GRAIN WEIGHT AND SIZE ASSESEMENT OF SOME ROMANIAN WINTER BARLEY GENOTYPES UNDER DIFFERENT SOWING DENSITIES

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Abstract

Grain weight and size are among the main traits used for characterizing a barley variety in order to recommend it for malt industry. Moreover, the first evaluated trait to know the yield destination is the grain weight which is determined by the grain length and width. In the malt industry, the grain size is an important characteristic having into account the fact that the potential extract is proportional to the size of the grain. This trait depends on genotypes, environment and crop technology, as well as on the interactions between these factors.

The objective of this paper has been the assessment of the grain weight (expressed through the thousand grain weight - TGW) and the grain size fractions (2.8 mm, 2.5 mm, and 2.2 mm), as well as the yield potential for the Romanian winter barley genotypes in order to establish further usage. In this respect, twenty-five winter barley genotypes created at National Agriculture Research and Development Institute Fundulea were investigated in 2017-2018 under two different sowing densities (350 grains/m^2 and 500 grains/m^2). Barley samples have been analyzed for grain weight using Contador (electronic seeds counter) and screening machine Sortimat for sieving fractions at different grain size (2.8 mm, 2.5 mm, and 2.2 mm).

Obtained data has been statistically analyzed by ANOVA. Analyses of variance revealed a significant variation of TGW and grain size between genotype and sowing density. According to the 20th European Brewery Convention (EBC) of evaluation malting barley varieties, the requested minimum value of TGW for malt industry is 42 g and more than 80% of grains have to remain on the sieves of 2.8 mm and 2.5 mm. Under low sowing density (350 grains/m2) the values of TGW ranged between 48.1 and 55 grams, while for the second sowing density (500 grains/m2) the values ranged between 41.4 and 50.2 grams. The grain size fraction of 2.8 mm showed a better proportion value (97.2%) under low sowing density comparing with the value of the same grain size fraction obtained under high sowing density (92.8%). All tested winter barley genotypes registered an increased yield under low sowing density (5804 - 9304 kg/ha) comparing with the yield obtained at high sowing density (4074 - 6978 kg/ha).

Keywords*: winter barley, sowing density, grain weight, grain size, yield.*

INTRODUCTION

Barley is used as a raw material in the malt and beer industry, in animal feed and also in human nutrition in various forms (flakes, fleas). Approximately 25% of the barley produced globally is used for malt and beer due to its low protein content (http://faostat.fao.org/)

The continuous growth of worldwide population and the reduction of arable land determine an improvement of barley yield, this trait being a major challenge for the barley breeding program in the context of climate change (Fischer and Edmeades, 2010). In order to obtain a higher and qualitive barley yield, to contracarate weather fluctuations, it is necessary to introduce new sequences in growing barley tehnology (Tanaka and Nakano, 2019). Beside that, the nitrogen management has the final impact on the barley grain weight and size (www.yara.com).

In their study, WANG ET AL. found in 2019 that grain weight and size are the main components of barley yield and quality and also the main target of barley breeding. MAGLIANO

ET. AL. (2014) showed that between grain size (percentage >2.5 mm) and grain protein content there is a negative relationship, this correlation being attributed to the presence of smallest grains.

The barley grain has three dimensional parameter (length, width, and thickness) and all these determine grain weight and size. These traits are strongly related with barley yield and malt quality (ZHANG ET AL., 2012). Grain size is affected by the genotype and the environment (COVENTRY ET AL., 2003) and is determined by pre-anthesis plant development and post-anthesis physiological traits affecting translocation of assimilate to the developing grain (Fox et al., 2006).

Generally, for a barley variety the grain starch content is proportional to the size of the grains, which makes the large and uniform grains increase the yields when are transformed into malt and subsequently into beer. This parameter is a variety characteristic, but it is also influenced by the applied technology. According to the 20^{th} European Brewery Convention (EBC) of evaluation malting barley varieties, the requested minimum value of thousand grain weight (TGW) for malt industry is 42 g and more than 80% of grains have to remain on the sieves of 2.8 mm and 2.5 mm.

For example, in Australia, grain size is the minimum retention (% by weight) of grain above a 2.5 mm slotted screen, the specifications for the MALT1, MALT2 and MALT3 grades being 70%, 62% and 58% respectively (GTA Barley Standards, 2018-2019). Increased grain size is associated with quality for malting barley such as higher malt extract and moderate grain protein (Burger and La Berge, 1985).

In Romania, there is a reference document for TGW (SR ISO 520) and two specifications for malt, barley for malt Ro no. 1 and barley for malt Ro no. 2. Also, there are mentioned three grades (according to Grading Manual of Grains for Consumption, 2017): minimum percent seeds 2.5 and 2.8 mm Grade I, Grade II and Grade III respectively 85%, 75% and 70%. The malt and beer industry use as raw material the seeds >2. 5mm (according to SR 13477). All the seeds <2.5 mm are used for feeding.

The objective of this paper has been the assessment of the grain weight (expressed through the thousand grain weight - TGW) and the grain size fractions (2.8 mm, 2.5 mm, and 2.2 mm), as well as the yield potential for the Romanian winter barley genotypes in order to establish further usage.

MATERIAL AND METHODS

Twenty five winter barley genotypes (varieties and breeding lines), created at National Agriculture Research and Development Institute Fundulea (NARDI Fundulea) during the period 2003-2018, known as having different grain weight and size, were tested under two sowing conditions in field trials at NARDI Fundulea in 2017-2018.

The barley genotypes were tested at two sowing densities (350 grains/m^2 and 500 grains/m^2) in three replications, with a nitrogen rate of 46 kg N/ha (100 kg of urea/ha). A randomised blocks design was used with the plots having 4 m of length, each plot having 8 rows at 17 cm between rows.

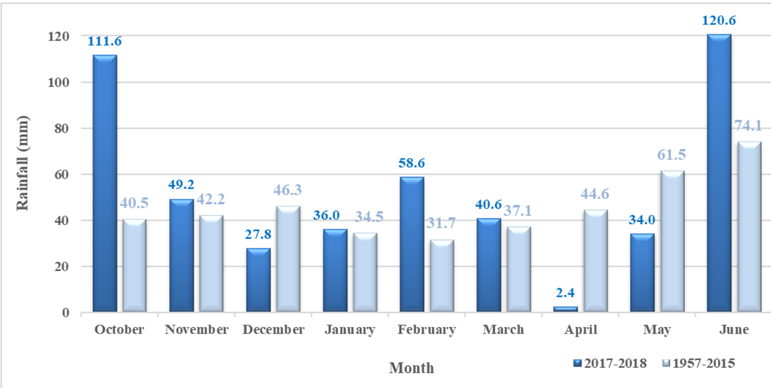
Grain yield was determined by weighing the obtained grains on each replication, and it was calculated in kg/ha expressed at 14% moisture content.

In order to assess the grain weight and size (assortment SI+II), from each replication a sample was taken and the seeds were conditioned by a Hege thresher. With a Contador instrument (Pfeiffer Germany) the grain weight was determined and expressed in grams as TGW (1000 grains per replication weighed on electronic balance with two decimals).

According to the analysis methods recommended by the European Brewing Convention (EBC), the assortment was determined with the help of the Sortimat, a sorter provided with three slots with the following dimensions: 2.8, 2.5, and 2.2 mm (EBC method 3.11.1). The 100 g sample is placed on the upper screen of the apparatus and 3 minutes ± 10 seconds are sorted at a sorting speed of 300-320 rpm. The 4 resulting fractions (2.8, 2.5, 2.2 mm and foreign bodies) were weighed with an accuracy of 0.01 g. The result is expressed as a percentage.

The obtined results were analised by ANOVA.

The registered data regarding meteorological conditions were delivered by the Weather station of NARDI Fundulea (Figures 1 and 2).



` Figure 1. Average rainfall (mm) during 2017-2018 and long term average (1957-2015)

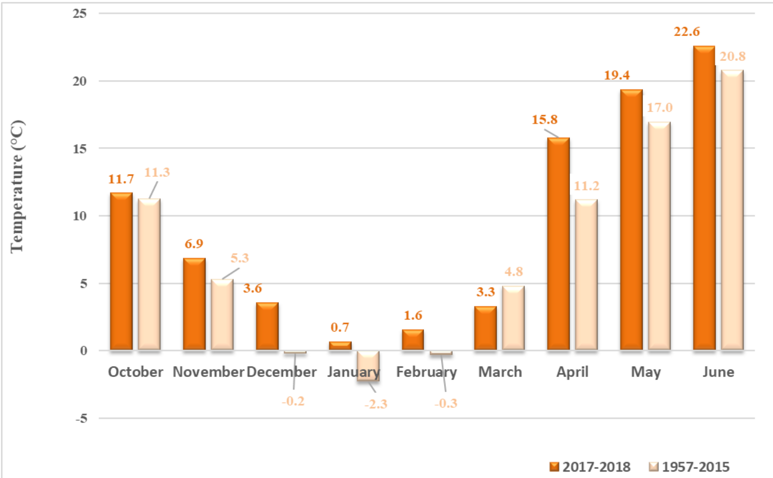


Figure 2. Montly average temperature during 2017-2018 and long term average (1957-2015)

Compared to multiannual average (44.6 mm) the rainfall quantity registered in April 2018 was very low (2.4 mm), while in June the rainfall was over multiannual average with 46.5 mm. Regarding temperatures, the average during April–June was higher than the multiannual values, differences between them exceding 4oC in April meanwhile during May-June differences being between 1.8 and 2.4oC.

RESULTS AND DISCUSSION

In order to reach the objective, we started from the analysis of the factor's varieties/lines, densities and their interaction, taking into account the evolution of temperature and rainfall factors, which characterized the 2017-2018 year at NARDI Fundulea.

ANOVA of the studied parameters revealed different effects of variety/line, sowing densities and their interaction (Table 1). Influence of variety/line was significant for grain yield, grain weight and size. The response of study traits (grain yield and grain weight and size) to different sowing densities was similar, showing a significant effect of the sowing density. The variety/line and sowing density interaction was not significant for grain yield and grain size, but significant for grain weight. This aspect could be explained by the genetic differences between genotypes regarding the assimilate translocation from the leaf to the ear, beginning from the heading data to grain physiological maturity.

Table 1

ANOVA for grain yield, grain weight and size in winter barley varieties trials (2017-2018)

Source of variation	Grain yield		Grain weight		Grain size	
	F	P-value	F	P-value	F	P-value
Variety/line (V/L)	5.486**	2.33E-12	15.346**	9.40E-24	2.053**	0.007
Sowing density (SD)	366.511**	5.69E-10	1047.084**	8.72E-55	60.627**	0.000
V/L x SD	1.267^{ns}	3.23E-35	1.734*	0.031	1.341^{ns}	0.158

* significant at a probability level of p<0.05; **significant at a probability level of p<0.01; ns-insignificant

Differences between genotypes were reflected by the variation of the average yield from 5804 to 9304 kg/ha for the sowing density of 350 grains/m^2 and from 4074 kg/ha to 6978 kg/ha for the sowing density of 500 grains/m^2, the highest differences (Table 2) being registered by the F8-8-12 line (4081 kg/ha) and the lowest by the F8-11-12 line (1378 kg/ha).

The obtained results showed differences for both the genetic potential of each winter barley genotype and the influence of the sowing densities used as a sequence in the technology of winter barley cultivation. Regarding the yield, all the tested genotypes responded favourable when they have been experimented at a lower sowing density. The yield level of tested genotypes (winter cultivars and lines) at classical density (500 grains/m^2) oscillated between 4074 kg/ha (F8-6-17) and 6978 kg/ha (V24). From the same biological material, but tested at low grain density (350 grains/m^2), it was highlighted the Simbol variety (9111 kg/ha) and the V24 breeding line (9304 kg/ha) with the highest yield level (Figure 2).

The winter barley genotypes showed a different behaviour regarding TGW, the values ranging from 41.4 g to 50.2 g at classical sowing density (500 grains/m^2), while in the case of lower density (350 grains/m^2), the recorded values increased considerably from 48.1 g to 55.0 g (Table 3). In 2018, a number of 23 winter barley genoytpes registered TGW values higher than 42.0 under classical density (500 g/m^2), while under the low density all the tested genotypes registered values over the standard (Figure 4). In the sowing condition of 350 grains/m^2, TGW as quality parameter raised in average with 7 grams.

Table 2

Average values of grain yield, under two sowing densities in 2017/2018 year

No.	Variety/line	Grain yield (kg/ha)		Difference (kg/ha)
		Sowing density of 350 grains/m^2	Sowing density of 500 grains/m^2	
1	Dana	7119	5211	1907
2	Cardinal FD	7752	6004	1748
3	Univers	6689	5107	1581
4	Ametist	8648	6348	2300
5	Smarald	**5804**	4085	1719
6	Simbol	9111	5537	3574
7	F8-19-10	7459	5726	1733
8	F8-20-10	8467	5633	2833
9	ONIX	7881	5204	2678
10	F8-2-12	7289	5607	1681
11	F8-3-01	7867	5267	2600
12	F8-1-12	7081	4207	2874
13	F8-3-12	7230	5496	1733
14	F8-4-12	7522	5967	1556
15	F8-5-12	8163	5430	2733
16	F8-6-12	7841	5548	2293
17	F8-7-12	7319	5256	2063
18	F8-8-12	7259	4267	2993
19	F8-10-12	8667	4585	**4081**
20	F8-11-12	7411	5530	1881
21	F8-2-13	7696	6319	**1378**
22	F8-5-13	8233	5600	2633
23	F8-6-17	6185	**4074**	2111
24	V24	**9304**	**6978**	2326
25	V25	7533	5767	1767
	Average	**7661**	**5390**	**2271**

LSD 5% - 705 kg

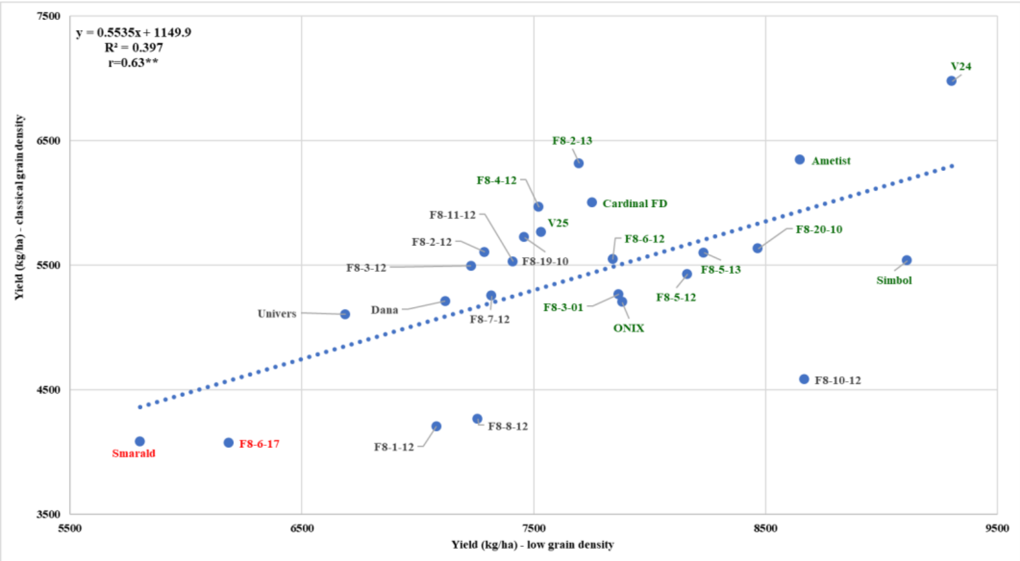


Figure 3. Average yield obtained under different sowing densities per unit area in 25 winter barley varieties and lines

Table 3

Average values of grain weight (TGW), under two sowing densities in 2017/2018 year

No.	Variety/line	Grain weight – TGW (g)		Difference (g)
		Sowing density of 350 grains/m^2	Sowing density of 500 grains/m^2	
1	Dana	53.1	46.6	6.4
2	Cardinal FD	50.5	42.2	8.3
3	Univers	51.4	43.0	8.4
4	Ametist	55.9	49.3	6.7
5	Smarald	53.0	**41.4**	**11.6**
6	Simbol	53.1	44.5	8.6
7	F8-19-10	51.0	43.7	7.4
8	F8-20-10	50.8	41.8	9.1
9	ONIX	50.6	44.7	5.9
10	F8-2-12	54.3	47.8	6.5
11	F8-3-01	**55.0**	**50.2**	4.8
12	F8-1-12	50.1	43.4	6.8
13	F8-3-12	49.8	43.8	6.0
14	F8-4-12	54.5	48.5	6.0
15	F8-5-12	53.1	47.4	5.7
16	F8-6-12	53.5	47.4	6.1
17	F8-7-12	52.9	46.3	6.6
18	F8-8-12	54.4	46.9	7.5
19	F8-10-12	52.9	47.2	5.7
20	F8-11-12	50.8	45.8	**5.1**
21	F8-2-13	52.5	45.7	6.8
22	F8-5-13	51.5	45.6	5.9
23	F8-6-17	**48.1**	42.2	6.0
24	V24	55.0	46.7	8.3
25	V25	54.7	46.9	7.8
	Average	**52.6**	**45.6**	**7.0**

LSD 5% - 1.3g

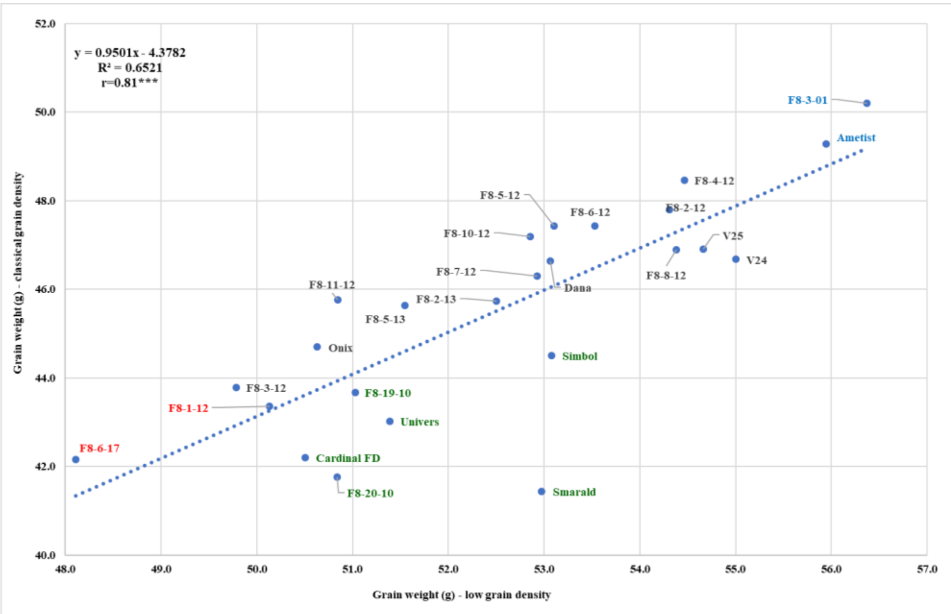


Figure 4. Average grain weight (TGW) under different sowing densities per unit area in 25 winter barley varieties and lines

The value for the 2.8 mm grain size recorded at the classical density (500 grains/m^2) was between 86.8 and 97.0 %, while in the second sowing condition (350 grains/m^2) was between 95.3 and 98.6%, which revealed a substantial improvement of this parameter in all tested genotypes, due to a reduced number of grains per unit area (Table 4). The winter breeding barley line F8-3-01 has registered the smallest differences (from 95.7 to 96.3%) and the biggest improvement of this parameter was from 86.8 to 96.4% (Simbol variety with 9.6%).

Table 4

Average values of grain size (2.8 mm), under two sowing densities in 2018 year

No.	Variety/line	Grain size (%)		Difference (%)
		Sowing density of 350 grains/m^2	Sowing density of 500 grains/m^2	
1	Dana	96.9	91.4	5.6
2	Cardinal FD	97.3	93.7	3.6
3	Univers	**98.6**	94.0	4.6
4	Ametist	**98.6**	96.3	2.3
5	Smarald	**98.6**	94.8	3.8
6	Simbol	96.4	**86.8**	**9.6**
7	F8-19-10	98.0	95.3	2.7
8	F8-20-10	96.6	92.1	4.5
9	ONIX	96.9	92.4	4.5
10	F8-2-12	96.7	95.4	1.2
11	F8-3-01	96.3	95.7	**0.6**
12	F8-1-12	95.5	90.1	5.4
13	F8-3-12	95.6	88.0	7.6
14	F8-4-12	96.1	95.0	1.0
15	F8-5-12	97.7	94.2	3.5
16	F8-6-12	96.7	92.1	4.6
17	F8-7-12	97.4	92.2	5.3
18	F8-8-12	97.7	89.5	8.2
19	F8-10-12	97.6	88.4	9.2
20	F8-11-12	**95.3**	90.4	4.9
21	F8-2-13	98.5	**97.0**	1.5
22	F8-5-13	98.2	92.7	5.6
23	F8-6-17	97.2	94.7	2.5
24	V24	98.3	94.6	3.6
25	V25	97.9	92.9	5.0
	Average	**97.2**	**92.8**	**4.4**

LSD 5% - 0.74%

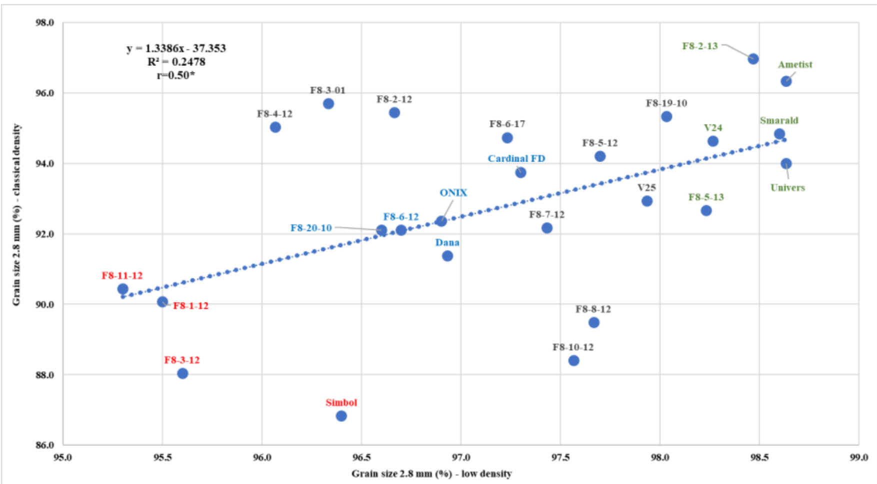


Figure 5. Average grain size (2.8 mm) under different sowing densities per unit area in 25 winter barley varieties and lines

CONCLUSIONS

Testing the varieties of winter barley and the perspective lines in a technology with different technological sequences, has as a result the characterization of their behavior from a quantitative and qualitative point of view, but also the possibility of establishing cultivation recommendations within the agricultural farms in order to obtain maximum yield leading to economic efficiency.

The genotype used, the sowing density as well as the interaction genotype x sowing density can be a decisive factor in obtaining a high level of production but also in expressing the quality potential.

The sowing density of 350 grains/m^2 had a positive impact on the agronomic traits resulting in the qualitative improvement of the raw material for malt and beer.

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