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Study On Effect Of Heat Stress During Grain Filling Stage On Seed Stress Enzymes In Bread Wheat

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ABSTRACT
Wheat (Triticum aestivum L.) is a widely adapted crop. It is grown from temperate, irrigated to dry and high-rain-fall areas and from warm, humid to dry, cold environments. Generally stress (moisture/heat) has deleterious effect on overall growth and development of crop. There is a scanty of study related to high stress during seed development and maturation on stress enzyme in wheat. The present investigation was carried out with the material comprised of six each heat tolerant and susceptible varieties which were sown on two date i.e. normal (20th November) and late sown (20th December). The observations were recorded at grain filling stage (heading to maturity). Heat tolerant varieties had performed better at different stages of seed development in comparison to susceptible. For normal as well as late sown heat tolerant varieties having more dehydrogenase, peroxidase, catalase and superoxide dismutase activity at all stages than heat susceptible. All stress enzyme activity was higher in late than normal sowing which was in concurrence with high temperature during seed development. Commonly varieties had performed better for all characters studied in normal than late sowing at all stages of seed development.
Key words: Heat stress, tolerant, susceptible, dehydrogenase, peroxidase, catalase and superoxide dismutase

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INTRODUCTION

Wheat (*Triticum aestivum* L.) is a widely adapted crop and is generally grown from temperate to subtropical countries in the world. The area expand to warm, humid to dry and cold environments. This wide adaptation have been possible due to the plant genome (2n=42, AABBDD), which is having three different sources in wild. This type of genome provides great plasticity to the crop. Wheat is a C3 plant and as such it thrives in cool environments. As temperature raises the plant experience heat stress, then quality and production both will reduce as plant does not have Kranz Anatomy to nullify this stress. Wheat is the second most important cereal crops of India. In India it is grown northern as well as central part. It is producing on the area of 29.65 mha with production 92.46 mt and productivity 3.118 t/ha (Anonymous, 2013).

Planting of high quality seed is a key component of all cropping systems in world. High seed quality is needed to ensure adequate plant populations, with reasonable seeding rates, in a range of field conditions. A lot of variation in seed quality has been attributed to differences in environmental conditions prevailing during the development and maturation of the seed while still on the mother plant (Datta *et al.,* 1972; Peacock and Hawkins 1970). Unfavourable environmental conditions (high temperature, difference between day and night temperatures, rainfall, relative humidity and sun shine) during seed development and maturation in the field can reduce seed quality.

The constantly rising ambient temperature is considered one of the most detrimental stresses among the components of environment. The global air temperature is predicted to rise by 0.2°C per decade, which

will lead to 1.8-4.0°C higher in temperature than the current level by 2100 (IPCC, 2007). This prediction is creating apprehension among scientists, as high temperature (HT) stress has known effects on the several life processes of organisms, acting directly or through the modification of surrounding environmental components. Plants cannot move to more favourable environments; consequently, plant growth and developmental processes are substantially affected by high HT stress (Lobell *et al.,* 2003, 2007). High temperature stress causes multifarious, and often adverse, alterations in plant growth, development, physiological processes, and yield (Hasanuzzaman *et al.,* 2012, 2013). One of the major consequences of HT stress is the excess generation of reactive oxygen species (ROS), which leads to oxidative stress (Hasanuzzaman *et al.,* 2012, 2013). Plants continuously struggle for survival under various environmental stress conditions including HT. A plant is able, to some extent, to tolerate heat stress by physical changes within the plant body and frequently by creating signals for changing metabolism. Plants alter their metabolism in various ways in response to HT, particularly by producing compatible solutes that are able to organize proteins and cellular structures, maintain cell turgor by osmotic adjustment, and modify the antioxidant system to re-establish the cellular redox balance and homeostasis (Valliyodan and Nguyen, 2006; Janska *et al.,* 2010)

Plant responses to HT vary with the degree of temperature, duration and plant type. At extreme HT, cellular damage or cell death may occur within minutes, which may lead to a catastrophic collapse of cellular organization (Ahuja *et al,* 2010). Heat stress affects all aspects of plant processes like germination, growth, development, reproduction and yield (Hasanuzzaman *et al.,* 2013; Mittler and Blumwald, 2010; Lobell *et al.,* 2011; McClung and Davis, 2010). Heat stress differentially affects the stability of various proteins, membranes, RNA species and cytoskeleton structures, and alters the efficiency of enzymatic reactions in the cell for which the major physiological processes obstacle and creates metabolic imbalance (Ruelland and Zachowski, 2010; Suzuki *et al*., 2011, 2012; Pagamas and Nawata, 2008).

Several reactive oxygen species (ROS) like superoxide radicals, hydroxyl radicals, and hydrogen peroxide are produced in the cells in a natural fashion, but overproduction of these compounds can be harmful (Esfandiari*et al.,* 2007). Heat stress triggers the production and accumulation of ROS (Sairam *et al.,* 2000; Almeselmani *et al.,* 2009). Hence their detoxification by antioxidant systems is important for protecting plants against heat stress (Asada, 2006; Suzuki and Mittler, 2006). The antioxidant defense system in plants involves both enzymatic and non-enzymatic antioxidant systems. The enzymatic antioxidant system includes ascorbate peroxidase, dehydroascorbatereductase, glutathione S-transferase, superoxide dismutase, catalase, guaiacol peroxidase, and glutathione reductase (Noctor and Foyer, 1998).

Superoxide dismutase converts $O_2^-$to hydrogen peroxide, whereas catalase and peroxidases breakdown hydrogen peroxide. Catalase eliminates hydrogen peroxide by catalyzing its decomposition to H_2O and O_2. ROS for guaiacol peroxidise–mediated reactions (Goyal and Asthir, 2010).Balla*et al.* (2009) demonstrated that upon exposure to heat stress, during the reproductive phase, activities of enzymatic antioxidants were substantially increased in heat-tolerant genotypes of wheat. The activities of catalase and superoxide dismutase have been correlated with heat stress (34/22◦C) during the reproductive phase (Zhao *et al.,* 2007), as well as the capacity to acquire thermo tolerance (Almeselmani*et al.,* 2009). The oxidative damage to cellular components is limited under normal growing conditions due to efficient processing of ROS through a well coordinated and rapidly responsive antioxidant system consisting of several enzymes and redox metabolites. However, under various abiotic stresses the extent of ROS production exceeds the antioxidant defence capability of the cell, resulting in cellular damages. Tolerance to high temperature stress in crop plants has been reported to be associated with an increase in antioxidant enzymes activity (Sairam *et al*., 2000; Rui *et al*., 1990; Gupta *et al*., 1993; Badiani *et al*., 1994; Zhau *et al*., 1995).

There is a scanty of study concerned to effect of high temperature stress during seed development and maturation on stress enzyme in wheat. Therefore present study was conducted to evaluate the effect of high temperature stress on wheat varieties in relation to stress enzyme activity.

The study entitled was carried out at C.C.S. Haryana Agricultural University, Hisar. Meteorological data on temperature (˚C), relative humidity (%) rainfall (mm) and sunshine (hour) during the reproductive phase at grain filling and development stages for both the years was recorded (table 1). Comparatively higher temperature was recorded at different stages under late than normal sowing condition.

Table1. Average value during a week of different climatic factors in normal and late sowing condition in both the year

WAA/ Sowing time	First Year													
	1.5		2.5		3.5		4.5		5.5		6.5		Mean	
	NS	*LS*	*NS*	*LS*	*NS*	*LS*	*NS*	*LS*	*NS*	*LS*	*NS*	*LS*	*NS*	*LS*
T (max) °C	29.26	28.29	28.63	28.69	28.69	31.24	31.24	34.66	34.66	35.57	35.57	35.93	**31.34**	**32.40**
T (min) °C	11.97	13.10	13.1	14.72	13.53	16.7	14.72	13.10	14.62	14.72	16.7	16.7	**14.11**	**15.13**
Diff °C	17.29	15.19	15.53	16.52	15.16	18.87	16.52	15.19	20.04	16.52	18.87	18.87	**17.24**	**17.27**
SS (hr)	8.30	8.40	9.10	8.30	7.20	9.10	8.30	8.40	9.70	8.30	9.10	9.10	**8.62**	**8.50**
RH (%)	92.00	96.00	97.00	78.00	89.00	69.00	78.00	96.00	75.00	78.00	69.00	69.00	**83.33**	**78.00**
	Second Year													
T (max) °C	24.70	28.75	25.90	28.70	28.70	28.20	28.20	31.40	31.40	32.50	32.50	34.04	**28.57**	**30.60**
T (min) °C	8.80	13.25	11.50	13.80	13.90	15.00	15.00	14.30	14.30	14.70	14.70	17.68	**13.03**	**14.79**
Diff °C	15.90	15.50	14.40	14.90	14.80	13.20	13.20	17.10	17.10	17.80	17.80	16.36	**15.53**	**15.81**
SS (hr)	10.00	9.65	8.30	7.80	7.20	6.70	6.70	9.90	9.90	9.80	9.80	9.00	**8.65**	**8.81**
RH (%)	89.50	93.00	91.80	88.20	86.90	84.40	84.40	79.20	79.20	88.30	88.30	68.60	**86.68**	**83.62**

The seed of twelve varieties i.e., six heat tolerant (WH 1080, WH 1021, WH 1100, PBW 373, PBW 590, Raj 3765) six susceptible (WH 147, WH 711, DBW 17, PBW 343, PBW 621, HD 2967) have been raised in the field with recommended cultural practices. In each year, the sowing was done at two times i.e. normal sowing (20-25 November) and late sowing (20-25 December). Each variety was raised in a plot size of 5x2m. The samples of each genotype were taken at an interval of one week from the field. The observations on dehydrogenase activity, peroxidase, catalase, and superoxide dismutase activity were recorded in the laboratory.

DHA test was performed as per Kittock and Law (1968). The activity of Dehydrogenase has been expressed as O D g^{-1} ml^{-1}. Peroxidase activity was determined by the method of Shannon *et al.* (1966), following the oxidation of O-dianisidine in the presence of hydrogen peroxide (H_2O_2). The activity of peroxidase has been expressed as change in absorbance per minute per gram of fresh weight (ΔA/min/g FW). The catalase activity was assayed by the method as described by Aebi (1983) with little modification based on the reduction of potassium dichromate to chromic acetate by hydrogen peroxide. The activity of catalase has been expressed as change in absorbance per minute per gram of fresh weight (ΔA/min/g FW). Superoxide dismutase was assayed by measuring its ability to inhibit the photochemical reduction of NBT according to Giannopolitis and Ries, 1977 with some modification. Log A560 was plotted as a function of volume of enzyme extract used in the reaction mixture. From the resultant graph, volume of enzyme extract corresponding to 50 percent inhibition of the photo chemical reaction was obtained and considered as one enzyme unit. The activity Superoxide dismutase has been expressed as change in absorbance per minute per gram of fresh weight (ΔA/min/g FW).

RESULT AND DISCUSSION

A considerable and significant increase in the activity of peroxidase at late sown was recorded in all heat tolerant and susceptible varieties, however, variety like Raj 3765, PBW 373 and WH 1080 among tolerant and among susceptible DBW 17 and PBW 343 showed greater increase in peroxidase activity than other, which indicate that these varieties have better scavenging capacity and higher tolerance to heat stress than others (table 2). The studies also observed that the content of peroxidase enzyme was higher in general for all heat tolerant than susceptible varieties under study. Asthir*et al*. (2009) reported higher peroxidase activity in heat tolerant as well as susceptible varieties under elevated temperature condition in wheat, however, heat tolerant shown higher activity than susceptible. Larkindale*et al*. (2005) also observed that heat tolerant genotypes show higher level and activity of antioxidant enzymes. Significance of peroxidase activity in temperature stress tolerance has also been reported by other workers (Chakraborty and Pradhan 2005; Almeselmani *et al*., 2006).

Table 2. Peroxidase activity (ΔA/min/g FW) and Catalase activity (ΔA/min/g FW) of different heat tolerant and susceptible varieties in normal and late sowing in both the year

	First Year				Second Year			
	POX		CAT		POX		CAT	
	NS	*LS*	*NS*	*LS*	*NS*	*LS*	*NS*	*LS*
Raj 3765	84.49	106.94	**38.08**	**39.97**	85.56	88.25	37.02	36.82
PBW590	88.40	108.40	34.13	35.70	84.16	89.13	32.45	31.26
WH 1080	**93.56**	**109.46**	28.11	29.55	**91.32**	**94.29**	31.32	27.06
PBW373	87.45	105.56	36.27	37.82	82.36	86.36	28.19	35.94
WH 1100	88.65	108.65	37.38	39.15	84.41	89.38	**37.94**	**37.15**
WH 1021	81.00	105.00	26.67	28.53	86.75	90.23	26.92	26.35
Mean	87.26	107.34	33.44	35.12	85.76	89.61	32.31	32.43
PBW343	78.34	101.25	27.70	29.39	80.53	**83.56**	28.29	27.45
PBW621	84.45	102.36	28.34	30.12	84.21	88.54	22.96	22.00
DBW17	79.95	103.95	26.50	26.95	**85.32**	**89.56**	26.08	25.23
WH147	82.64	102.85	**30.50**	**32.32**	78.36	84.56	**30.33**	**29.02**
HD2967	82.10	103.47	27.70	29.42	81.86	86.83	28.29	27.65
WH711	**85.56**	**105.39**	28.95	29.75	80.65	83.07	27.95	27.15
Mean	82.17	103.21	28.28	29.66	81.82	86.02	27.32	26.42
Value of t_{cal}	**2.48***	**4.41****	**2.49***	**2.56***	**2.40***	**2.32***	**2.37***	**2.67***

** Significant @ p=0.01; * Significant @ p=0.05

Catalase activity increased significantly at late sown condition and tolerant varieties Raj 3765 and WH 1100 and among susceptible PBW 343 and WH 147 showed greatestincrease at all stages of DAA (table 2). Catalase activity is also associated with the scavenging of H_2O_2 and an increase in its activity is related with increase in stress tolerance (Foyer *et al*., 1997; Upadhyaya*et al*., 1990; Olmos et al., 1994; Karus*et al*., 1995).

Table 3. Superoxide dismutase activity (ΔA/min/g FW) and Dehydrogenase activity (O D g^{-1} ml^{-1}) of different heat tolerant and susceptible varieties in normal and late sowing in both the year

	First Year				Second Year			
	SOD		DHA		SOD		DHA	
	NS	*LS*	*NS*	*LS*	*NS*	*LS*	*NS*	*LS*
Raj 3765	55.18	63.82	0.425	0.389	53.23	57.10	0.417	0.401
PBW590	55.50	60.36	0.412	0.395	55.05	57.50	0.404	0.395
WH 1080	**60.36**	**67.43**	0.405	0.387	**58.73**	**65.66**	0.397	0.386
PBW373	55.27	59.86	0.442	0.405	55.34	56.36	0.434	0.411
WH 1100	53.95	57.62	0.398	0.384	55.42	54.86	0.396	0.386
WH 1021	53.86	58.00	**0.458**	**0.412**	54.21	58.62	**0.462**	**0.420**
Mean	55.69	61.18	0.42	0.40	55.33	58.35	0.42	0.40
PBW343	53.18	**61.00**	0.381	0.362	50.00	53.86	0.401	0.376
PBW621	**55.81**	57.60	0.361	0.354	52.14	56.10	0.381	0.374
DBW17	53.26	55.82	0.372	0.351	**54.79**	54.35	0.392	0.379
WH147	45.78	50.36	0.365	0.344	44.52	51.83	0.385	0.375
HD2967	49.13	58.23	**0.389**	**0.363**	47.23	**56.12**	**0.409**	**0.383**
WH711	49.46	53.26	0.361	0.346	47.11	51.03	0.381	0.375
Mean	51.10	56.05	0.37	0.35	49.30	53.88	0.39	0.38
Value of t_{cal}	**2.58***	**2.35***	**4.93****	**3.34****	**3.52****	**2.52***	**NS**	**NS**

** Significant @ p=0.01; * Significant @ p=0.05

A significantly higher activity of SOD at late sown was recorded in all heat tolerant and susceptible variety, however, variety Raj 3765 and WH 1080 among tolerant whereas among susceptible DBW 17 and PBW 343 showed greater increase in SOD activity than others, which indicate that these varieties have better scavenging capacity and higher tolerance to heat stress than other varieties (table 3). Many workers (Upadhyaya*et al*., 1990; Jagtap and Bhargava, 1995; Davidson *et al*., 1996) have reported involvement of SOD in temperature stress tolerance.

The present study has shown the difference of dehydrogenase activity among heat tolerant and susceptible variety of wheat. It has also shown that there is difference in enzyme activity between normal and late sown condition. Generally enzyme activity is decreases with the rise in the ambient temperature. This study had also shown that dehydrogenase activity was lower in late sown condition than normal in both the year; however, difference was less due to low temperature difference between normal and late

sown temperature. The enzyme activity was recorded higher for variety PBW 373 and WH 1021 among heat tolerant and for that HD 2967 among susceptible varieties. Activity of dehydrogenase was as like other growth enzymes in plant.

There is significant mean difference between heat tolerant and susceptible varieties for normal sown and late sown for all enzymes under study. For normal as well as late sown heat tolerant varieties was having more peroxidase, catalase, superoxide dismutase activity and dehydrogenase, at all stages than heat susceptible. All stress enzyme activity was higher in late than normal sowing which was in concurrence with high temperature during seed development.

Vigour indices, dehydrogenase, peroxidase, catalase or superoxide dismutase can be used as a reliable predictor in variety development programme for heat tolerant other than yield.

REFERENCES

1. Aebi, H. 1983. Catalase in vitro. *Methods in Enzymology*. **105**: 121-126.
2. Ahuja, I., de Vos, R. C. H., Bones, A. M. and Hall, R. D. 2010**.** Plant molecular stress responses face climate change. *Trends Plant Sci.* **15**: 664-674.
3. Almeselmani, M., Deshmukh, P. S. and Sairam, R. K. 2009. High temperature stress tolerance in wheat genotypes: Role of antioxidant defence enzymes. *Acta Agron. Hungar.* **57**: 1-14.
4. Almeselmani, Moaed., Deshmukh, P. S., Sairam, R. K., Kushwaha, S. R. and Singh, T. P. 2006. Protective role of antioxidant enzymes under high temperature stress. *Plant Science* **171**: 382-388.
5. Asada, K. 2006. Production and scavenging of reactive oxygen species in chloroplasts and their functions. *Plant Physiol*. **141**: 391-396.
6. Asthir B., Koundal A., Bains N.S. Putrescine modulates antioxidant defense response in wheat under high temperature stress. 2012. *Biol. Plant.* **56**:757–761.
7. Badiani, M., Schenone, G., Paolacci, A. R. and Fumagalli, I. 1994. Daily fluctuations of antioxidant in bean (*Phaseolus vulgaris* L.) leaves. The influence of climatic factors, *Agrochimica* **38**: 25–36.
8. Balla K., Bencze S., Janda, T. and Veisz, O. 2009. Analysis of heat stress tolerance in winter wheat. *Acta Agron. Hung*. **57**:437–444.
9. Chakraborty U., Pradhan, D. 2011. High temperature-induced oxidative stress in *Lens culinaris*, role of antioxidants and amelioration of stress by chemical pre-treatments. *J. Plant Interact.* **6**:43–52.
10. Davidson, J. E., Whyte, B., Bissinger, P. H. and Schiestl, R. H. 1996. Oxidative stress is involved in heat induced cell death in *Saccharomyces cerevisiae*, *Proc. Natl. Acad. Sci. U.S.A*. **93**: 5116–5121.
11. Esfandiari, E., Shekari, F., Shekari, Farid And Esfandiari, M. 2007. The effect of salt stress on antioxidant enzymes activity and lipid peroxidation on the wheat seedling. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*. **35**(1): 48-56.
12. Foyer, C. H., Lopez-Delgado, H., Dat, J. F. and Scott, I. M. 1997. Hydrogen peroxide and glutathione-associated mechanisms of acclamatory stress tolerance and signaling, *Physiol. Plant.* **100**: 241–254.
13. Giannopolitis, C. N. and Ries, S. K. 1977. Superoxide dismutase. I. Occurrence inn higher plant . *Plant Physiol.* **59**: 309-314.
14. Goyal, M. and Asthir, B. 2010. Polyamine catabolism influences antioxidative defense mechanism in shoots and roots of five wheat genotypes under high temperature stress. *Plant Growth Regulation* **60**(1): 13-25.
15. Gupta, A. S., Webb, R. P., Holaday, A. S. and Allen, R. D. 1993. Over expression of superoxide dismutase protect plants from oxidative stress. Induction of ascorbate peroxidase in superoxide dismutase over expression plants, *Plant Physiol.* **103**: 1067-1073.
16. Hasanuzzaman, M., Hossain, M. A., da Silva, J. A. T. and Fujita, M. 2012. Plant Responses and Tolerance to Abiotic Oxidative Stress: Antioxidant Defences is a Key Factor. In *Crop Stress and Its Management: Perspectives and Strategies*; Bandi, V., Shanker, A.K., Shanker, C., Mandapaka, M., Eds.; Springer: Berlin, Germany pp 261-316.
17. Hasanuzzaman, M., Nahar, K. and Fujita, M. 2013. Extreme Temperatures, Oxidative Stress and Antioxidant Defense in Plants. In *Abiotic Stress-Plant Responses and Applications in Agriculture*; Vahdati, K., Leslie, C., Eds.; InTech: Rijeka, Croatia. pp 169-205.
18. Intergovernmental Panel on Climate Change (IPCC). Climate change 2007. The physical science basis. In *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*; Cambridge University Press: Cambridge, UK, 2007.
19. Jagtap, V. and Bhargava, S. 1995. Variation in the antioxidant metabolism of drought tolerant and drought susceptible varieties of *Sorghum bicolor* (L.) Moench exposed to high light, less water and high temperature stress. *J. Plant Physiol.* **145**: 195–197.
20. Janska, A., Marsik, P., Zelenkova, S. and Ovesna, J. 2010. Cold stress and acclimation: What is important for metabolic adjustment? *Plant Biol.***12**: 395-405.
21. Karus, T. E., McKerise, B. D. and Fletcher, R. A. 1995. Paclobutrazol induced tolerance of wheat leaves to paraquat may involve increased antioxidant enzyme activity. *J. Plant Physiol*. **145**: 570–576.
22. Kittock, D. L. and, Law, A. G. 1968. Relationship of seedling vigour to respiration and tetazolium chloride reduction by germinating wheat seeds. *Agron. J.* **1**: 417-425.
23. Larkindale, J. Hall, J. D., Knight, M. R. and Elizabeth, V. 2005. Heat Stress Phenotypes of Arabidopsis Mutants Implicate Multiple Signaling Pathways in the Acquisition of Thermotolerance. *Plant Physiol*. **138**(2): 882–897.

24. Lobell, D. B. and Asner, G. P. 2003. Climate and management contributions to recent trends in U.S. agricultural yields. *Science*, **299**, doi:10.1126/science.1078475.
25. Lobell, D. B. and Field, C. B. 2007. Global scale climate-Crop yield relationships and the impacts of recent warming. *Environ. Res. Lett.*, **2**, doi:10.1088/1748-9326/2/1/014002.
26. Lobell, D. B., Schlenker, W. and Costa-Roberts, J. 2011. Climate trends and global crop production since 1980. *Science*. **333**: 616-620.
27. McClung, C. R. and Davis, S. J. 2010. Ambient thermometers in plants: From physiological outputs towards mechanisms of thermal sensing. *Curr. Biol.* **20**: 1086-1092.
28. Mittler, R. and Blumwald, E. 2010. Genetic engineering for modern agriculture: Challenges and perspectives. *Ann. Rev. Plant Biol.* **61**: 443-462.
29. Noctor, G. and Foyer, C. H. 1998.Ascorbate and Glutathione: Keeping Active Oxygen under Control. Annual Review of Plant Physiology and Plant Molecular Biology. **49**: 249-279.
30. Olmos, E., Harnandez, J. A., Sevilla, F. and Hellin, E. 1994. Induction of several antioxidant enzymes in the selection of salt tolerant cell line of *Pisum sativum*. *J. Plant Physiol.* **144**: 594–598.
31. Pagamas, P. and Nawata, E. 2008. Sensitive stages of fruit and seed development of chili pepper (*Capsicum annuum* L. var. Shishito) exposed to high-temperature stress. *Sci. Hort.* **117**: 21-25.
32. Ruelland, E. and Zachowski, A. 2010. How plants sense temperature. *Environ. Exp. Bot.* **69**: 225-232.
33. Rui, R. L., Nie, Y. Q. and Tong, H. Y. 1990. SOD activity as a parameter for screening stress tolerant germplasm resources in sweet potato (*Ipomoea batatas* L.), Jiangsu, *J. Agric. Sci.* **6**: 52–56.
34. Sairam, R. K., Srivastava, G. C. and Saxena, D. C. 2000. Increased antioxidant activity under elevated temperature: a mechanism of heat stress tolerance in wheat genotypes. *Biol. Plant*. **43**: 245-251.
35. Sairam, R. K., Srivastava, G. C. and Saxena, D. C. 2000. Increased antioxidant activity under elevated temperature: a mechanism of heat stress tolerance in wheat genotypes. *Biol. Plant*. **43**: 245-251.
36. Shannon, L., Kay, E. and Lew, J. 1966. Peroxidase Isozymes from Horseradish Roots. I. Isolation and Physical Properties. *J. Biol. Chem*. **241**(9): 2166–2172.
37. Sinha, J. P., Modi, B. S., Nagar, R. P., Sinha, S. N. and Vishwakarma, Manoj. 2001. Wheat seed processing and quality improvement. *Seed Res.***29**: 171-178.
38. Suzuki, N. and Mittler, R., 2006. Reactive oxygen species and temperature stresses: a delicate balance between signaling and destruction. *Plant. Physiol*. **126**: 45–51.
39. Suzuki, N., Koussevitzky, S. Mittler, R. and Miller, G. 2012. ROS and redox signalling in the response of plants to abiotic stress. *Plant Cell Environ.* **35**: 259-270.
40. Suzuki, N., Miller, G., Morales, J., Shulaev, V., Torres, M. A. and Mittler, R. 2011. Respiratory burst oxidases: The engines of ROS signaling. *Curr. Opin. Plant Biol.* **14**: 691-699.
41. Upadhyaya, A., Davis, T. D., Larsen, N. H., Walser, R. H. and Sankhla, N. 1990. Uniconazole-induced thermotolerance in soybean seedling root tissue. *Physiol. Plant*. **79**: 78–84.
42. Valliyodan, B. and Nguyen, H. T. 2006. Understanding regulatory networks and engineering for enhanced drought tolerance in plants. *Curr. Opin. Plant Biol.* **9**: 189-195.
43. Zhao, Hui., dai Tingbo, Jing Qi., Jiang, Dong. and Cao, Weixing. 2007. Leaf senescence and grain filling affected by post-anthesis high temperature in two different wheat cultivars. *Plant Growth Regul.* **51:** 149-158.
44. Zhau, R. G., Fan, Z. H., Li, X. Z., Wang, Z. W. and Han, W. 1995. The effect of heat acclimation on membrane thermo-stability and reactive enzyme activity. *Acta Agron. Sin.* **21**: 568–572.

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