EFFECTS OF HEAT STRESS IN WHEAT. A review

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Abstract

Wheat productivity is adversely affected by rise in temperature. Wheat production is estimate to loss 6% with each 1°C rise in temperature, The outmost discovery from this review are high temperature decreases germination of seeds, dimish grain growth duration, degenerates mitochondria, substantial influence on chlorophyll content and reduction of photosynthesis.

Keywords: Wheat, Heat stress, Chlorophyll, Photosynthesis

INTRODUCTION

Bread wheat (*Triticum spp*.) is a self-pollinating annual plant, hexaploid (AABBDD) with the chromosome number of 42 and a genomic size of 16 GB. It has three progenitors namely *Triticum urartu*, *Aegilops speltoides* and *Aegilops tauscii*. Wheat belongs to the family Poaceae (grasses) [1].

ABIOTIC STRESS

Living organisms have evolved inherent mechanisms to cope up it the abiotic stresses. Plants are immovable, so it restraint their behavioral reaction to different stresses and places a forceful prominence on cellular and physiological mechanisms of adaptation and protection [2].There are many abiotic stresses such as elevated temperature, chemical toxicity, drought and oxidative stresses etc are consequential menacing to agriculture and become the predominant source of crop loss globally, minimize standard yields for vital crop plants [3]

HEAT STRESS

The utmost problems in most cereal crops cultivated in South East Asia are the heat stress. Elevated temperature beyond a threshold cause irreversible demolition to the function of plant and development or modification of metabolism, growth and yield reduction [4]. The expansein that heat stress harms the plants is a complex issue. It based on the intensity, duration, rise in temperature, other environmental conditions such as the high temperature occurs (during the daytime or the nighttime) and where it occurs (in the air or the soil) [5]. Global warming has become a crucial threat for sustainable agriculture in worldwide. Genome-wide analysis of Abiotic stress responsible for drought, heat stress and their combination in wheat seedlings and compared them with transcriptional response. Shows that stress-response pathways incline to be extremely over represented among overlapped genes under heat stress and their combination [6].

PROCEDURE OF HEAT STRESS

Plant resistance to inflated temperature may be reach through diverse mechanisms, including modification at the whole-plant levels [7]. Higher activity in the photosynthetic apparatus is exhibit by heat tolerant grass species and cultivars [8] [9] when exposed to prior optimal temperature carbon allocation and nitrogen uptake rates become higher. [10] [11]. Oxidative stress in grasses is generated by heat stress so that species and cultivars exhibit disparity in the activities of antioxidant enzymes associated with difference in heat forbearance [12].

The notworthy outcome on protein metabolism, including protein degradation, protein accumulation inhibited, and induction of certain protein synthesis, depending on the level and duration of heat stress [13]. Middling heat response presumes down regulation of proteins functioning in lipid biogenesis, cytoskeleton structure, sulfate assimilation, amino acid biosynthesis, nuclear transport and antioxidant response [14].

MORPHOLOGICAL EFFECTS OF HEAT STRESS ON WHEAT

The impediment of seed germination in wheat is the predominant effect of heat stress [15] [16]. Affects on embryonic cell in wheat which reduces crop stands through impairing seed germination and emergence by ambient temperature around 45°C [17]. The plant meristems and reduction in plant growth by promoting leaf senescence and abscission and by reducing photosynthesis mainly affects by heat stress [18]. The plant growth duration by reducing seed germination and maturity periods are amending by heat stress ranging from 28 to 30°C [19]. Plants grown under optimum or low temperature has higher biomass than warm environment produces. Adverse effects on leaf development and productive tiller formation in wheat are affected by day and night temperature around 30 and 25°C [20]. In wheat production, the prevalence of reproductive stage heat stress has been found to be more detrimental [21]. During reproductive phase one degree rise in average temperature can cause severe yield loss in wheat [22] [23]. With 6-8°C increase in temperature during grain development cause the dimished grain growth duration and growth rate in wheat varieties [24]. Mitochondria is degenerated, the protein expression profiles alters, reduction of ATP accumulation, and oxygen uptake in imbibing wheat embryos, results in increased occurrence of loss of seed quality relating to seed mass, vigor, and germination by high temperature stress [25] [26]. Reduction in seed mass by accelerating seed growth rate and by shortening the grain-filling periods in wheat arise due elevation in temperature of 1–2°C [27]. Heat shock arises in the reduction of grain filling duration, kernel weight and head weight of lines, but the kernel number remained the same. Substantial changes were also seen among cultivars in the reduction in grain weight per ear, kernel number and single kernel weight under heat stress [28]. Inflated temperature reduce the rate of photosynthetic, viable leaf area, mass of shoot and grains, weight of the kernel and content of sugar at maturity and water use capability are lowered [29].

PHYSIOLOGICAL EFFECTS OF HEAT STRESS ON WHEAT

ROOT

Wheat growth was affected more by heat stress in roots, the cooling effect of no-till (NT) on soil may minimize the risk of root heat stress and benefit the yield compared with conventional tillage (CT). Reducing root heat stress especially during the grain growth stage and slightly increasing pre-seeding soil moisture, no-till increased above-ground biomass (33-160%) and grain yield (18-147%) annually [30].

Otayk studied the 12 wheat genotype under four environmental conditions and observed that plant height and spike length was significantly influenced by genotypes [31].

CHLOROPHYLL

Heat stress had a influence on the chlorophyll content and antioxidant enzyme activity in two winter wheat varieties (Plainsman V and Mv Magma),reported that the activity of enzyme Glutathione-s-transferase, ascorbate peroxidase (APX) and catalase were enhanced in Plainsman V and that of Glutathione-s-transferase and catalase in Mv Magma [32]. The comparative physiological changes under timely and late sown conditions in wheat genotypes found that heat stress affects chlorophyll content and leaf area index in sensitive genotypes whereas proline and malonialdehyde content were higher in tolerant genotypes under late sown condition. Moreover, higher heat susceptibility index of wheat genotypes viz., HS-240 and K-0-307 [33].

WATER

Changing ambient temperature is commonly found to be most erratic in Plant water status. Dehydration in plant tissue causes restriction of growth and development of plants these are caused by Elevation in temperature. An upper limit of maintaining water status of a crop, during flowering is 31°C [34]. wheat plants exposed to heat stress substantially decrease the water capacity and the relative water content in leaves, and reduce photosynthetic productivity. when there’s increase in leaf temperature [35]. High temperature imposed after tillering shows reduction of water potential in wheat and the reduction was higher in genotypes susceptible to heat stress [36]. Different antioxidants are related with dehydration tolerance and are stimulated under heat stress. Due to increased transpiration in stressed leaves and dropping of osmotic potential [37]. Increased hydraulic conductivity of cell membrane as well as plant tissues primarily for increased aquaporin activity [38] and reduction of water viscosity are caused by heat stress [39].

PHOTOSYNTHESIS

The awful growth performance in wheat, due to Photosynthesis. It is a preponderance sensitive physiological event [40]. The photosynthesis is depleted, due to this leaf area expansion decreased, dimished photosynthetic machinery, premature leaf aging and wheat production reduction are the important effect of heat stress [41] [42]. Interference of thylakoid membranes, causes hindrance in the activities of membrane-associated electron carriers and enzymes,that results in a reduction of photosynthesis rate these are caused by heat stress in wheat [43]. The rate of leaf photosynthesis are minimizes by the inactivation of chloroplast enzymes, predominantly induced by oxidative stress. Depletion of net photosynthetic rate due to heat stress is frequently attributed to expand non-photorespiratory processes [44]. The restrictions of photosynthetic activities is the outcome of reduced soluble protein, Rubisco and Rubisco binding proteins [45] [46]. leaf exposed to inflated temperature near about 40°C either in day or night causes a considerable modification in Rubisco and Rubisco activase and these alterations are irreversible under dark conditions in Wheat [47]. Heat stress inhibited chlorophyll accumulation at 45° C for 8 h in leaves of wheat cultivars and cause complete inhibition of photosynthesis by inhibition of Photosystem II [48]. Changes in photosynthesis leads to a shortened life span and diminished plant productivity due to heat stress [49]. An experiment was conducted with two genotypes of wheat Hindi 62 (heat tolerant) and PBW 343 (heat susceptible). Senescence was characterized by measuring photosynthesis related process and endoproteolytic activity during non-stress environment (NSE) besides, heat-stress environment. Heat tolerant, having pale yellow flag leaf with larger area, cooler canopy under higher temperature was maintained than heat susceptible. Hindi 62, shows a slower rate of senescence than PBW 343 during HSE, contribute towards heat stability [50].

CONCLUSION

There is a need of omics based approaches for decoding the complexity of traits linked with abiotic stress for increasing the production of wheat.

REFERENCES

1. J. Dvorák, P. Terlizzi, H. B. Zhang and P. Resta, "The evolution of polyploid wheats: identification of the A genome donor species", Genome, vol. 36, no.1, (**1993**), pp.21-31.
2. A. Wahid, S. Gelani, M. Ashraf and M. R. Foolad, "Heat tolerance in plants: An overview", Environmental and Experimental Botany, vol.61, no. 3, (**2007**), pp. 199-223.
3. P. Rodziewicz, B. Swarcewicz, K. Chmielewska, A.Wojakowska and M. Stobiecki "Influence of abiotic stresses on plant proteome and metabolome changes", Acta Physiologiae Plantarum, vol. 36, no. 1, (**2014**), pp 1–19.
4. J. R. Porter, "Rising temperatures are likely to reduce crop yields," Nature, vol. 436, (**2005**), pp. 174.
5. D. Y. Sung, E. Vierlingand and C. L. Guy, "Comprehensive expression profile analysis of the Arabidopsis hsp70 gene family" , Plant Physiology, vol.126, (**2001**), pp. 789-800.
6. Z. Liu, J. Qin, X. Tian, S. Xu, Y. Wang, H. Li, X. Wang, H. Peng, Y. Yao, Z. Hu, Z. Ni, M. Xin and Q. Sun, "Global profiling of alternative splicing landscape rersponsive to drought, heat and their combination in wheat (Triticum aestivum L.)" , Plant Biotechnology Journal, vol. 16, (**2017**), pp. 1-13.
7. A.Wahid, S.Gelani ,M. Ashraf and M. R. Foolad , "Heat tolerance in plants: An overview", Environmental and Experimental Botany, vol. 61, (**2007**), pp.199-223.
8. Z. Ristic, U. Bukovnik and P. V. V. Prasad , " Correlation between heat stability of thylakoid membranes and loss of chlorophyll in winter wheat under heat stress", Crop Science, *vol.* 47, (**2007**), pp. 2067-2073.
9. S. I. Allakhverdiev, V. D. Kreslavski, V. V. Klimov, D. A. Los, R. Carpentier and Mohanty P ," Heat stress: an overview of molecular responses in photosynthesis" ,Photosynthesis Research, vol. 98, (**2008**),pp 541-550.
10. B. Huang and C. Xu, "Identification and characterization of proteins associated with plant tolerance to heat stress", Journal of Integrative Plant Biology, *vol.* 50, (**2008**), pp. 1230-1237.
11. J. H. Zhang, W. D. Huang ,Y. P. Liu and Q. H. Pan, "Effects of temperature acclimation pretreatment on the ultrastructure of mesophyll cells in young grape plants (*Vitis vinifera* L. cv. Jingxiu) under cross-temperature stresses", Journal of Integrative Plant Biology, *vol.* 47, (**2005**), pp. 959-970.
12. S. Dash and N. Mohanty, "Response of seedlings to heatstress in cultivars of wheat: growth temperature-dependent differential modulation of photosystem 1 and 2 activity, and foliar antioxidant defense capacity," Journal of Plant Physiology, vol.159, (**2002**), pp. 49-59.
13. P. Monjardino , A. G. Smith and Jones R J, " Heat stress effects on protein accumulation of maize endosperm", Crop Science vol.45, (**2005**), pp.3-10.
14. S. Ferreira, K. Hjern, M. Larsen,G. Wingsle, P. Larsen ,S. Fey ,P. Roepstorff and M. P. Salome, "Proteome profiling of *Populus euphratica* Oliv. upon heat stress", Annals of Botany, vol. 98, (**2006**), pp. 361-77.
15. M. Johkan, M. Oda, T. Maruo and Y. Shinohara, "Crop production and global warming", Edited S. Casalegno, Global warming impacts-case studies on the economy, human health, and on urban and natural environments. Rijeka, Croatia, (**2011**), pp 139–152.
16. A. Hossain, M. A. Z. Sarker, M. Saifuzzaman, D. Teixeira, J. A. Silva, M. V. Lozovskaya and M. M Akhter, "Evaluation of growth, yield, relative performance and heat susceptibility of eight wheat (Triticum aestivum L.) genotypes grown under heat stress", Int J Plant Production, vol.7, (**2013**), pp. 615–636.

17. J. Essemine, S. Ammar and S. Bouzid, "Impact of heat stress on germination and growth in higher plants: physiological, biochemical and molecular repercussions and mechanisms of defence", J Biol Sci, vol.10, (**2010**), pp. 565–572.
18. K. Kosova, P. Vitamvas, I.T. Prasil and J. Renaut, "Plant proteome changes under abiotic stress-contribution of proteomics studies to understanding plant stress response", J Proteome, vol. 74, (**2011**), pp.1301–1322.
19. Y.Yamamoto, R. Aminaka, M. Yoshioka, M. Khatoon, K. Komayama, D. Takenaka, A. Yamashita, N. Nijo, K. Inagawa, N. Morita, T. Sasaki and Y. Yamamoto, " Quality control of photosystem II: impact of light and heat stresses", Photosynth Res, vol. 98, (**2008**) pp.589–608.
20. M. A. Rahman, J. Chikushi, S. Yoshida and A. J. M. S. Karim, Growth and yield components of wheat genotypes exposed to high temperature stress under control environment", Bangladesh J Agric Res, vol.34, (**2009**), pp.361–372.
21. A. Nawaz, M. Farooq, S. A. Cheema, A. Wahid, "Differential response of wheat cultivars to terminal heat stress", Int J Agric Biol, vol.15, (**2013**), pp. 1354–1358.
22. D. Bennett, A. Izanloo, M. Reynolds, H. Kuchel, P. Langridge and T. Schnurbusch, " Genetic dissection of grain yield and physical grain quality in bread wheat (Triticum aestivum L.) under water limited environments", Theor Appl Genet, vol. 125, (**2012**), pp. 255–271.
23. Q. Yu, L. Li, Q. Luo, D. Eamus, S. Xu, C. Chen, E. Wang, J. Liu and D. C. Nielsen, "Year patterns of climate impact on wheat yields", Int J Climatol, vol. 34, (**2014**), pp. 518–528.
24. C. Viswanathan, R .C. Khanna, "Effect of heat stress on grain growth, starch synthesis and protein synthesis in grains of wheat (Triticum aestivum L.) varieties differing in grain weight stability", Journal of Agronomy Crop Science, vol.186, (**2001**) , pp.1-7.
25. K. Balla, I. Karsai, S. Bencze and O. Veisz, "Germination ability and seedling vigour in the progeny of heat-stressed wheat plants", J Acta Agron Hung, vol. 60, (**2012**), pp.299–308.
26. J. G. Hampton, B. Boelt, M. P. Rolston and T. G. Chastain, "Effects of elevated CO2 and temperature on seed quality", J Agric Sci. vol. 151, (**2013**), pp.154– 162.
27. K. Nahar, K. U. Ahamed and M. Fujita "Phenological variation and its relation with yield in several wheat (Triticum aestivum L.) cultivars under normal and late sowing mediated heat stress condition",Not Sci Biol, vol.2, (**2010**), pp. 51–56.
28. V. Mohammadi, M. R. Qannadha, A. A. Zali, B. Yazdi-Samadi, "Effect of Post Anthesis Heat Stress on Head Traits of Wheat", International Journal of Agriculture and Biology, vol.1, (**2006**) , pp. 42-44.
29. N. H. Shah and G. M. Paulsen, "Injury to photosynthesis and productivity from interaction between high temperature and drought during maturation of wheat", Plant Soil, vol.4, (**2005**), pp. 67-74.
30. H. Wang, R. Lemke, T. Goddand and C. Sprout, "Tillage and root heat stress in wheat in central Alberta", Canadian Journal of Soil Science, vol. 87, (**2007**), pp.3-10.
31. S. M. Otayk, "Performance of yield and stability of wheat genotypes under high stress environments of the central region of saudi Arabia", Journal of Abdulaziz university-Meterology, Environment and Arid Land Agriculture sciences, vol. 21, (**2010**), pp. 81-92.
32. K. Balla, S. Benlza, T. Janda and O. Veirz, "Analysis of heat stress tolerence in winter wheat" , Acta Agronomica Hungaria, vol.57, (**2009**), pp. 437-444.
33. K. Dhyani, M. W. Ansari, Y. R. Rao, R. S. Verma, A. Shukla and N. Tuteja, "Comparative physiological response of wheat genotypes under terminal heat stress" , Plant Signaling and Behavior , vol. ED-8, (**2013**),pp 45-64.

34. N. J. Atkinson and P. E. Urwin, "The interaction of plant biotic and abiotic stresses: from genes to the field", J Exp Bot, vol.63, (**2012**), pp.3523–3543.
35. M. Farooq, A. Wahid, N. Kobayashi, D. Fujita, S. M. A. Basra, "Plant drought stress: effects, mechanisms and managemen", Agron Sustain Dev, vol.29, (**2009)**, pp.185–212.
36. M. Almeselmani, P. S. Deshmukh and R. K. Sairam, "High temperature stress tolerance in wheat genotypes: role of antioxidant defense enzymes", Acta Agron Hungar, vol. 57, (**2009**), pp. 1–14.
37. P. Ahmad, C. A. Jaleel, M. A. Salem, G. Nabi and S. Sharma, "Roles of enzymatic and nonenzymatic antioxidants in plants during abiotic stress", Crit Rev Biotechnol, vol. 30, (**2010**), pp. 161–175.
38. M. C. Martinez-Ballesta, L. Lopez-Perez, B. Muries, O. Munoz-Azcarate and M. Carvajal, "Climate change and plant water balance: the role of aquaporins - a review. Edited E.Lichtfouse, Climate change, intercropping, Pest control and beneficial microorganisms. Springer, Netherlands, (**2009**), pp. 71–89.
39. H. Cochard, J. S. Venisse, T. S. Barigah, N. Brunel, S. Herbette, A. Guilliot, M.T. Tyree and S. Sakr, " Putative role of aquaporins in variable hydraulic conductance of leaves in response to light", Plant Physiol,vol. 143, (**2007**), pp. 122–133.
40. B. Feng, P. Liu, G. Li, S. T. Dong, F. H. Wang, L. A. Kong and J. W. Zhang, "Effect of heat stress on the photosynthetic characteristics in flag leaves at the grain-filling stage of different heat-resistant winter wheat varieties", J Agron Crop Sci, vol. 200, (**2014**), pp.143–155.
41. M. Ashraf and P. J. C. Harris, "Photosynthesis under stressful environments: an overview", Photosynthetica, vol. 51, (**2013**), pp. 163–190.
42. S. Mathur, D. Agrawal and A Jajoo, "Photosynthesis: response to high temperature stress", J Photochem Photobiol B: Biol, vol. 137, (**2014**), pp. 116–126.
43. Z. Ristic, U. Bukovnik, I. Momcilovic, J. Fu, P. V. V. Prasad, "Heat induced accumulation of chloroplast protein synthesis elongation factor, EF-Tu, in winter wheat", J Plant Physiol, vol.165, (**2008**), pp. 192–202.
44. E.A. Ainsworth and D. R. Ort, "How do we improve crop production in a warming world?", Plant Physiol, vol.154, (**2010**), pp.526–530.
45. M. A. J. Parry, M. Reynolds, M. E. Salvucci, C. Raines, P. J. Andralojc, X.G. Zhu, G. D. Price, A. G. Condon and R. T. Furbank, "Raising yield potential of wheat. II Increasing photosynthetic capacity and efficiency", J Exp Botany, vol.62, (**2011**), pp 453–467.
46. M. Hasanuzzaman, K. Nahar, M. M. Alam, R. Roychowdhury and M. Fujita "Physiological, biochemical, and molecular mechanisms of heat stress tolerance in plants", Int J Mol Sci, vol. 14, (**2013**), pp. 9643–9684.
47. S. Mathur, A. Jajoo, P. Mehta and S. Bharti, "Analysis of elevated temperature-induced inhibition of photosystem II using chlorophyll a fluorescence induction kinetics in wheat leaves (*Triticum aestivum*)", Plant Biology, vol. 13, (**2011**), pp. 1–6.
48. B. Efeoglu1, S. Terzioglu, "Photosynthetic responses of two wheat varieties to high temperature", EurAsian Journal of BioSciences , vol.3, (**2009**), pp.97-106 .
49. B. Barnabas, K. Jager and A. Feher, "The effect of drought and heat stress on reproductive processes in cereals", Plant, Cell and Environment, vol. 31, (**2008**), pp. 11–38.
50. S. Chauhan, S. Srivallis, A. R. Nautiyal and R. C. Khanna, "Wheat cultivars differing in heat tolerance show a differential response to monocorpic senescence under high temperature strees and the involvement of serine protease", Photosynthetica, vol. 47, (**2009**),pp. 536-547.