EFFECT OF TEMPERATURE STRESS AND WATER SHORTAGE ON THOUSAND GRAIN WEIGHT OF SELECTED WINTER WHEAT VARIETIES

HLAVACOVA MARCELA[1, 2], POHANKOVA EVA[1, 2], KLEM KAREL[1, 2], TRNKA MIROSLAV [1, 2]

[1]Global Change Research Centre, Academy of Sciences of the Czech Republic, v. v. i.
Belidla 986/4a, 603 00 Brno
[2]Department of Agrosystems and Bioclimatology
Mendel University in Brno
Zemedelska 1, 613 00 Brno
CZECH REPUBLIC

Marci.Hlava.22@gmail.com

Abstract: The aim of the presented study was to assess the effect of high temperatures and water shortage during anthesis on thousand grain weight (TGW) of two winter wheat varieties (Tobak and Pannonia). In addition, numbers of grains per spike were also assessed. The six growth chambers were used to simulate heat stress conditions within following gradient of temperature maxima: 26°C (control chamber), 29, 32, 35, 38 and 41°C. The relative humidity (RH) course and photosynthetically active radiation (PAR) intensity were controlled via protocols. Additionally, drought stressed (dry) and well-watered (wet) treatments were established within each growth chamber. The plants were removed from the growth chambers after 14 days and they were left until a full maturity, exposed to actual weather conditions. The TGW at 14% moisture were evaluated for particular treatments within both winter wheat varieties. TGW was generally more affected by high temperatures under drought stress than in well-watered conditions. The results revealed that Pannonia TGW was much more affected by the water deficiency in combination with high temperature (particularly 38 and 41°C) than Tobak TGW.

Key Words: growth chamber, temperature stress, Thousand Grain Weight (TGW), water shortage stress, winter wheat

INTRODUCTION

A wheat is considered to be particularly sensitive to extremely high temperatures during the reproductive stage (Saini et al. 1983, Marcellos, Single 1984, Alghabari et al. 2014, Vara Prasad, Djanaguiraman 2014). With global warming, the frequency of high temperatures occurring around anthesis is predicted to increase in Europe (Semenov, Shewry 2011, Stratonovitch, Semenov 2015). Therefore, the presented study is focused on the assessment of the difference between thousand grain weight (TGW) of the two winter wheat varieties when exposed to the high temperatures and water shortage stresses during the phenological stage of anthesis.

MATERIAL AND METHODS

Plant material and pre-experiment and within-experiment treatments

Two winter wheat varieties (Tobak and Pannonia) were sown (in the number of 2 seeds per 1 pot) on October 22nd, 2014 into black plastic pots with inner dimensions of 10.5 × 10.5 × 21.5 cm. Tobak was selected as a one of a modern winter wheat variety, bred in conditions of temperate zone and recommended for the Czech Republic (CISTA 2015). Pannonia was selected due to its supposed resistance to drought and to higher temperatures (Palík et al. 2009), and so it appears to be suitable for growing within the future climatic conditions predicting more frequent drought periods and higher temperatures. The soil used for pots filling came from the experimental station in Polkovice (altitude 199 m a.s.l., 49°23′30″ North latitude, 17°15′33″ East longitude) within Moravia in the Czech Republic.

Based on soil probes, the soil type was qualified as a luvic chernozem with loess as a mother substrate. The pots were placed onto the concrete floor of the vegetation hall of Mendel pavilion of Mendel University in Brno where the pots were exposed to ambient weather conditions until reaching the boot stage. To protect the pots from freezing these were surrounded by the expanded clay. The protection against diseases was ensured by fungicide applications (see Table 1 lower for the overview). The whole nitrogen dose was applied at once (March 17th, 2015) using ammonium nitrate dissolved in water (0.29 g of fertilizer per 14 ml of water per 1 pot to supply the dose of 90 kg N per ha). The aphid infestation was controlled by three applications of an insecticide Plenum (Syngenta) in concentration 0.1% (on May 28th, 2015, on June 2nd, 2015, and on June 4th, 2015), and by one application of an insecticide KARATE WITH ZEON TECHNOLOGY 5 CS in concentration 0.05% (on June 23, 2015). The pots were subsequently transported to Global Change Research Centre, Academy of Sciences of the Czech Republic, v. v. i. on May 15th, 2015 and put into six growth chambers (FS 3400, PSI, CZ) for acclimation to individual temperature treatments (on May 15th in the case of Pannonia, on May 22nd in the case of Tobak) at the boot stage of development.

Table 1 Overview of fungicide treatments and application dates

Application date	Fungicide applied	Fungicide concentration [%]
March 31, 2015	PROSARO® 250 EC	0.13
April 14, 2015	Fandango® 200 EC	0.4
April 28, 2015	PROSARO® 250 EC	0.28

The growth chambers protocols and water stress establishment

Tables 2 and 3 below show temperature and PAR, RH protocols respectively running within each chamber. The PAR (photosynthetic active radiation) intensity and RH (relative humidity) course was the same within all chambers. The pots were divided into 2 groups: well-watered (wet) and drought stressed (dry) with 7 replications (pots) for each combination of water regime and temperature.

Table 2 Protocols within the growth chambers (CH) – daily temperature (t) course (CH 1 = control chamber) presented in °C, the values of individual environmental factors changed continuously between two time points

Time	CH 1 t [°C]	CH 2 t [°C]	CH 3 t [°C]	CH 4 t [°C]	CH 5 t [°C]	CH 6 t [°C]
0:00	20	20	20	20	20	20
4:00	18	18	18	18	18	18
6:00	18	18	18	18	18	18
12:00	26	29	32	35	38	41
14:00	26	29	32	35	38	41
20:00	22	22	22	22	22	22
24:00	20	20	20	20	20	20

Table 3 Protocols within the growth chambers – PAR (photosynthetically active radiation, presented in µmol · m^{-2} · s^{-1}) and RH (relative humidity, presented in %), the values of individual environmental factors changed continuously between two time points

Time	PAR [µmol · m^{-2} · s^{-1}]	RH [%]
0:00	0	85
4:00	0	90
6:00	0	90
12:00	1500	45
14:00	1500	45
20:00	0	75
24:00	0	85

The actual volumetric soil moisture was measured using ThetaProbe Soil Moisture Sensor (Delta-T Devices Ltd, http://www.delta-t.co.uk) for feedback control of irrigation. The soil moisture was maintained below 30% of the maximum water holding capacity within the pots of the dry variant, and it was maintained to not decrease below 70% in the case of the wet variant.

Thousand grain weight (TGW) assessment

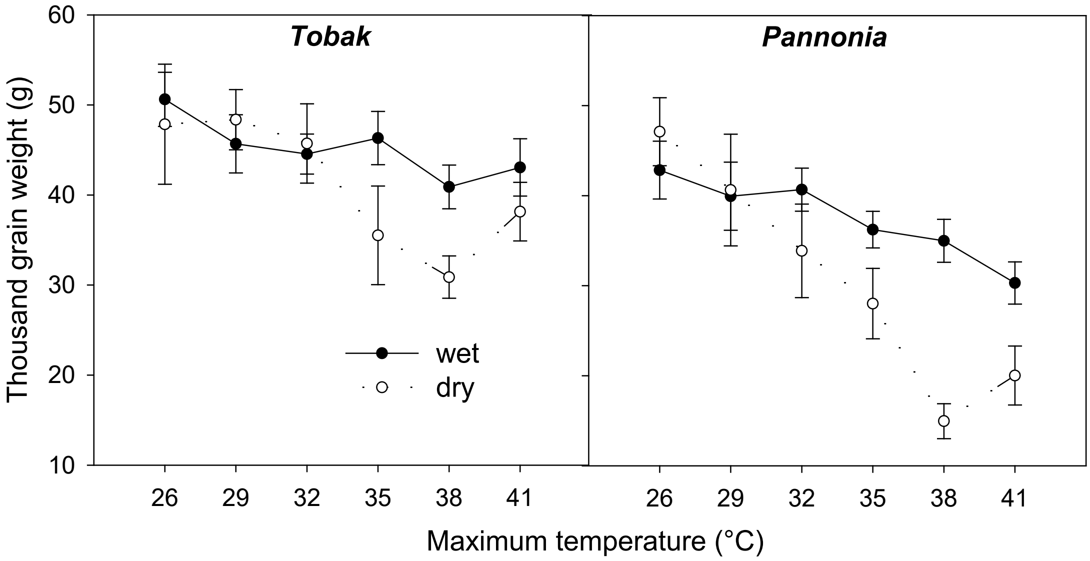
Both varieties were harvested manually. Grain numbers per main spikes within particular temperature and water stress treatments were counted, and also grain weight per main spikes at actual moisture and as a dry matter was found out using balances with accuracy of 0.001 g. The TGW was assessed by the dry matter conversion into 14% moisture and grain weights were evaluated by the actual-moisture weight also recalculated to 14% moisture where actual moisture (Act.m.) was calculated based on Hellevang (1995). The final TGW at 14% moisture ($TGW_{14\%}$) was calculated by the following equation (eq. 1):

$$TGW_{14\%} = \frac{TGW_{Act.m.} \times (100 - Act.m.)}{100 - 14} \quad (1)$$

RESULTS AND DISCUSSION

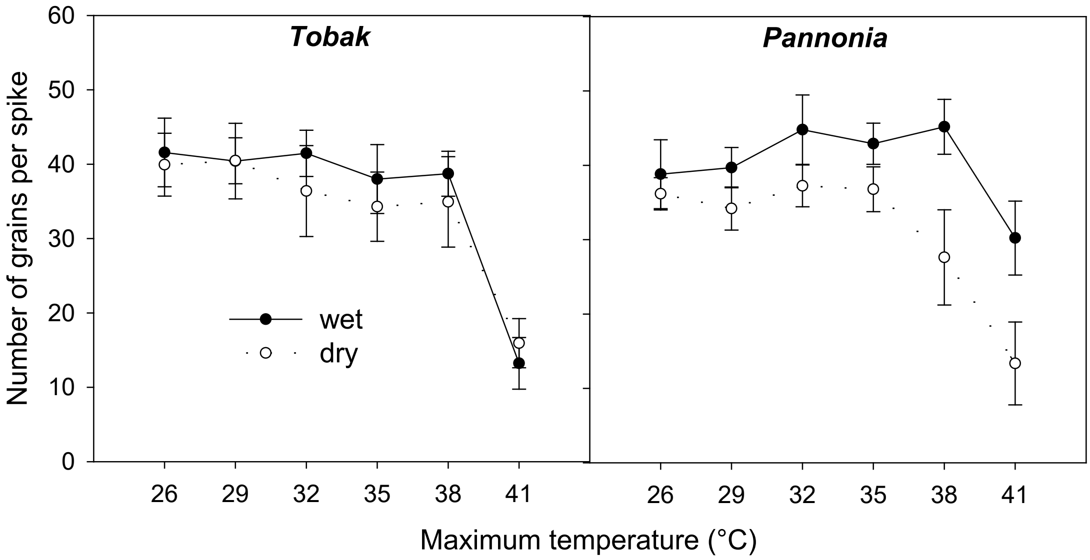
The responses of TGW to temperature and water regime treatments for individual varieties are shown in the Figure 1. The means were calculated from the data for main spikes for both sown plants per pot. The results show that high temperatures have a negative effect on TGW particularly when combined with drought stress. While under sufficient water supply was the decrease of TGW considerably lower and was observed in a variety Tobak at temperatures above 38°C and in variety Pannonia at temperatures above 35°C, under drought stress was this decrease found at temperatures above 35°C and 32°C for Tobak and Pannonia respectively. TGW decline was generally more pronounced in variety Pannonia which is surprising finding given the fact that the variety comes from warmer region (Serbia). This significant decline of TGW with temperature in the variety Pannonia is evident in both water regime treatment, i.e. sufficiently supplied by water and drought stressed. This temperature effect is significant in the case of combination of higher temperatures with drought stress. The drought stress treatments show also shift in temperature optima for TGW among varieties. While in the case of a variety Tobak it is obvious the temperature optimum for TGW around 29–32°C, then for variety Pannonia it is lower and it ranges around 26°C. In the case of plants adequately supplied with water, this shift is less pronounced. The results also show that at the highest temperature (41°C), in combination with drought, there is an increase of TGW within both varieties. This increase can be attributed to a significant drop in the number of grains per spike (see Figure 2) at the highest temperature which is then compensated by the increase of TGW.

Figure 1 Thousand grain weight (expressed in grams) at 14% moisture, means (points) and 95% confidence intervals are presented (n>7)



When compared with the general mean value for Tobak TGW reaching 46 g (CISTA 2015), this value was reached within dry variant at 26°C (control), and wet variant at the same temperature showed even higher value (slightly above 50 g). The situation was completely different for Pannonia where the general mean TGW value is 50 g (Palík et al. 2009) and this value was not reached in any case during the presented study (only the value reached within dry variant at 26°C was very close). While Pannonia is classified as a variety very resistant to drought and it is suitable for warmer areas, the combination of severe drought and extremely high temperatures can cause the markedly negative affect on TGW values. Tobak is also categorized as a variety strongly resistant to dry periods, nevertheless, the TGW values showed that the negative effect of the extremely high temperature and severe drought does not affect the TGW values as markedly as in the case of Pannonia.

Figure 2 Number of grains per spike (expressed in pcs), means (points) and 95% confidence intervals are presented (n>7)



The mean number of grains per spike was calculated from the data for main spikes for both sown plants per pot (Figure 2). While in variety Tobak the well-watered treatment showed similar number of grains per spike up to the temperature of 32°C, under drought stress the decrease of grain number was observed already at the temperatures above 29°C. However, the minimal drop in grain number was found in both treatments at the temperature 41°C. Contrary to variety Tobak, Pannonia evinced increasing number of grains per spike at the temperatures from 26 to 32°C with reaching maximum at the temperatures between 32–38 and 32–35°C in wet and dry treatment respectively, followed by the rapid decrease at 38°C within dry and at 41°C within wet variants. There is also more pronounced difference in grain number per spike between wet and dry treatments compared to variety Tobak. The results on number of grains per spike show that variety Pannonia responds very positively on water supply even at higher temperatures. When the water supply is sufficient, Pannonia variety is able to produce much more grains than under drought stress even at the higher temperatures.

CONCLUSION

The results showed that negative effect of high temperatures on TGW and also on number of grains is more pronounced under drought stress and combination of these two factors more affects Pannonia than Tobak.

ACKNOWLEDGEMENT

The research was financially supported by the Ministry of Education, Youth and Sports of CR within the National Sustainability Program I (NPU I), grant number LO1415. This article was written at Mendel University in Brno as a part of the project IGA AF MENDELU no. TP 7/2015 with the support of the Specific University Research Grant, provided by the Ministry of Education, Youth and Sports of the Czech Republic in the year of 2015.

REFERENCES

Alghabari F., Lukac M., Jones H. E., Gooding M. J. 2014. Effect of Rht alleles on the tolerance of wheat grain set to high temperature and drought stress during booting and anthesis. *Journal of Agronomy and Crop Science*, 200(1): 36–45.

CISTA (Central Institute for Supervising and Testing in Agriculture) [ed.] 2015. *Cereals and leguminous plants 2015*. 1st ed. Praha: CISTA. (Obilniny a luskoviny 2015).

Hellevang K. J. 1995. Grain moisture content effects and management. *NDSU Extension Service* [online]. AE-905. [2015-09-18]. Available from: https://www.ag.ndsu.edu/extension-aben/documents/ae905.pdf

Kulas L. 2015. Winter cereals 2015: wheat, barley, Triticale, rye. *OSEVA, a. s.* [online]. [2015-09-18]. Available from: http://www.osevabzenec.cz/zd/oseva_ozimy2015.pdf (Ozimé obilniny 2015: pšenice, ječmen, tritikale, žito).

Marcellos H., Single W. 1984. Frost injury in wheat ears after ear emergence. *Australian Journal of Plant Physiology*, 11(2): 7–15.

Palík S., Burešová I., Edler S., Sedláčková I., Tichý F., Váňová M. 2009. *Methodology for growing of winter wheat for bakery purposes*. Kroměříž: Agrotest fyto, s. r. o. (Metodika pěstování ozimé pekárenské pšenice).

Saini H. S., Sedgley M., Aspinall D. 1983. Effect of heat stress during floral development on pollen tube growth and ovary anatomy in wheat (*Triticum aestivum* L.). *Australian Journal of Plant Physiology*, 10(2): 137–144.

Semenov M. A., Shewry P. R. 2011. Modelling predicts that heat stress, not drought, will increase vulnerability of wheat in Europe. *Scientific Reports*, 1(66).

Stratonovitch P., Semenov, M. A. 2015. Heat tolerance around flowering in wheat identified as a key trait for increased yield potential in Europe under climate change. *Journal of Experimental Botany*, 66(12): 3599–3609.

Vara Prasad P. V., Djanaguiraman M. 2014. Response of floret fertility and individual grain weight of wheat to high temperature stress: sensitive stages and thresholds for temperature and duration. *Functional Plant Biology*, 41(12): 1261–1269.