# Field selection of winter wheat genotypes tolerant to water shortage with a mobile automatic rain shelter (MARS) and chemical desiccation

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## ABSTRACT

Drought tolerance of wheat was tested by measuring the water retention ability of excised flag leaves, and the translocation capacity of stem reserves by a desiccation method in a conventional pedigree breeding program of Cereal Research Non-Profit Co. (CRC) in Szeged. A mobile automatic rain shelter (MARS) construct was developed and applied in nursery. The MARS, parallel with ideal water supply gives a good chance for field testing of relatively high number of genotypes for drought tolerance. Using the automatic rain shelter which was installed in the year 2006, advanced lines of winter wheat could be tested for tolerance water shortages under irrigated (control treatment) and under dry conditions. Withdrawal of water caused significant effects on the genotypes tested.

Based on these testing methods mentioned we have developed a novel breeding system by which we can routinely select for drought resistance. The methods applied can easily be incorporated into our working pedigree breeding system.

## INTRODUCTION

In all over the world stresses are the most limiting factors in crop production. The improvement of the yields under stress conditions therefore must combine the high yield potential and specific factors, which are able to protect the crop against reductions due to different abiotic and biotic stresses. The most important abiotic stress in Europe is the shortage of water (=drought). Although there are new sensing methods available (Tamás et al. 2007) drought stress can not be measured precisely in the field. Since drought stress may be different in strength, continuity and timing year after year, the field selection for drought tolerance *per se* is a difficult project.

Winter wheat (*Triticum aestivum L.*) is a quite stress tolerant species, but even under European conditions (especially in Eastern and Middle Europe) drought may cause remarkable losses in grain yield and quality. In a breeding program for resistance to environmental stresses the most important step is to find a proper selection method by which we can characterize tolerance and susceptibility, and we can run an effective selection system. In this paper we report the outcomes of our efforts in the improvement of drought tolerance.

## MATERIALS AND METHODS

Our breeding system is a modified pedigree method, based on manual crossing, head selection from $F_2$ generation until uniform head-rows are available. Generally $F_4$ generation information yields trials, later four-replicated yield trials, and final multi-location performance tests help selecting the best ones among the advanced lines. The quality tests of $F_5$ generation and parallel scoring in rust (*P. recondita, P. graminis*) and virus nurseries (under provocative conditions) provide additional information for the successful selection (Fig. 1.)

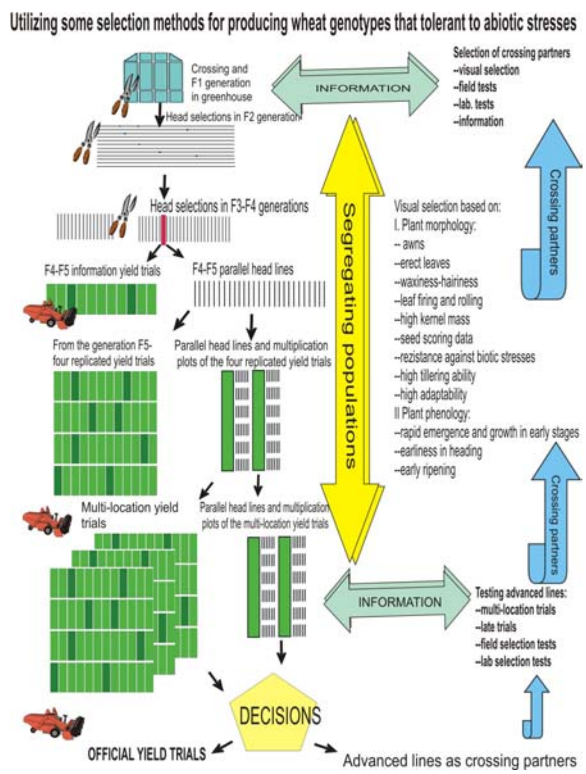


Figure 1. Wheat breeding system for producing drought tolerant genotypes

In the early generations ($F_3$-$F_5$) visual scoring of morphological and phenological characters is the only effective method to evaluate the drought tolerance of large number of genotypes (10000-20000 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 beneficial parameters for drought tolerance.

Several researchers reported that the high initial leaf water content and the low rate of water loss due to the desiccation were related to the drought resistance and may be used as a selection method (McCaig and Romagosa 1991). According to this method flag leaves were harvested from the field in the early morning. After keeping them in a controlled environment room for 8 hours, their desiccated weight was recorded, and the dry weight of the leaves was determined after a total desiccation. From these data we calculated their **water retention capacity** (the proportion of the initial and dessiccated relative water content two times: at late boot stage and after heading of the most genotypes.

By using **chemical desiccation** we also test the plants` ability to support grain filling by translocated stem reserves after anthesis (Fig. 2.) (Blum, 1998). Desiccant (2% $NaClO_3$ solution) spraying on each entry was done 14 days after anthesis . Kernel weight reduction due to the post-anthesis stress was assessed by comparing treated with control plots for each entry.

Figure 2. The effect of the chemical desiccation

A **mobile automatic rain shelter** (MARS, Fig. 3.) was constructed in the nursery of CRC in Szeged. 85 genotypes have been tested on two-row plots in three replicates in the 2006/2007. MARS 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 neighbouring soil profile. Drought was monitored by two automatic meteorological stations which continuously measure the rainfall, sun radiation, dew point, soil moisture, soil temperature, air temperature, and wind direction and speed.

Figure 3. The mobile automatic rain shelter

Withdrawal of water started at springtime ($10^{th}$ of March at three to four-leaf stage), and symptoms of drought became visible from the beginning of May.

The effects of drought were evaluated by the relative water content of excised leaves, repression of the yield components and grain yield and the difference between the canopy temperature of stressed / control plots of the different genotypes. This method has been considered to be effective in screening wheat genotypes for drought tolerance as tolerant genotypes can maintain photosynthesis (and evaporation) longer (Winter et al. 1988).

## RESULTS AND DISCUSSION

Water retention ability: we found a variation of 20 - 79 % water loss in relative water content of the excised leaves after the 8-hour desiccation. This method can test the cuticular resistance (=dehydration avoidance) of the flag leaves only and no correlation was found with the results of the other tests.

Due to the chemical desiccant treatment wheat varieties differed in a range of 17 - 55 % reduction of kernel weight and this response was correlated with the response to the late season drought among the genotypes tested. The best correlation with MARS data were found with grain yield (r = 0,628 - 0,836 ).

The effect of water withdrawal (under MARS) did not caused significant differences on plant height and thousand kernel weight, while significantly decreased grain yield and changed heading time and canopy temperature.

On average, grain yield of the 85 genotypes decreased by 16,1 %, while heading time became earlier by more than 8 days. In canopy temperature we could find a significant variation among the genotypes (22 - 28 ºC).

This selection process was running parallel with the yield tests. At the end of the breeding system less than 60-70 advanced lines were tested in our multi-location yield performance network and in the MARS as well. The collected and recorded data helped 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.

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 Jászság (1999), GK Szálka (2000), GK Ati (2001), GK Csongrád (2001), GK Békés (2005), GK Csillag (2005), GK Hunyad (2005) are reputed tolerant, and performed very well under stress conditions, too.

## CONCLUSION

The water retention capacity of the excised flag leaves is an important characteristic under water-prone conditions, so by measuring this trait we can screen hundreds of lines within a short period of time. Since the stomata close immediately after excision, water loss can only be decreased by the cuticle. In this case morphological traits like leaf pubescence or the presence of epicuticular wax will have special importance. Determining the canopy temperature 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 several replications and a lot of control measurements (on check genotypes).

There is no single selection method for achieving progress in drought tolerance. A breeding program can be successful by using the appropriate combination of different selection criteria. The best way to pyramid different genes which are advantageous under stress conditions is the recurrent selection. These selection methods have been applied in our conventional winter wheat breeding program. By this way we can find the most tolerant and productive candidates which can perform well even under sub-optimal soil and climatic conditions.


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