BREEDING WHEAT FOR TOLERANCE TO DROUGHT AT THE CEREAL RESEARCH NON-PROFIT COMPANY

LÁSZLÓ CSEUZ

Cereal Research Non-Profit Company
Department of Cereal Breeding
Szeged H-6726 Alsókikötő sor. 9. Hungary
laszlo.cseuz@gabonakutato.hu

ABSTRACT
At the Cereal Research Non-Profit Co. two decades ago we developed a selection program for drought tolerance of wheat by the chemical desiccation method and the flag leaves' water retention ability (CSEUZ ET AL., 2002). As our testing methods were developing, after we started irrigation tests, we begin to select for drought tolerance by the remote thermometry of canopy surface (photosynthetic activity during drought stress). Since the year 2006 a mobile automatic rain shelter helps the selection for the tolerance to water shortages *per se* in the field. In this test we evaluate 50-60 advanced wheat lines together the check varieties are planted under the rain shelter and in the control (irrigated) treatment yearly.
The 0.33 m^2 plots are planted in three replications in both treatments. During the life cycle of the genotypes we evaluate the changes of the most important agronomy characters (plant height, heading and flowering date, canopy temperature measurements data, thousand kernel mass, and grain yield) due to the water withdrawal.
Also important information can be got from the multi-location yield trials especially at drier locations and/or in drier years. The advance in drought tolerance can be found among our latest registered wheat varieties and numerous new winter wheat candidates with a higher level of adaptability to dry environments: wheat varieties GK Csongrád (2001), GK Hunyad (2005), GK Békés (2005), GK Csillag (2005), GK Berény (2010) are reputed tolerant, and performed very well under stress conditions, too.

Keywords: drought tolerance, wheat, selection, rain shelter, canopy temperature

INTRODUCTION

The main factors limiting the world's plant production at present are environmental stresses. Drought, one of the most significant abiotic stresses, makes plant production impossible on more than one third of the world's arable land, and also causes huge variations of the grain yield on the cultivated areas. Drought stress is a highly complex phenomenon. Its strength, length, timing, or co-occurrence with other abiotic stresses (heat stress, salt stress, etc.) is altering year after year under our conditions. Therefore, if we want to start a breeding program first we must find those most important selectable characteristics which are playing significant role in adaptation and tolerance to water deficits.
Under our conditions the goal is to produce genotypes which are resistant to drought in every developmental stage of their life cycle.
In spite of the fact that winter wheat *(Triticum aestivum* L.*)* is a quite stress tolerant crop plant, water deficiency may cause remarkable losses in grain yield and quality. Grain yield improvement under drought stress conditions must combine the high yield potential and specific factors, which are able to protect the grain yield against reductions due to water shortages. Since the weather and natural water supply in Hungary is changing year by year, grain yield data are not suitable to judge the tolerance level of cultivated genotypes. Among the difficulties in conventional breeding are the facts, that drought tolerance and yield capacity are mostly negatively correlated to each other and in consequence of the

complexity of drought resistance, the selection for certain characteristics will not prove successful, and there is no accepted method with which we could reliably test these characteristics. We have to evaluate the tolerance level of genotypes by means of simple, fast but reliable testing methods, which can be applied in the field or even in laboratories and can be performed independently of the weather conditions. In this paper we demonstrate our efforts in this field.

MATERIAL AND METHOD

Wheat breeding system at the CRNC is a modified pedigree method, based on manual crossing, head selection from F2 generation until uniform head-rows are available. Generally from F4 generation information yields trials, later four-replicated yield trials, and at last multi-location performance tests help selecting the best ones among the advanced lines. From the generation of F5, quality tests and parallel scoring in rust (*P. recondita, P. graminis*) and virus nurseries (under provocative conditions) give additional information for the successful selection. In the younger, segregating generations (F3-F5) visual scoring of morphological and phenological characters is the only effective method to evaluate the drought tolerance of large number of genotypes (15,000-20,000 accessions per year). The most important traits that may be checked visually are: leaf firing, leaf rolling, leaf color under serious stress, the hairiness or glaucosity of the leaves, kernel size and healthiness. Fast seedling emergence, rapid phenological development in spring, earliness in heading, anthesis and maturity are also advantageous parameters when the goal is drought tolerance.

For testing drought tolerance *per se* in the field, mobile automatic rain shelter was constructed and installed in the nursery of CRC in Szeged (*Fig.1*).

Figure 1. The automatic rain shelter

The rain shelter covers a 720 square meter area. Rain sensors set the closing mechanism which completely covers the field plots by a convertible plastic tunnel. Drain ditches prevent the side-wetting from the neighboring soil profiles. Drought can be traced by two automatic meteorological stations which continuously measure the rainfall, sun radiation dew point, soil moisture, soil temperature, air temperature, wind direction and speed.

62 winter wheat genotypes have been tested on two-row plots in three replications in the

2011/2012 wheat year. Most of the tested genotypes were the advanced breeding lines of the Cereal Research Non-Profit Co. and check varieties. All the genotypes were planted in two-row plots in 3 replications by a Wintersteiger Seedmatic sowing machine in October, 2011. Plot size was 0.33 m^2. The effects of drought were evaluated by measuring plant height, acceleration in heading time, depression of the yield components, grain yield and the difference between the canopy temperatures of stressed/control plots of the different genotypes. This method has been considered to be effective in screening wheat genotypes for drought tolerance (BLUM, 1988, INAGAKI AND NACHIT, 2008, CSEUZ ET AL. 2002, 2008) since tolerant genotypes can maintain photosynthesis (and evaporation) longer which lowers their canopy temperature. Canopy temperature was determined by infrared thermometer (Crop Trak, Spectrum Technologies Inc.). All measurements were subjected to analysis of variance by MS Excel program.

RESULTS

The effect of water withdrawal (under MARS) caused significant differences on plant height and thousand kernel mass, and significantly decreased grain yield and changed heading time and canopy temperature.

Among the tested genotypes, plant height was 66.83 cm in the treated (shaded) and 77.69 cm in the control treatment. Water shortage decreased plant height by 10.9 cm which means a 14% depression.

Sensitive genotypes' depression in growth was less moderate than that of the tolerant ones.

Water stress also affected heading time. Mean of heading time was 136.1 days after the first of January (16th of May) in the control treatment while it happened on the 13th of May in the stress treatment. Here heading accelerated, and on the average of the tested genotypes heading time started 2.7 days earlier, which means a 2.0% shorter time from the beginning of the year.

On the average of the 62 genotypes tested, grain yield decreased by 30.5%, while thousand kernel mass (TKM) decreased by 10.8%. The two-row plots' average grain yield was 396 g in the irrigated, and 273 g in the stress treatment, which means a 30.6% depression. Only about 35% of grain yield loss could be explained by TKM depression. The rest of the yield depression could happen due to the lower number of fertile and productive spikes. The higher number of secondary spikes also decreased the difference of TKM between the two treatments.

Table 1. The effects of water deficiency on the tested genotypes

Treatments	Plant height	Heading time	TKM	Grain yield	Canopy temperature
	cm	days	g	g	^oC
Control treatment	77.7	136.1	41.5	396.0	25.2
Stress treatment	66.8	133.2	37.0	273.0	30.4
Difference	10.9	2.9	4.5	123.0	-5.2
LSD.%	*5.3*	*1.5*	*4.2*	*26.9*	*27.9*
Control %	86.0	97.9	89.1	68.9	120.6

Midday canopy temperature measurements were executed on three hot days, the 10^{th}, 12^{th} and on the 15^{th} of June. The most characteristic data were found on the 12^{th} of June. Air temperature was 36 ºC during the measurements. Canopy temperature was 25.2 ºC on the average of the control plots and 30.4 in the treated (stressed) treatments.
Generally the result of drought stress trials has no correlation to yield data. The best correlation with measured data were found with grain yield (r = 0,628 - 0,836***).

CONCLUSIONS

Rain shelter is an appropriate equipment to generate drought stress in the field. However selecting for drought tolerance even using this equipment is a difficult project.
Comparing the canopy temperature of the control and stressed wheat plots is a very fast screening method, by which single measurements can be made within a few seconds. Even hundreds of genotypes can be measured easily. However, the results can be affected by numerous factors such as wind, moving clouds, the angle of the equipment, the density of the canopy etc. so the results must be based on replicated measurements and a competent number of control measurements (on check genotypes).
This selection process was running parallel with the yield tests. The collected and recorded data helps us in decision making for the best genotypes. At last among the high yielding and stress tolerant lines we were able to find the most tolerant and productive ones which could perform well under sub-optimal soil and climatic conditions. Significant improvement in drought tolerance of future wheat varieties can only be achieved by the combination of all these data. The advance in drought tolerance can be found among our latest registered wheat varieties and numerous new winter wheat candidates with a higher level of adaptability to dry environments. Bread wheat varieties GK Csongrád (2001) GK Hunyad (2005), GK Békés (2005), GK Csillag (2005), GK Berény (2010) are reputed tolerant to water shortages, and performed very well under stress conditions, too.

ACKNOWLEDGEMENTS

We acknowledge that present work was supported by the following projects:

"BIOCEREAL" (Breeding cereals for conventional and ecological growing conditions) HUSRB /1002/ 214/ 045 IPA Hungarian – Serbian Cross-border Co-operation Program.

Project on Preservation of Genetic Cereal Resources (MVH, 263/0601/3/14/2011) 2011-2015

REFERENCES

BLUM, A. (1998): Improving wheat grain filling under stress by stem reserve mobilization. In: H.-J. Braun et al. (eds.), Wheat: Prospects for Global Improvement. Kluwer Academic Publishers. p:135-141.
CSEUZ, L., PAUK, J., KERTÉSZ, Z., MATUZ, J., FÓNAD, P., ERDEI, L. (2002): Breeding drought tolerant wheat genotypes: selection methods. EUCARPIA Cereal Section Meeting 21-25 November 2002. Salsomaggiore, Italy p: 171.

CSEUZ, L., PAUK, J.,FÓNAD, P., KOVÁCS, E., MATUZ, J. (2008): Field selection of winter wheat genotypes tolerant to water shortage with a mobile automatic rain shelter (MARS) and chemical desiccation. In: R. APPELS, R. EASTWOOD, E. LAGUDAH, P. LANGRIDGE, MACKAY, M., MCINTYRE, L., SHARP, P. (Eds.) Proceedings of the 11th International Wheat Genetics Symposium. Sydney: Sydney University Press.

INAGAKI, M.N., NACHIT, M.M. (2008): Visual monitoring of water deficit stress using infrared thermography in wheat In: R. APPELS, R. EASTWOOD, E. LAGUDAH, P. LANGRIDGE, MACKAY, M., MCINTYRE, L., SHARP, P. (Eds.) Proceedings of the 11th International Wheat Genetics Symposium. Sydney: Sydney University Press.