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VARIABILITY OF SEMINAL ROOTS ANGLE IN SOME ROMANIAN BARLEY GENOTYPES

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Abstract

Drought tolerance of plants as a complex character, makes the choice of physiologycal traits, selection methods and breeding to be are very difficult. Breeding of barley (and not only) focused on higher production under water stress, which led to relatively good progress. Now, however, when a so-called `plateau` of production has been reached, the focus is on the search for those secondary features that can ensure further progress. Root phenotyping is as important as shoot phenotyping, because plant's ability to uptake moisture and nutrients mainly depends on root architecture. Therefore, root phenotyping is important for crop breeding, although under field conditions, screening roots by phenotyping is a very difficult task. Our previous research shows that in case of winter wheat for most of Romania and for regions with similar conditions, winter wheat breeding should aim at creating mainly cultivars with large seminal roots angle that could better use rainfall falling during the vegetation season, but also cultivars with a small seminal roots angle that can improve the access to water in the soil depth profile during severe drought conditions. In this study we evaluated the root system architectural traits for several Romanian barley genotypes and association with yield. Our results shown that the angle of seminal roots varied from about 44° in cultivar F-8-3-01 to more than 120° in some inbreed lines. Will be discussed if breeding new barley cultivars with efficient root systems carries great potential to enhance resource use efficiency and plant adaptation to unstable climate from Romania.

***Key words**: winter barley, seminal root angle, yield.*

INTRODUCTION

In Romania, climate change has led in recent years to an intensification of water deficits (often associated with heat), in almost all areas of the country, with negative effects on crops. Creating of winter barley varieties resistant to drought and heat is an important goal of breeding from the world and in Romania as well.

It is known that drought tolerance is a complex trait making the search for efficient selection, breeding and screening methods difficult. The traits related to root architecture are more less studied but are important for known the use of moisture from the deep layers of the soil and can be used to improve the adaptation of barley genotypes to soil water deficiency. Root system architecture is also important for nutrient use efficiency (Lynch, 2019). By exploring the subsoil, a steep and deep root system is beneficial not only for accessing water from the soil depth (Singh et al., 2011), but also for N capture from the soil profile. In contrast, a shallow but dense root system is not only better for using rainfall during the vegetation season (Liao et al., 2006), but also has advantages regarding P capture and should also be useful for capture of K, Ca, and Mg in acid soils (Lynch, 2019).

Finally, the root system is important in barley for lodging resistance, by its effect on anchorage strength. Crook and Ennos (1994) reported that plants with stronger, more widely spread coronal roots produced larger soil cones during anchorage failure and resisted larger forces, while Pinthus (1967) found high correlations between root spreading angles and lodging rates from a series of field trials grown under various environmental conditions.

Several studies on wheat, rice, sorghum, etc. have shown that a small angle in seedlings is a precursor of a deep root system and large branches in soil depth. These characteristics are advantageous for terminal drought conditions, when there is water stored in the soil depth (Manschadi et al., 2006; Uga et al., 2011; Mace et al., 2012; Christopher et al., 2013). Every extra millimetre of water extracted during filling grain has produced a plus yield of 55 kg ha^{-1} (Manschadi et al., 2008). In sorghum, a small root angle was associated with the phenotype "stay-green", due to improving the access of water in the soil depth profile (Singh et al., 2011).

Recent study (Petcu et al., 2020) shown than in Romanian conditions winter wheat breeding should aim at creating mainly cultivars with large seminal roots angle that could better use rainfall falling during the vegetation season, but also cultivars with a small seminal roots angle that can improve the access to water in the soil depth profile during severe drought conditions.

In case of winter barley, previous studies shown that the availability of barley mutants affecting seminal root angle and number is limited. A mutant with a highly geotropic root system was identified through a chemically mutagenized barely population; however, the population was reported to be unstable and display inconsistent phenotypes (Bovina et al., 2011). As a result of the challenges associated with accurately and efficiently phenotyping roots, the relationship between root traits and yield is still uncertain in barley (Robinson, 2016).

The objectives of this study is to established the variability of several winter barley genotypes for root angle and an attempt to evaluate the relationship between seminal root angle and grain yield of winter barley grown in several years under the continental climate of Romania.

MATERIALS AND METHODS

Seminal root angle was measured in several winter barley cultivars, which has performed in NARDI Fundulea.

For determination the seminal root angle, we were inspired by the work of Richard et al. (2015) and used 1 L transparent pots. The transparent pots were filled with two types of soils mixture (70% turba and 30% chernozem soil). Seeds were sown at a depth of 2 cm every 2.5 cm along the pot wall. The seeds were carefully placed vertically, embryo downwards and facing the wall to facilitate root growth along the transparent wall. Three grains of each genotype were sown, 3 seeds x 4 replications. After sowing, the clear pots were wrapped in aluminum foil and placed in dark-colored paper bags to exclude light from the developing roots. The pots were watered after sowing and no additional water or nutrients were supplied there after this.

The roots were photographed at 10 days after sowing, then foto images were transferred in PC. The angle between the first pair of seminal roots was measured with ImageJ software (http://rsb.info.nih.gov/ij/). The exemple of seminal root angle measurement is give in Figure 1.

Figure 1. Illustration of seminal root angle measurement of the first pair of seminal roots

Available data about grain yield recorded in 24 yield trials in several locations during 2014-2019, which included at least ten of the cultivars characterized for seminal root angle, were used for computing correlation coefficients.

Data about grain yield in yield trials were available from the National Agricultural Research and Development Institute Fundulea (44°26`N latitude and 26°31`E longitude), and seven Agricultural Research Stations (ARDS) from different regions of the country: ARDS Teleorman (44°07`N - 25°45`E), ARDS Şimnic (44°36`N - 25°45`E), ARDS Valu lui Traian (44°16`N - 28°48`E), ARDS Livada (47°50`N - 21°93`E), ARDS Mărculeşti (44°40`N - 27°50`E), ARDS Secuieni (44°78`N - 24°85`E) and ARDS Brăila (45°28`N - 27°97`E). These included a large variation of weather and soil conditions, as well as crop management. For example, soil conditions varied from chernozem to luvisol, and crop management included various preceding crops, and sowing dates.

Concerning the rainfall, at Fundulea average annual rainfall is 571 mm, of which 72% during the vegetation period, especially in May-June.

In the summer season, only 35% of the total annual precipitation falls, these being torrential. The frequency of droughty years is over 40%. At Şimnic annual precipitation is about 540-550 l/sqm, very unevenly distributed during the vegetation season.

Data were analysed using the statistical analysis of variance and correlation analysis was used to study the relationship between seminal root angles and recorded grain yield.

RESULTS AND DISCUSSIONS

A significant variability was found between the studied genotypes for seminal roots angle. The analysis of variance showed a significant effect of barley cultivars for the probability of 95 and 99% (Table 1).

Table 1. The analysis of variance for seminal root angle of studied barley cultivars

Source	Sum of Squares	DF	S^2	Calculated F	Ft 5%	Ft 1%
Total	12599.3	29				
Replicates	37.620	2				
Plots	10057.4	9	1117	8.1	2.4	3.5
Error	2464.2	18	136			

The seminal roots angle varied from about 44° in cultivar F 8-3/01(Figure 3) to more than 92° (Figure 4) in cultivar Simbol (Figure 2).

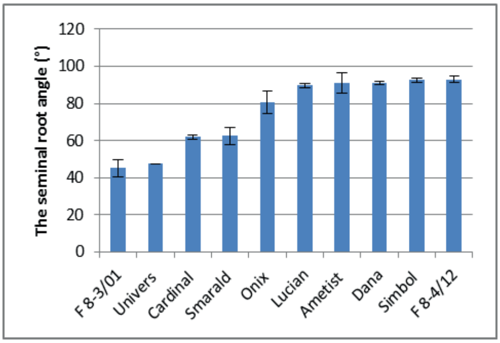

Figure 2. Genotypic variation of the seminal rootangle in studied barley genotypes

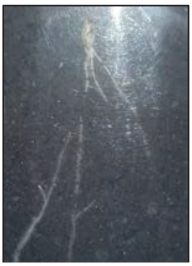

Figure 3. Seminal root angle for F 8-3/01 genotype (44°)

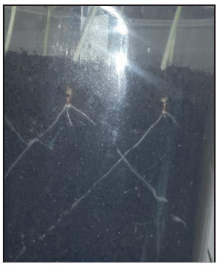

Figure 4. Seminal root angle for Simbol genotype (93°)

A high degree of variation in phenotypes for root angle was observed in the panel of 59 barley genotypes (Figure5). Seminal root angle ranged between 42° and 120° with a mean of 78°.Threerespectively four breeding line had the lowest and highest seminal root angle, respectively.

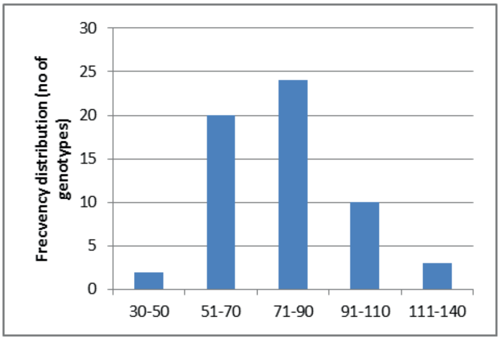

Figure 5. Frequency distribution for the seminal rootangle in different barley breeding lines

Studies show that, wild and landrace barley germplasm tend to have a narrow root angle (Bengough et al., 2004; Hargreaves et al., 2009; Sayed et al., 2017), which is thought to be a consequence of originating in water-limited environments where access to deep-stored soil moisture was critical for survival. In addition, wild and landrace lines appear to produce fewer roots than their modern counterparts. For example, the study by Bengough et al. (2004) reported a mean root angle for wild barley of 40° with an average root number of three. In comparison, modern cultivars were reported to have a wider angular spread of up to 120° and a higher root number of up to seven (Bengough et al., 2004). On the other hand Arifuzzaman et al. (2014, 2016) shown that barley genotypes with a winter growth habit, and thus a longer vegetative growth phase, had a larger more vigorous root system.

The diversity of conditions included in the study was reflected in the yields of the analysed cultivars, which varied from 3664 kg ha^{-1} at Şimnic in 2015 to 8720 kg ha^{-1} at Fundulea in 2014. The smallest yields were obtained in 2015, a year characterized by drought, especially during the grain filling and in Şimnic, characterized as a dry area (Table 2).

Table 2. The grain yield of 10 winter barley cultivars in 8 locations and 6 years (48 environments)

Location	Year					
	2014	2015	2016	2017	2018	2019
Fundulea	8720	7073	6530	6249	7060	7015
Mărculești	5972	5885	7457	7375	6665	8689
Valu lui Traian	5533	6487	6951	4632	5495	4782
Teleorman	5965	5457	6706	7638	4414	7190
Șimnic	4097	3664	5152	5783	4615	-
Secuieni	6423	4382	4851	6018	7748	4865
Brăila	5386	5185	5812	5009	5205	5906
Livada	7268	4366	4515	5146	4331	5013
Average yield/year	5709	4946	5554	5981	5692	6209

Grain yield of the studied cultivars averaged across the 48 environments varied from 5602 to 6298 kg/ha, with highest yields obtained in new cultivars (Smarald, Cardinal and Lucian) and lowest yield inthe old cultivar Dana (Table 3).
Maximum yields varied from 5967 kg/ha in Ametist to 6672 kg/ha in Cardinal, while minimum yield varied from 4324 kg/ha in Dana to 5561 kg/ha in Ametist.
Average yield was correlated with maximum yield but not with minimum yield and seminal root angle (Table 4).

Table 3. Average, maximum and minimum grain yields and yield amplitude in 10 winter barley cultivars

Cultivars	Average yield	Maximum yield	Minimum yield	Amplitude
Dana	5602	6118	4324	1794
Cardinal	6291	6672	5116	1556
Univers	5843	6456	4865	1591
Ametist	6088	5967	5561	406
Smarald	6298	6231	5458	773
Simbol	6124	6438	4818	1619
Onix	6027	6438	5148	1290
Lucian	6176	6544	5053	1491
F8-3-01	5735	6174	4659	1515
F8-4-12	5926	6542	4808	1734

Yield amplitudes were very large, from 406 to 1796 kg/ha and were correlated with minimum and maximum yield, but not withaverage yield and seminal root angle (Table 4). Similar result were obtained by Mustăţea et al. (2009).

Table 4. Correlations between seminal root angle, average yield and several stability parameters

Parameters	Seminal root angle	Average yield	Maximum yield	Minimum yield	Amplitude
Seminal root angle	1				
Average yield	0.12	1			
Maximum yield	-0.015	0.38	1		
Minimum yield	0.013	0.78**	-0.07	1	
Amplitude	-0.018	-0.46	0.58*	-0.86***	1

The coefficients of correlation between the seminal root angle of wheat cultivars and grain yield of the respective cultivars varied very much, from -0.07 to +0.46, when all studied cultivars were taken into consideration (Figure 3). On the other hand excluding the cultivar Danathose correlation was insignificant, expressed by a correlation coefficient from 0.10 to 0.51 suggesting the tendency of positive correlation between yield and seminal root angle (Figure 6).

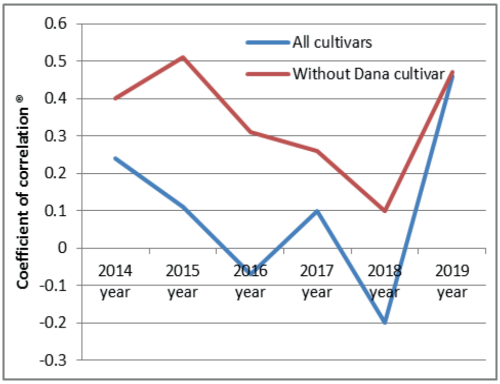

Figure 6. Histogram of the correlation coefficients between seminal root angle and grain yield

Our results suggest that, in the environmental conditions represented by most of the 48 analysed yield trials, a small seminal root angle, corresponding to a deep root system was not associated with higher grain yield but there is a tendency of positive correlation between large seminal angle and barley yield.

CONCLUSIONS

The seminal root angle of Romanian barley genotypes varied from 43° to 120°. This diversity of seminal root angle of Romanian barley germplasms offer large opportunity for breeding of winter barley.
Yields recorded for several Romanian winter wheat cultivars in a representative sample of 48 yield trials, covering a wide range of environments from Romania, showed not significant correlation with seminal root angles. With all of this there was a tendency of positive correlation between large seminal angle and yield of our barley cultivars.

Many studies propose that root traits are essential for drought adaptation and will pave the way to a second green revolution in low-input systems.

In this context we suggest that cultivars with large seminal roots angle could better use rainfall during the vegetation season, from superficial soil layers and will be suitable for most of Romania and for regions with similar conditions.

Breeding of winter barley should aim at creating diverse cultivars, including mainly cultivars with large seminal roots angle that could better use rainfall during the vegetation season, from superficial soil layers.

This could be beneficial in capitalizing small amounts of precipitation during periods of drought or to capture more nutrients with minimal metabolic costs, thus freeing up energy for the crop to invest in other developmental process, such as above-ground biomass, but also cultivars with a medium seminal roots angle that can improve the access to water in the soil depth profile during severe drought conditions.

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