Volume 52(1):97-100, 2008
Acta Biologica Szegediensis
http://www.sci.u-szeged.hu/ABS

ARTICLE

Testing drought tolerance of wheat by a complex stress diagnostic system installed in greenhouse

Petra Majer[1], László Sass[2], Tamás Lelley[3], László Cseuz[1], Imre Vass[2], Dénes Dudits[2], János Pauk[1]*

[1]Departement of Biotechnology, Cereal Research Non-Profit Co., Szeged, Hungary, [2]Institute of Plant Biology, Biological Research Center, Hungarian Academy of Sciences, Szeged, Hungary, [3] Universität für Bodenkultur Wien, IFA Tulln, Austria

ABSTRACT Drought is one of the most important abiotic stress factors and depending on the season it can seriously limit wheat production. Breeding for drought tolerance is becoming a more and more important challenge in case of crop plants, notably in wheat. The breeding process includes the characterization of the basic breeding materials in aspect of performance under well-watered and drought stressed conditions. In our experiments we set up a complex stress diagnostic system in the greenhouse of the Cereal Research Non-profit Company where we could analyze the responses of different winter and spring wheat cultivars to drought. Wheat plants were grown under ideal water regime (watering to 60% of the 100% soil water capacity) and under drought stress conditions (watering to 20% of the 100% soil water capacity). The effect of water withholding on plant growing was tracked by a digital imaging system on the basis of number of plant pixels. After harvesting, plant heights, spike lengths, grain numbers and total grain weights were measured and values of well-watered and stressed plants were compared. Here the measured parameters of two drought tolerant (Sardari, GK 11-05) and two drought sensitive (Kärtner Früh, Jing 411) wheat genotypes are presented to prove the competence of our system in characterizing drought tolerance of wheat plants.
Acta Biol Szeged 52(1):97-100 (2008)

KEY WORDS
wheat
drought stress
diagnostic system

Drought is one of the most important abiotic stress factors. Depending on the season drought can limit crop production seriously. Plant responses to drought stress are complex mechanisms which include molecular changes and extend to the whole plant metabolism influencing the morphology and phenology of plants (Blum 1996; Chaves et al. 2003; Condon et al. 2004; Molnár et al. 2004).

Breeding for drought tolerance is becoming a more and more important challenge in case of crop plants, notably in wheat. The breeding process includes the characterization of the basic breeding materials in the aspect of performance under well-watered and drought stressed conditions. In recent years there have been many approaches to select wheat genotypes which are resistant to drought, for example by improving water use efficiency (Blum 2005; Chaerle et al. 2005; Hu et al. 2006), using drought resistance indices (Mardeh et al. 2006) or simulating drought conditions in greenhouse experiments (Gáspár et al. 2005; Hoffmann and Burucs 2005).

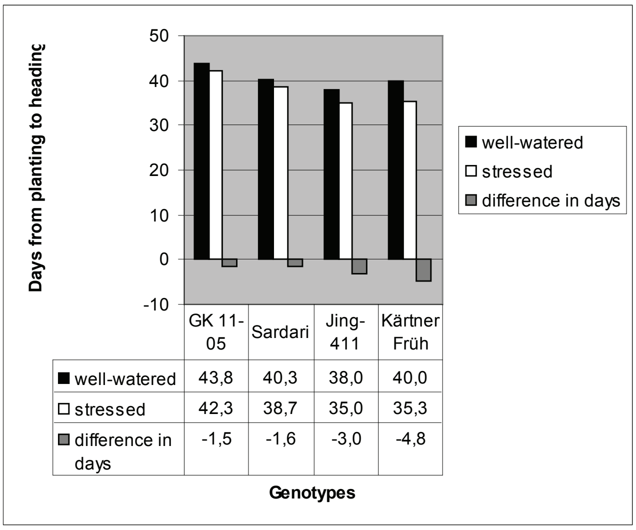
It is clear that an extensive approach is needed to test such a complex trait as drought tolerance. Therefore, in our experiments a complex stress diagnostic system was set up in the greenhouse of the Cereal Research Non-profit Company where we could analyze the responses of different winter and spring wheat cultivars to drought. In this way tolerant genotypes could be selected. Different genotypes were tested in our system but here the results of two drought tolerant and two drought sensitive cultivars from different origin are presented.

Materials and Methods

Tolerant genotypes were Sardari (from Iran) and GK 11-05 (CRCo. genotype), the two sensitive genotypes were Kärtner Früh (Austrian wheat cultivar) and Jing 411 (Chinese wheat cultivar). Wheat seedlings were vernalised at 3°C for 6 weeks. Plants were transferred into pots containing mixture of 50% Terra peat soil and 50% Maros sandy soil, two in each pot. Equal quantities of chemical fertilizer (Substral Osmocote Plus) were put in each pot at the time of planting. After a week, plants were thinned and one was left in each pot.

Of each genotype, four pots were exposed to drought stress conditions and the four others were treated as controls. Water capacity of soil was determined and pots were watered twice a week, to 20% (stressed) and 60% (well-watered) of 100% soil water capacity, respectively. Watering was done automatically by a plant mover system including a balance in connection with a computer-mediated peristaltic pump. As pots had a radiofrequency identifier, watering data could be stored automatically by computer. Days to heading were registered individually for each plant. The effect of water

*Corresponding author. E-mail: janos.pauk@gk-szeged.hu



	GK 11-05	Sardari	Jing-411	Kärtner Früh
■ well-watered	43,8	40,3	38,0	40,0
□ stressed	42,3	38,7	35,0	35,3
■ difference in days	-1,5	-1,6	-3,0	-4,8

Figure 1. Days from planting to heading in the different treatments (well-watered and stressed).

withholding on plant growing was tracked weekly by a digital imaging system on the basis of number of plant pixels (Olympus Camedia C-7070 digital camera).

Plants were harvested after ripening. Plant heights (measured from ground to the last node) and spike lengths (without awn) were measured. Shoots were dried at 40°C for 4 days to permanent water content. Shoot dry weight, number of grains and total grain yield weight were measured.

Results

In our greenhouse diagnostic system the plants grown under drought conditions were significantly differ in their morphological aspects and in their yield parameters from the well-watered plants. Drought had serious effects on plant growing (green and dry weights): stems were thinner and spikes were smaller than those of their ideally watered parallels. Yield depression was remarkable in case of all varieties, but depressions were more significant in sensitive genotypes.

In case of days from planting to heading the sensitive Jing 411 and Kärtner Früh genotypes responded with earlier heading to stress (Fig. 1). Earlier heading is a general response of sensitive wheat plants to drought. In case of GK 11-05 and Sardari there were no significant differences in the time of heading in the two treatments.

Here the growing curves of the two winter wheat varieties are presented (Fig. 2). On these figures the horizontal axis represents the time while the vertical axis represents the "green weight" of the plant calculated from the pixels gained from digital imaging. As it is shown in Figure 2., the GK 11-05 have not reduce growing in response to stress until the end of the growing period, while the sensitive Jing 411 was stopped growing after heading and used up its so far collected reserves to produce grain.

Figure 3. shows the genotypes in aspect of their agrobotanical (plant height, spike length, dry weight) and yield parameters (grain number, grain weight), where 100% represents the values of the well-watered plants. Since wheat varieties from different origin differ in their morphological and agronomical parameters, it is better to compare the parameters of the genotypes in relative values (percentages) instead of absolute values. In the yield parameters of the tolerant varieties there were less depression in response to stress. The most significant differences between treatments could be observed in the number of seeds. However in case of plant height and spike length all varieties suffered only a slight depression. There were differences in shoot dry weight,

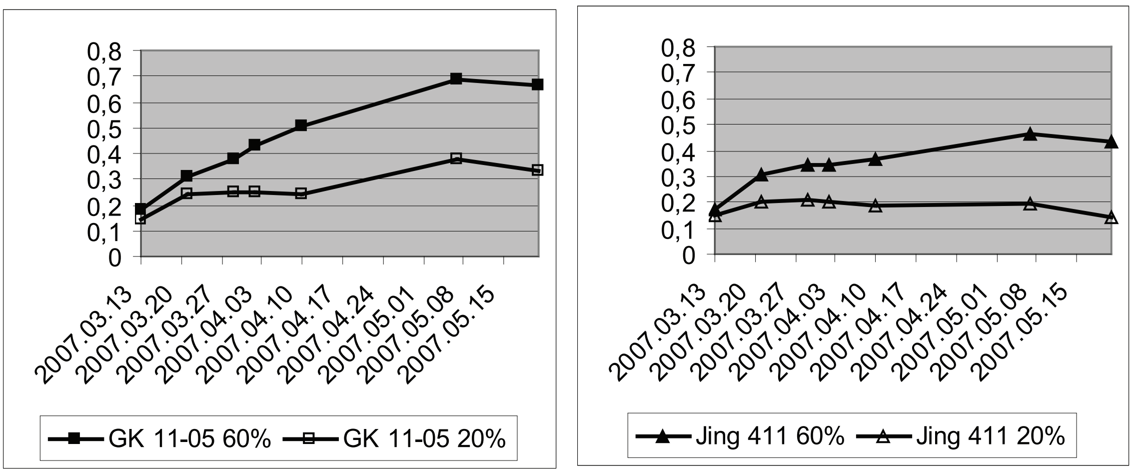


Figure 2. Growing curves of well-watered and stressed plants. Days of heading: GK 11-05 well-watered: 08.04.04, stressed: 08.04.03; Jing 411 well-watered: 08.03.30, stressed: 08.03.27.

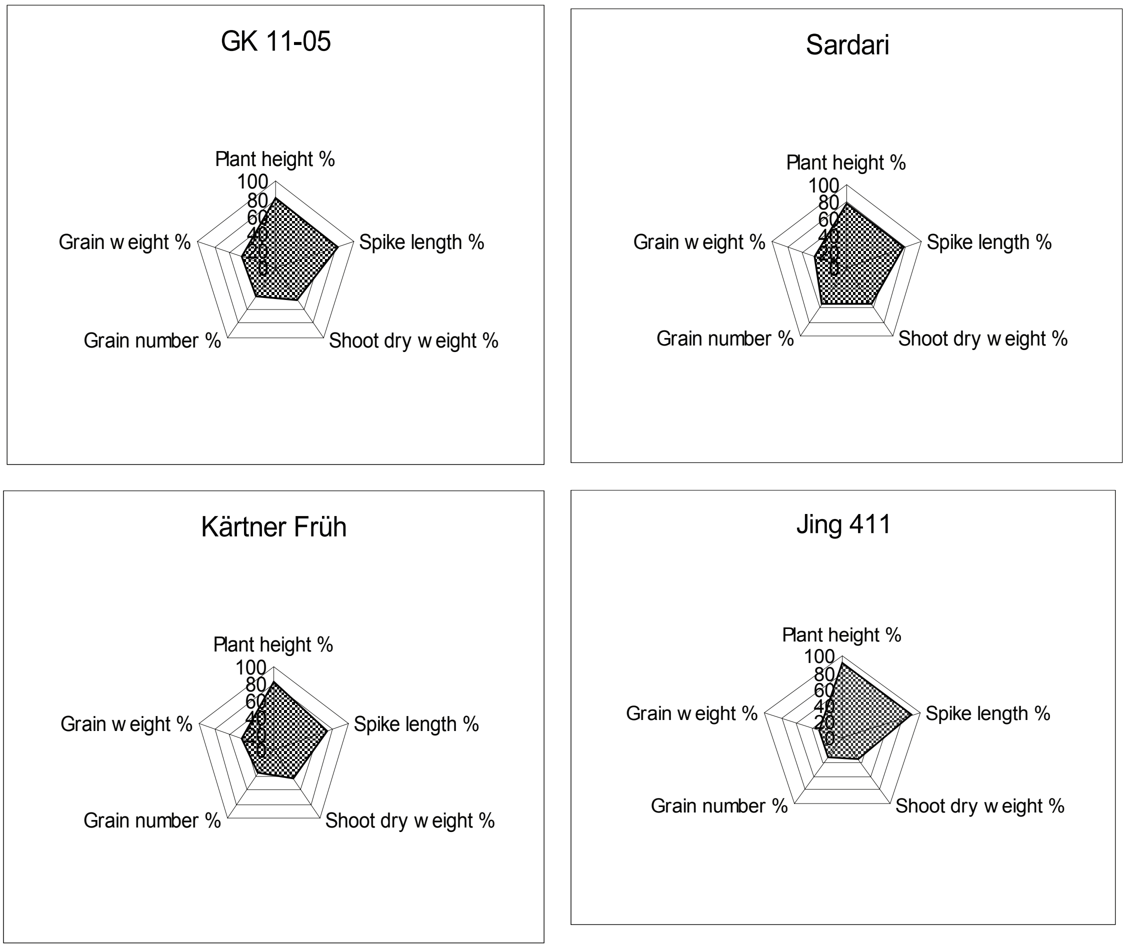


Figure 3. Changing in agrobotanical and yield parameters in response to drought stress. 100% represents the values of the well-watered (control) plants.

too: the tolerant Sardari and GK 11-05 varieties suffered 45 and 55% depression respectively, while the sensitive Kärtner Früh and Jing 411 varieties suffered 60 and 67% depression, respectively. Therefore the polygons representing the tolerant and the sensitive genotypes differ in their areas.

Discussion

In our greenhouse stress diagnostic system we could analyze the responses of different wheat genotypes by modeling drought stress. Water withholding had serious effects in case of all wheat genotypes on morphological and yield parameters. Sensitive genotypes responded with earlier heading and therefore shortened life cycle to stress (Hoffmann and Burucs 2005). The varieties referred to as tolerant had no significant differences in the time of heading. Hence, registering the time of heading proved to be a useful tool to characterize genotypes.

Tracking the growing rate of plants can serve as a useful tool in testing the varieties for drought tolerance. Digital imaging is a modern and non-invasive method in evaluating green weight of the plants on the basis of pixel number without cutting and measuring them (Kacira and Ling 2001). Furthermore, with this method the growing of the plants can be followed week by week and a growing curve can be drawn for each plant and (a cumulated growing curve) for each genotype. Hence, the size of control and stressed plants can be compared at any period of growing.

There were no significant differences between the genotypes tested in the depression in plant height and stem length, but shoot dry weight was more reduced in sensitive genotypes than in tolerant ones. Therefore it can be assumed that shoot dry weight measured after harvesting is also a relevant parameter in characterizing wheat genotypes for drought tolerance.

Yield parameters are the most important agronomical traits in selecting drought tolerant genotypes. The depression in grain number and total grain yield was significantly smaller in tolerant genotypes. We would like to note that to select a drought tolerant genotype with high yield, one have to consider not only the yield stability but the high yield at good producing conditions, too (Araus et al. 2002). In respect to this, our results can be completed with this factor by using different stress indices (Mardeh et al. 2005). However, there have not been any reports on using stress indices in greenhouse experiments yet. Greenhouse experiments mean somehow artificial conditions to field crops like wheat. Therefore are results gained in greenhouse experiments are further evaluated by comparing them to the results of our nursery tests.

Besides characterizing wheat genotypes in aspect of drought tolerance our stress diagnostic system can also be useful in testing other plant species (e.g.: rice, barley) for different kinds of abiotic stresses, like heat, frost and for biotic stresses, too. Mapping populations can also be screened effectively in our diagnostic system.

The system is currently under development, we are going to broaden the range of measured parameters by installing infrared thermal imaging and fluorescent imaging systems. These modern non-invasive methods could complete our diagnostic system by giving a better physiological characterization of plants (Chaerle and Van Der Straeten 2001).

Acknowledgements

We would like to thank Dr. János Györgyey for providing Jing 411 genotype. This work was supported by GVOP-3.1.1.-2004-05-0096/3.0, NKFP 4 064 2004 and NAP_BIO2006-ALAP3-0 1435/2006 research grants.

References

Araus JL, Slafer GA, Reynolds MP, Royo C (2002) Plant breeding and drought in C_3 cereals: What should we breed for? Annals Bot 89:925-940.

Blum A (1996) Crop responses to drought and the interpretation of adaptation. Plant Growth Regul 20:135-148.

Blum A (2005) Drought resistance, water-use efficiency, and yield potential—are they compatible, dissonant, or mutually exclusive? Aust J Agr Res 56:1159–1168.

Chaerle L, Saibo N. Van Der Straeten D (2005) Tuning the pores: towards engineering plants for improved water use efficiency. Trends Biotechnol 23(6):308-315.

Chaerle L, Van Der Straeten D (2001) Seeing is believing: imaging techniques to monitor plant health. Biochim Biophys Acta 1519:153-166.

Chaves MM, Maroco JP, Pereira JS (2003) Understanding plant responses to drought – from genes to the whole plant. Funct Plant Biol 30:239-264.

Condon AG, Richards RA, Rebetzke GJ, Farquhar GD (2004) Breeding for high water-use efficiency. J Exp Bot 55(407):2447-2459.

Gáspár L, Czövek P, Fodor F, Hoffmann B, Nyitrai P, Király I, Sárvári É (2005) Greenhouse testing of new wheat cultivars compared to those with known drought tolerance. Acta Biol Szeged 49(1-2):97-98.

Hoffmann B and Burucs Z (2005) Adaptation of wheat (*Triticum aestivum* L) genotypes and related species to water deficiency. Cereal Res Commun 33(4):681-687.

Hu YC, Shao HB, Chu LY, Gang W (2006) Relationship between water use efficiency (WUE) and production of different wheat genotypes at soil water deficit. Colloid Surface B 53:271-277.

Kacira M, Ling PP (2001) Design and development of an automated and non-contact sensing system for continuous monitoring of plant health and growth. Transactions of the ASAE 44(4):989-996.

Mardeh AS, Ahmadi A, Poustini K, Mohammadi V (2006) Evaluation of drought resistance indices under various environmental conditions. Field Crop Res 98:222-229.

Molnár I, Gáspár L, Sárvári É, Dulai S, Hoffmann B, Molnár-Láng M, Galiba G. (2004) Physiological and morphological responses to water stress in *Aegilops biuncialis* and *Triticum aestivum* genotypes with differing tolerance to drought. Funct Plant Biol 31:1149-1159.