Original Research Article

Evaluation of wheat varieties for terminal heat stress under normal and high temperature

Abstract:

Climate change and global warming have increasingly become relevant factors in recent years in determining the success of wheat production under heat stress condition. Throughout its growth period wheat crop requires varying degrees of temperature to achieve ideal growth. Any variation from the required temperature i.e. a non-uniform temperature adversely affects a plants growth, physique, morphology and yield according to the time, crop development stage and severity of the stress encountered. Many places where wheat is grown have high temperatures at the time of grain filling which is a major constraint on yield potential. A field experiment was conducted during the rabi season o 2020-21 at Student's Instructional Farm of Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh to evaluate the performance of wheat varieties under heat stress. The treatment for the experiment consisted of sowing at three different dates i.e. D_1 (30^{th} November), D_2 (15^{th} December), D_3 (30^{th} December). It was observed that time of sowing decreased substantially almost all the yield components measured viz; number of ear bearing tillers per plant, number of grains per ear, ear length (cm), grain yield per plant (g), biological yield per plant (g), which caused severe reduction of yield in V_1 (PBW-343) and V_2 (HD-2967). This reduction was caused due to onset of high temperature during crop growth and particularly grain filling. Variety V_3 (Halna) reduced the detrimental effect of heat stress by improving physiological traits which ultimately helped in obtaining higher yield.

Keywords: wheat, heat stress, tillers, ear number, grain yield, biological yield

Introduction

Wheat (*Triticum aestivum* L.) is one of the major cereal crops on which one third of the world population relies for its staple diet after rice. In India it is the second most cultivated crop. India is the second largest producer of wheat with around 31.45 million-hectare area under the crop giving 107.59 million tonnes production and 3421 kg/ha productivity (Agriculture statistics at a Glance, 2020). Wheat kernel consist of four main parts; seed coat (10% of the kernel weight), aleurone layer (6%), starchy middle i.e. the endosperm (81%), and germ (3%). Consumption of wheat is popular throughout the world due to its unique viscoelastic and adhesive properties of gluten protein. This property facilitates the production of processed foods. Various wheat products commonly used in daily life are whole wheat flour rich in vitamin A and B, maida (white flour) has less vitamin B and protein content, rawa (fine semolina), suji (course semolina), noodles, vermicelli and other products.

Climate change and geological stress can be attributed to high temperatures, droughts, salinity, waterlogging, and mineral toxicity on agricultural productivity due to rise in global temperatures. Heat stress can be defined as the rise in temperature for a period and beyond the point that results in an irreversible damage to the plant growth and development (Bita and Gerats, 2013). Heat stress caused by high temperatures is when the air temperature rises above threshold level for an extended period causing injury to crop plants or irreversible damage (Teixeira *et al*., 2013). Production of wheat has been curtailed by a number of factors, the major one being increased temperatures which effect production and reduces nutritional value of wheat. More than 7 million hectares of wheat grown in around 50 countries are continuously harmed by the effect of high temperatures (Wahid *et al*., 2007). Plants show decreased nutrient uptake and photosynthetic efficiency at temperature above the ideal and length of time for organ growth (leaf, tiller, spike) shortens in various stages of wheat crop development. Many places where wheat is grown have high temperatures at the time of grain filling period, which is a major constraint on yield potential. Heat stress considerably decreases the number of leaves, the area of leaves and wheat grows vegetatively for a longer time. It has also been shown that heat stress during wheat reproductive growth is detrimental to chloroplast activity, minimizing the activity of wheat's source organs and reducing its sink capacity. This results in lower production and leaf senescence, resulting in reduction of green leaf area during the reproductive process. Wheat yield loss is caused in part by the rapid leaf senescence resulting in fewer productive tillers on plant. Wheat growth and development are affected by temperatures above 32 which is considered as a major obstacle to grain weight and yield during grain filling stage, decreasing yield by 3-5 percent for every 1 rise in temperature above 15 (Wollenweber et al., 2003). A terminal heat stress, which delays maturity and substantially reduces grain size, weight, and production, occur at anthesis stage and during grain filling stage (Kamal et al., 2013). Thus keeping in mind the detrimental effect of high temperature on the yield components and yield potential of wheat crop it is important to develop varieties which can withstand this effect without the yield being compromised. The present study was conducted keeping in view the effect of elevated temperature on wheat to screen wheat variety that can perform better even under terminal heat stress.

Materials and Methods

The field study was conducted at Student's Instructional Farm of Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh during the rabi season of 2020-21. Geographically the experimental site is situated 42km away from Ayodhya on Ayodhya- Raibarielly road between latitude of 24.4° to 26.56° north and longitude of 82.12° to 83.98° east on an elevation of 113 meters in the gangetic alluvium of eastern Uttar Pradesh. The experiment was conducted in field containing silt loam soil with three varieties PBW-343, HD-2967 and Halna. The whole experiment was planned under split plot design with three replications along with three treatments. The treatment given were namely; D_1 (30^{th} November), D_2 (15^{th} December), D_3 (30^{th} December). Tillers were recorded at maximum tillering stage and effective tillers were observed at physiological maturity of different wheat varieties. Yield attributes 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 were observed after harvesting. Harvest index was calculated using formula: Harvest Index (%) = (Economic Yield/Biological Yield) * 100. 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 regarding number of tillers per plant, dry matter of plant and Relative Water Content as effected by different time of sowing was recorded at 60, 75, 90 DAS and is represented in Table 1. In general, it was observed that at D_1 (30th Nov) maximum number of tillers per plant, dry matter of plant and RWC was obtained in V_2 (HD-2967). At D_2 (15th Dec) maximum number of tillers per plant, dry matter of plant and RWC was obtained in V_2 (HD-2967) and at D_3 (30th Dec) maximum number of tillers per plant, dry matter of plant and RWC was obtained in V_3 (Halna). Minimum number of tillers per plant, dry matter of plant and RWC was obtained in V_3 at D_1 and D_2. It was observed that late variety V_3 (Halna) when sown early i.e. D_1 showed a significant decrease in number of tillers while when early variety V_1 (PBW-343) and V_2 (HD-2967) were sown late then also number of tillers significantly decreased due to onset of unfavorable environmental conditions for crop. The data also showed significant variation with regard to dry matter per plant. Varieties sown early i.e. D_1 showed significantly high dry matter per plant as compared to D_2 and D_3. It was evident from the data that date of sowing D_1(30th Nov) reduced the RWC of late variety V_3 (Halna) as compared to V_1 and V_2 at all stages of observation. Similarly, late sowing i.e. D_3(30th Dec) caused reduction in RWC of varieties V_1 (PBW-343) and V_2 (HD-2967) at all stages of observation compared to V_3.

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

	Number of tillers per plant								
Treatments	60DAS			75 DAS			90DAS		
	V_1	V_2	V_3	V_1	V_2	V_3	V_1	V_2	V_3
D_1	4.5	4.7	3.4	5.5	5.7	4.3	4.4	4.7	3.5
D_2	4.4	4.5	3.9	5.4	5.6	4.4	4.4	4.6	3.6
D_3	4.5	4.7	3.9	4.4	4.3	5.3	3.4	3.5	4.4
	S.Em±	CD at 5%		S.Em±	CD at 5%		S.Em±	CD at 5%	
Variety	0.13	0.39		0.07	0.21		0.05	0.16	
Treatment	0.05	0.20		0.05	0.20		0.05	0.20	
V*T	0.12	0.36		0.12	0.36		0.09	0.27	

	Dry weight per plant (g)								
Treatments	60DAS			75 DAS			90DAS		
	V_1	V_2	V_3	V_1	V_2	V_3	V_1	V_2	V_3
D_1	23.9	25.7	21.9	27.5	28.9	24.1	33.2	34.1	30.5
D_2	23.3	24.3	22.7	27.0	28.1	25.4	32.3	33.1	32.6
D_3	21.7	22.5	23.9	24.0	25.2	27.2	29.3	30.8	34.1
	S.Em±	CD at 5%		S.Em±	CD at 5%		S.Em±	CD at 5%	
Variety	0.71	2.18		0.47	1.43		0.43	1.31	
Treatment	0.47	1.85		0.35	1.36		0.67	2.65	
V*T	1.22	3.77		0.81	2.49		0.74	2.28	

	Relative Water Content (%)								
Treatments	60DAS			75 DAS			90DAS		
	V_1	V_2	V_3	V_1	V_2	V_3	V_1	V_2	V_3
D_1	77.1	78.8	70.5	74.1	75.7	68.5	71.1	72.7	66.1
D_2	76.9	77.8	71.0	74.0	74.8	69.0	70.6	71.4	66.4
D_3	71.4	71.9	76.2	69.3	69.3	73.2	67.2	68.1	70.2
	S.Em±	CD at 5%		S.Em±	CD at 5%		S.Em±	CD at 5%	
Variety	0.84	2.58		0.83	2.55		0.84	2.58	
Treatment	0.52	2.06		0.50	1.98		0.43	1.69	
V*T	1.45	4.48		1.43	4.41		1.45	4.47	

Components of yield

Effect of different time of sowing on the three main components of yield ear length, ear bearing tillers per plant and number of grains per ear was observed and is represented in table 2. It was observed that at D_1(30th Nov) and D_2(15th Dec) maximum ear length, number of ear bearing tillers per plant and number of grains per ear was observed in V_2 and at D_3 (30th Dec) maximum ear length, number of ear bearing tillers per plant and number of grains per ear was observed in V_3. Minimum ear length, number of ear bearing tillers per plant and number of grains per ear was observed in V_3 irrespective of their time of sowing. Data pertaining to ear length indicated that delayed sowing of early variety V_1 (PBW-343) and V_2 (HD-2967) significantly reduced the ear length with a maximum reduction of 10.12% recorded for V_2 also it is observed that ear length was increased in V_3 (Halna) at D_3 (late sown) as compared to D_1 and D_2 by about 9.25 percent. In case of number of ear bearing tillers per plant it was evident from pooled data that early sowing i.e. D_1 (30th Nov) and D_2 (15th Dec) reduced significantly ear bearing tillers of late variety V_3 (Halna) as compared to late sown i.e. D_3(30th Dec). It was also evident from the data that early sowing i.e. D_1 (30TH Nov) and D_2 (15th Dec) scaled down the grain number per ear of the late variety V_3 (Halna) as compared to D_3.

Table 2: 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	9.24	9.38	8.24	4.80	5.04	3.99	41.05	41.72	35.39
D_2	9.04	9.16	8.63	4.64	4.72	4.08	40.69	41.51	36.11
D_3	8.32	8.43	9.08	4.14	4.22	4.54	35.38	36.16	40.29
	S.Em±	CD at 5%		S.Em±	CD at 5%		S.Em±	CD at 5%	
Variety	0.16	0.50		0.13	0.41		0.36	1.11	
Treatment	0.14	0.53		0.13	050		0.26	1.00	
V*T	0.28	0.87		0.23	0.70		0.62	1.93	

Yield

Effect of different time of sowing on grain yield per plant, biological yield per plant and test weight was observed and is represented in table 3. It was observed that at D_1(30th Nov) and D_2(15th Dec) maximum grain yield per plant, biological yield per plant and test weight was observed in V_2 and at D_3 (30th Dec) maximum grain yield per plant, biological yield per plant and test weight was observed in V_3. Minimum grain yield per plant, biological yield per plant and test weight was observed in V_3 for D_1 and D_2. Data pertaining to grain yield indicted that delayed sowing of early variety V_1 (PBW-343) and V_2 (HD-2967) significantly reduced the grain yield. In case of biological yield, it was evident from pooled data that time of sowing significantly affected the biological yield per plant of all the varieties. It was also evident from the data that delayed sowing of early varieties V_1 (PBW-343) and V_2 (HD-2967) significantly scaled down the test weight however maximum reduction in test weight was observed for late sown variety V_3 (Halna) under early sowing condition i.e. D_1 (30th Nov).

Table 3: Effect of different time of sowing on grain yield per plant, biological yield per plant and test weight on different wheat varieties

	Grain yield per plant (g)			Biological yield per plant (g)			Test weight (g)		
Treatments									
	V_1	V_2	V_3	V_1	V_2	V_3	V_1	V_2	V_3
D_1	12.81	14.52	10.38	18.74	20.88	17.54	41.44	41.84	38.42
D_2	12.46	14.06	10.92	18.67	20.53	17.81	39.08	39.58	38.51
D_3	10.72	10.96	11.56	17.61	17.93	19.68	36.47	36.74	40.21
	S.Em±	CD at 5%		S.Em±	CD at 5%		S.Em±	CD at 5%	
Variety	0.33	1.03		0.31	0.97		0.25	0.77	
Treatment	0.23	0.90		0.29	1.15		0.32	1.24	
V*T	0.58	1.78		0.55	1.68		0.43	1.34	

Discussion and Conclusion

The present study indicated that heat stress is one of the major abiotic stresses impairing the growth of wheat crop at any developmental stage (Viswanathan and Khanna-Chopra, 2001, Hennessy *et al*., 2008, Farooq *et al*., 2011). Heat stress severely effects the grain filling due to a marked reduction in flag leaf and ear photosynthesis at high temperatures (Blum *et al*., 1994). Several studies reporting variation in the tolerance to high-temperature stress among genotypes of wheat have been conducted (Al-Khatib and Paulsen 1984, Wardlaw *et al*., 1989, Tahir and Nakata, 2005) indicating that heat-susceptible wheat genotypes show reduced photosynthesis and premature senescence under heat stress during reproductive development. This leads to reduced yields due to pollen sterility and seed abortion, and subsequently lowers seed weight, grain yield and dough quality.

In the present study it was observed that when late sown variety i.e. V_3 (Halna) was sown early D_1(30th Nov) it showed a significant decrease in the number of tillers similarly when the early varieties V_1 (PBW-343) and V_2 (HD-2967) were sown late tiller number was reduced and this was due to onset of unfavorable environmental conditions. A similar result of tillering was observed by Donaldson *et al.*, (2001). Time of sowing also significantly reduced the Relative Water Content (RWC) and dry matter content of the plants with Halna showing the most depression under early sowing condition as it is a late sown variety. These observations are supported by the work of Ahmad *et al.*, (2010) and Shahzad *et al*., (2007).

Grain yield being a multifactorial trait is determined by several components like tillers per plant, ear length, ear bearing tillers per plant and number of grains per ear, biological yield, 1000 grain weight of plant (test weight). Delay in sowing of wheat than normal date of sowing decreased substantially almost all the yield components and thereby yield in turn. Reduction percentage was more in case of PBW-343 and HD-2967 compared to Halna due to it performing better under high temperature conditions. Data pertaining to ear length indicated that delayed sowing of early varieties V_1 (PBW-343) and V_2 (HD-2967) significantly reduced the ear length with a maximum reduction of 10.12% for V_2. However, an increase in ear length 9.25% was observed for late variety Halna under late sown condition D_3 when compared to D_1 and D_2. These findings were in accordance to the work conducted by Praveen *et al.* (2018). The ear length was significantly reduced by date of sowing due to unfavorable environmental conditions like high temperature along with wind velocity and low water content at crop growth stage. The current study also suggested that early sowing i.e. D_1(30th Nov) and D_2 (15th Dec) reduced the number of ear bearing tillers plant^{-1} of late variety Halna. However, perusal of data revealed that late planting of early varieties V_1 (PBW-343) and V_2 (HD-2967) resulted in smaller number of ear bearing tillers plant^{-1}. These results are in agreement with those of Simons and Hunt (1983). The results thus suggested that a high number of tillers in late April and early May is important for high yields. It was also concluded that the number of fall produced tillers was important in determining yields. When tillering occurs mainly in spring, spike numbers are restricted by low tiller production and greater tiller death (Thill *et al.* 1978; Musick and Duesk, 1980).

It is also evident from the study that less number of grains per ear at late sowing of 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). The early sowing resulted in better development of grains due to longer growing period available. The data also clearly indicates that the three dates of sowing D_1 (30th Nov), D_2 (15th Dec), D_3 (30th Dec) significantly affect the grain yield plant^{-1} and biological yield plant^{-1} of all the varieties V_1 (PBW-343), V_2 (HD-2967) and V_3 (Halna). Lower grain yield at early sowing of V3 was mainly due to smaller number of tillers and smaller number of grains per spike. Decrease in biological yield under high temperature stress has been advocated by Singh *et al*. (2001 and 2007). Grain yield is the product of number of grains per plant, ear length, individual grain weight and biological yield and hence a reduction in all these components under late sowing condition accounted for greater decrease in grain yield. The crop sown early showed highest biological yield as compared to late sown in case of V_1 and V_2, while V_3 (late sown variety) showed minimum biological yield at early sowing as compared to late sown condition. This result is in line with Jat *et al*. (2013). Time of sowing significantly suppressed the test weight of all varieties. Delayed sowing of early varieties V_1 (PBW-343) and V_2 (HD-2967) significantly reduced the test weight with a maximum reduction of 12.18% recorded for V_2 at D_3 (30th Dec). this result is in accordance with the findings of Akhtar *et al*. (2006). This is because delayed sowing shortens the duration of developmental stages thereby ultimately reducing grain filling period resulting in lower grain weight (Spink *et al*., 2000). Smith and Humphreys (2001) reported that at high temperature the duration of grain filling period is reduced with a net effect of low kernel weight. High temperature coupled with desiccating winds during the month of March-April leads to forced maturity late sown wheat and results in reduction of test weight (Singh and Dhaliwal, 2000).

The present investigation makes it explicit that growth and phenological parameters like tillers per plant, dry weight per plant and Relative Water Content (RWC) of V_1 (PBW-343), V_2 (HD-2967) and V_3 (Halna) was found maximum in D_1, D_1 and D_3, respectively at 60, 75 and 90 days after sowing. Yield and yield contributing factors like ear bearing tillers per plant, number off grains per plant, ear length, grain yield per plant, biological yield per plant and test weight for V_1 (PBW-343), V_2 (HD-2967) and V_3 (Halna) was found maximum in D_1, D_1 and D_3, respectively. Maximum grain yield was recorded from crop sown on D_1 (30th Nov) and this is because yield attributes were adversely affected by delayed sowing which led to forced maturity due to high temperature. V_3 (Halna) is not affected by delayed sowing because Halna is a heat tolerant variety and thus is less affected by delayed sowing and thereby heat stress on the other hand V_1 (PBW-343) and V_2 (HD-2967) being timely sown varieties showed a substantial decrease in the yield due to heat stress attributed to delayed sowing.

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