ADAPTATION STRATEGIES TO CLIMATE CHANGE – THE SEED VIGOUR

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Seed vigour is the ability of seeds to germinate and form the basis for a new plant under stress conditions (drought, low temperatures, the lack of nutrients). In rapidly changing climatic conditions seed vigour become increasingly important seed characteristics. Vigorous seeds are able to withstand stressful environmental conditions at an early stage of growth (e.g. so-called "drought escape"). The aim of the study was to evaluate the seed vigour of barley (Hordeum vulgare L.) and winter wheat (Triticum aestivum L.) in dry and cold conditions and to quantify the relationship between seed vigour and root system size. The vigour of the seeds was evaluated in the laboratory under the influence of drought stress -0.5 MPa in a water solution of polyethylene glycol (PEG 6000) and temperature of 10 °C. Testing of relationships between the size of the root system and the vitality of seeds did not yield conclusive correlation. However, a closer correlation can be expected only in dry years. Thanks to the digital image of the roots appointed four varieties of maternal plants, sown in 2013 in containers in 4 variants of the water regime (variant with natural rainfall, drought unstressed variant at the level of the field water capacity of soil, drought stressed variant at 50 % of available water-holding capacity of soil and highly drought stressed variant at soil wilting point), evaluated with a program WinRHIZO, has been proved a positive correlation between the root system size of the maternal plants and vigour of their seeds. It means, plant breeding could contribute to resolving problems associated with shortages of water for cereal cultivation. Correlation between vigour and the root system size was evaluated also for 37 winter wheat genotypes (significant correlations were not found during the one year period). Analysis of variance (ANOVA) proved a statistically significant difference between genotypes in the determination of vigour.

Keywords: drought, seed vigour, root system size, WinRHIZO

INTRODUCTION

In recent years, the vigour of seeds is accented as a perspective selection criterion for the selection of genotypes that are tolerant of abiotic stresses (drought, cold). The methods that are standardly used for determining vigour are restricted to a simple physiological fact, i.e. germinated/ungerminated (Klimešová et al., 2014).

Vigour tests, which measure only one factor determining the vigour of seeds are untrustworthy. Only a combination of several factors can give a good prediction of field emergence because the seed vigour is determined by many factors (Hampton, Coolbear, 1990). It is obvious that a certain year as a one of abiotic factors has significant impact on the vigour (temperature and rainfall before harvest). Testing of development has therefore increasingly important due to the scale of global climate changes. Laboratory testing of “seed germination” under ideal conditions does not provide adequate results that indicate the quality of seeds in a natural or stress conditions. "Seed vigour" is necessary to know the real behaviour of the seeds under stress conditions for practical use (Hampton and TeKrony, 1995; Chloupek et al., 2008).

Due to the applicability of knowledge in practice, there are growing efforts to unite the knowledge about seed vigour with other characteristics. These include the relationship of the seed vigour and the root system size as a potential parameter for a breeding of new genotypes. These two characteristics should be able to provide higher yields and have the ability to react to the stress conditions (drought, heat). The seed vigour determines the rate of the growth rate of the germ, which leads to faster development of the photosynthetic apparatus and better resistance to stress conditions in the field (Farahani and Marouf, 2011). The plants grown from more vigour seeds faster overshadow the soil surface due to the fast emergence and thereby reduce water loss at the beginning of vegetation (Spielmeyer et al., 2007).

The aim of this study was to investigate the relations between the size of the root system and seed vigour and *vice versa* for winter wheat (*Tritium aestivum* L.) and spring barley (*Hordeum vulgare* L.) under drought stress conditions.

MATERIALS AND METHODS

Spring barley seed vigour evaluation

Four spring barley malting varieties were mutually crossed in 2010 in a diallel manner; i.e., each variety was crossed with all others, including reciprocally (as both mothers and fathers). The final 12 combinations were obtained in a greenhouse and F_1 generation was then sown in field conditions. A combination from progeny (in F_3 generation) were selected for the greatest and for the smallest seed vigour. The pot experiment with mentioned four populations was established in the spring of 2014. The plants were grown in soil in containers with a volume of 0.2 cubic meters in four variants of moisture regime (variant 1 with natural rainfall, unstressed variant 2 at the level of the field water capacity of the soil, stressed variant 3 at the level of 50 % of available water holding capacity and heavily stressed variant 4 at the level of soil wilting point (always in duplicate replication). Volumetric soil moisture was continuously recorded by sensors VIRRIB (AMET Velké Bílovice). Differentiated water supply was started in the stage of stem elongation (BBCH 30). The size of the root system was measured during stem elongation, heading and grain filling. The results of the size of the root system were compared with the parameters of the vigour of seeds, meant the length of a germ and roots and the root and germ surface after 7, 11 and 18 days of cultivation and after 18 days the weight of biomass (see below).

The seed vigour was determined as the percentage of germinated seeds in a certain stress conditions, i.e. at cold temperature of 10 °C and physiological drought of -0.5 MPa in a water solution of polyethylene glycol (PEG 6000) at a concentration of 193 g of PEG 6000 to 1000 ml of water. Simultaneously, a control variant was established (with the cold stress at the temperature of 10 °C and optimal humidity). The seed vigour was evaluated after 7, 11 and 18 days by scanning method of germinated caryopsis using Epson Perfection 700 photo. The image (the length of the germ and roots) was then digitally analyzed with WinRHIZO software (Regent Instruments Inc., Quebec, Canada).

Winter wheat seed vigour evaluation

For evaluation of winter wheat seed vigour 37 winter genotypes were used. Seed germination and vigour were tested on each sample (seed vigour test is described above). The seed germination was defined as a control variant in laboratory conditions at the temperature of 22 °C and relative humidity 85 to 90 %, on filter paper. Each variant (seed vigour test, cold stress test, seed germination test) was founded with 50 seeds (three samples of each test). As a properly germinated was evaluated the seed, whose germ length achieves at least half the length of the caryopsis with a minimum no. of three roots. The percentage of germinated seeds were evaluated after 7 and 14 days. The results were assessed by analysis of variance (ANOVA) and correlation analysis with software STATISTICA 10.

The seeds of 37 genotypes were sown in the field conditions in Branišovice (South Moravia, the Czech Republic, Central Europe) on parcels of 1×6 meters each in 4 repetitions. 16 selected genotypes were sown in pots (volume of 0.2 cubic meters) in the area of Mendel University in Brno. Plants were exposed to different soil moisture conditions. The root system size was measured during vegetation in all variants.

Root system size measurement

To determine of the root system size measuring of electrical capacity was used (Heřmanská et al., 2015). The size of the root system was measured in the nanofarads (nF) by parallel capacitance at frequency1 kHz. The impedance bridge ESCORT ELC-131d LCR meter (Escort Instruments Corporation, Taiwan) was used for measurement. The method is based on detection of electric charge accumulated on the membranes of living structures in the root system of the plant, which is generated in a closed circuit. It was therefore measured the electrical capacity of the root system in relation to the soil in which the plant grew up, including the finest structures of the root system.

RESULTS

Spring barley

Average seed vigour (12 combinations and their parents) was in 2012 when the stress caused by drought -0.2 MPa 85.6 %, when stress -0.5 MPa 52.9 %. Observed influences of drought stress levels (pot trial) and locality (field trial) on the seed vigour were statistically significant ($P \leq 0.01$). From the F_3 generation were selected the combination with the highest vigour and lowest vigour. These combinations and their parents were sown on experimental locality Hrubčice and Želešice in spring 2013. In 2013, the average vigour of seeds (average of combinations and their parents) in the variant without drought stress 94.5 %, while drought stress 94.7 % -0.2 MPa, during stress caused by drought -0.5 MPa 66.2 %. Observed correlation between seed vigor by combination in F_3 generation (2012 harvest) and F_4 generation (2013 harvest) was r = 0.886 **. The results showed that barley seed vigour is an attribute affecting the field emergence and malting quality. The increased seed vigour can be successfully achieved with traditional breeding methods (Ullmannová et al., 2013). Relationship between the size of the root system and the seed vigour was not significantly correlated. However, a closer correlation can be expected only in dry environments.

Winter wheat

The correlation between the size of the root system and the seed vigour of 37 genotypes, sown in the field area, at the stage of stem elongation does not indicate relation between the root system and the vigour. In the phase of heading the closer correlation was already reflected (r = 0.255), but the relation was not statistically significant. Correlation between the size of the root system in both phenological stages of growth is equal to r = 0.500 (significant on $P \leq 0.01$). The seed vigour and its impact on root system formation under field conditions was not confirmed (in 2015). Demonstration of the seed vigour and root system size is strongly dependent on the environmental conditions, therefore to validate the results it is necessary to evaluate the all results of multi-year experiments.

Pot experiment

Expected significant environmental impact on the seed vigour and the size of the root system is not entirely conclusive. According to the results of the correlations of individual measurements of root system genotypes sown in terms of the pot experiment, is the effect of environment less significant. In the stage of stem elongation and at variant of middle drought stress the size of the root system appear as the smallest at genotype no. 23 (2.76 nF), 22 (3.12 nF) and 9 (25.30 nF). The largest root system was observed in genotypes no. 36 (5.17 nF), 30 (4.70 nF) and 14 (4.64 nF). When compared to the heavy drought stress variant, results are in the most cases the same. The smallest root system, have the samples no. 3 (2.30 nF), 23 (2.31 nF) and 24 (3.35 nF). And the highest genotypes no. 36 (3.34 nF), 14 (3.30 nF) and 5 (3.30 nF).

However, change of the size of the root system at different genotypes was observed at the stage of heading, during the stress variations significant difference deepened between genotypes with large and small root system. Between genotypes was also demonstrated highly statistically significant difference.

When comparing root system size of mentioned genotypes and their vigour (e.g. the most restoring genotype with the smallest root system size no. 22 to 88 % and the most significant root system size no. 36 i.e. 88.7 %), it is clear that varieties do not respond to stress conditions cause by drought by changing the size of the root system. Seed vigour was therefore not entirely influence factor, as a matter of environmental conditions, but it remains one of the most significant influence of genotype.

CONCLUSION

The method of selection of genotypes according to the root system size and seed vigour appears to be a good promising method for the selection and breeding of those genotypes that are better able to cope with adverse environmental effects.

Acknowledgement

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.

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