International Research Journal of Natural and Applied Sciences
Vol. 3, Issue 1, Jan 2016 IF- 2.818 ISSN: (2349-4077)
© Associated Asia Research Foundation (AARF)
Website: www.aarf.asia Email : editor@aarf.asia , editoraarf@gmail.com

EVALUATION OF WHEAT (*TRITICUM AESTIVUM* L) GENOTYPES FOR HEAT TOLERANCE AT GRAIN FILLING STAGE

Shambhoo Prasad*[1], Ajit Tiwari[1], Navnesh Kumar[1], Bandana Jaiswal[1], Sonam Singh[1], Rakesh Dwivedi[1], Ajay Kumar[1], Adesh Kumar[1], Sujeet Kumar[2] and B.N. Singh[1]

[1]Department of Plant Molecular Biology and Genetic Engineering, Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad-224229, U.P., India
[2]U.P. Council of Agricultural Research, Luchnow, U.P.

ABSTRACT

An experiment was conducted with 8 wheat varieties to see the genetic variability in wheat for heat stress tolerance at grain filling stage during rabi season 2013-14. Heat stress treatment was given by delayed sowing of 60 days from normal date of sowing (15 November) so that reproductive stage of wheat varieties could experience severs heat stress. The wheat varieties K 911, AAI 11, HUW 658 and NW 4035 had high membrane stability index (MSI), canopy temperature depression (CTD) and total chlorophyll content (SPAD) at grain filling stage and less percent reduction in grain number per spike, grain yield and test weight over control. Thus, MSI, SPAD and CTD can be taken as physiological indices for screening heat stress tolerance in wheat in the way of developing high yielding heat tolerant wheat varieties by wheat breeding programme.

Introduction

Wheat is the important food grain crop of India as well as many parts of the world. Now a day's heat stress at grain filling stage in wheat is becoming a common problem in northern part of India. High temperature above $>35^{0C}$ affects final grain weight by reducing the duration of grain filling due to suppression of current photosynthesis [1] and by directly inhibiting starch biosynthesis in the endosperm [2].

Grain growth depends on the availability of assimilates and ability of grains to utilise for the synthesis of reserves. In wheat assimilates availability is generally considered not to

be limited by grain growth but lies mainly in the ability of grains to synthesize reserves. Nearly seventy percent of wheat grains are made up of starch, so the activity of starch

Key world: Heat stress, Wheat, Heat stress, Chlorophyll, MTS, CTD, Yield and Tolerance

synthase is very important during grain filling. Plant metabolic activity greatly affected when temperature rises beyond the threshold level (5°C –10°C) and causes irreversible damage to plant growth and development resulting with low yield [3]. Damaging effects of heat stress depends on its intensity, duration and developmental stage plants [4].

High temperature also disrupts water, ion and organic solute movement across the membrane, which interferes with photosynthesis and respiration [5]. Wheat genotypes that had high Membrane stability index, canopy temperature depression and stay green duration at grain filling stage are considered for heat tolerance and it uses as physiological indices for screening tolerant wheat varieties. This study is concerned with evaluation of heat tolerance wheat varieties with help of physiological indices at grain filling stage.

Materials and methods

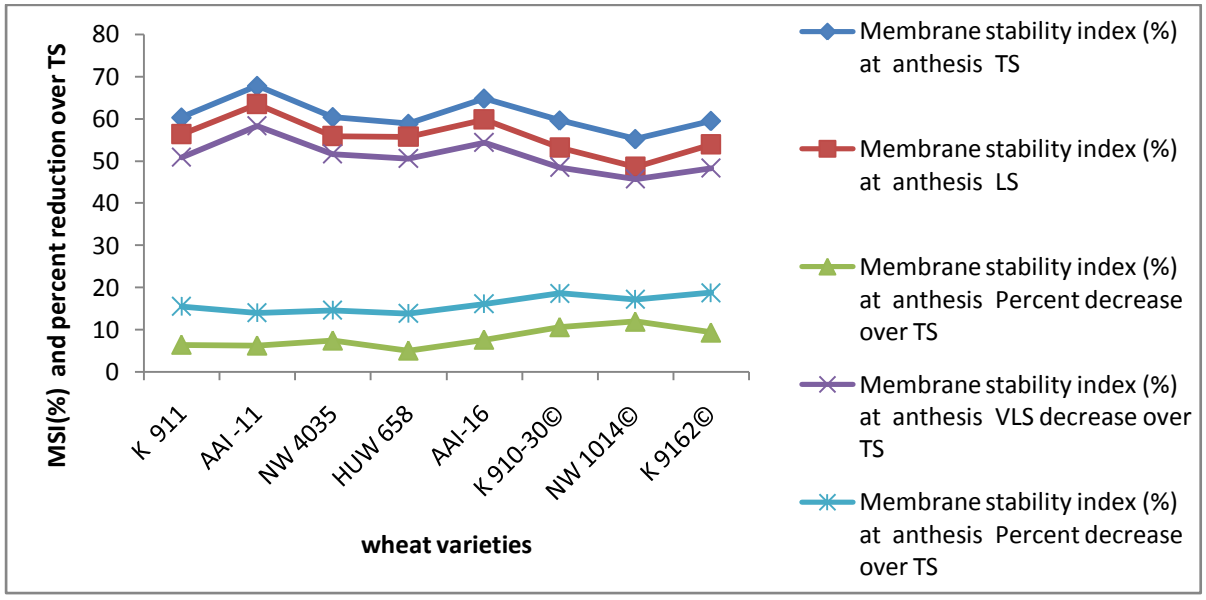
An experiment was conducted with four wheat varieties K 911, AAI 11, NW4035, AAI 16, K910-30, NW 1014 and K 9161 at instructional farm of N.D. University of Agriculture and Technology, Kumarganj, Faizabad in rabi season 2013-14. Heat stress was given by delayed sowing of 60 days (15 January, 2014) from normal date of sowing (15 November, 2013) so that the reproductive phase of wheat could experience severe heat stress. General agronomical practices were adopted time to time as per need of the crop. The temperature at the time of grain filling stage varied from 36 to 39 ^{oC} in delayed sown wheat crop. Membrane stability index [6] canopy temperature depression [7] and total chlorophyll content [8] were recorded in control verses treatment at the grain filling stage. Number of grain spike^{-1} were recorded by selecting main spike of five plants and average out to one as considered grains spike^{-1}. Grain yield of five randomly selected one square metre area were taken at physiological maturity and average out to one as grain yield in gram per square metre. Test weight was recorded by randomly counting 1000 seeds and weighted in gram.

Results and discussion

Membrane stability index (MSI) significantly varied among wheat genotypes under normal, late sown and very late sown condition (Fig.1). High MSI under normal condition was recorded in AAI-11(67.8%), AAI-16 (59.8%) and while low in NW 1014 (55.2%) and

HUW-658(58.8%) under normal sown condition. Heat stress significantly reduced the membrane stability in late and very late sown condition invariably but extent reduction was high in very late sown condition in compare to late sown condition. High reduction in MSI was recorded in K 9162 (18.8 %) and K-910-30 while low in HUW-658 (13.9%), AAI -11 (14.0% and NW 4035 (14.6%) under very late sown condition.

Fig.1: Effect of heat stress on membrane stability index (%) of wheat varieties and its percent reduction over timely sown (TS) condition at grain filling stage.

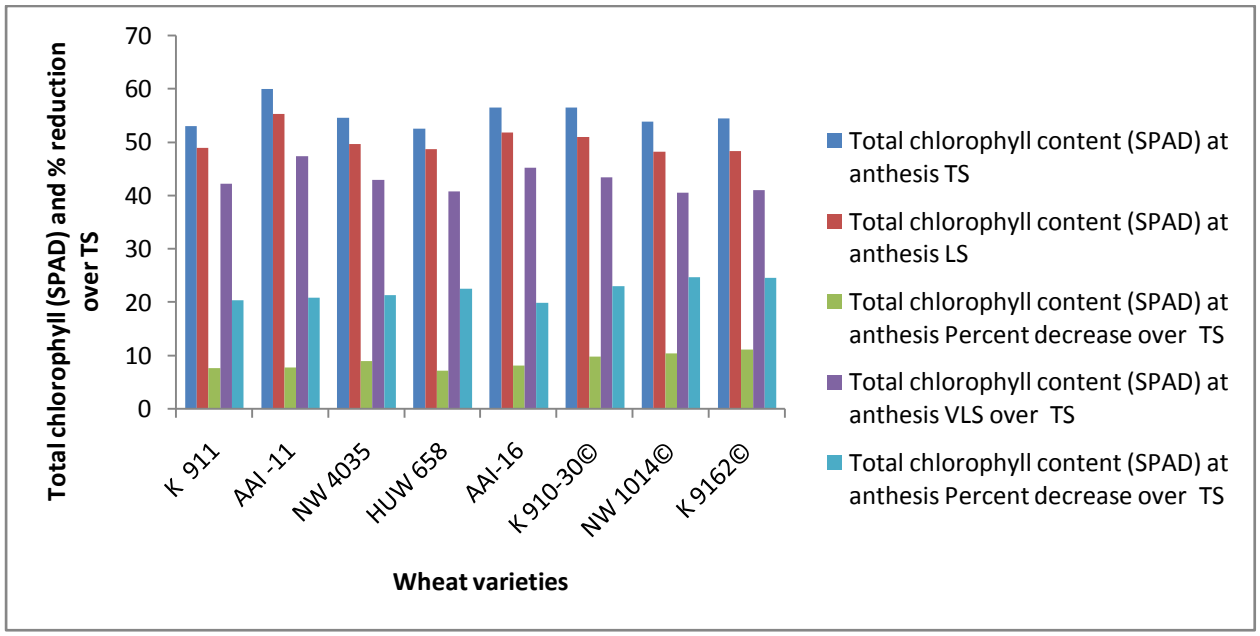


TS: Timely sown; LS: Late sown; VLS: Very late sown

Cell membrane and organelle membranes are made of lipo-protein. Lipid moiety are disorganised due to lipid peroxidation under heat stress environment. So integrity of membranes disrupts under heat stress and it measures as electrolytes leakage by MSI. Tolerant plant showed less leakage due to accumulation of high saturated fatty acid and monounsaturated fatty acids, formation of heat shock proteins and maintains integrity of membranes even under heat stress regimes [9].

The total chlorophyll content (SPAD) significantly varied among wheat genotypes under normal, late and very late sown condition at anthesis (Fig.2). Heat stress significantly reduced the total chlorophyll content under late and very late sown condition. High reduction in SPAD value was noted in K 9162 (24.6%), NW 1014 (24.7%) while low in AAI-16 (19.9%) and K-911(20.4%) under very late sown condition.

Fig.2: Effect of heat stress on total chlorophyll content (SPAD) of wheat varieties and its percent reduction over timely sown condition at grain filling stage.



TS: Timely sown; LS: Late sown; VLS: Very late sown

The mechanism of heat stress tolerance in wheat varieties related to chlorophyll synthesis and maintenance of photosystem. The heat-induced deterioration of PSII leads to considerable perturbance in electron transport mediated by PSII. From a number of studies, it is evident that changes occurring in the ultra structure of thylakoid membranes above 40°C cause dissociation of the LHCII Chl*a*/*b*-proteins from the PSII core complex[10]. Heat stress enhances the senescence by reducing total chlorophyll content at grain filling stage. Tolerant wheat varieties maintain leaf chlorophyll and stay green under heat stress regimes. Stay green at anthesis is an indicator of heat tolerant trait [11].

Canopy temperature depression (CTD) nearly same under timely sown but abruptly increase under late and very late sown condition irrespective of wheat genotypes (Table.3). Highest CTD increase was recorded in AAI-11(75 %) while lowest in AAI-11(5.8 ^{o}C) followed by AAI-16 (3.8 ^{o}C) and K910-30(3.8 ^{o}C) under late sown condition while under very late sown condition highest CTD was recorded in AAI-11(7.1 ^{o}C) and lowest in HUW 658 (5.8 ^{o}C) and followed by K-911(5.8 ^{o}C) and K-910-30 (5.9 ^{o}C).

Fig.3: Canopy temperature depression (^{o}C) of wheat varieties under various date of sowing and its percent increase over timely sown condition at grain filling stage.

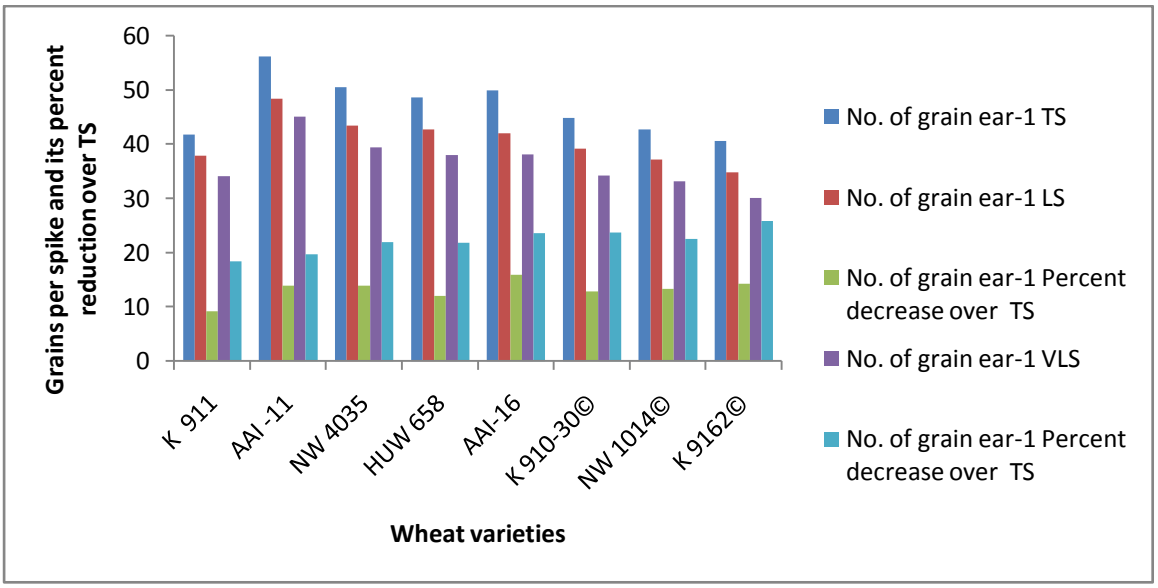
Name of genotypes	Canopy temperature depression (^{o}C) at anthesis					
	TS	LS	Percent increase over TS	VLS	Percent increase over TS	Mean
K 911	2.3	3.7	60.9	5.8	152.2	3.93
AAI -11	3.3	5.8	75.8	7.1	115.2	5.4
NW 4035	2.6	4.0	53.8	6.1	134.6	4.23
HUW 658	2.6	3.8	46.2	5.8	123.1	4.06
AAI-16	2.7	4.7	74.1	6.2	129.6	4.53
K 910-30©	2.6	3.8	46.2	5.9	126.9	4.1
NW 1014©	2.6	3.9	50.0	6.1	134.6	4.2
K 9162©	2.6	3.8	46.2	6.0	130.8	4.13
Mean	0.33	0.26		0.31		4.33
C D (5%)	0.33	0.26		0.31		
SEm	0.11	0.09		0.10		
CV	7.1	3.6		2.9		

TS: Timely sown; LS: Late sown; VLS: Very late sown

Canopy temperature depression (CTD) is a deviation of canopy temperature of plant from environmental temperature. CTD is used as selection criteria for heat tolerance in plant. Heat tolerant wheat varieties maintain high CTD by efficient stomatal conductance and evaporation by aerial portion [12]. The high CTD varieties perform better under heat stress as cool canopy provide ambient environmental condition to heat sensitive enzymes to function in better way under high temperature stress [7, 12].

Grain number spike^{-1}significantly varied among wheat genotypes (Fig.4). Heat stress reduced the grain number spike^{-1} under late and very late sown condition irrespective of wheat genotypes. Genotypes under very late sown condition showed high reduction in compare to late sown condition. Under very late sown condition high reduction was noted in K-9162 (25.81 % and K-910-30 (23.68 %) while low in K-911(18.36%) and AAI-11(19.69 %) over timely sown condition.

Fig.4: Effect of heat stress on grains spike^{-1} of wheat varieties under different date of sowing and its percent reduction over timely sown condition at grain filling stage.

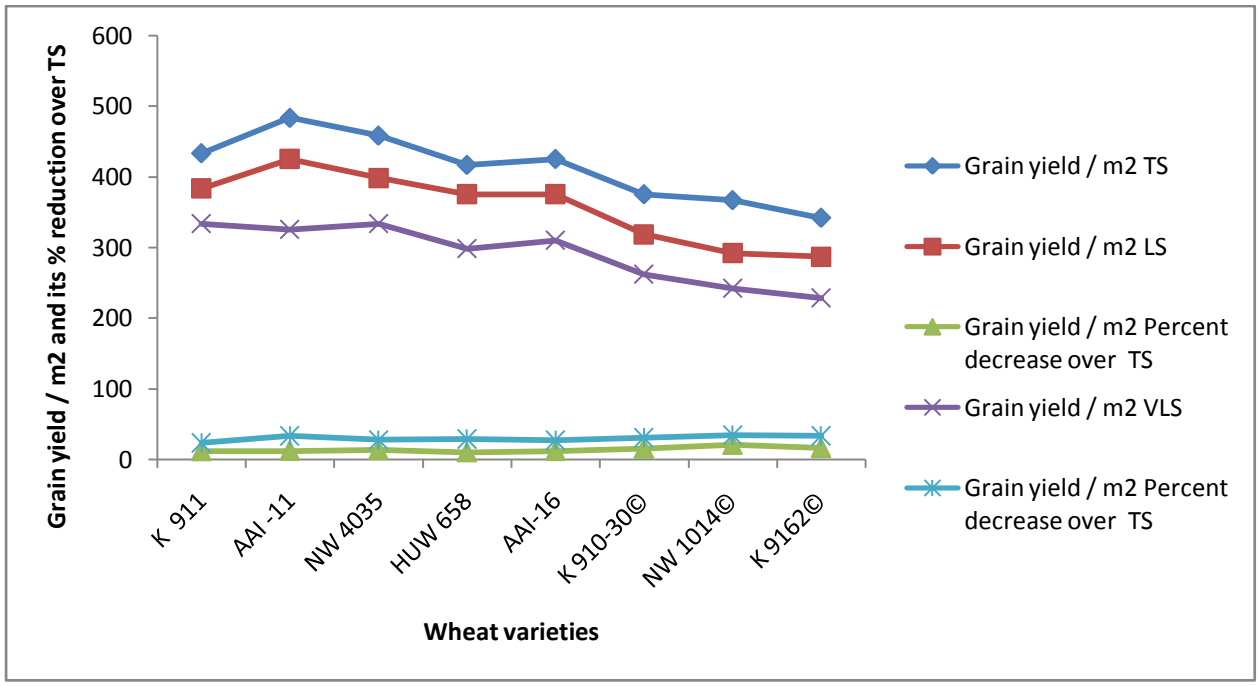


TS: Timely sown; LS: Late sown; VLS: Very late sown

Heat stress reduces the number of grains per spike when temperature exceed above 32^{oC}. It affects spiklet initiation, floral organ differentiation, pollination and fertilization. High temperature speedup spike development, spiklet number and ultimately reduces grains per spike [13].

Wheat genotypes showed genetic variability in grain yield m^{-2} (Fig.5). Heat stress significantly reduced the grain yield under late and very late sown condition irrespective genotypes. But extent of reduction was noted significantly high in very late sown condition in comparatively late sown condition. High reduction was recorded in NW 1014 (34.09%) and K-9162 (33.17%) while low in K-911 (23.08) AAI-16 (27.06 %) and NW4035 (27.27%) under heat regime over timely sown condition.

Fig.5: Effect of heat stress on grain yield m^{-2} of wheat varieties under different date of sowing and its percent reduction over timely sown condition at grain filling stage.

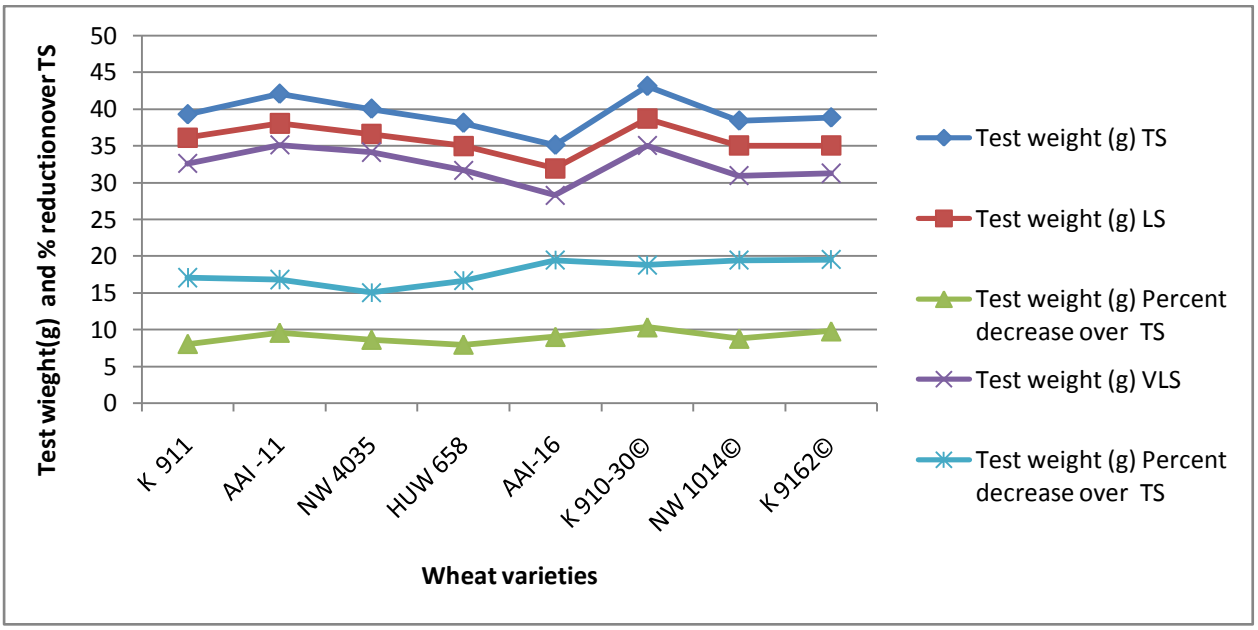


TS: Timely sown; LS: Late sown; VLS: Very late sown

Grain yield reduced by 5 to 10 per 1^0C increase in maximum / minimum temperature due to reduction in biomass, productive tillers, flowering period, grain number and 1000 grain weight. High temperature stress accelerates the plant development and resulted in overall reduction in plant size [14]. A number of studies established an increase in respiration, reduction in photosynthesis, inhibition of starch synthesis in kernels, reduction in kernel number and weight [15] and overall acceleration of senescence as a result of heat stress. The final effect of all these physiological changes is reduction of yield under heat stress.

The wheat genotypes showed genetic variability in 1000 grain weight (Fig.6). Heat stress significantly reduced the test weight under late and very late sown condition. But the genotypes under very late sown condition showed high percent reduction comparatively late sown condition. Under very late sown condition high reduction was recorded in K-9162 (19.52 %) and NW 1014 (19.45 %) AAI-11 and low in NW 4035 (15.06%) and AAI-11(16.81%) over timely sown condition.

Fig.6: Effect of heat stress on test weight (g) of wheat varieties under different date of sowing and its percent reduction over timely sown condition at grain filling stage.



TS: Timely sown; LS: Late sown; VLS: Very late sown

The increasing temperatures (from 25/14 to 31/20ºC), during grain growth, decreases grain size and promotes grain shrinking, thus implicating a reduction of individual grain weight [16]. In wheat, both grain weight and grain number appeared to be sensitive to heat stress, as the number of grains per ear at maturity declined with increasing temperature [17].

Conclusion

Among the eight wheat varieties K 911, AAI 11, HUW 658 and NW 4035 showed tolerant on the basis of high MSI, CTD and stay green at grain filling stage by less reduction in yield and yield component

Acknoledgment

Authors are very thankful U.P. Council of Agricultural Research for providing financial assistance during research work.

Reference

1. Tahir ISA, and Nakata, N (2005) Remobilization of nitrogen and carbohydrate from stems of bread wheat in response to heat stress during grain filling. Crop Sci. **191**: 106–115

2. Spiertz JHJ, Hamer RJ, Xu H, Primo-Martin C, Don C, Van der Putten PEL (2006) Heat stress in wheat (*Triticum aestivum* L.): Effects on grain growth and quality traits. Eur. J. Agron. **25**: 89–95.

3. Porter JR (2005) Rising temperature are likely to reduced crop yields. Nature 436: 174.

4. Sung DY, Kaplan F, Lee KG, Guy LC (2003) acquired tolerance to temperature extreme. Trends in plant Sci 8: 179-187.

5. Wahid A, Gelani S, Ashraf M, Foolad MR (2007) Heat tolerance in plants: an overview. Environ Expt Botany 61: 199-223.

6. Saadalla MM, Quick JS, Shanahan JF(1990) Heat tolerance in winter wheat. II. Memberane thermostability and filed performance. Crop Sci 30(6):1248-1251.

7. Reynolds, MP, Nagarajan S, Razzaque MA, Ageeb OAA (2001) Breeding for adaptation to environmental factors, heat tolerance. Reynolds, M. P., J. I. Ortiz-Monasterio, A. McNab (eds), Application of physiology in wheat breeding, Cimmyt, Mexico, DF, 124-135.

8. Minolta. 1989. SPAD-502 owner's manual. Industrial Meter Div. Minolta Corp., Ramsey, N.J.

9. Zhang M, Barg R, Yin M, Gueta-Dahan Y, Leikin-Frenkel A, Salts Y (2005b) Modulated fatty acid desaturation via overexpression of two distinct omega-3 desaturases differentially alters tolerance to various abiotic stresses in transgenic tobacco cells and plants. Plant J. 44 361–371.

10. Wahid A, Gelani S, Ashraf M, Foolad MR (2007) Heat tolerance in plants: an overview. Environ Exp Bot; 61:199-223.

11. Harris JA, Hobbs RJ, Higgs E, Aronson J (2006) Ecological restoration and global climate change. Restoration Ecology 14: 170– 176.

12. Lopes MS, Reynolds MP (2010). Partitioning of assimilates to deeper roots is associated with cooler canopies and increased yield under drought in wheat. Funct Plant Biol.37:147–156.

13. Zhao H, Dai T, Jiang D, Cao W (2008) Effects of high temperature on key enzymes involved in starch and protein formation in grains of two wheat 1320 cultivars. *J.* Agron. Crop Sci. **194**: 47–54

14. Nagarajan, S, and Rane J (2002). Physiological traits associated with yield performance of spring wheat *(Triticum aestivum* L.) under late sown condition. Indian .J. Agric. Sci **72:** 135-140.

15. Mohammadi M (2012) Effects of kernel weight and source-limitation on wheat grain yield under heat stress. Afr J Biotechnol 11: 2931-7

16. Dias AS, Bagulho AS, Lidon FC (2008) Ultrastructue and biochemical traits of bread and durum wheat grains under heat stress. Brazz. J. Plant Physiol. 20: 323–333

17. Ferris R, Ellis RH, Wheeler TR, Hadley P (1998) Effect of high temperature stress at anthesis on grain yield and biomass of field-grown crops of wheat. Ann. Bot. 82: 631–639