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Impact of elevated night temperature stress on phenological and physiological parameters in wheat (*Triticum aestivum* L.)

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Abstract
An experiment was conducted in the laboratory of the Department of Plant Physiology for two consecutive years to analyze the effect of elevated night temperature stress in wheat crop with respect to certain phenological and physiological parameters in wheat taking two genotypes viz. HUW-234 (relatively heat tolerant) and Sonalika (relatively heat susceptible). Significant differences were observed with respect to phenological parameters where days to 50% Earhead emergence, days to 50% anthesis and days to maturity was found to decrease in the plants kept under stressed condition (25 ^{0}C/ 24 ^{0}C day and night) than those kept under control (25 ^{0}C/15 ^{0}C day and night). Similar results were obtained with regard to physiological parameters such as dry weight at maturity, grain growth rate, grain filling duration and chlorophyll stability index. Overall the variety HUW-234 was statistically found to be more tolerant to night temperature stress than the variety Sonalika as evident from more percent reduction in Sonalika than those observed in HUW-234 due to high night temperature stress.

Keywords: Night temperature stress, days to 50% Anthesis, wheat, chlorophyll stability index

Introduction

Abiotic stresses are one of the main determinant and constraints for realizing optimal performance of wheat crop. Among these stresses, high night temperature stress is an important factor limiting reproductive growth and finally crop yield. Future climate scenarios suggest that global warming may be beneficial for the wheat crop in some regions, but could reduce productivity in zones where optimal temperatures already exist. For example, by 2050, as a result of possible climate shifts in the Indo-Gangetic Plains (IGPs)-currently part of the favorable, high potential, irrigated, low rainfall mega-environment, which accounts for 15% of global wheat production-as much as 51% of its area might be reclassified as a heat-stressed, irrigated, short-season production mega-environment. In addition, climate models foresee that there will be a relatively greater increase in night time temperatures as compared to daytime temperatures. Over the past century global daily minimum temperatures increased more than twice compared to increases in daily maximum temperatures (Easterling *et al*. 1997) [3]. Recent studies have shown that historical yields of rice (Peng *et al*. 2004) [8] and wheat (Lobell *et al*. 2007) [6] were strongly correlated with minimum (night time) temperatures, rather than daytime maximum temperatures. High temperatures of 30 to 40 °C are common in wheat-growing regions during the crop life cycle and it can decrease yields by 50% or more (Al khatib and Paulsen 1984, 1990) [1, 2]. Wheat crops are often exposed to high temperature stress during the reproductive stages of crop development in most wheat-growing regions of the world. High temperatures during reproductive development cause serious damage to wheat when they occur just before or during anthesis. Global mean surface air temperature has increased by 0.5 °C in the 20th century and is predicted to increase further by 1.5-4.5 °C by the end of 21st century (Intergovernmental Panel on Climate Change 2007) [5].

Thus keeping in mind the importance of high night temperature stress in defining wheat yield and physiology, an experiment was conducted to study its effect on certain phenological and physiological parameters.

Materials and Methods

Disease free and healthy seeds of two genotypes of Wheat, HUW-234 and Sonalika, were obtained from Department of Genetics and Plant Breeding, Institute of Agricultural Sciences, BHU, Varanasi. The research programme involved two experiments comprising of one Laboratory experiment in the Department of Plant Physiology and the other Pot experiment in the Poly house of Horticulture unit, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (India), during *rabi* (winter) season of years 2015-16 and 2016-17 in which the work done in the first year was replicated and validated in second year. The seeds were grown in 15 cm. diameter pots. The pots were maintained in growth chambers (3m x 3m) at optimum temperature (25 ^{0}C/15 ^{0}C day and night) till 60 DAE (days after emergence). After 60 DAE, plants were subjected to high night temperature stress (25 ^{0}C/24 ^{0}C). Statistical design followed was two factorial CRD.

Result and Discussion

There were significant differences observed in almost all the phenological and physiological parameters recorded. With regard to days to 50% Earhead emergence, there was 7.46 and 8.24% percent reduction over control under high night temperature regime in HUW-234 and Sonalika respectively in both the years but more percent reduction was observed in the variety Sonalika than in HUW-234 (Table 1.). The similar trends were reported by Ferris *et al.* 1998 [4]. Data pertaining to days to 50% anthesis showed similar trend i.e. more percent reduction in the variety Sonalika than in HUW-234 observed in both the years (Table 1.). There was 5.61 and 631% reduction in both the varieties under night temperature stress. For days to maturity, both the variety matured early under elevated night temperature in comparision to optimum temperature but among genotype, Sonalika matured more early than HUW-234 in both the growing season (Tables 1.). Similar findings were obtained by Stone *et al*. 1994 [11]. Under physiological parameters, dry weight at maturity decreased significantly under high night temperature regime in both the varieties in both the years with more percent reduction being observed in the variety Sonalika than in HUW-234 (Table 2.). There was 45.02 and 57.17% reduction in both the varieties over control. Similar trend was observed by Saini *et al.* 1983. Grain growth rate also decreased significantly under elevated night temperature with similar results obtained as the case with dry weight (Table 2.). There was 15.33% reduction in the variety Sonalika over control. This finding was justified by the work of Porter and Gawith, 1999 [9]. Grain filling duration was also reduced in response to night temperature stress with more reduction being observed in Sonalika than in HUW-234. Similar inferences were made by Wheeler *et al.* 1996 [12]. Chlorophyll stability index (CSI) parameter of the variety Sonalika was found to be more sensitive to high night temperature than of the variety Sonalika with more significant reduction observed at 75 DAE in both the years. There was 21.81% reduction in CSI in variety Sonalika under night temperature stress. (Table 3.)

Table 1: Impact of elevated night temperature on phenological parameters of two wheat varieties

Temperature Variety	Days to 50% Earhead Emergence			Days to 50% Anthesis			Days to Maturity		
	OT	**HNT**	**Mean**	**OT**	**HNT**	**Mean**	**OT**	**HNT**	**Mean**
HUW-234	80.33	74.33 (7.46)	77.30	89	84 (5.61)	86.50	115.00	107.7 (6.34)	111.3
Sonalika	89.70	82.30 (8.24)	86.00	95	89 (6.31)	92.00	124.00	110.00 (11.29)	117.00
Mean	85.00	78.33 (7.84)	81.66	92	86.50 (5.97)	89.25	119.50	108.83 (8.92)	114.16
Anova	S. em ±	LSD ≤0.05		S. em ±	LSD ≤0.05		S. em ±	LSD ≤0.05	
V	0.68	2.71		0.50	1.97		0.51	2.03	
T	0.68	2.71		0.50	1.97		0.51	2.03	
VXT	0.97	3.84		0.70	2.79		0.72	2.87	

Where OT-optimum temperature, HNT-High night temperature
Note- Figure in parenthesis indicate percent reduction from control i.e. OT.

Table 2: Impact of elevated night temperature on dry weight at maturity (g) and grain growth rate (mg per day) of two wheat varieties

Temperature Variety	Dry Weight at Maturity (g per plant)			Grain Growth Rate (mg per day)		
	OT	**HNT**	**Mean**	**OT**	**HNT**	**Mean**
HUW-234	13.26	7.29 (45.02)	10.27	1.50	1.27 (15.33)	1.37
Sonalika	12.33	5.28 (57.17)	8.80	1.24	1.23 (0.80)	1.23
Mean	12.80	6.30 (50.78)	9.54	1.35	1.25 (7.40)	1.30
ANOVA	S. em ±	LSD ≤0.05		S. em ±	LSD ≤0.05	
V	0.29	1.17		0.04	0.16	
T	0.29	1.17		0.04	0.16	
VXT	0.42	1.65		0.06	0.23	

Where OT-optimum temperature, HNT- High night temperature
Note-Figure in parenthesis indicate percent reduction from control i.e. OT.

Table 3: Impact of elevated night temperature on grain filling duration (days) and chlorophyll stability Index (at 75 DAE) of two wheat varieties

Temperature Variety	Grain Filling Duration (days)			Chlorophyll Stability Index		
	OT	**HNT**	**Mean**	**OT**	**HNT**	**Mean**
HUW-234	26	23.70 (8.84)	24.90	74.30	67.46 (9.20)	71.00
Sonalika	29	21.00 (27.58)	25.00	73.08	57.14 (21.81)	65.11
Mean	27.50	22.30 (18.90)	24.91	74.00	62.30 (15.81)	68.00
ANOVA	S. em ±	LSD ≤0.05		S. em ±	LSD ≤0.05	
V	0.72	2.83		0.37	1.49	
T	0.72	2.83		0.37	1.49	
VXT	1.01	4.01		0.46	2.10	

Where OT- optimum temperature, HNT- High night temperature
Note- Figure in parenthesis indicate percent reduction from control i.e. OT.

Conclusion

High night temperature stress is an important abiotic stress which hinder many physiological functions of the wheat crop resulting in poor crop stand, restricted reproductive growth and ultimately low yield of the crop. Reduction in the phenoloical parameters is an indication of the squeezing of wheat phenology which allows for forced maturity of the crop owing to less number of days available for reproductive growth thus directly effecting the yield. A marked reduction observed in physiological parameters such as dry weight at maturity, grain growth rate, grain filling duration and chlorophyll stability index reflects the susceptibility of the wheat crop to high night temperature regime which is an evident problem in recent climate change scenario. Among the varieties tested, HUW-234 was found to be more tolerant to elevated night temperature stress than the variety Sonalika. The parameters being measured and recorded in this experiment can also be used for screening large number of germplasm/cultivar for night temperature stress.

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