^{c}
	HD-2967	56.6^{e}	43.8^{d}	29.4^{b}	23.7^{a}
	HD-3086	58.1^{d}	40.35^{e}	30.4^{a}	23.1^{b}
Late sown	PBW-723	67.5^{c}	45^{c}	27.4^{f}	19.4^{f}
	HD-2967	74.8^{a}	48.3^{a}	28.2^{d}	19.8^{e}
	HD-3086	73.5^{b}	47.4^{b}	28.4^{c}	20^{d}
Very late sown	PBW-723	46.2^{g}	30.1^{g}	26.1^{g}	17.1^{i}
	HD-2967	42.1^{i}	28.8^{h}	27.7^{e}	18.4^{g}
	HD-3086	44.1^{h}	28.5^{i}	25.1^{h}	17.9^{h}
LSD at 5 %		0.05	0.06	0.06	0.05

followed by corresponding value in HD-2867 and PBW-723.

Relative water content and leaf water potential under different sowing conditions

The relative leaf water content were relatively higher in case of timely sown crop followed by late sown and Very late sown crop but the reduction in terms of percentage is more in very late sown crop followed by late sown and timely sown crop varieties. The percentage reduction in very late sown crop as compared to the timely sown crop was 11.8, 7.1, 10.3, 10.0 and 16.0% in PBW-723, 8.4, 6.0, 7.7, 7.8 and 14.5% in HD-2967, 9.4, 5.8, 8.8, 4.4 and 14.1% in HD-3086 at tillering, jointing, booting, flowering and grain-filling stages respectively. In varietal comparison they had shown highly significant in different growth stages. The percentage reduction is relatively more in very late sown crop as compared to the timely sown crop shown in (Fig. 2).

Leaf water potential measured in the leaf of the plant grown under different sowing condition in wheat crop was found to be higher in third sown crop as compared to the timely sown crop. The percent reduction as compared to timely sown crop was found to be 10.5 to 18.7% under PBW-723, 6.3 to 17.1% in HD-2967 and 7.0 to 14.6% HD-3086 at tillering, jointing, flowering and grain-filling stages respectively. Percentage reduction of leaf water potential in very late sown crop as compared to the late sown crop was 4.9 to 11.8% in PBW-723, 4.6 to 10.0% in HD-2967, 5.4 to 10.2% in HD-3086 at tillering, jointing, flowering and grain-filling stages respectively. Leaf water potential measured the stress in the plant. This showed that due to higher terminal heat stress in the very late sown crop plants were

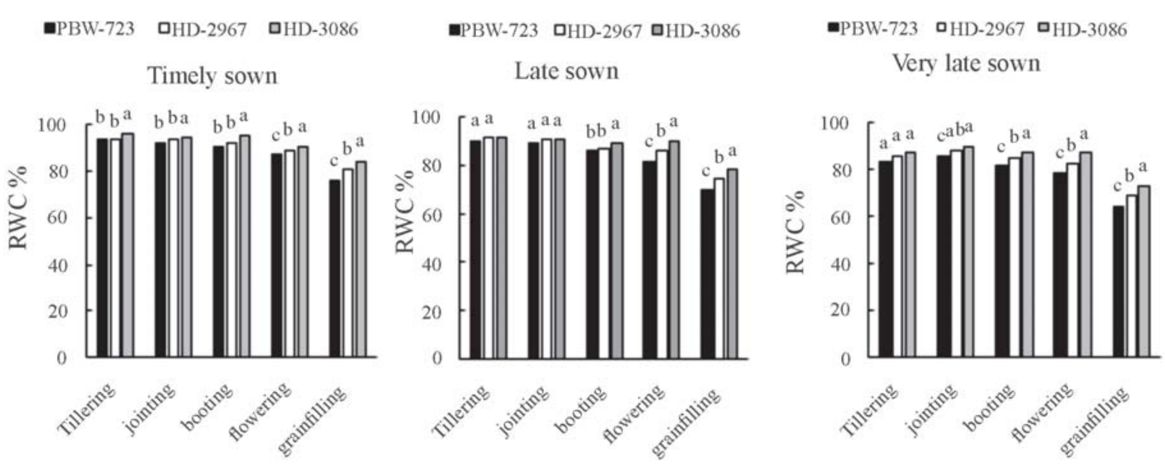

Fig. 2. Relative water content under different sowing conditions in wheat during crop growing season

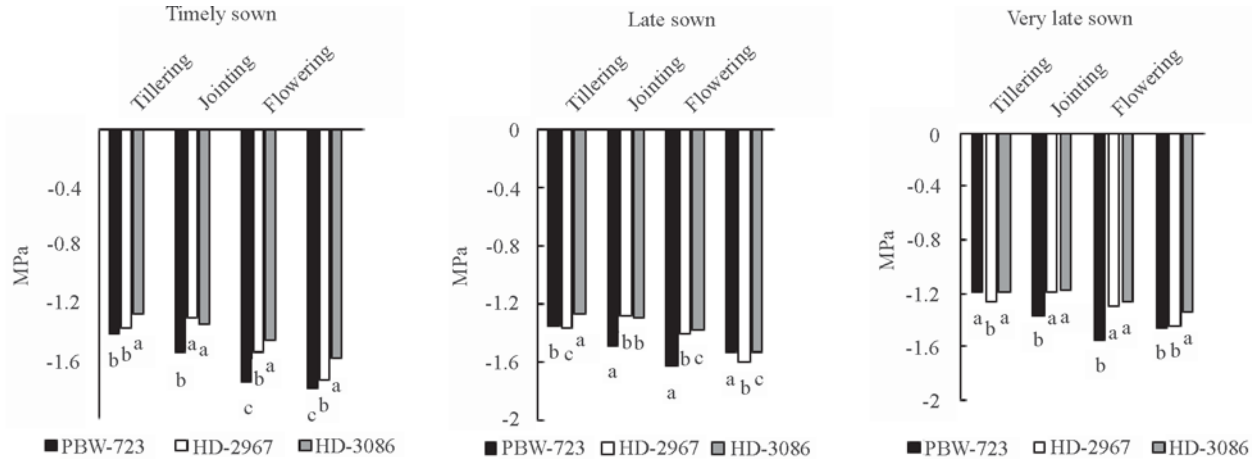

Fig. 3. Leaf water potential under different sowing conditions in wheat during crop growing season

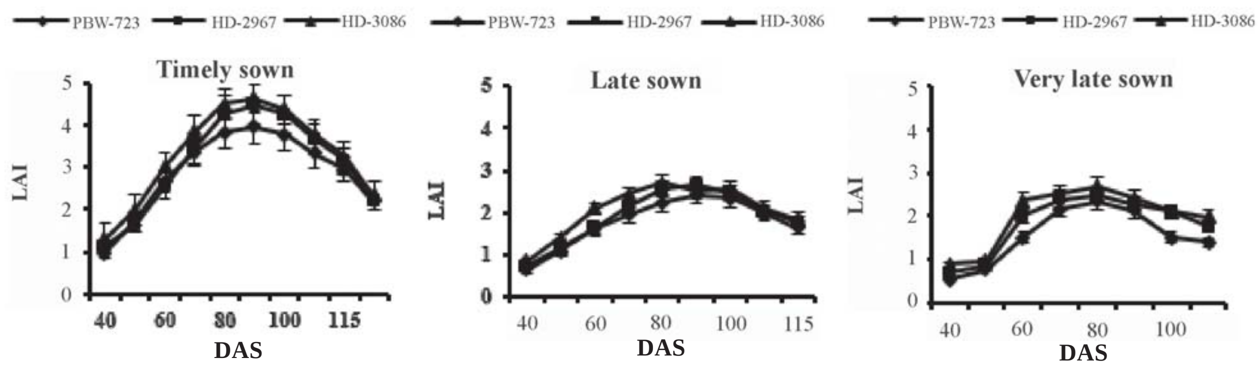

Fig. 4. Leaf area index under different sowing conditions in wheat during crop growing season

in more stress than the plant grown in timely sown crop shown in (Fig. 3).

Leaf area index under different sowing conditions

Leaf area index is an important parameter for the crop growth studies since it is useful in interpreting the capacity of a crop for producing dry matter in terms of the intercepted utilization of radiation and amount of photosynthesis synthesized. The seasonal profile of wheat LAI for different treatments in 2017-18 is shown in (Fig. 4). In case of all the treatments LAI profile showed a typical pattern of first increased during vegetative phase, then reached peak at flowering stages and after that decreased due to senescence. Timely sown crop showed highest LAI as compared to the late sown and very late sown crop. The reduction of leaf area in terms of percentage was higher in very late sown crop as compared to the timely sown crop was 44.1 to 58.6%, 40.8 to 52.4% and 33.5 to 47.4% in PBW-723, HD-2967 and HD-3086 respectively. Very late sown crop attained peak LAI much earlier with lower value than the timely sown and late sown crop. Similar observation was reported by Vashisth *et al.* (2011) in mustard that the maximum LAI was found at flowering stage and thereafter declined towards maturity. This indicates that delay in sowing resulted in significant growth loss and shortening of length of season. It was observed that the leaf area index (LAI) was higher in HD-3086 followed by HD-2967 and PBW-723.

Biomass under different sowing conditions

Total biomass production observed during different growth stages under different treatment sowing conditions are shown in (Fig. 5). In this study the changes in biomass are significantly decrease in very late sown crop as compared to the late sown and timely sown crop. Biomass

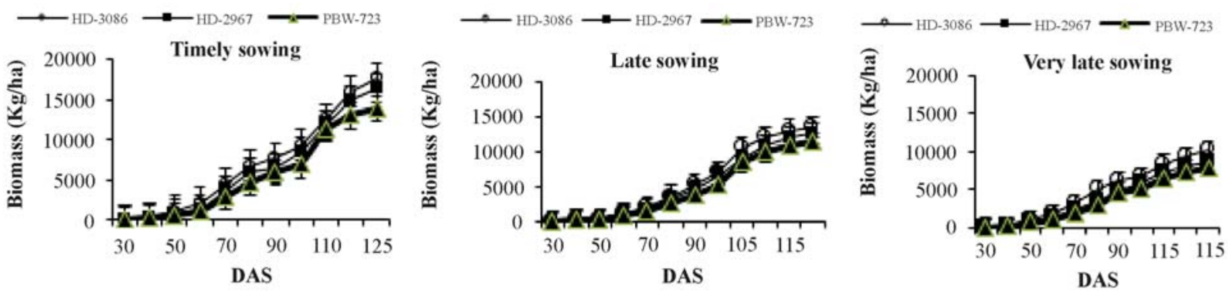

Fig. 5. Biomass under different sowing conditions in wheat during crop growing season

production varied from 46.3 to 59.7, 47.3 to 55.9, 42.6 to 51.2% in PBW-723, HD-2967, HD-3086 under very late sown as compared to the timely sown crop with a mean value of 53, 51.6, 46.9% in different phonological stages. Greater reduction in biomass was observed in PBW-723 as compared to HD-3086 and HD-2967 in all sowing conditions. Vashisth *et al.* (2012) reported increase in the dry matter with a positive correlation between dry matter and leaf area index at flowering and final dry matter production. Kar and Chakravarty (2001) reported 6 and 22% reduction in biomass production in the mustard crop sown in late and very late sown conditions.

Chlorophyll content under different sowing conditions

Chlorophyll concentration is usually an indicator of nutritional stress, photosynthetic capacity and developmental stage (senescence). Chlorophyll concentration was found to be higher in timely sown followed by late sown and very late sown crop (Fig. 6.). It has been shown that the reduction of percentage chlorophyll content was higher in very late sown crop compared to the timely sown crop was 8.1, 10.7, 13.9, 14.9% in PBW-723, 8.5, 7.7, 11.8, 12.1% in HD-2967 and 2.2, 2.4, 8.2, 10.5% in HD-3086 respectively. Similarly it was found that the reduction of chlorophyll was higher in very late sown crop as compared to the late sown crop which is comparatively lower than the timely sown crop. Very late sown crop has greater effect on chlorophyll content due to more temporal stress and early senescence.

Grain yield under different sowing conditions

The final grain yield production at the harvest were significantly reduced in very late sown crop as compared to the timely sown and late sown crop. It was observed that the percent reduction of yield was 37.7, 9.2, 6.3% in PBW-723, HD-2967, HD-3086 under very late sown crop compared to the timely sown crop, the maximum yield reduction occurred in PBW-723 under all treatments followed by HD-2967 and HD-3086, this may be due to the higher temperature reduced vegetative growth. Percent reduction in yield in the late sown crop as compared to the timely sown crop were 21.7, 3.2, 1.6% in PBW-723, HD-2967,

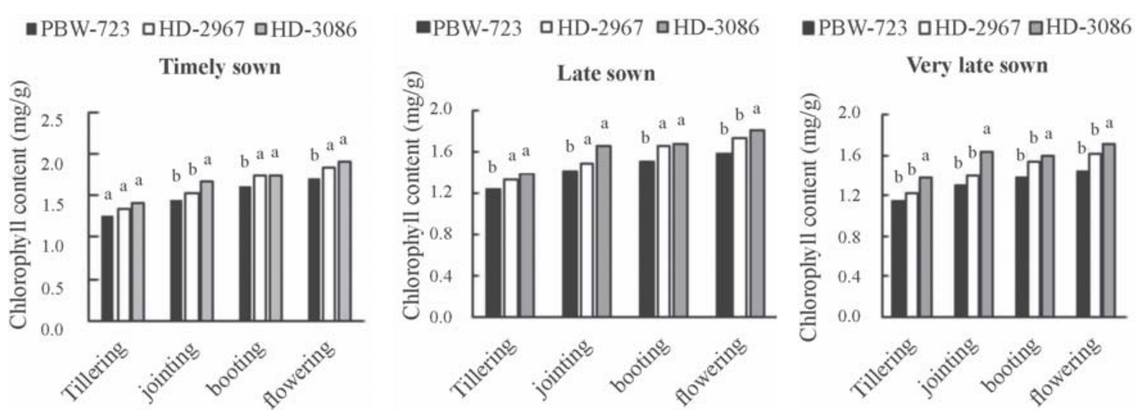

Fig. 6. Chlorophyll content under different sowing conditions in wheat during crop growing season

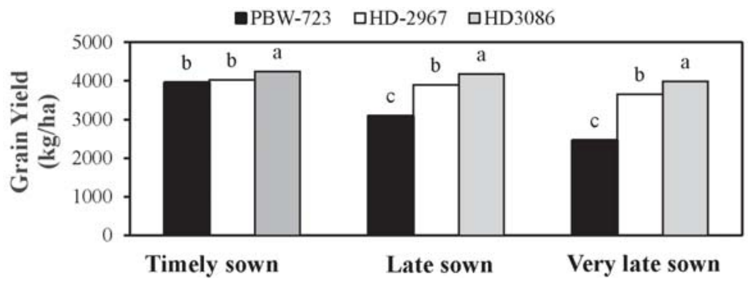

Fig. 7. Grain yield under different sowing conditions in wheat during crop growing season

HD-3086 respectively. Grain yield varied significantly in different sowing conditions. The grain yield was 3900, 4020, 4240 kg ha^{-1} for timely sown crop, 3100, 3890, 4173 kg ha^{-1} for late sown crop and 2466, 3550, 3980 for very late sown crop in PBW-723, HD-2967, HD-3086 respectively (Fig. 7).

Conclusion

From the study it was observed that among all the three sowing conditions timely sown crop was perform better for wheat crop followed by late sown and very late sown condition. The yield had highest value in HD-3086 followed by HD-2697 and PBW 343 under all sowing conditions. The yield was higher under timely sown crop due to favourable weather conditions during different phonological stages. Percent reduction of yield in very late sown crop compared to the timely sown crop was 37.7, 9.2, 6.1% in PBW-723, HD-2967, HD-3086 respectively. Since the reduction was less in HD-3086 followed by HD-2967 and PBW-723, therefore HD 3086 can be recommended for semi arid environment of north India.

Acknowledgement

The author thanks Post Graduate School, ICAR-IARI, New Delhi for financial assistance. Thanks are due to Director, ICAR-IARI, New Delhi and Head, Division of Agricultural Physics for providing the facilities.

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Received: June 1, 2018; Accepted: June 27, 2018