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PHYSIOLOGICAL IMPACT OF HEAT STRESS ON WHEAT VARITIES AT DIFFERENT GROWTH STAGES

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ABSTRACT

Wheat (*Triticum aestivum* L.) is regarded as an important staple food crop globally and is sensitive to high temperature (HT) during reproductive stages in comparison to vegetative stages. High-temperature stress is a major abiotic constraint and is projected to reduce crop yield there by threatening food security. A field investigation entitled "Effect of high-temperature stress on yield of various wheat varieties at different growth stages" was conducted at the Students Instructional Farm of the Acharya Narendra Deva University of Agriculture and Technology Kumarganj, Ayodhya (UP) during Rabi season of 2021-22. The experiment was planned under SPD (Split plot Design) with three replications and treatment consisting of three dates of sowing viz; D_1 (15th November), D_2 (30th November), and D_3 (15th December). Results indicated that growth attributes such as plant height, number of tillers plant^{-1}, dry matter plant^{-1}, and membrane stability index were significantly affected by the date of sowing. When late sown variety was planted timely all the growth attributes showed a drastic reduction with respect to late sowing (15th December) However, V_1 and V_2 showed comparatively good performance in terms of growth attributes when sown early D_1 and D_2. Performance of V_3 was very good as compared to V_1 and V_2 when sown delayed D_3 i.e. facing high temperature stress. Time of sowing decreased substantially almost in all the yield components measured viz; the number of ear bearing tillers^{-1}, number of grains ear^{-1}, ear length (cm), grain yield plant^{-1} (gm), biological yield plant^{-1} (g), and test weight (g) and harvest index which caused severe reduction of yield in V_1 and V_2. Overall growth attributes physiological traits and yield, as well as yield components of the wheat crop, was adversely affected by the time of sowing due to the onset of high temperature during crop growth and particularly grain filling. Variety i.e., V_3 (Kundan) reduced the detrimental effect of heat stress by improving physiological traits which ultimately helped in obtaining higher yield.
***Keywords* :** Wheat (*Triticum aestivum* L.), heat stress, growth stages.

Introduction

Wheat (*Triticum aestivam* L.) is the most important cereal crop belongs to family poaceae. In world total area is 220.83 mh and production 775.7 Mt of wheat crop (United States Department of Agriculture, 2020-21). In India total wheat area is 31.36 mh and production 107.9 Mt (United States department of agriculture, 2020-21). Wheat is a Rabi season crop, and it is long, self-pollinated crop, with fibrous root system. Primary root arises from embryo at germination and secondary roots emerge from the point above the primary root and crown root are found above seed but below the soil surface. The inflorescence, ear or head or spike and grain is caryopsis. In light of potential climate change, many stresses that impact plant growth and development have become a major source of worry. Wheat genotypes express a differential response to chronic heat stress as well as to heat shock (Kamal *et al.,* 2010). Vegetative growth and the reproductive phase in wheat, differ in their sensitivity to temperature (Almeselmani *et al.,* 2011). Climate change could also strongly affect wheat production, which account for 21% of global food production and 200 million hectares of farm land worldwide (Ortiz *et al.,* 2008). Global climate change, the occurrence of extreme weather events such as heat and drought stress has significantly increased, in terms of frequency, extent and duration (Field *et al.,* 2014). In wheat, the optimum temperature required is around 21˚C during reproductive growth (Porter and Gawith, 1999). Temperature higher than 33˚C at this stage leads to significant decline in leaf photosynthesis and imbalance of reductive-oxidative state, reduced grain filling duration, and obvious yield loss (Ugarte *et al.,* 2007). Delayed sowing of wheat exposes its grain filling stage to high temperature (Pandey *et al.,* 2015). The optimum temperature required during wheat anthesis and grain filling ranges between 12–22 ˚C. Exposure to temperature above 30 ˚C at pre or post anthesis stage reduces the grain filling rate in wheat and thereby decreases grain yield and quality (Stone and Nicolas, 1995). Globally, modern agriculture is under intense environmental pressure (Foley *et al.,* 2011). The effects of soil moisture limited supply and weather variability on crop output could be either favorable or unfavorable (Joshi and Kar, 2009). The unfavorable effects of climate change on crop production constitute a threat to global food security, and it is expected that rising temperatures will have a greater impact on maintaining wheat production (Tripathi *et al.*, 2016). According to Ortiz *et al*. (2008) reduced agricultural production due to climate change affects 200 million hectares of farmland and 21% of the world's food supply. The greatest consequences of rising temperatures will be felt at latitudes, notwithstanding the possibility of some advantages at high latitudes (where about 100 million ha of wheat are grown, producing about 280 million tons of grain annually). Depending on agricultural systems (such as rain fed versus irrigated, spring versus winter type), as well as biotic and abiotic restrictions, 12 distinct macro environments have been developed globally for breeding objectives (Braun et al, 2010). Environmental stresses such as high temperatures, deficient soil moisture, nutrient stress, low light intensity, etc. have a negative impact on the growth and development of wheat. Wheat is normally sown in India around November or December, and it is harvested in the warmer months of March or April. If temperature rises over a specified threshold for a predetermined period of days, it impacts wheat development, grain fertility, leaf senescence, and immediate crop maturity. Increased leaf-area index (LAI) and radiation interception are ascribed to increased crop growth brought on by nitrogen fertilizer (Caviglia and Sadras, 2001). The rapid senescence process is accelerated by the high heat stress at the grains filling point, which causes premature damage to the chlorophyll and a reduced ratio of chlorophyll (a & b) (AlKhatib & Paulsen, 1984 and Harding *et al*., 1990). High night time temperature also decreased grain number per spike (Chowdhary and Wardlaw, 1978). The present investigation was conducted keeping in view the effect of high temperature stress on the yield of various wheat varieties at different growth stages.

Materials and Methods

The present investigation was conducted during the Rabi season of 2020-21 at Student's Instructional Farm of Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh. Geographically the location of the experimental site is 42 km away from Ayodhya on Ayodhya- Raibarielly road between latitude of 26.47° North and longitude of 81.12° East with an elevation of 113 meters in the gangetic alluvium of eastern Uttar Pradesh and is subjected to weather extremes. The climate of district Ayodhya falls under a semi-arid zone with a mean annual rainfall of 1100 mm, of which about 80% is received during the monsoon season (November to April) with few showers in winter. Meteorological data i.e. temperature, rainfall, relative humidity, and sunshine hours of the experimental site were collected from a meteorological observatory situated at Kumarganj, the main campus of the University and are represented in Figure 1. A total of 27 plots were taken for study with the plot size of 5m*4m and spacing of 20cm*10cm. Five plants were taken from each plot as sample for recording the observations. The whole experiment was planned under split plot design with three replications along with three treatments. The three varieties PBW-343, HD-2967 and Kundan were taken in replications. The varieties selected i.e. PBW-343 and HD-2967are popular high yielding varieties in the North Eastern Plain Zone (NEPZ) for timely sown conditions but they are susceptible to temperature stress while Kundan is a popular late sown high yielding variety which is tolerant to high temperature stress. The treatment given were namely; D_1 (30^{th} November), D_2 (15^{th} December), D_3 (30^{th} December). The three sowing dates were concluded based on the optimum sowing time for timely sown and late sown varieties of wheat so that due to a rise in temperature in later developmental stages heat stress may be experienced by the varieties. In the case of timely sown varieties, the optimum time of sowing is mid-November and for late sown varieties it is the first fortnight of December. Tillers were recorded at maximum tillering stage and effective tillers were observed at physiological maturity of different wheat varieties. Dry matter of plant was recorded by oven drying the plant sample at 80^0C for 24hours. Relative Water Content (RWC) of plant was measured using fresh weight, dry weight and turgid weight of plant by method described by Turner and Beg (1981). Yield contributing factors such as, ear bearing tillers per plant, number of grains per ear, ear length and number of grains per plant was recorded a few days before harvesting. The grain yield and biological yield was observed after harvesting. Harvest index was calculated using formula: Harvest Index (%) = (Economic Yield/Biological Yield) * 100. Test weight was recorded by taking 1000 well filled grains having moisture content 12-15% from the samples of each treatment and measuring their weight. The data recorded on various growth and yield attributes was subjected to statistical analysis by Fisher method of analysis of variance. Significance of various treatments was judged by comparing calculated, F value with Fisher's F value at 5 percent level.

Results

Growth and phenological parameters

The data on number of tillers plant^{-1} and dry matter plant^{-1} as affected by different time of sowing was recorded at 60, 75 and 90 DAS is represented in Table 1. It is apparent from the data that maximum number of tillers plant^{-1} was recorded at 75 DAS irrespective of days of sowing. At D_1, maximum number of tillers plant^{-1} and dry matter plant^{-1} was obtained in V_2. At D_2, maximum number of tillers and dry matter plant^{-1} was obtained in V_2 and at D_3 maximum number of tiller plant^{-1} and dry matter plant^{-1} was obtained in V_3. Data pertaining to the influence of varieties and planting windows on number of tillers plant^{-1} showed that late variety *i.e.,* V_3 (Kundan) when sown early (D_1-15^{th} November) showed that number of tillers plant^{-1} significantly decreased. Similarly, when early varieties *i.e.,* V_1 and V_2 were sown late then the number of tillers plant^{-1} significantly decreased. This is due to onset of unfavorable environmental condition for crop**.** In general, dry matter accumulation by plant continued to increase at successive growth stages and the highest dry-mater plant^{-1} was recorded at 90 DAS. The data showed significant variation among different sowing dates and genotypes with respect to dry matter plant^{-1}.PBW-343, HD-2967 varieties sown early *i.e.,* D_1 showed significantly highest dry matter plant^{-1} as compared to D_2 and D_3.

Data regarding relative water content of wheat and membrane stability index content as influenced by time of sowing have been presented in Table 2. The critical observation of data reveals that in general the relative water content and membrane stability index reduced with plant age in all the cases. At D_1, highest RWC and maximum membrane stability index was obtained in V_2. At D_2, highest RWC and maximum membrane stability index was obtained in V_2. It is evident from the data that date of sowing D_1 reduced the relative water content of late variety V_3 (Kundan) as compared to V_1 (PBW-343) and V_2 (HD-2967) at all the stages of observation. Late sowing i.e., D_3 caused reduction in the relative water content and membrane stability index of varieties V_1 and V_2 in comparison to sowing early at D_1 at each stages of crop growth stage.

Components of yield

Data on ear length, ear bearing tillers per plant and number of grains per ear of wheat varieties as influenced by time of sowing have been presented in Table 3. Data further showed that the ear length differed significantly of different varieties of wheat. At D_1 and D_2, maximum ear length was recorded in V_2. At D_3, maximum ear length was obtained in V_3. Minimum ear length was recorded in V_3 at D_1. However, it is clear from data that the ear length was increased in V_3 at D_3 (late sown) as compared to D_1 and D_2. Data also revealed that the number of ear bearing tillers plant^{-1}also differed significantly of cultivars of wheat. At D_1 and D_2, maximum number of ear bearing tiller plant^{-1} was obtained in V_2 while at D_3 maximum number of ear bearing tiller plant^{-1} was obtained in V_3. It evident from the pooled data that early sowing *i.e.,* D_1 and D_2 reduced the number of ear bearing tillers plant^{-1} of late variety V_3 (Kundan) as compare to late sown *i.e.,* D_3. Maximum number of grains ear^{-1} was obtained in V_2 for D_1 and D_2. At D_3 maximum number of grains ear^{-1} was obtained in V_3. Minimum number of grains ear^{-1} was recorded in V_1 at D_3. It is evident from the data that delayed sowing D_3 reduced the grain number ear^{-1} of varieties V_1 and V_2 while showing a very less effect on V_3.

Yield

Data pertaining to grain yield plant^{-1}, biological yield per plant, test weightand harvest index of wheat as influenced by time of sowing have been presented in Table 4. Further, data indicate that the grain yield per plan differed significantly for different wheat varieties. At D_1 and D_2, highest grain yield plant^{-1} was obtained in V_2 while at D_3 highest grain yield plant^{-1} was obtained in V_3. Minimum grain yield plant^{-1} was recorded in V_3 at D_1. Highest biological yield plant^{-1}at D_1 and D_2, was obtained in V_2 and at D_3 it was obtained in V_3. Lowest biological yield plant^{-1} was recorded in V_3 at D_1. It is clear from the data that the three date of sowing D_1, D_2 and D_3 significantly affect the biological yield plant^{-1} of all the varieties. Test weight was also affected by the time of sowing of the crop. At D_1 and D_2, maximum test weight was found in V_2. At D_3 maximum test weight was obtained in V_3. Minimum test weight was recorded in V_1 at D_3. It is evident from the data that delayed sowing of early varieties V_1 (PBW-343) and V_2 (HD-2967) significantly reduced the test weight. Maximum reduction of 7.64% was recorded in V_1 at D_3 (*i.e.,* late sown) also at $D_1$and D_2, highest harvest Index was obtained in V_2 *i.e.,* 47.79 (%) and 45.55 (%) respectively. At D_3 (15 Dec) highest harvest Index was obtained in V_3 *i.e.,* 44.54 (%). Lowest harvest Index was recorded in V_1 at D_3 (15 Dec).

Table 1: Effect of different time of sowing on number of tillers per plant and dry matter of plant recorded at 60, 75, 90 Days after Sowing (DAS) on different wheat varieties

	Number of tillers per plant									**Dry weight per plant (g)**								
Treatments	**60DAS**			**75 DAS**			**90DAS**			**60DAS**			**75 DAS**			**90DAS**		
	V_1	V_2	V_3	V_1	V_2	V_3	V_1	V_2	V_3	V_1	V_2	V_3	V_1	V_2	V_3	V_1	V_2	V_3
D_1	5.6	5.8	4.6	6.7	6.8	5.6	6.5	6.6	5.4	24.45	26.28	22.73	28.52	29.53	25.64	34.54	35.64	31.54
D_2	5.5	5.7	4.9	6.4	6.6	5.8	6.3	6.5	5.6	24.12	25.14	23.54	28.06	29.10	26.65	33.32	34.14	32.43
D_3	5.3	5.4	5.5	6.3	6.5	6.6	6.2	6.3	6.4	22.43	23.51	24.76	25.05	26.54	28.54	30.54	31.45	34.10

	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em ±	CD at 5%
Variety	0.13	0.40	0.07	0.22	0.05	0.13	0.73	2.25	0.48	1.47	0.44	1.30
Treatment	0.05	0.16	0.05	0.15	0.05	0.17	0.48	1.91	0.36	1.40	0.69	2.05
V*T	0.12	0.37	0.12	0.37	0.09	0.26	1.26	3.88	0.83	2.56	0.76	2.15

Note: The values were analyzed with analysis of variance (ANOVA); S.Em± represents standard error of mean; CD represent the critical difference value to test the level of significance between means (P>0.05)

Table 2: Effect of different time of sowing on Relative Water Content and Membrane Stability Index recorded at 60, 75, 90 Days after Sowing (DAS) on different wheat varieties

	Relative Water Content (%)									**Membrane Stability Index**								
Treatments	**60DAS**			**75 DAS**			**90DAS**			**60DAS**			**75 DAS**			**90DAS**		
	V_1	V_2	V_3	V_1	V_2	V_3	V_1	V_2	V_3	V_1	V_2	V_3	V_1	V_2	V_3	V_1	V_2	V_3
D_1	77.14	78.79	70.49	74.05	75.76	68.62	71.17	72.71	66.73	53.45	54.67	52.34	45.34	46.84	44.96	41.43	43.34	40.87
D_2	76.98	77.75	72.09	73.85	74.98	69.23	70.28	71.28	67.87	52.54	53.53	51.65	44.78	45.78	43.89	40.87	41.87	39.32
D_3	70.98	76.79	75.56	68.21	69.96	72.12	68.67	67.99	70.18	48.65	49.76	47.87	43.66	44.65	41.43	38.76	39.87	37.55

	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em±	CD at 5%	S.Em ±	CD at 5%
Variety	0.88	2.71	0.87	2.68	0.88	2.25	0.84	2.58	0.83	2.55	0.84	2.58
Treatment	0.55	1.70	0.53	1.60	0.45	1.40	0.52	1.61	0.50	1.60	0.43	1.30
V*T	1.52	4.70	1.50	4.63	1.52	4.45	1.45	4.48	1.43	4.41	1.45	4.47

Note: The values were analyzed with analysis of variance (ANOVA); S.Em± represents standard error of mean; CD represent the critical difference value to test the level of significance between means (P>0.05)

Table 3: Effect of different time of sowing on ear length, ear bearing tillers per plant and number of grains per ear on different wheat varieties

Treatments	Ear length (cm)			Ear bearing tillers per plant			Number of grains per ear		
	V_1	V_2	V_3	V_1	V_2	V_3	V_1	V_2	V_3
D_1	9.4	9.5	7.6	6.3	6.5	5.2	42.15	43.77	36.69
D_2	8.9	9.1	8.4	6.2	6.4	5.4	41.76	42.55	37.18
D_3	8.3	8.4	9.2	5.5	5.8	5.9	36.34	37.76	41.54
	S.Em±	CD at 5%		S.Em±	CD at 5%		S.Em±	CD at 5%	
Variety	0.16	0.52		0.13	0.42		0.38	1.17	
Treatment	0.14	0.45		0.13	0.42		0.27	0.82	
V*T	0.29	0.90		0.24	0.72		0.65	2.03	

Note: The values were analyzed with analysis of variance (ANOVA); S.Em± represents standard error of mean; CD represent the critical difference value to test the level of significance between means (P>0.05)

Table 4: Effect of different time of sowing on grain yield per plant, biological yield per plant and test weight on different wheat varieties

Treatments	Grain yield per plant			Biological yield per plant			Test weight (g)			Harvest Index		
	V_1	V_2	V_3	V_1	V_2	V_3	V_1	V_2	V_3	V_1	V_2	V_3
D_1	10.22	11.48	6.62	22.68	24.02	15.83	40.57	41.30	38.59	45.06	47.79	41.81
D_2	9.60	10.41	7.76	21.40	22.85	17.74	39.10	40.20	39.92	44.85	45.55	43.74
D_3	7.21	8.08	9.48	16.51	18.94	21.28	37.47	38.74	40.21	41.76	42.66	44.54
	S.Em±	CD at 5%		S.Em±	CD at 5%		S.Em±	CD at 5%		S.Em±	CD at 5%	
Variety	0.35	1.08		0.33	1.02		0.26	0.81		0.15	0.46	
Treatment	0.24	0.75		0.30	0.91		0.34	1.02		0.13	0.41	
V*T	0.61	1.87		0.58	1.76		0.45	1.36		0.25	0.76	

Note: The values were analyzed with analysis of variance (ANOVA); S.Em± represents standard error of mean; CD represent the critical difference value to test the level of significance between means (P>0.05)

Discussion

Present study revealed high temperature stress induced due to delay in sowing time at vegetative stage or reproductive stage severely decreased the plant growth and development. Heat stress severely affects the grain filling due to a marked reduction in flag leaf and ear photosynthesis at high temperatures (Blum *et al*., 1994). Reduction in total number of tillers especially in timely sown varieties i.e., PBW- 343, HD-2967, clearly showed that effect of time of sowing on growth as well as development of crop. These results are in conformity with those of Donaldson *et al.* (2001) and Matuz and Aziz (1990), Verma, Lavkush *et al.* (2023). Time of sowing also significantly reduced dry matter content, Relative Water Content (RWC) and membrane stability index particularly in PBW-343 and HD-2967. Similar result was also obtained for dry matter content by Behera *et al*. 1994, Kumar and Sharma 2003 and Shahzad *et al.,* 2007. Wheat plants exposed to heat stress substantially decrease the water potential and the relative water content in leaves (Farooq *et al.,* 2009). Almeselmani *et al.* (2009) observed that high temperature (35/25°C) imposed after tillering showed a significantly reduction of water potential in wheat, and the reduction was higher in genotypes susceptible to heat stress. This is because of increased transpiration in stressed leaf and dropping of osmotic and to a greater extent for reduced water viscosity. The relative water content controls the leaf tissue turgor pressure which ultimately maintains the activities of leaf resulting to high rate of photosynthesis. Saxena *et al.* (2016), Verma, Lavkush *et al*. (2023) observed that under late sown condition, relative water content, membrane stability index was lower compared to timely sown condition in all the genotypes due to high temperature induced injury.

Yield of crop is determined by several contributing components known as the yield components. In the current study it is clearly evident that delay in sowing of the crop lead to wheat crop being to high temperature than optimum required for the crop production leading to a decline in the various yield contributing factors and thus in turn yield of the crop itself. Time of sowing significantly censored the ear length of all the varieties. Delayed sowing of early variety V_1 (PBW-343) and V_2 (HD-2967) significantly reduced the ear length. This finding was in accordance with Praveen *et al.* (2018). This is due the unfavorable weather conditions like high temperature, wind velocity and low water content at crop growth stage. Perusal of data also revealed that the late planting of early varieties V_1 and V_2 resulted in a smaller number of ear bearing tiller plant^{-1}. The results are in agreement with those of (Simons and Hunt, 1983) and (Darwinkel, 1978). Less number of grains ear^{-1} in late sowing in V_1 and V_2 was due to less production of photosynthates due to shorter growing period. These results are in line with those of Shahzad *et al.* (2002). Differences in number of grains per ear among varieties might be attributed to their genetic variability (Haider, 2004). The early sowing resulted in better development of the grains due to longer growing period Shahzad *et al*. (2002).

Lower grain yield at early sowing in V_3 was mainly due to a smaller number of tillers, a smaller number of grains per spike weight. These results are in accordance with those of Spink *et al*. (2000), Shahzad *et al*. (2002) while lower yield of early sown varieties V1 and V2 is due temperature extreme at the reproductive stage that reduces the period of grain filling and thereby lading to shorter grain size and less number of grains per ear. Decrease in biological yield under hyper thermal stress has been also advocated by *Singh et al.* (2001). Grain yield is the product of number of grains per plant, ear length, individual grain weight and biological yield and hence reduction in all these components under late sowing accounted for greater decrease in grain yield. Delay in sowing after the optimum date showed decreasing trend in the yield of the crop. The crop sown on early showed highest biological yield as compared to late sown in V_1 and V_2, while V_3 (Late variety) showed minimum biological yield at early sown as compared to late sown. This result is in line with Jat *et al.* (2013). Effect of time of sowing on data pertaining to test weight indicated that delayed sowing of early varieties V_1 (PBW-343) and V_2 (HD-2967) significantly reduced the test weight. This result is in accordance with the finding of Khan, (2000) and Akhtar *et al.* (2006). This is due to the delayed sowing which shortens the duration of each development phase and ultimately reduces grain filling period resulting in lower grain weight Spink *et al*. (2000). It shows that the earlier planted crop enjoyed a prolonged growth period and favorable pre-heading conditions, which have had a carry-over effect on grain weight via stem reserves or the setting of potential grain weight soon after anthesis Ortiz-Monasterio *et al*. (1994).

It is evident from the data the effect of time of sowing D_1, D_2 and D_3 significantly affect the harvest Index of all the varieties V_1 (PBW-343), V_2 (HD-2967) and V_3 (Kundan). Mamrutha *et al.* (2020) reported that the increasing temperature especially the High night temperature (HNT) is a major constriction for sustaining global food production under changing climate scenario. As a result of recent climate change, episodes of abrupt night temperature rises have occurred, either throughout the crop cycle or during certain growth stages with significant reductions in grain yield (GY), harvest Index (HI).

The study makes it evident that growth parameters like plant height, number of tillers plant^{-1}, dry weight plant^{-1} and relative water content of V_1, V2 and V_3 was found maximum in D_1, D_1 and D_3 respectively at 60, 75 and 90 DAS and membrane stability index of V_1, V_2 and V_3 was found maximum in D_1, D_1 and D_1 respectively at 60, 75 and 90 DAS. Yield and yield contributing parameters like EBT plant^{-1}, No. of grain plant^{-1}, ear length (cm), grain yield plant^{-1}, biological yield plant^{-1}, test weight (g) and harvest index for V_1 (PBW-343), V_2 (HD-2967) and V_3 (Kundan) was found maximum in D_1, D_1 and D_3 respectively. Maximum grain yield was recorded from the crop sown on D_1 (i.e., 15 November) and this may be because, yield attributes was adversely affected by delayed sowing which leads to forced maturity because of high temperature. V_3 (Kundan) is not affected by delayed sowing because Kundan is a heat tolerant variety. So, is lesser affected by heat stress and also by delayed sowing and hence can be recommended for areas that are frequently affected by high temperature stress during the reproductive stage of wheat crop growth.

References

Akhtar, M., Cheema, M.S., Jamil, M. and Ali, L. (2006). Effect of time of sowing on some important characters of wheat, (*Triticum aestivam* L.): genotypes. *J. Agric. Res*., 44(4):255-259.

Al-Khatib, K., and Paulsen, G.M. (1984). Mode of high temperature injury to wheat during grain development. *Physiologia plantarum*, 61(3): 363-368.

Almeselmani, M., Deshmukh, P.S. and Sairam, R.K. (2009). High temperatures tresstolerance in wheat genotypes: role of antioxidant defense enzymes. *Acta Agron Hungar,* 57: 1–14

Almeselmani, M., Teixeira da Silva, J.A. and Deshmukh, P. (2011). Stability of different physiological characters, yield and yield components under high temperature stress in tolerant and susceptible wheat genotypes. *Fruit, Vegetable and Cereal Science and Biotechnology*, 5(2): 86-92.

Anonymous (2020). United states department of agriculture and foreign agricultural service. Circular series world agricultural production. Pp. 9-18.

Behera, A.K. (1994). Response of wheat (*Triticum aestivam* L.) varieties to sowing dates. *Indian Journal of Agronomy*, 39(1): 171-173.

Braun, H. J., Atlin, G., and Payne, T. (2010). Multi-location testing as a tool to identify plant response to global climate change. *Climate change and crop production*, 1: 115-138.

Caviglia, O.P. and Sadras, V.O. (2001). Effect of nitrogen supply on crop conductance, water-and radiation-use efficiency of wheat. *Field Crops Research*, 69(3): 259-266.

Chowdhury and Wardlaw (1978). The effect of temperature on kernel development in cereals. *Australian Journal of Agricultural Research,* 29: 205-223.

Darwinkel, A. (1978). Pafterns of tillering and grain production of winter wheat at a wide range of plant densities. *Neth.J.Agric.Sci*., 26: 383-398.

Donaldson, E., Schillinger, W.F. and Dofing, S.M. (2001). Straw production and grain yield relationship in winter wheat. *CropScience*, 41: 100-106.

Field, C.B. and Barros, V.R. (Eds.). (2014). *Climate change 2014–Impacts, adaptation and vulnerability: Regional aspects*. Cambridge University Press.

Foley, J.A., Ramankutty, N., Brauman, K.A., Cassidy, E.S., Gerber, J.S., Johnston, M. and Zaks, D.P. (2011). Solutions for a cultivated planet. *Nature*, 478(7369): 337-342

Jat, L.K., Singh, S.K., Latare, A.M., Singh, R.S. and Patel, C.B. (2013). Effect of date of sowing and fertilizer on growth and yield of wheat in an inceptisol of varanasi. *Indian Journal of Agronomy,* 58(4): 611-614.

Joshi, N.L. and Kar, A. (2009). Contingency crop planning for dry land area in relation to climate change. *Indian J Agron,* 54(2): 237-152.

Kamal, A.H.M., Kim, K.H., Shin, K.H., Choi, J.S., Baik, B.K., Tsujimoto, H. and Woo, S.H. (2010). Abiotic stress responsive proteins of wheat grain determined using proteomics technique. *Australian Journal of Crop Science*, 4(3): 196-208.

Khan, N.A. (2000). Simulation of wheat growth and yield under variable sowing date and seeding rate (Doctoral dissertation, M.Sc. Thesis, Department of Agronomy, University Agriculture, Faisalabad).

Kumar, R. and Sharma, S.N. (2003) Effect of levels of nitrogen on wheat as influenced by date of sowing. *Annals of Agricultural Research*, 24(1): 104-110.

Mamrutha, H.M., Rinki, K., Venkatesh, K., Gopalareddy, K., Khan, H., Mishra, C.N. and Singh, G.P. (2020). Impact of high night temperature stress on different growth stages of wheat. *Plant Physiology Reports*, 25(4): 707-715.

Matuz, J. and Aziz, J.S. (1990). The effect of sowing season on Iraqi and Hungarian wheat varieties. *Cereal Research Communication*, 18(1-2): 41-43.

Ortiz, R., Sayre, K.D., Govaerts, B., Gupta, R., Subbarao, G.V. Ban, T. and Reynolds, M. (2008). Climate change: can wheat beat the heat. *Agriculture, Ecosystems and Environment*, 126(1-2): 46-58.

Ortiz-Monasterio, J.I.R., Dhillonb, S.S. and Fischer, R.A. (1994). Date of sowing effects on grain yield and yield components of irrigated spring wheat cultivars and relationships with radiation and temperature in Ludhiana, India. *Field Crops Res*., 37: 169-184.

Pandey, G.C., Mamrutha, H.M., Tiwari, R., Sareen, S., Bhatia, S., Siwach, P., and Sharma, I. (2015). Physiological traits associated with heat tolerance in bread wheat (*Triticum aestivum* L.). *Physiology and Molecular Biology of Plants*, 21(1): 93-99.

Porter, J.R. and Gawith, M. (1999). Temperatures and the growth and development of wheat: a review. *European Journal of Agronomy*, 10(1): 23-36.

Praveen, K.M., Mehera, B., Madhu, B.M. and Amith, G. (2018). Effect of different dates of sowing on growth and yield attributes of different cultivars of wheat (*Triticum aestivum* L.) under Allahabad condition. *Journal of Pharmacognosy and Phytochemistry*, 7(5): 3443-3446.

Saxena, D.C., Prasad, S.S., Parashar, R. and Rathi, I. (2016). Phenotypic characterization of specific adaptive physiological traits for heat tolerance in wheat. *Indian Journal of PlantPhysiology,* 21(3):318-322.

Shahzad, K., Bakht, J., Shah, W.A., Shafi, M. and Jabeen, N. (2002). Yield and yield components of various wheat cultivars as affected by different sowing dates. *Asian Journal of Plant Science*, 1(5): 522-525.

Shahzad, M.A., Wasi-ud-Din, Sahi, S.T., Khan, M.M., Ehsanullah and Ahmad, M. (2007). Effect of sowing dates and seed treatment on grain yield and quality of wheat. *Pakistan Journal of Agricultural Science*, 44(4): 581-583.

Simons, R.G. and Hunt, L.A. (1983). Ear and tiller number in relation to yield in a wide range of genotypes of winter wheat. *Z. Pflanzenzhuchtg*, 90: 249-258.

Singh, T. and Dhaliwal, G.S. (2000). Performance of wheat varieties under late sowing conditions in south western region of Punjab. *J. Res. Pb. Agri. Univ*., 37(3-4): 181-183.

Spink, J.H., Semere, T., Sparkes, D.L., Whaley, J.M., Foulkers, M.J., Clare, R.W. and Scott, R.K. (2000). Effect of sowing date on plant density of winter wheat. *Ann. App.Biol*., 137: 179-188.

Spink, J.H., Kirby, E.J.M., Forest, D.L., Sylvester-Bradley, R., Scott, R.K., Fouke's, M.J., Clare, R.W. and Evans, E.J. (2000). Agronomic implications of variation in wheat development due to variety, sowing, site and season. *Plant, Variety and Seed*, 13: 91-105.

Stone, P.J. and Nicolas, M.E. (1995). A survey of the effects of high temperature during grain filling on yield and quality of 75 wheat cultivars. *Australian Journal of Agricultural Research*, 46(3): 475-492.

Tripathi, A., Tripathi, D.K., Chauhan, D.K., Kumar, N. and Singh, G.S. (2016). Paradigms of climate change impacts on some major food sources of the world: a review on current knowledge and future prospects. *Agriculture, Ecosystems and Environment*, 216: 356-373.

Ugarte, C., Calderini, D.F., and Slafer, G.A. (2007). Grain weight and grain number responsiveness to pre-anthesis temperature in wheat, barley and triticale. *Field Crops Research*, 100(2-3): 240-248.

Verma, L., Singh, A. K., Singh, S., Tiwari, D., Zaidi, S. T., Yadav, R. K., ... & Singh, A. K. (2023). Temperature Stress its Impact on Yield of Various Wheat Varities at Different Groth Stages. *National Academy Science Letters*, 1-7.