Possibility of selection for higher seed vigour of barley

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Abstract: High seed vigour is a precondition for fast and homogenous field emergence and good malting quality in barley. The aim of this study was to (i) assess the possibility of selection for greater vitality of barley seeds (*Hordeum vulgare* L.) in conditions of drought and cold, (ii) to quantify the relationship between the size of the root system of the parental plants and seed vigour of progeny. The root system size was measured by its electrical capacitance directly in field. The seed vigour of four spring varieties of malting barley and their mutual 12 combinations was assessed in three variants (without drought stress, under drought stress of -0.2 MPa and -0.5 MPa), in two years (2012 and 2013) and on the two locations (Hrubčice and Želešice). The vigour of 12 combinations from two locations was compared with vigour of their parents. Highly significant correlation was found in 2012 between the vigour of the mothers and their progenies ($r = 0.832$; $P = 0.01$), between that of fathers and of their progenies ($r = 0.882$; $P = 0.01$) and between the vigour of both parents and their progenies ($r = 0.894$; $P = 0.01$). The correlation between seed vigour combinations in F_3 generation (harvest 2012) and in F_4 generation (harvest 2013) was $r = 0.886$. This is another evidence for potential effective breeding for the seed vigour.

Key-Words: barley, root system size, seed vigour, stress conditions, drought escape

Introduction

The development of seed quality testing has become increasingly important due to global climate change. Laboratory testing of seed is usually carried out in ideal conditions (optimal temperature and air humidity). However, for practical purposes it is necessary to know the real behavior of seeds outside the optimum conditions [1]. Environmental factors affecting germination process significantly [2]. Seed quality is often understood as the vigour and viability of seeds [3; 4; 5; 6]. The most-used method of assessing the quality of seeds is testing of seed germination (realized under laboratory conditions). This characteristic of seeds indicates the ability to germinate in ideal conditions (ie. potential of seeds). Nevertheless, as noted above, for detecting the properties of the seeds is also important to test seed germination under field conditions or in conditions close to the situation in the field. It is in a situation where the plant is exposed to a stressful to temperatures, lack of water or nutrients [1]. At this point comes to the fore vigour of seeds, or the ability of seeds to germinate under stressful conditions. Vigour tests are according to [1] divided into three groups: tests based on germination, physiological and biochemical tests and multifactor tests. Most of them are based on the principle of simulation stress conditions. In any case, the ability of repeatability and reproducibility of methods are important.

The root system was due to lack of appropriate methods in breeding programs neglected. But recently is proved as successful the method of measuring the size of the root system by electric capacity [7]. The root system is cited as the most sensitive organs of the plant. Due to physiological and morphological characteristics responds the root system to the external environment sensitively than the aboveground part. In the absence of water is also affected by the passage of nutrients through membranes, and up to 40% [8]. In case of stress caused by lack of water react roots by growth of small diameter roots. This helps to enlargement of surface, through which is perhaps the absorption of water from the soil. During stress period may come up to growth of roots into the deeper soil layers [9]. Important is whether grain vigour affects the rate of growth of the root system – whether is correlated with the size of the root system. It would make sense for higher resistance to drought („drought escape“). The roots have a certain degree of "memory" [10]. This feature is important in plant breeding. Successful selection focused on vigour increase may lead to tolerance of progeny to drought. The more vital seeds are then able to avoid any dryness in a period of stand establishment. In a case that it soon creates a sufficiently large root system it will be more resistant to drought and vegetation will be better emanate.

The purpose of this study was to obtain information about seed vigour of different genotypes of spring barley (in the case of stress incurred cool and dry); the ability to transfer the character to posterity; and interconnection of the root system with the grain vigour.

Material and methods

The spring barley malting varieties *Diplom*, *Jersey*, *Prestige* and *Saloon* 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 resulting 12 combinations (mark as U1 – U12; Parentage of the combinations:

U1 – Prestige × Saloon; U2 – Prestige × Jersey; U3 – Prestige × Diplom; U4 – Saloon × Prestige; U5 – Saloon × Jersey; U6 – Saloon × Diplom; U7 – Jersey × Prestige; U8 – Jersey × Saloon; U9 – Jersey × Diplom; U10 – Diplom × Prestige; U11 – Diplom × Saloon; U12 – Diplom × Jersey) were reproduced in winter 2010/2011 in a glasshouse. F_2 and F_3 generation was sown on 2012 and 2013 in a field at the Hrubčice Plant Breeding Station in the Czech republic (49°26'41.160"N, 17°11'54.940"E) in a fertile lowland (elevation 210 m; long-term annual average temperature, 8.5°C; long-term total annual rainfall, 578 mm; soil type, Haplic Chernozem with 38–39% clay particles) and at the Želešice Plant Breeding Station (49°07'10.390"N, 16°35'35.057"E) in a fertile lowland (elevation 205 m; long-term annual average temperature, 9.3°C; long-term total annual rainfall, 511 mm; soil type, Haplic Luvisol with 37% clay particles). Each combination was sown in four replicates between the two parents in rows consisting of 12 plants spaced at 0.1 × 0.1 m.

The root system size was measured in nanofarads [11]. One wire of the capacitance meter was connected using a clamp to all the basal parts of the plant of equal height. This height was near the soil but not in contact with it. The second wire, which leads the measuring current to the soil, was grounded in the spacing, midway between the measured plants. An impedance bridge ESCORT ELC-131D LCR meter (Escort Instruments Corporation, Taiwan) was used and set to parallel measured capacitance at a frequency of 1 kHz.

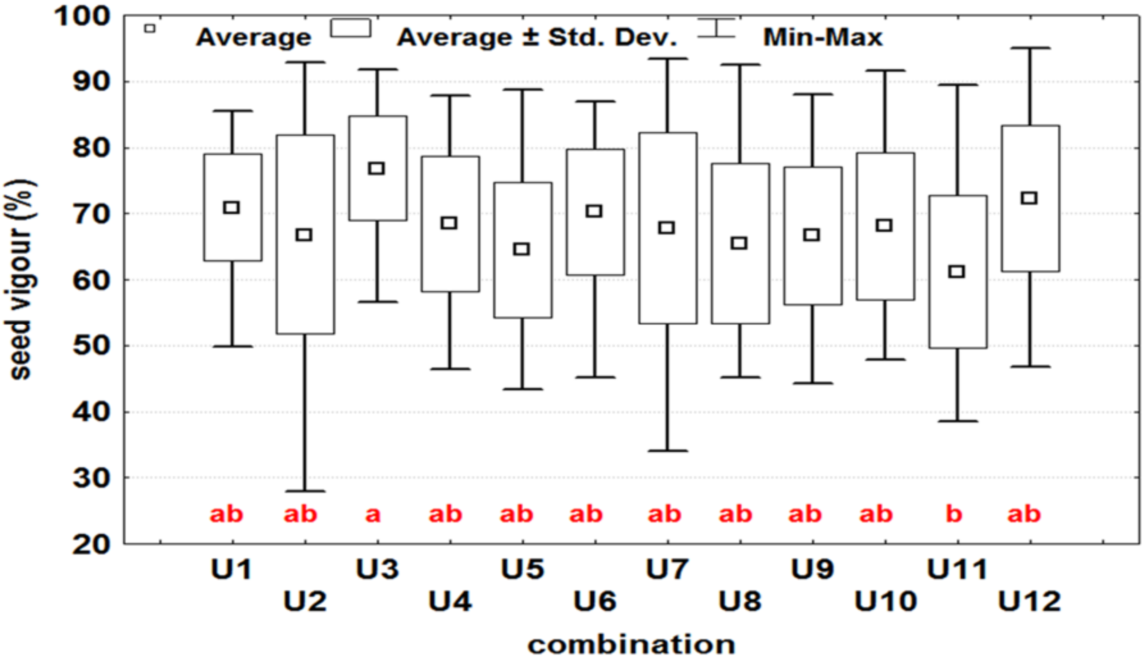
After dormancy, i.e., after approximately 100 days after harvest, the seed vigour was evaluated. The vigour of grains of the 12 combinations and their parents was evaluated at a low air temperature of 10°C and under a drought stress of -0.2 MPa and -0.5 MPa using a water solution of polyethylene glycol (PEG) 6000 [11;12] and without drought stress using of distilled water (control variant).

Each combination and parents was evaluated for 4 samples (2 locations × 2 years). The grains were placed between filter paper moistened with the PEG solution on stainless surfaces coated with plastic to prevent evaporation, which could change the solution concentration, in climate boxes (Q-CELL ST5/B/40) for 14 days. Vital, i.e., normal, seeds were regarded as those producing at least three roots when the hypocotyl attained at least one half of the grain length and were without mould.

Results and discussion

Evaluation of the average vigour of the combinations without regard to drought intensity is shown in Fig. 1. Significant differences are marked by different letters; different were only combinations U3 (Prestige × Diplom) and U11 (Diplom × Saloon). Average vigour of seed (12 combinations and their parents) was in 2012 when drought stress -0.2 MPa 85.6%, during stress -0.5 MPa 52.9%. Effects of drought stress level and locality on vigour of seeds were statistically significant (P = 0.01).

Fig. 1 Seed vigour of 12 resulting combinations (2012)



From the F_3 generation were selected combinations with highest vigour (U12 – Želešice – vigour 84%; U3 – Želešice – vigour 89%; U2 – Želešice – vigour 81%) and with the lowest vigour (U11 – Želešice – vigour 61%; U5 – Hrubčice – vigour 45%; U9 – Hrubčice – vigour 53%). These combinations and their parents were sown in experimental locations Hrubčice and Želešice the spring of 2013. In 2013, the average vigour of seeds (diameter of combinations and also of their parents) in the variant without drought stress 94.5% in a period of drought stress 94.7% -0.2 MPa and during stress by drought -0.5 MPa 66.2%.

The correlation between vigour of seeds by combinations in F_3 generation (harvest 2012) and in the F_4 generation (harvest 2013) was 0.886. The results showed that barley seed vigour is a trait affecting the field emergence and malting quality. The increased vigour can be successfully achieved with traditional breeding methods [13].

Testing the relationship between the size of the root system and vigour of seeds yielded no conclusive correlation (Tab. 1). However, a closer correlation can be expected only in dry years.

Table 1 Relationship between root system size (RSS) measurements and grain vigour (expressed by the correlation coefficients)

Treatment	Locality	RSS stem elongation	RSS heading	RSS grain filling	RSS average of 3 measurements
Control	Hrubčice	-0.239	0.061	-0.140	-0.166
	Želešice	-0.333	0.247	-0.082	-0.209
	Average	-0.088	0.110	-0.078	-0.076
Low stress	Hrubčice	-0.171	0.076	-0.043	-0.105
	Želešice	0.031	0.272	0.182	0.198
	Average	0.119	0.234	-0.006	0.151
Medium stress	Hrubčice	-0.047	0.279	0.102	0.057
	Želešice	-0.121	-0.064	-0.139	-0.199
	Average	0.064	0.144	-0.087	0.069

Conclusion

It can be seen that the vigour of parents was significantly correlated with vigour of their progeny. This is another evidence for potential effective breeding for the vigour. A higher response to selection can be expected for the grain vigour.

Our results indicate the possibility of the successful selection for higher seed vigour as an indicator of agronomic and malting quality, even in favourable weather years (the highest vigour during both years in average ranged between 85–94.5 % during drought stress 0.2 a 52.9–66.2% during drought stress 0.5). The results show, that barley seed vigour is a polygenic trait with importance for field emergence and also for malting quality, with good prospects of improvement by traditional breeding methods.

Acknowledgements

This work was supported by a project of the Czech Ministry of Agriculture, QI111C080.

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