Environment. Technology. Resources. Rezekne, Latvia
Proceedings of the 14th International Scientific and Practical Conference. Volume 1, 60-64

Physiological Response of Some Wheat Cultivars to Thermal Stress

Tatjana Dunaiska
Institute of Life Sciences and Technologies, Daugavpils University,
Parades Str. 1A, Daugavpils, Latvia. tatjanadunaiska@ymail.com

Anna Batjuka
Institute of Life Sciences and Technologies, Daugavpils University,
Parades Str. 1A, 121, Daugavpils, Latvia. anna.batjuka@du.lv

Aleksandrs Petjukevičs
Institute of Life Sciences and Technologies, Daugavpils University,
Parades Str. 1A, 122, Daugavpils, Latvia. aleksandrs.petjukevics@du.lv

Nataļja Škute
Institute of Life Sciences and Technologies, Daugavpils University,
Parades Str. 1A, Daugavpils, Latvia. natalja.skute@du.lv

***Abstract*. Plants are exposed during their development to the influence of various stressful factors, both abiotic and biotic in natural conditions of habitation. Thermal stress is likely the most important abiotic factor that adversely affects plant growth and development. Wheat (Triticum aestivum L.) is one of the most economically important crops worldwide. In this study, three Latvian winter wheat cultivars ´Creator´, ´Galerist´, and ´Skagen´ were used as a research model that were subjected to short-term high temperature (42°C, 1 h) and analyzed for the following growth parameters (maximum length of root, length of first leaf and coleoptile as well as seedlings weight). In general, short-term high temperature caused an insignificant reduction in almost all growth criteria like the first leaf growth, coleoptile growth, seedlings weight, and maximal root growth in wheat cultivars ´Skagen´ and ´Galerist´ at the 6th day of development. Furthermore, almost all growth characteristics were stimulated by short-term high temperature in the wheat cultivar ´Creator´. A slowing of the growth processes under the influence of short-term thermal stress revealed varietal specificity on the impact of this stressor on the morphological structure of cereal, which makes it possible to diagnose the stress tolerance of wheat cultivars.**

Keywords: high temperature, growth parameters, Triticum aestivum L., wheat cultivars.

I. INTRODUCTION

As a consequence of climate change, the prevalence of extreme environmental conditions, including extreme weather events and increased average temperatures cause significant loss of production and a decrease in yield for cereals and other cultivated plants leading to huge economic losses. IPCC has projected a temperature increase of 1.8 - 4°C by 2100 [1]. Rising global average temperature leads to increasing irregular and unexpected warm spells during autumn, and therefore natural chilling requirements to break dormancy are at risk. Therefore, modeling and studying the possible effects of climate change on some morphological and physiological processes in agricultural plants is extremely relevant.

Temperature is one of the major factors controlling plant development, in particular germination of seeds. As non-moving organisms, plants rely on physiological responses and morphological alterations in order to survive under environmental factors such as high light intensities, extreme temperatures, drought, or high salinity that adversely affect plant growth and development. Among the environmental stresses, thermal stress is one of the most limiting factors of plant growth and productivity that has a great impact on agricultural production causing a variety of physiological, biochemical, and morphological dysfunctions in living organisms [2-3]. Morphologically the most typical symptom of heat stress injury to plants is the reduction of growth [4]. At the physiological level, heat stress inhibits the rate of photosynthesis and increases the level of reactive oxygen species and oxidative stress parameters [5]. To overcome problems caused by such an unpleasant environment plants developed a defense system through hormonal and antioxidant responses. Usually, under heat stress

Print ISSN 1691-5402
Online ISSN 2256-070X
https://doi.org/10.17770/etr2023vol1.7298

conditions, increasing stress level is detrimental to plant growth and may result in marked alterations in its morphological features including shoot and root growth inhibition, and diminishing of leaf area and total biomass production [6]. Therefore, to maintain the high productivity and quality of wheat cultivars under thermal stress, detailed knowledge of their impact on plant development and growth regulation is crucial for studying plant adaptation which is important both for basic research and application in agriculture.

Wheat (*Triticum aestivum* L.) is one of the important domesticated cereals in worldwide production that is cultivated on about 217 million ha in a range of environments largely temperate as well as under tropical and subtropical temperatures, which an annual production of about 651 million tons [7]. This distribution implies that the crop is versatile and adapted to different growth conditions [8]. This crop represents a major resource for food and feed; especially in Europe and North America as well as in Latvia it provides approx. 54.9% (2021) of the total cereal production [9]. It was shown that when wheat plants were exposed to thermal stress, many growth parameters, including plant length, fresh and dry weights, the relative growth rate as well as leaf area tended to decrease [10-11]. The growth, development, reproduction, as well as defense, and acclimation of higher plants, are influenced by various stressful factors, both abiotic and biotic. Since adverse climatic weather events are likely to continue, there is therefore an urgent need to use rational and system-based approaches to develop crop plants with increased tolerance to both biotic and abiotic stress factors.

The present study was designed to elucidate the morphological alterations in three Latvian wheat cultivars (cv. 'Creator', 'Galerist', 'Skagen') exposed to short-term high temperature.

II. MATERIALS AND METHODS

Plant material and growth conditions

Three Latvian commercial etiolated winter wheat (*Triticum aestivum* L.) cultivars: 'Creator', 'Galerist', and 'Skagen' that are common in Latvia were used in this study. The seeds were germinated under the controlled condition at 26°C on moist filter paper in darkness for 24 h. After 24 hours of germination on moist filter paper, containers with etiolated wheat seedlings of equal length were transferred to a plant growth chamber maintained at 26°C and 75% relative humidity in the darkness. On the 4th day of development etiolated wheat seedlings of equal length were separated into two groups: one group of three winter wheat cultivars continued growth at 26°C, but another experimental group was subjected to short-term (1 h) high temperature (42°C). After a short-term (1 h) high temperature (42°C) plant material (first leaves, coleoptiles, and roots) was harvested and analyzed for the following growth parameters (maximum length of root, first leaf, and coleoptile length).

Morphological parameters

To assess the impact of short-term high temperature on some plant growth parameters e.g. maximum length of root, length of first leaf, and coleoptile, seedlings weight, the 6-day-old wheat seedlings were chosen randomly and the lengths in cm were measured using a graduated ruler with a precision of 1 mm. The growth parameter values were compared with those of the control groups. Fresh wheat seedlings were weighed to determine their weight (g/seedling) from 30 seedlings.

Statistical analysis

All the data are reported as mean ± standard deviation (SD). Each value was the mean (n=30) of 3 replicates. The significant difference between the experimental and the control group was set at $P \leq 0.05$.

III. RESULTS AND DISCUSSION

Many crops often encounter extreme heat stress during the growing reproductive periods, which brings greater loss of agricultural production, thus highlighting a greater need for understanding how plants respond to adverse conditions with the hope of improving the tolerance of plants to environmental stress. High temperature affects germination, seedling growth, and overall wheat crop growth and productivity [12]. The morphological alterations of plants are closely subjected to environmental influences. Morphological responses such as accelerated stem elongation allow a plant to escape from stressful environmental conditions [13].

The obtained results indicate that among wheat cultivars used in this study, wheat cultivar 'Skagen' showed more susceptibility to short-term (1 h) high temperature (42°C) since it showed declined all growth parameters, especially leaf length (8%) when compared with 'Creator', and 'Galerist' (Fig. 1). Recent researchers have demonstrated that high-temperature stress causes a loss of cell water content for which the cell size and ultimately the growth is reduced [14]. On the other hand, the inhibition of wheat growth characteristics under high-temperature stress would also be due to the reduction in net assimilation rate which is also another reason for the reduced relative growth rate [15]. It has been previously reported that the length of the first leaf and the maximum length of roots significantly declined in etiolated wheat seedlings exposed to prolonged high-temperature stress [16].

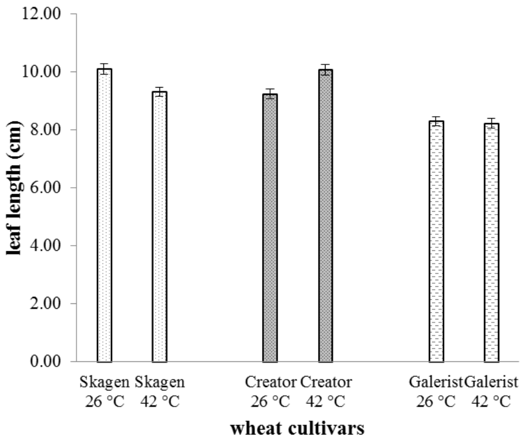

Fig. 1. Length changes of the leaf after exposure to short-term (1 h) high temperature (42°C) of Skagen, Creator, and Galerist cultivars. Each value is mean ± SE of three replicates.

Wheat coleoptiles are cylindrical organs that function for a relatively short period at the early stage of ontogenesis that sheath the first leaf [17]. The data presented revealed that short-term high temperature practically did not change the coleoptile length in studied wheat cultivars 'Skagen' and 'Galerist' compared with the control (Fig. 2).

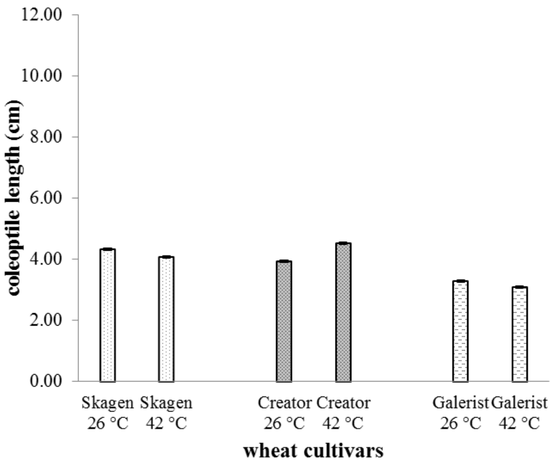

Fig. 2. Length changes of the coleoptile after exposure to short-term (1 h) high temperature (42°C) of Skagen, Creator, and Galerist cultivars. Each value is mean ± SE of three replicates.

The present results are supported by that of researchers [18], who reported that the maize coleoptile was heat tolerant at all stages of seedling development. Furthermore, our previous studies have shown that prolonged high-temperature exposure did not significantly affect the coleoptile length at the early and late stages of *Triticum aestivum* L. development (cv. Harmony) [16]. Wheat seedlings adapt to stress environments by different mechanisms, including changes in the morphological and developmental patterns as well as biochemical and physiological processes. Moreover, the current results showed that in wheat cultivar 'Creator', the lengths of the first leaves and coleoptile were stimulated by 14% under short-term high temperature. The stimulation of coleoptile growth at the early stages of development would almost certainly be due to active DNA synthesis [17] and most likely thermal stress stimulates cell division and therefore can influence growth processes.

The current results showed that short-term high temperature practically did not change the seedlings' weight in etiolated wheat cultivar 'Galerist'. The extent of reduction was more obvious in wheat cultivars 'Skagen' (11%) and 'Creator' (13%) (Fig. 4).

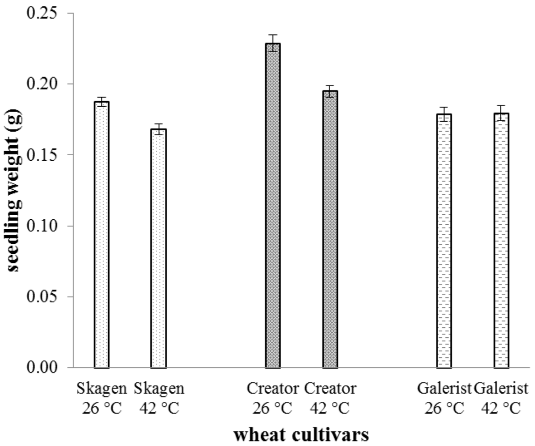

Fig. 4. Seedlings' weight changes after exposure to short-term (1 h) high temperature (42°C) of Skagen, Creator, and Galerist cultivars. Each value is mean ± SE of three replicates.

These results were in agreement with those of many authors [19-20] who reported that high temperature reduced the weight of plants. The deleterious effect of thermal stress on growth characteristics under thermal stress may be attributed to the alteration in cell division and cell elongation [21]. Additionally, the decrease in growth attributes of wheat seedlings under thermal stress may be probably due to the production of reactive oxygen species (ROS) which can pose a threat to cells by causing peroxidation of lipids and ultimately programmed cell death (PCD) [22]. Our previous findings demonstrated that in leaves and coleoptiles of etiolated wheat seedlings and grown under normal daylight conditions enhanced ROS production was induced leading to membrane biochemical and functional alterations [23-24].

The present work showed that the maximum length of the root is insignificantly affected by short-term heat stress in wheat cultivar 'Skagen' but it stimulated in wheat cultivars 'Creator' (23%) and 'Galerist' (16%) (Fig 3).

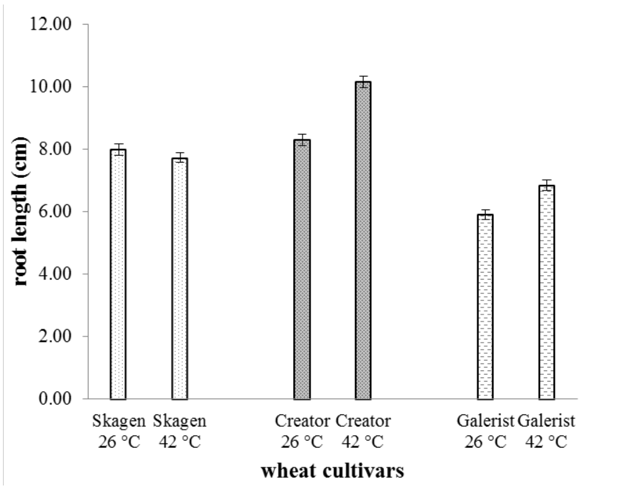

Fig. 3. Length changes of the root after exposure to short-term (1 h) high temperature (42°C) of Skagen, Creator, and Galerist cultivars. Each value is mean ± SE of three replicates.

These results were supported by researchers [25] who observed that heat-tolerant genotypes of wheat seedlings had insignificant root lengths in response to thermal stress. However, results from the previous experiments indicated that prolonged high-temperature exposure completely inhibited the growth of the root [16]. Thermal stress is assumed to reduce root growth of heat-stressed wheat plants by inhibiting root formation, branching, and growth of the existing roots. Therefore plants must develop a vigorous root system that allows them to grow and overcome any stress conditions. In this respect, morphologically, the most typical symptom of a thermal stress injury in plants is growth retardation due to the inhibition of cell expansion and a decrease in wall extensibility. The slowing of the growth processes under the influence of thermal stress revealed varietal specificity on the morphological structure of cereal, which makes it possible to diagnose the stress tolerance of cultivars in adverse conditions. That stimulates local organic farmers to use wheat cultivars that are better adapted to local environmental conditions and have the ability to resist the stress of abiotic factors.

IV. CONCLUSIONS

The *Triticum aestivum* L. growth was insignificantly affected by short-term high temperature in three Latvian cultivars ‘Creator’, ‘Galerist’, and ‘Skagen’ in comparison to non-stressed plants. According to the obtained results, wheat cultivars ‘Skagen’ and ‘Galerist’ would be classified as a species susceptible, because its growth, such as maximum length of root, length of first leaf, and coleoptile as well as seedlings fresh weight was affected by thermal stress in comparison to ‘Creator’. Furthermore, in the wheat variety ‘Creator’, the almost all growth characteristics were stimulated under short-term high temperature. Finally, measuring the morphological parameters of three Latvian wheat cultivars gave a good indication of the plant status under short-term high temperature revealing varietal specificity on the morphological structure of cereal, which it possible to define stress tolerance of variety in stress conditions for future epigenetic study.

REFERENCES

[1] IPCC. The Synthesis Report of the Intergovernmental Panel on Climate Change. Cambridge, Cambridge University Press, 2007.

[2] A. Batjuka and N. Škute, "Evaluation of superoxide anion level and membrane permeability in the functionally different organs of *Triticum aestivum* L. exposed to high temperature and antimycin A," Curr. Sci., vol. 117(3), pp. 440-447, 2019. http://dx.doi: 10.18520/cs/v117/i3/440-447

[3] M. Savicka and N. Shkute, "Some morphological, physiological and biochemical characteristics of wheat seedling *Triticum aestivum* L. organs after high-temperature treatment," Ekologija (Liet Moksl (Spausd)), vol. 58(1), pp. 9-21, 2012. http://dx.doi: 10.6001/ekologija.v58i1.2346

[4] S. Bhattarai, J.T. Harvey, D. Djidonou, and D.I. Leskovar, "Exploring morpho-physiological variation for heat stress tolerance in tomato," Plants, vol. 10, pp. 1-22, 2021. http://dx.doi: 10.3390/plants10020347

[5] A. Batjuka, N. Škute, and A. Petjukevičs, "The influence of antimycin A on pigment composition and functional activity of photosynthetic apparatus in *Triticum aestivum* L. under high temperature," Photosynthetica, vol. 55(2), pp. 251-263, 2017. https://doi.org/10.1007/s11099-016-0231-9

[6] M. Hasanuzzaman, K. Nahar, A.M. Alam, R. Roychowdhury, and M. Fujita, "Physiological, biochemical, and molecular mechanisms of heat stress tolerance in plants," Int. J. Mol. Sci., vol. 14, pp. 9643-9684, 2013. https://doi: 10.3390/ijms14059643

[7] FAO FAOSTAT agriculture dat. Agricultural production 2009. FAO, Rome, 2012.

[8] A.R. Dakhim, M.S. Daliri, A.A. Mousavi, and A.T. Jafroudi, "Evaluation vegetative and reproductive traits of different wheat cultivars under dry farming condition in north of Iran," J. Basic. Appl. Sci. Res., vol. 2(7), pp. 6640-6646, 2012.

[9] Latvijas Lauksaimniecība 2021, Latvijas Republikas Zemkopības ministrija, 1-207, 2022.

[10] L. Lu, H. Liu, Y. Wu, and G. Yan, "Wheat genotypes tolerant to heat at seedling stage tend to be also tolerant at adult stage: The possibility of early selection for heat tolerance breeding," Crop J., vol. 10, pp. 1006-1013, 2022. https://doi: 10.1016/j.cj.2022.01.005

[11] M.S.E. Suliman, S.B.M. Elradi, N.E.A. Nimir, G. Zhou, G. Zhu, M.E.H. Ibrahim, and A.Y.A. Ali, "Foliar application of 5-aminolevulinic acid alleviated high temperature and drought stresses on wheat plants at seedling age," Chil. J. Agric. Res., vol. 81(3), pp. 291-299, 2021. http://dx.doi.org/10.4067/S0718-58392021000300291

[12] S. Sharma, V. Singh, H. Tanwar, V.S. Mor, M. Kumar, R.C. Punia, M.S. Dalal, M. Khan, S. Sangwan, A. Bhuker, C.S. Dagar, S. Yashveer, and J. Singh, "Impact of high temperature on germination, seedling growth and enzymatic activity of wheat," Agriculture, vol. 12, pp. 1-19, 2022. https://doi.org/10.3390/agriculture12091500

[13] Y. Zhang, G. Liu, H. Dong, and C. Li, "Waterlogging stress in cotton: Damage, adaptability, alleviation strategies, and mechanisms," Crop J., vol. 9, pp. 257-270, 2021. https://doi.org/10.1016/j.cj.2020.08.005

[14] M. Ashraf, "Some important physiological selection criteria for salt tolerance in plants," Flora, vol. 199, pp. 361-376, 2004. https://doi.org/10.1078/0367-2530-00165

[15] N. Akter and M.R. Islam, "Heat stress effects and management in wheat. A review," Agron. Sustain. Dev., vol. 37, pp. 1-17, 2017. https://doi.org/10.1007/s13593-017-0443-9

[16] A. Batjuka and N. Škute, "Assessing the effect of antimycin A on morphophysiological parameters in *Triticum aestivum* L. exposed to high temperature," J. Cent. Eur. Agric., vol. 22(2), pp. 361-368, 2021. https://doi.org/10.5513/JCEA01/22.2.2816

[17] B.F. Vanyushin, L.E. Bakeeva, V.A. Zamyatnina, and N.I. Aleksandrushkina, "Apoptosis in plants: specific features of plant apoptotic cells and effect of various factors and agents," Int. Rev. Cytol., vol. 233, pp. 135-179, 2004. https://doi: 10.1016/S0074-7696(04)33004-4.

[18] I. Momcilovic and Z. Ristic, "Expression of chloroplast protein synthesis elongation factor, EF-Tu, in two lines of maize with contrasting tolerance to heat stress during early stages of plant development," J. Plant Physiol., vol. 164, pp. 90-99, 2007. https://doi: 10.1016/j.jplph.2006.01.010

[19] H.A. Hussain, S. Men, S. Hussain, Y. Chen, S. Ali, S. Zhang, K. Zhang, Y. Li, Q. Xu, C. Liao, and L. Wang, "Interactive effects of drought and heat stresses on morphophysiological attributes, yield, nutrient uptake and oxidative status in maize hybrids," Sci. Rep., vol. 9, pp. 1-12, 2019. https://doi.org/10.1038/s41598-019-40362-7

[20] V.M. Rodríguez, P. Soengas, V. Alonso-Villaverde, T. Sotelo, M.E. Cartea, and P.Velasco, "Effect of temperature stress on the early vegetative development of *Brassica oleracea* L.," BMC Plant Biol., vol. 15, pp. 1-9, 2015. https://doi.org/10.1186/s12870-015-0535-0

[21] S. Fahad, A.A. Bajwa, U. Nazir, S.A. Anjum, A. Farooq, A. Zohaib, S. Sadia, W. Nasim, S. Adkins, S. Saud, Z. Ihsan Muhammad, H. Alharby, C. Wu, D. Wang, and J. Huang, "Crop production under drought and heat stress: plant responses and management options," Front. Plant Sci., vol. 8, pp. 1-16, 2017. https://doi.org/10.3389/fpls.2017.01147

[22] P. Sharma, A.B. Jha, R.S. Dubey, and M Pessarakli, Reactive oxygen species, oxidative damage, and antioxidative defense mechanisms in plants under stressful conditions. J. Bot., vol. 1, pp. 1-26, 2012. https://doi.org/10.1155/2012/217037

[23] A. Batjuka and N. Škute, "The effect of antimycin A on the intensity of oxidative stress, the level of lipid peroxidation and antioxidant enzyme activities in different organs of wheat (*Triticum aestivum* L.) seedlings subjected to high temperature," Arch. Biol. Sci, vol. 69(4), pp. 743-752, 2017. https://doi.org/10.2298/ABS160706134B

[24] A. Batjuka, "Cyclical assessment of superoxide anion-radical generation and characterization of linking physiological parameters in wheat (*Triticum aestivum* L.) seedlings," Curr. Sci., vol. 122(1), pp. 93-98, 2022. https://doi: 10.18520/cs/v122/i1/93-98

[25] L. Lu, H. Liu, Y. Wu, and G. Yan, "Wheat genotypes tolerant to heat at seedling stage to tend to be also tolerant at adult stage: The possibility of early selection for heat tolerance breeding," Crop J., vol. 10, pp. 1006-1013, 2022. https://doi.org/10.1016/j.cj.2022.01.005