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Research Article

Effect of Heat Stress on Yield and Quality Parameters in Different Wheat Species

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ABSTRACT

A field experiment was conducted during rabi season of 2011-12 at Main Agricultural Research Station, University of Agricultural Sciences, Dharwad to evaluate the effect of heat stress on growth, physiology and productivity in different wheat species under normal irrigated conditions. The experiment consisted of 12 genotypes (UAS-320, NIAW-1415, NIAW-34, HI-1571, DWR-1006, UAS-415, UAS-428, UAS-439, DDK-1025, DDK-1029, MACS-2971 and HW-1098) belonging to cultivated species viz. Triticum aestivum, Triticum durum and Triticum dicoccum and were laid out in a factorial randomized block design with three replications. The different temperature regimes were maintained by manipulating the date of sowing. Significant differences were observed in Yield parameters like grain yield, harvest index, 1000 Grain weight, No. of spikes, Spike length and Spike weight and quality parameters like protein and β-carotene with different temperature regimes. Among the treatments, low temperature regime exhibited superiority over high temperature regime, while giving a better response to most of the yield contributing characters the grain yield per hectare was low in HI-1571 and NIAW-34, the reduction due to high temperature was very low in these genotypes thus indicating the high temperature tolerance. Among the genotypes, the maximum reduction in the yield was recorded in UAS-439 and UAS-428. The genotype UAS-439 and UAS-415 while maintaining the high yield under low and high temperature regime, its reduction due to high temperature was mainly attributed to the significant reduction in the 1000-grain weight, spike length, spike weight and number of spikes, thus indicating their use in breeding the wheat genotypes for tolerance to heat stress.

Keywords: *Triticum aestivum, Yield, Temperature, Spike.*

INTRODUCTION

Wheat (*Triticum* spp.) is one of the most important cereal crops of the world. Wheat is a winter season crop grown in the tropics and subtropics despite the relatively high temperature that occur during the growth cycle. Heat stress is an important constraint to wheat productivity affecting growth stages specially anthesis and grain filling.

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It has already been established that heat stress can be a significant factor in reducing the yield and quality of wheat and is a major challenge to wheat productivity in India (Joshi et al., 2007).

MATERIALS AND METHODS

A field experiment was conducted to evaluate the effect of heat stress on morpho-physiological and growth parameters in different wheat species under normal irrigated conditions. The experiment consisted of 12 genotypes belonging to the cultivated species; *Triticum aestivum*, *Triticum durum* and *Triticum dicoccum* and were arranged in a factorial randomized block design (FRBD) with three replications. The low temperature regimes was maintained by early or normal sowing and high temperature regime was maintained by late sowing and also daily maximum and minimum temperature recorded under both the temperature regimes of crop growth. The Yield parameters like grain yield, harvest index, 1000 Grain weight, No. of spikes, Spike length and Spike weight and quality parameters like protein and β-carotene were studied.

RESULTS AND DISCUSSION

The data on the grain yield (Table 1) indicated that it was significantly influenced by temperature regimes, genotypes and their interaction. In general, there was reduction in grain yield due to high growth temperature. Among the genotypes, UAS-439 (5566.79 kg ha^{-1}) recorded significantly higher grain yield and HI-1571 (4125.08 kg ha^{-1}) recorded the lowest yield under low temperature regime. The genotype, NIAW-1415 had the lowest per cent reduction in grain yield (9.4%) followed by HW-1098 (9.8%) and DDK-1029 (9.9%). Among the genotypes, UAS-439 had significantly higher HI (54.13%) and HI-1571 (38.53%) had lowest HI under low temperature regime. Acevedo et al. (1990) reported that heat stress during anthesis to maturity affects mainly assimilate availability, translocation of photosynthates to grain and the synthesis and deposition of starch in the developing grain. The lowest weight was recorded in HI-1571 under both temperature regimes. The reduction in the total grain weight due to elevated growth temperatures was mainly attributed to a reduction in individual grain weight and a small reduction in grain number (Bhullar & Jenner, 1983).

It was observed from the data that the reduction in grain yield was minimum in NIAW-1415 (9.4%) followed by HW-1098 (9.8%) and DDK-1025 (9.9%) under high temperature regime, though the yielding ability under favorable temperature (low temperature regime) was low in NIAW-34 and HI-1571. The maximum reduction in grain yield due to high temperature regimes was observed in UAS-439 (20.7%) and UAS-428 (17.0%) followed by UAS-415 (16.3%) and NIAW-34 (14.5%). The studies of Wardlaw et al. (1980) and Wiegand and Cuellar (1981) showed that over the range of 12 to 26^{0}C increase in mean temperature. These results are in conformity with our findings.

The lower grain yield due to increase in growth temperature was attributed to decrease in 1000-grain weight and to spore length to some extent. Low grain weight is believed to result from the combined effects of the duration and rate of grain filling process. Decreased duration of grain filling would decrease the final grain weight unless offset by an increase in the rate of grain filling. It is supplemented by the dates of physiologic maturity in 107 days under high temperature regime as compared to 115 days under low temperature regime. Sofield et al. (1977) showed that an increase in the temperature from 15/10 to $21/16^{0}$C (day/night) would reduce the duration of kernel filling from 60 to 36 days. The duration in grain growth decreased further from 36 to 22 days with an increase in temperature form 21/16 to $30/25^{0}$C. It is quite possible that in some cases, the decrease in the duration of grain filling would be compensated by an increase in the grain growth rate. Friend et al. (1963) reported that an increase in temperature from 10 to 30^{0}C caused earlier floral initiation. This effect could result from either an increased rate of production of flower inducing substances or from an increased sensitivity of meristematic cells to a given level of flower inducing substance. The reduction in the total grain weight due to elevated growth temperatures was mainly attributed to a reduction in individual grain weight and a small reduction in grain number (Bhullar & Jenner, 1983).

The data on harvest index (HI) indicated a significant reduction due to high growth temperature in all the genotypes among the genotypes, the maximum reduction was observed in UAS-428, UAS-439 and UAS-415. However, the maximum HI under high temperature regime was recorded in UAS-439 and UAS-415. The reasons for the decrease in HI would be mainly because of the poor translocation of photosynthates from source to sink or may be because of the poor production of dry matter itself. Acevedo et al. (1990) reported that heat stress during anthesis to maturity affects mainly assimilate availability, translocation of photosynthates to grain and the synthesis and deposition of starch in the developing grain. The genotypic differences in harvest indices depict the relative efficiency of these genotypes in terms of the development of the phloem channels and the better source sink relationship.

There was significant reduction in (Table 2) spike weight due to high growth temperature in all the genotypes among the genotypes the maximum spike weight noticed in UAS-439, under both the temperature regimes, the minimum spike weight was recorded in HI-1571 under both the temperature regimes. The genotype, UAS-439 was significant with all genotype. There was a significant reduction in number of spikes due to high growth temperature in all the genotypes. Among the genotypes, the maximum number of spikes was noticed in UAS-439, UAS-415 and UAS-428 under both the temperature regimes. The minimum number of spikes was recorded in HI-1571 under high temperature regimes and NIAW-34 and HI-1571 under low temperature regimes. The genotypes which had maximum number of green leaves at the latter stages exhibited more number of spikelets per spike at harvest. These findings corroborate the results of Rawson (1970).

There was a significant reduction in spike length due to high growth temperature in all the genotypes. Among the genotypes, the maximum spike length was noticed in UAS-439 under both the temperature regimes. The minimum spike length was recorded in HI-1571 under both the temperature regimes. The maximum 1000-grain weight was recorded in UAS-439 in both the temperature regimes followed by UAS-415. Similar results were reported by Bhutta et al. (1981) and Khan et al. (1981) who stated that the spike length is closely related with grain yield. The 1000-grain weight was drastically reduced due to high growth temperature in all the genotypes. The lowest weight was recorded in HI-1571 under both temperature regimes.

The protein content (Table 3) was more at high temperature regime compared to low temperature regime. Among the genotypes DDK-1025 (14.52%) recorded significantly higher protein content over other genotypes under low temperature regimes. This was followed by UAS-415 (14.40%), DWR-1006 (13.97%), DDK-1029 (13.63%) and UAS-428 (13.35%). The lowest protein content was recorded in HI-1571 (12.18%) under low temperature regime. The maximum protein content under high temperature was observed in UAS-415 (14.20%) followed by DDK-1029 (13.58%), DDK-1025 (13.33%), UAS-428 (13.27%) and NIAW-1415 (12.97%). The lowest protein content under high temperature regime was observed in HI-1571 (11.93%). All the genotypes showed significant differences among themselves. The deposition of protein is determined by the level of substrate supply (Barlow et al., 1983). And the higher protein content may be governed by 1000 grain weight as there is increase in the grain weight there will be increase in amino acid content in the grain.

The β-carotene content (Table 3) decreased at high growth temperature as compared to low growth temperature in all the genotypes. Among the genotypes, NIAW-34

(5.52 ppm) had significantly higher β-carotene content over the other genotypes under low temperature regime. This was followed by UAS-428 (5.47 ppm), NIAW-1415 (5.19 ppm), UAS-439 (4.67 ppm) and DDK-1025 (4.64 ppm). The lowest β-carotene was recorded in DWR-1006 (3.85 ppm). Under high temperature regime also, UAS-428 (4.74 ppm) recorded significantly higher β-carotene content over other genotypes. This was followed by HI-1571 (4.57 ppm), NIAW-34 (4.50 ppm), UAS-439 (4.47 ppm) and DDK-1025 (4.46 ppm). The lowest β-carotene content was noticed in DWR-1006 (3.77 ppm).

Table 1: Influence of temperature regimes on grain yield (kg ha^{-1}) and harvest index (%) in wheat genotypes

Genotypes	Grain yield (kg ha^{-1})			Harvest index (%)		
	Temperature regimes					
	Low	High	Mean	Low	High	Mean
UAS-320	4700.00	4194.43 (10.8)*	4447.22	43.92	39.97	41.95
NIAW-1415	4505.55	4083.33 (9.4)	4294.44	41.66	39.70	40.68
NIAW-34	4416.68	3777.78 (14.5)	4022.22	41.42	36.73	39.08
HI-1571	4125.08	3627.76 (12.1)	3951.43	38.53	35.27	36.90
DWR-1006	4611.13	4119.45 (10.7)	4365.29	44.84	40.78	42.81
UAS-415	5277.76	4416.00 (16.3)	4846.88	51.32	42.94	47.13
UAS-428	5261.12	4366.00 (17.0)	4813.56	51.16	42.45	46.80
UAS-439	5566.79	4416.66 (20.7)	4991.72	54.13	42.95	48.54
DDK-1025	4716.66	4250.03 (9.9)	4483.35	45.86	41.33	43.59
DDK-1029	4855.55	4283.00 (11.8)	4569.27	47.21	41.65	44.43
MACS-2971	4921.55	4344.43 (11.7)	4632.99	47.85	42.24	45.05
HW-1098	4555.55	4111.12 (9.8)	4333.33	44.30	40.06	42.18
Mean	**4792.78**	**4165.83**		**46.02**	**40.51**	

	Grain yield S.Em.±	Grain yield C.D. at 5%	Harvest index S.Em.±	Harvest index C.D. at 5%
Temperature regimes	68.03	258.50	0.44	1.65
Genotypes	166.63	633.20	1.06	4.05
Interaction	235.65	895.48	1.51	5.72

Table 2: Influence of temperature regimes on spike length (cm), 1000 grain weight (gm), spike weight per spike (gm) and number of spikes per hill at different growth stages in wheat genotypes

Genotypes	1000 Grain weight			No. of spikes			Spike length			Spike weight		
	Temperature regimes											
	Low	High	Mean	Low	High	Mean	Low	High	Mean	Low	High	Mean
UAS-320	49.44	46.32	47.88	6.0	5.2	5.6	16.19	15.28	15.74	2.58	2.49	2.54
NIAW-1415	47.44	43.92	45.68	5.3	4.7	5.0	13.73	13.22	13.47	2.33	2.22	2.28
NIAW-34	47.39	43.83	45.61	5.0	4.6	4.8	13.21	12.77	12.99	2.19	2.09	2.14
HI-1571	47.04	43.20	45.12	5.0	4.1	4.6	12.80	12.13	12.47	2.14	1.91	2.03
DWR-1006	48.36	45.73	47.04	6.0	5.0	5.5	15.21	15.10	15.16	2.37	2.32	2.35
UAS-415	52.54	51.74	52.14	8.0	6.3	7.2	18.37	17.73	18.05	3.26	3.03	3.15
UAS-428	52.28	49.78	51.03	8.0	6.0	7.0	17.50	16.51	17.00	3.05	2.98	3.01
UAS-439	57.46	53.28	55.37	8.0	7.3	7.7	18.91	18.28	18.60	3.65	3.57	3.61
DDK-1025	49.86	46.82	48.34	6.5	5.4	6.0	16.37	15.48	15.93	2.61	2.51	2.56
DDK-1029	51.18	47.18	49.18	7.0	5.6	6.3	16.88	16.15	16.52	2.81	2.70	2.76
MACS-2971	51.35	48.50	49.93	7.1	5.8	6.5	17.40	16.31	16.85	3.05	2.83	2.94
HW-1098	48.21	45.51	46.86	6.0	4.8	5.4	14.53	13.53	14.03	2.36	2.29	2.33
Mean	**50.21**	**47.15**		**6.49**	**5.41**		**15.92**	**15.21**		**2.70**	**2.58**	

	1000 Grain weight S.Em.±	1000 Grain weight C.D. at 5%	No. of spikes S.Em.±	No. of spikes C.D. at 5%	Spike length S.Em.±	Spike length C.D. at 5%	Spike weight S.Em.±	Spike weight C.D. at 5%
Temperature regimes	0.27	1.02	0.09	0.35	0.21	0.81	0.04	0.15
Genotypes	0.66	2.50	0.22	0.85	0.52	1.99	0.10	0.37
Interaction	0.93	3.53	0.32	1.20	0.74	NS	0.138	NS

Table 3: Influence of temperature regimes on protein (%) and b-carotene (ppm) in wheat genotypes

Genotypes	Protein			β-carotene		
	Temperature regimes					
	Low	High	Mean	Low	High	Mean
UAS-320	12.30	12.64	12.47	4.50	4.23	4.37
NIAW-1415	12.97	13.19	13.08	5.19	4.24	4.72
NIAW-34	12.60	12.77	12.68	5.52	4.50	5.01
HI-1571	11.93	12.18	12.06	4.59	4.57	4.58
DWR-1006	13.27	13.97	13.62	3.85	3.77	3.81
UAS-415	14.20	14.40	14.30	4.38	4.23	4.31
UAS-428	13.27	13.35	13.31	5.47	4.74	5.10
UAS-439	12.37	12.39	12.38	4.67	4.47	4.57
DDK-1025	13.33	14.52	13.93	4.64	4.46	4.55
DDK-1029	13.58	13.63	13.61	4.38	4.35	4.36
MACS-2971	12.68	12.83	12.76	3.86	3.78	3.82
HW-1098	12.81	12.96	12.89	4.47	4.38	4.43
Mean	**12.94**	**13.24**		**4.63**	**4.31**	

	Protein S.Em.±	Protein C.D. at 5%	β-carotene S.Em.±	β-carotene C.D. at 5%
Temperature regimes	0.05	0.18	0.03	0.11
Genotypes	0.11	0.43	0.063	0.24
Interaction	0.16	0.61	0.089	0.34

CONCLUSION

Though, the grain yield per hectare was low in HI-1571 and NIAW-34, the reduction due to high temperature was very low in these genotypes thus indicating the high temperature tolerance. Among the genotypes, the maximum reduction in the yield was recorded in UAS-439 and UAS-428. The genotype UAS-439 and UAS-415 while maintaining the high yield under low and high temperature regime, its reduction due to high temperature was mainly attributed to the significant reduction in the 1000-grain weight, spike length, spike weight and number of spikes.

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