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Wheat under environmental stress: experiments with 25 elite genotypes within the CORNET network

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Abstract

German, Austrian and Hungarian wheat breeders and producers established a core set of 25 varieties (incl. 2 hybrid varieties) of winter wheat for testing and evaluation under different environments at 11 locations in the three countries in 2010. Different phenotypic data (heading date, grain yield, Hagberg falling number, wet gluten content, thousand kernel weight) were collected and evaluated. Hybrid variety Hyland showed high grain yield with good adaptability to humid conditions. Smallest changing of thousand kernel weights were observed for GK Petur, Hyland and Tacitus. Concerning quality traits Hyland was inferior to a lot of tested varieties. Hagberg falling number was well balanced when values were collected from 11 locations, but under extra Hungarian condition the differences were bigger. In Hungary highest values of falling number and wet gluten content were recorded for JB Asano, Element, Capo and GK Csongrád, and Exklusiv, Capo, Bitop and GK Békés, respectively. The presented and discussed results will be integrated in wheat improvement and the second year of the CORNET research programme „Wheat Stress“.

Keywords

Drought, quality, stress, *Triticum aestivum*, yield

Introduction

Crop plants have developed a number of strategies to survive with periods of moderate to severe drought. These include escape strategies such as early flowering, avoidance such as deep rooting, enhanced water-uptake efficiency or reduced water loss, as well as tolerance mechanisms that include maintenance of root growth under water limitation, the accumulation of osmotically active substances, antioxidants, and proteins that protect other protein (complexes) or membrane systems in root and shoot (BLUM 1996, INGRAM and BARTELS 1996, CHAVES et al. 2003, CONDON et al. 2004, MOLNÁR et al. 2004). There is an ongoing debate whether the exploitation of avoidance or tolerance mechanisms should be in the focus of plant breeding programs. However, it seems that exploitation of tolerance mechanisms may be more promising for the stabilization of crop yield under severe drought conditions as encountered in Near-East or African countries, as well as in Australia, although the corresponding adapted breeding material might have a lower yield potential (ARAUS et al. 2002).

High temperature and precipitation deficiency are extreme weather conditions that occur the most frequently in the Carpathian Basin and which have maximum influence on crop production. Responses to changes in climatic factors are fundamentally influenced by the genetically determined tolerance of the plants and the extent to which they are hardened against the given stress. The former can be altered by means of breeding, while the latter can be influenced by production technology. Abiotic stress research has a long history. Knowledge has been acquired on various plant defence mechanisms and their physiological background, and on the extent of genetic variability within the species, particularly in the case of drought tolerance. Nevertheless, only limited success has been achieved in incorporating traits associated with drought and heat tolerance into commercial varieties (BLUM 2005, CHAERLE et al. 2005, MARDEH et al. 2005, HU et al. 2006). This can be attributed to various factors. On the one hand, these types of stress may occur either separately or together in the course of the growing period, they may appear in various forms, and they may induce various stress responses in different stages of plant development, thus complicating simultaneous breeding for various types of drought and heat stress tolerance. On the other hand, although genetic, physiological and molecular biological analyses have already revealed many facets of these complex processes, no real breakthrough has yet been achieved in the development of molecular markers that could accelerate breeding or in the elaboration of specific biotechnological techniques.

Material and methods

Plant material

In total 25 genotypes were selected to test the adaptability of winter wheat genotypes in three countries at 11 locations (6 Germany, 3 Austria, 2 Hungary). The nursery comprised 2 German hybrid varieties (i.e. Hybred and Hyland) and

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23 traditional line varieties from Germany (i.e. Brilliant, JB Asano, Pegassos and Tiger), Austria (i.e. Bitop, Capo, Eurofit, Eurojet, Element, Exklusiv, Komárom, Midas and Tacitus), Hungary (i.e. GK Békés, GK Csongrád, GK Hunyad, GK Fény, GK Kalász, GK Petur, GK Rába and GK Szala), United Kingdom (i.e. Robigus) and France (i.e. Premio).

Experimental conditions

German field trials were conducted at 6 locations in 3 replications with a plot size between 5 and 9 m². Field trials were sown between 6 and 29 October 2009 with a sowing density of 350 grains m^{-2}. Pre-crops were spring barley, sugar beet, winter rapeseed, and oats. All 25 varieties developed well after winter but lodging was recorded at Roggenstein, Uffenheim, and Feldkirchen. In Morgenrot, 2 replications were damaged by wild pigs, partially up to 95%. With exception of Morgenrot, fungicide treatment (1-1.25 $l \cdot ha^{-1}$) was performed once at each location. Nitrogen was applied in total from 120 to 221 kg $N \cdot ha^{-1}$ on each location divided into three and four doses, respectively. The field trials were harvested between 8 and 21 August 2010; the harvested plot size varied between 4.5 and 6 m².

In Austria the experiments were carried out at three locations in the Pannonian region (i.e. Breitstetten, Tattendorf and St. Andrä). In Tattendorf and Breitstetten the nursery was established in an irrigated and rainfed trial. The experimental design was a randomized lattice design with three replications. Plot size varied from 8.0 to 13.5 m². Pre-crops were sorghum, rye and potato, respectively. Nitrogen application ranged in total from 129 to 140 kg $N \cdot ha^{-1}$ on each location divided into two and three doses. The precipitation in the Austrian trials was extremely above average (66% above the long-term precipitation from April until 21 July). The trials were harvested between 15 and 23 July.

In Hungary two parallel (irrigated, natural) experiments were carried out in Szeged and in Kiszombor (25 km east of Szeged). One experiment was carried out to test the most important agronomic parameters (incl. grain yield). All experiments were planted as a lattice design with four replications. Plot size was 6.5 m² at both locations. Pre-crop was winter rapeseed. Nitrogen fertilization was 68 kg $N \cdot ha^{-1}$ applied as 200 kg of NH_4NO_3 (34%) at both locations. The weather condition was extraordinary. From January until end of June the precipitation was 458.6 mm which is nearly equal with the previous whole year averages. Harvest was at 10 July.

Traits

In this contribution the results of only five important agronomic traits, i.e. heading time, grain, yield, thousand kernel weight (TKW), Hagberg falling number and wet gluten content are demonstrated and discussed.

Results

Heading time

This is one of the most important information in connection with ecological requirements and maturation time of the genotypes. Based on the data three different groups were separated: (i) early (GK Csongrád, GK Békés, GK Fény, GK Kalász, GK Rába, GK Petur, Tacitus and GK Hunyad), (ii) medium (Element, Hyland, Bitop, GK Szala, Premio, JB Asano, Komárom, Midas, Tiger and Capo) and (iii) late (Pegassos, Eurofit, Eurojet, Hybred, Brillant, Robigus and Exklusiv). Seven of the Hungarian varieties belong to the early type, while Austrian and German genotypes were predominantly found in the medium and late type group, as well as the French and English varieties. Hence, the Hungarian genotypes are significantly differing from the other genotypes in regard to this trait.

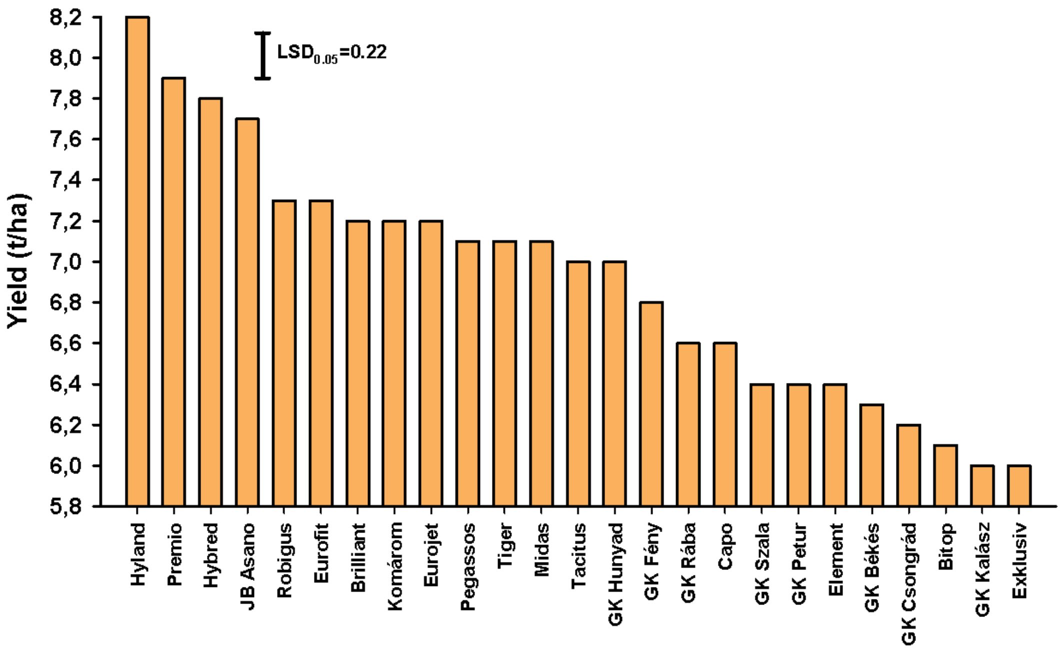

Figure 1: **Mean grain yield ($t \cdot ha^{-1}$) of the winter wheat core set over all 11 locations**

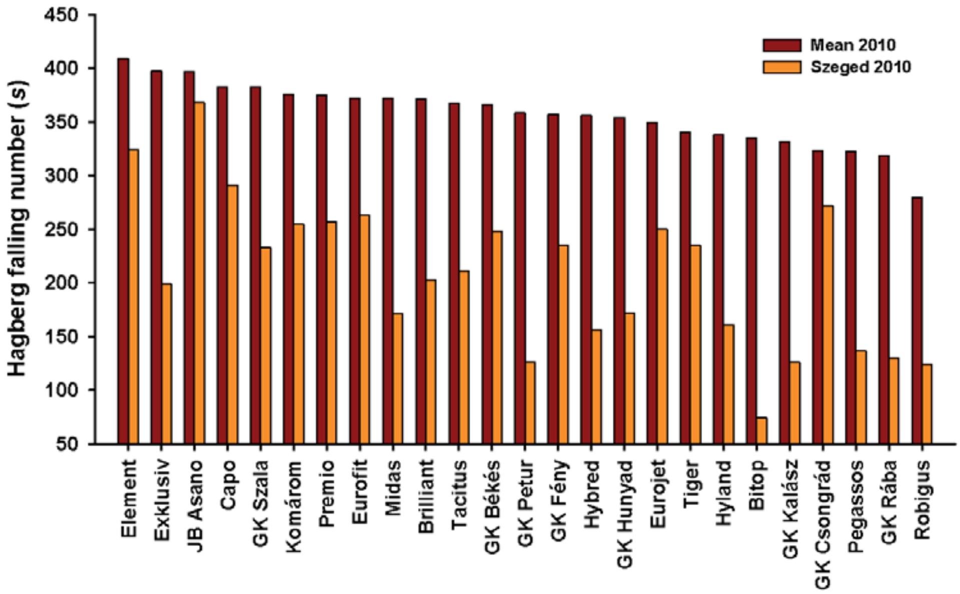

Figure 2: **Hagberg falling number of the winter wheat core set in Szeged, Hungary, and overall mean values (11 locations in Austria, Germany and Hungary, respectively)**

Grain yield

Significant differences were obtained for grain yield among locations and genotypes. The total mean yield was 6.93 $t \cdot ha^{-1}$. Mean grain yield was highest in Germany with 7.57 $t \cdot ha^{-1}$, followed by Austria with 6.75 $t \cdot ha^{-1}$ and Hungary with 6.03 $t \cdot ha^{-1}$. The wide range of yields (6 to 8.2 $t \cdot ha^{-1}$) demonstrates the wide genetic background of the genotypes. Based on the yield data seven significantly different groups were separated (*Figure 1*). The highest yield was produced by Hyland, one of the two German hybrid varieties. This genotype was the best in regard to grain yield in each country. The other hybrid achieved the third place after Premio.

Falling number

The Falling number test does not directly measure amylase enzyme activity, but measures changes in the physical properties of the starch portion of the wheat kernel caused by these enzymes during the test. Values <250 s indicate high levels of enzyme activity. In the past, cereal dealers have discounted wheat for falling number values <300 s. Falling number values are also important for the international wheat market, as many buyers from export markets request minimum limits of 250 to 350 s in their contracts. The extreme wet and rainy year 2010 was responsible for low falling numbers even in Hungary. Altogether, only eight varieties

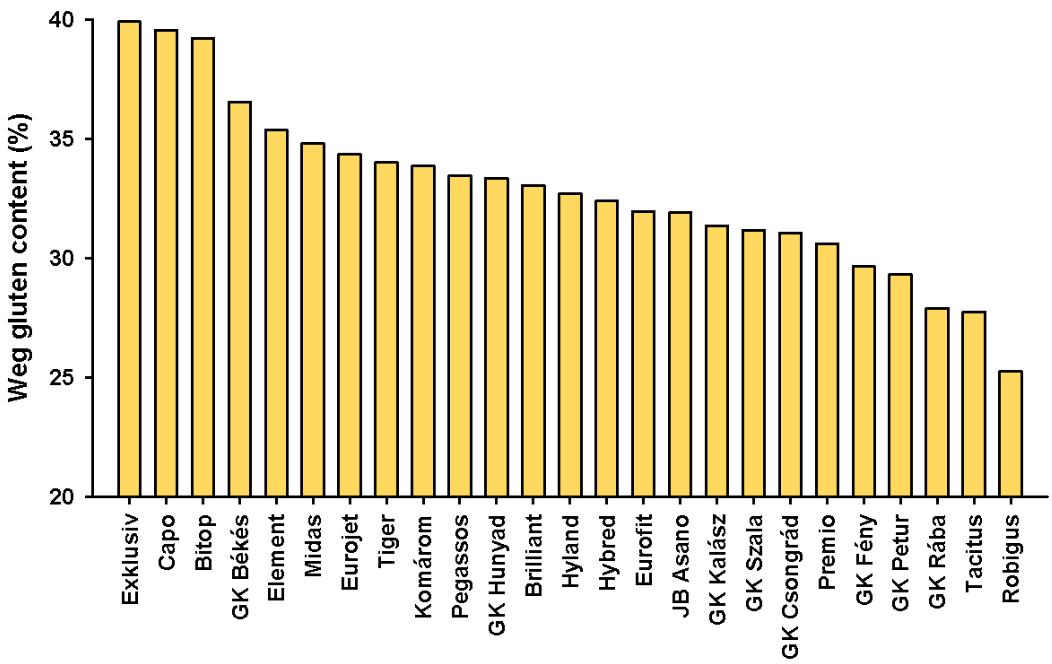

Figure 3: **Wet gluten content (%) of the winter wheat core set measured by NIRS (irrigated trial, Szeged, Hungary)**

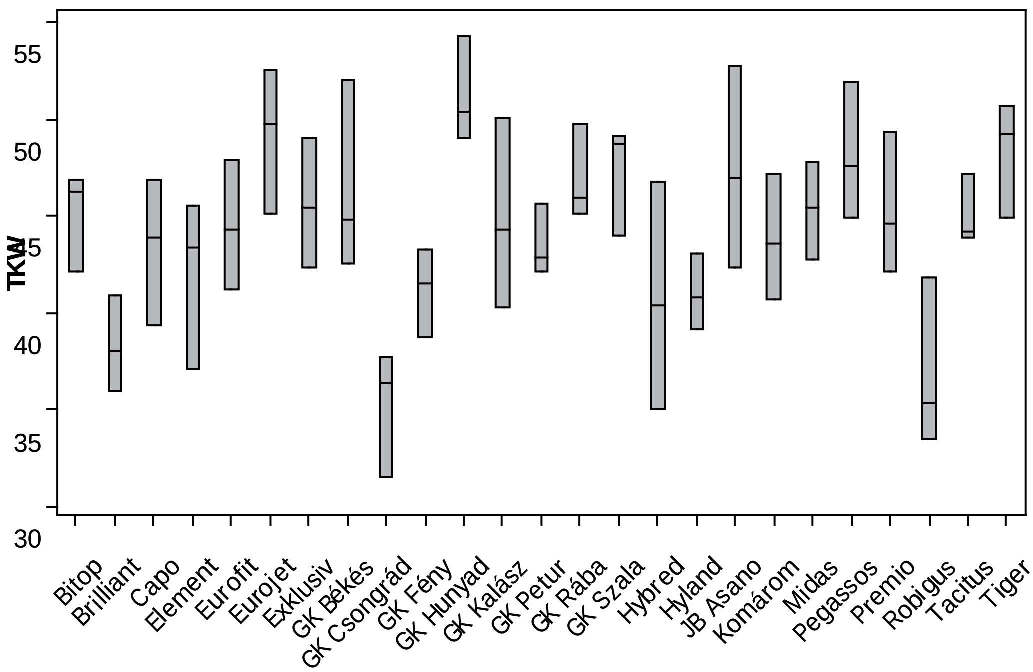

Figure 4: **Changing of TKW based on the data of 11 locations. Area of the boxes shows the sensitivity (variance) of the genotypes. The most sensitive genotype has the biggest box, while the most adaptable genotype has the smallest box.**

exceeded the value of 250 s in Hungary (*Figure 2*). Hagberg falling number was well balanced when values were collected from 11 locations, but under extra Hungarian condition the differences were bigger. In Hungary highest values of falling number were recorded for JB Asano, Element, Capo and GK Csongrád.

Wet gluten content

Wet gluten is a visco-elastic proteinaceous substance obtained after washing out the starch granules from wheat flour dough. The quality of the resulting gluten is a considerable index of the wheat baking potential. The wet gluten content (%) measured by near-infrared spectroscopy (NIRS) from the irrigated experiment in Szeged, Hungary, is shown in *Figure 3*. The three varieties Exklusiv, Capo and Bitop have the highest rate. Most of the varieties belong to the 30 to 36 % group. Five varieties showed a wet gluten content below 30%.

Thousand kernel weight

Changes in TKW is a good indicator of the sensitivity of genotypes to biotic and abiotic stresses. The statistical analysis revealed changing TKWs across locations. Small changes suggest adaptation to different field and weather conditions.

The smallest changes in TKW were observed for GK Petur, Hyland and Tacitus (*Figure 4*).

Discussion

Drought is one of the most important stress factors. The plants response to drought is a complex mechanism including molecular, physiological changes which influence the morphology and phenology of whole plants (BLUM 1996, CHAVES et al. 2003, MOLNÁR et al. 2004, BLUM 2005, 2005, HU et al. 2006). Field experiment of 25 winter wheat varieties were carried out in Austria, Germany and Hungary at 11 locations. Five agronomic traits (heading time, grain yield, TKW, Hagberg falling number, wet gluten content) were evaluated to reveal the adaptability of the genotypes. Based on heading time the Hungarian genotypes separated from the others. This fact shows the different weather conditions of experimental stations. The Hungarian climate in the Carpathian Basin is favorably for early or medium types of winter wheat.

Grain yield is the most important parameter, farmers require drought tolerant varieties with high yield potential at good and bad production conditions (ARAUS et al. 2002). The experiments revealed Hyland, Premio, Hybred, JB Asano, Robigus, Eurofit, Brilliant, Komárom and Eurojet as genotypes with a high yield potential. In all three countries the highest grain yield was recorded for Hyland. The second hybrid variety, Hybred, was on the third place in regard to grain yield. Yield difference between hybrid and conventional line varieties was not as significant as known for other crop species, e.g. maize. Nevertheless, the results underline the importance of hybrid winter wheat breeding.

Not only high yield potential, but also good baking quality is essential for a variety. In this experiment Hagberg falling number and wet gluten content were measured. In case of falling number, the highest values were measured in Hungarian samples of JB Asano, Element, Capo, GK Csongrád, Eurofit, Premio, Komárom and Eurojet. Exklusiv, Capo, Bitop, GK Békés, Element, Midas, Eurojet, Tiger and Komárom reached the highest values in wet gluten content. The two hybrid varieties took place on the second part of the range concerning the two quality parameters.

Analysis of TKW revealed a presumably good adaption for GK Petur, Hyland and Tacitus. These trait is the key to assure the competitiveness of a variety across different weather conditions. The data showed that Hyland has a high yield potential and a good adaptability. This combination of traits provided the first place of this genotype in each country. However, its quality was inferior to most of the tested genotypes.

The 2010 experiments represent only one-year results from the CORNET Wheat Stress winter wheat core set. For more correct results and conclusions the experiments of the second year have to be awaited.

Acknowledgements

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