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GENOTYPE, SEED RATE AND CLIMATE CONDITIONS INFLUENCE ON WINTER BARLEY AGRONOMIC PERFORMANCES

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Abstract

During 2017-2019 period a study was performed at NARDI Fundulea to assess the influence of genotype, seed rate and climate conditions influence on yield and three quality indices of winter barley (six-rows) grains.
Two seeding rates (SR) were compared: SR1 = 500 seeds/m² and SR2 = 350 seeds/m², and the optimum target seed density was suggested for winter barley genotypes in order to maximize grain yield response.
Analysis of variance for studied traits showed differences among the genotypes, seed rates and climatic conditions of the growing seasons (years), as well as: a significant influence of genotype and interactions of year climate conditions x genotype on yield, grain weight, protein and starch content; year climatic conditions influenced grain weight, protein and starch content while seed rate had effect on yield, grain weight and starch content; interaction between year climatic conditions and seed rate influenced significant only yield and grain weight; interactions between seed rate x genotype and year climate conditions x seed rate x genotype were significant only for grain weight.
Seeding rate of 350 seeds/m² (SR2) produced a higher yield, ranging from 6064 to 8082 kg/ha, comparing to seeding rate of 500 seeds/m² (SR1), where the yield ranged from 5840 to 7791 kg/ha. There was a slightly decrease in grain protein content and an increase of starch content associated with a lower seed rate.
Grain weight parameter (expressed as thousand grain weight) had a significant variation, ranging between 46.6 and 53.6 g under SR2, with an average increase of 3.5 g comparing with SR1.

***Key words**: barley, growing conditions, protein and starch content, seed rate, yield.*

INTRODUCTION

Barley (*Hordeum vulgare* L.) is an important annual grain crop that is used as raw material in the malt and beer industry, in animal feed and also in human nutrition. According to data from FAO Database, less than 25% of barley yield is accepted for malt industry because of the specific requirements regarding disease-free seeds, low protein content, plumpness of grains and none of the less seed uniformity (Brewing and Malting Barley Research Institute, 2010).
In this respect, recommended barley sowing rates for raw material used in malt and beer industry should be more precisely in order to achieve a desirable size uniformity to obtain homogenous malt (Wade and Froment, 2003) and also a low protein content to achieve a better endosperm modification (Mathre, 1997).
Some study revealed how seed rate influence the yield and grain quality and also using as integrated crop protection management as increasing the seed rate had a major impact against weeds (Paynter and Hills, 2009).
The raw industry requires quantity and quality and often this condition is not fulfilled from both points of view. To meet these requirements, other studies were performed (Canada) to see the seeding rate, nitrogen rate and cultivar effects on malting barley (O'Donovan et al., 2011) and how much does seed rate influence the barley performances (Paynter et al., 2016) regarding plant height, lodging, grain yield, grain weight, plumpness and grain protein content (Australia).
Trainor and Paynter (2017) from the Department of Agriculture and Food, Western Australia's barley agronomy team, recommended two different barley plant densities per square meter depending on the use of barley. Thus, for malt suggested 120-150 plants/m² and for feed 180 plants/m² but the seed rates were different depending on the weight of the barley grains.

In an experiment performed in India (2015-2017 period) there was studied the effect of sowing time, seed rates and row spacing on yield of barley (Singh et al., 2019) and has been found that the sowing rates used (87.50 and 96.25 kg/ha) did not influence barley grain yield.

In Romania, there are reduced published data about the effects of agronomic practices on winter barley such as low seed rate as technological sequence combined with variety and year climatic conditions influence.

Also, till now, there were not presented the Romanian winter barley varieties and lines response regarding grain yield capacity under a reduced seed rate and over different climatic conditions (at least three years).

The concept of this experiment is to see if a lower seed rate can conduct to obtain maximum grain yield from the tested genotype and which of them can be recommended for the low seed rate.

In parallel, it was intended to see how the grain weight, the protein and starch content change.

The seed rate optimization for a growing barley genotype in a farm is very important due to the cost per kilogram of seed. A low seed quantity used for sowing means for a farmer a substantial saving and the potential to be more profitable.

MATERIALS AND METHODS

Twenty winter barley genotypes (six-rows) developed at National Agricultural Research and Development Institute Fundulea (NARDI Fundulea) were sown for 3 years consecutively in trials, respectively 2017, 2018, and 2019 under two different seeding rates: classical one SR1 = 500 seeds/m^2 and lower seeding rate SR2 = 350 seeds/m^2. The researches were performed within Barley Breeding Field belonging to NARDI Fundulea, which is situated in the South Romania, close to Fundulea town (44°33' Northern latitude and 24°10' Eastern longitude). The twenty winter barley genotypes composed by eight varieties (Ametist, Cardinal FD, Dana, Lucian, Onix, Simbol, Smarald, and Univers) and 12 advanced lines (F8-2-12, F8-3-01, F8-3-12, F8-4-12, F8-5-12, F8-5-13, F8-6-12, F8-6-17, F8-10-12, F8-11-12, F8-19-10, V20) were evaluated for their response at a regularly nitrogen dose (a nitrogen rate of 46 kg active substance/ha, respectively 100 kg of urea/ha was applied every year in March), the preceding crop being peas.

A randomised blocks design was used with the plots having 6 m of length (8 rows at 12.5 cm between rows) in three replications. The seed rate was established every year for each variety and line based on their grain weight.

After harvest, the grain yield (GY) was determined by weighing the obtained grains from each replication, and then it was calculated in kg/ha and expressed at 14% moisture content. After the seeds cleaning by thresher, some quality grain parameters (grain weight, protein and starch content) have been determined in three replications: grain weight (GW) was determined by numbering of 1,000 grains with Contador (two replications of 500 seeds) and weighing them on the electronic balance with 2 decimals (so, the grain weight is expressed as the thousand grain weight - TGW); protein (P) and starch content (S) were determined by using INFRATEC 1245 on a quantity of 300 g grains for each sample in three replications (the values were expressed in percent).

Data obtained was analysed with MSTAT programme, the results were presented as minimum, mean and maximum, and as a measure of each studied parameter stability, the coefficient of variation (%) was calculated.

The following scale was used (Ceapoiu, 1968) to interpret the values of the coefficient of variation (CV), when:

- CV < 10% - low and very low variability;
- 10% < CV < 20% - medium variability;
- 20% < CV < 30% - high variability;
- CV > 30% - very large variability.

The objective of the present paper was to test and analyse twenty winter barley genotypes (varieties and lines) at two seed rates in order to:

- assess if there is a loss of grain yield for varieties and lines and determine the difference in their response due to these seed rates;
- find out how the seed rates influence the grain quality of the winter barley varieties and lines;
- recommend for the winter barley varieties the optimal seed rates to obtain the highest yield in the seed producer sector and also farms.

RESULTS AND DISCUSSIONS

Analysis of variance for the studied traits showed differences among the genotypes, seed rates and growing seasons (years), as follows (Table 1):

- a significant influence of genotype and interactions of year x genotype on yield, grain weight, protein and starch content;
- year influenced grain weight, protein and starch content while seed rate had effect on yield, grain weight and starch content;
- interaction between year and seed rate influenced significant only yield and grain weight; interactions between seed rate x genotype and year x seed rate x genotype were significant only for grain weight.

Table 1. Analysis of variance for main effects of year (climatic conditions), seed rate, genotype and their interactions

Source of variation	Degree of freedom	Probability			
		Yield	Grain weight	Protein content	Starch content
Year	2	n.s.	***	***	***
Seed rate	1	***	***	n.s.	***
Genotype	20	***	***	***	***
Y x SR	2	***	***	n.s.	n.s.
Y x G	38	***	***	***	***
SR x G	19	n.s.	**	n.s.	n.s.
Y x SR x G	38	n.s.	**	n.s.	n.s.
CV (%)		**10.5%**	**3.0%**	**5.8%**	**0.8%**

Significance: *** = p<0.001, ** = p<0.01 and n.s. = not significant.

Table 2. October - June rainfall (monthly sum) and temperatures (monthly mean) for 2017-2019 period

2016-2017 year									
Month	October	November	December	January	February	March	April	May	June
Rainfall (mm)	**74.4**	48.8	0.2	35.4	50.5	47.6	**73.4**	**65.8**	**96.4**
Temperature (°C)	10.3	5.7	**-0.3**	**-5.5**	**-0.1**	8.5	10.6	**16.8**	**22.2**
2017-2018 year									
Rainfall (mm)	**111.6**	49.2	27.8	36.0	58.6	40.6	**2.4**	**34.0**	**120.6**
Temperature (°C)	11.7	6.9	3.6	0.7	1.6	3.3	15.8	**19.4**	**22.6**
2018-2019 year									
Rainfall (mm)	10.8	23.0	43.0	53.8	21.4	22.4	**51.4**	**124.2**	**74.6**
Temperature (°C)	13.4	5.2	**-0.1**	1.5	4.1	9.3	11.2	**17.2**	**23.6**

In two consecutive years (2016 and 2017) in the second decade of October (Table 2) after the seedling, rainfall was high (over 74 and 110 mm respectively), which assured a proper establishment of barley plant density (data no shown). In the third year (2018), the rainfall quantity was low and the barley plants were established after two weeks from the sowing data with no influence of this.

During the winter period, the lowest mean temperature was registered in the first month of the 2017 year (-5.5°C in January) but without plant losses, while in 2018 was no negative mean temperatures and in 2019 the lowest temperatures was registered in December, but this was only -0.1°C.

Regarding the temperatures during the filling grain period (in the tested periods), it can be noticed that from one year to another, the mean temperature had increased in May from 16.8 to 19.4°C and in June from 22.2 to 23. 6°C.

So, the tested years were different and these climate characteristics influenced the winter barley development which had conducted to obtain conclusive yield and yield quality grain data.

The yield minimum value obtained was 5840 and 6064 kg/ha under SR1 and respectively SR2 (Figure 1). Maximum yield average response of the winter barley genotypes at the two seed rates was 7791 kg/ha for SR1 and 8082 kg/ha for SR2. The difference between minimum and maximum values of the barley yield of the two seeding rates was quantified in 2242 kg/ha which shows that the winter barley varieties and lines different behaviour is due to the barley specific genotype agronomic performances and their reaction to seed rate and interaction between year x seed rate and year x genotype.

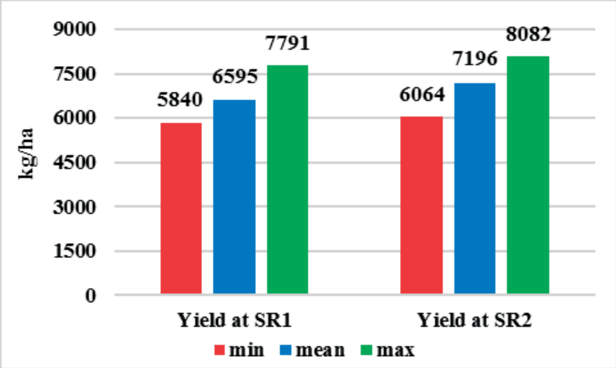

Figure 1. Yield average response of winter barley genotypes (minimum, mean and maximum values) at two seed rates (SR1 = 500 seeds/m^2 and SR2 = 350 seeds/m^2)

In the case of average response of the winter barley genotypes regarding the grain weight (expressed as thousand grain weight - TGW), this trait had an impressive increase from a minimum of 43.6 g to a maximum of 50.6 g at SR1 and from a minimum of 46.6 g to a maximum of 53.6 g at SR2 (Figure 2).
It can be noticed that the grain weight of the studied winter barley genotypes had registered the same difference (7.0 g) between minimum and maximum values at both seed rates, but the minimum value registered under SR2 was higher than the minimum value under SR1. Also, it can be noticed that the difference between the minimum values (from 43.6 to 46.6 g) and respectively the maximum values (from 50.6 to 53.6 g) registered at the two seed rates (SR1 and SR2) is of 3 g.
The value of protein content (Figure 3) had oscillated between 10.0 and 11.8% under SR1 and between 10.0 and 11.7% under SR2, which shows that the year, genotype and interaction between year x genotype had a significant influence on this quality seed parameter. Even the average values of differences between winter barley genotypes response as minimum, mean and maximum at the two seed rates are not so high (0.0% for minimum and 0.1% for maximum) among studied genotypes it is clear that appears a different assimilate translocation mechanism related to the climatic condition from the grain filling months (from May after anthesis till grain filling at the end of June).

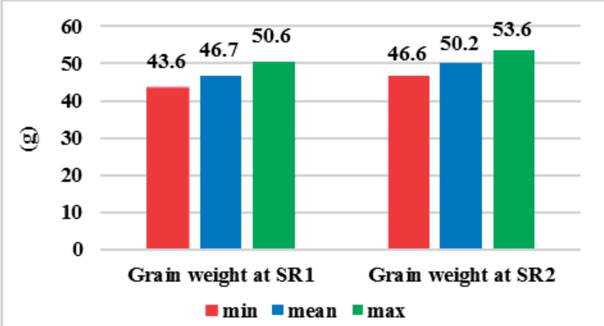

Figure 2. Grain weight (expressed as thousand grain weight - TGW) average response of winter barley genotypes (minimum, mean and maximum values) at two seed rates (SR1 = 500 seeds/m^2 and SR2 = 350 seeds/m^2)

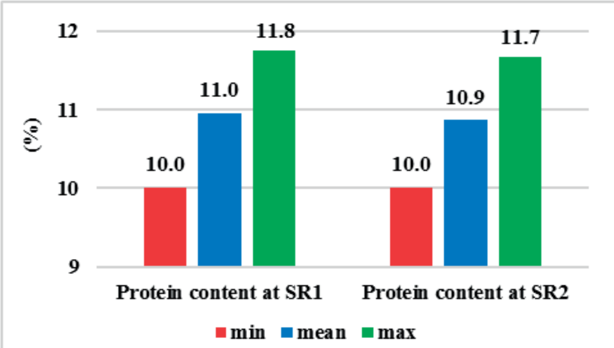

Figure 3. Protein content average response of winter barley genotypes (minimum, mean and maximum values) at two seed rates (SR1 = 500 seeds/m^2 and SR2 = 350 seeds/m^2)

Regarding the starch content (Figure 4), in average the response was almost similar for the minimum values, which were over 60% for both seed rates (61% at SR1 and 61.1% at SR2) as well as for the maximum values, which were about 63% for both seed rates (62.9% at SR1 and 63.1% at SR2).
The years during which the experiments were performed were characterized by especially climatic conditions being very favorable to achieve an equilibrium between protein and starch seed content.
Grain yield stability was well done illustrated by the coefficient of variation values (CV), this varied between 1.1-14.8% under SR1 (500 g.s/m^2) and from 2.0 to 14.6% under SR2 (350 g.s/m^2), according to Ceapoiu classification, 1968, which means a low and medium variation of this parameter under both seed rates (Figure 5).

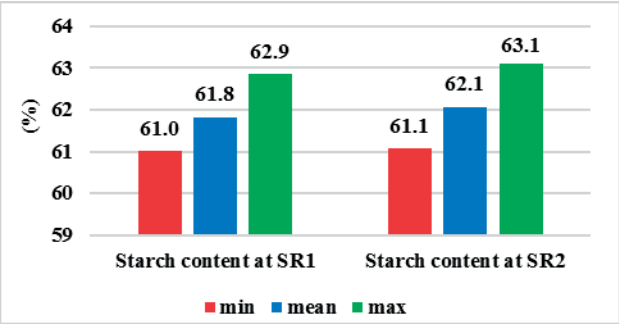

Figure 4. Starch content average response of winter barley genotypes (minimum, mean and maximum values) at two seed rates (SR1 = 500 seeds/m^2 and SR2 = 350 seeds/m^2)

The grain yield coefficient of variation for some of winter six row barley varieties and few advanced lines is different under the SR2. The winter barley varieties Dana, Univers, Lucian and advanced lines F 8-19-10, F 8-3-12, F 8-6-17 and V20 comparing with their CV under SR1, had registered a decreased CV (%) which showed a better yield stability under reduced sowing density (SR2). The smallest CV differences between SR1 and SR2 were recorded by winter barley varieties Ametist and Onix and advanced winter barley lines F 8-6-12 and F 8-5-13 (between 0.3 and 1.8%).

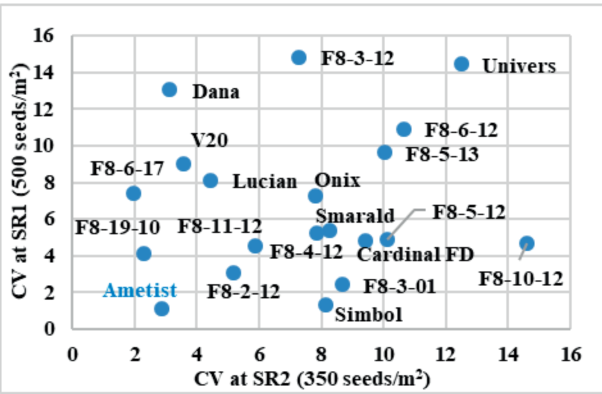

Figure 5. Grain yield coefficient of variation (CV) under SR1 and SR2, as mean of 3 years

Concerning grain yield coefficient of variation (Figure 5), older variety Univers and one advanced barley line F 8-6-12 registered higher values for both experimented conditions (Univers variety from 12.5 to 14.4% and F 8-6-12 from 10.6 to 10.9%). Most of varieties and lines had a small coefficient of variation under SR1 and SR2 (<10%). Two winter barley lines (F8-10-12 and F8-5-12) showed a better yield stability under SR1 (500 g.s/m^2) with a lower CV% (4.7% and respective 4.9%) while for SR2 (350 g.s/m^2) CV% was over 14.6% (F 8-10-12) and 10.1% (F 8-5-12) showing the yield instability for these 3 years.

Out of all winter barley varieties, Ametist had the smallest CV under both seed rates (Figure 5) while one of the oldest studied winter barley variety, Univers (registered in 2004) had a medium CV (over 12% under both conditions).

Grain weight coefficient of variation value (CV), was under 10% for all the tested winter barley genotypes (according to Ceapoiu classification, 1968), this means a low variation of this parameter (Figure 6) under both seed rates.

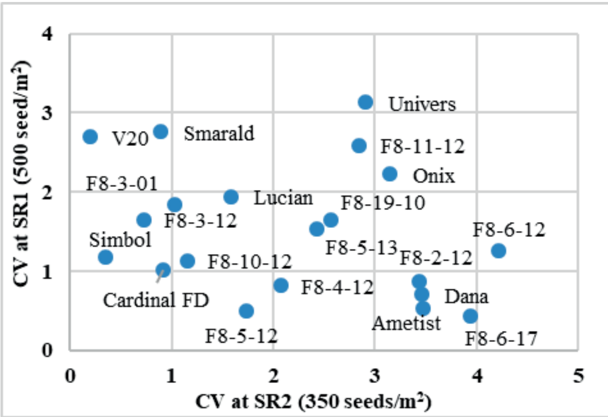

Figure 6. Grain weight coefficient of variation (CV) under SR1 and SR2, as mean of 3 years

This qualitative index (grain weight) is the only one which is influenced by the all source of variations (year, genotype, seed rate and their interactions).

The winter barley varieties Cardinal FD, Simbol, Lucian and advanced winter barley lines F 8-3-12, F 8-5-12, F 8-10-12, F 8-3-01 have maintained their CV under 2% under both seed rates revealing a good stability for grain weight for 3 years consecutively.

Also, protein content coefficient of variation was low (<10%), but the genotypes had reacted different at the tested seed rates (Figure 7). The variation of the grain protein content among the winter barley studied genotypes was narrow (from 10.0 to 11.8%) so only five genotypes had a higher CV than 5% (Ametist, F 8-5-12, V20, F 8-5-13, F 8-11-12). The lowest CV had Dana and Cardinal FD varieties (between 1 and 2%), the tendency being towards an increase of the protein content coefficient of variation under SR2. The low value of this increase showed that this trait is a prerogative of barley genotype under a low seed rate because it does not influence the protein content.

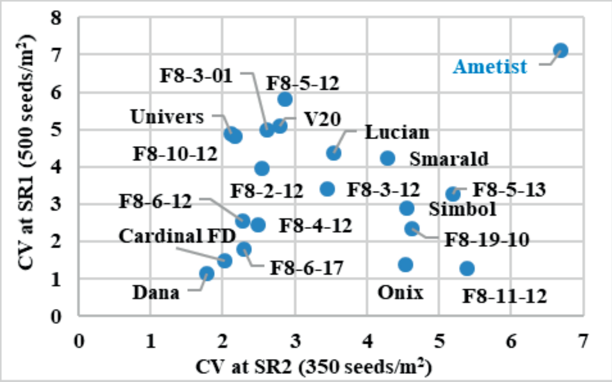

Figure 7. Protein content coefficient of variation (CV%) under SR1 and SR2, as mean of 3 years

Ametist variety CV regarding the protein content was almost equal under both seed rates (Figure 7), which means a similar protein content no matter seed rates, respectively it clearly showed that this variety cannot be influenced by the second seed rate (SR2) technological sequence.

Among the studied parameters, the starch content coefficient of variation was the lowest, this oscillating between 0 and 0.8% under SR2 and between 0 and 1.6% under the SR1 (Figure 8).

All the tested genotype had a lower CV of the starch content, but in the case of this quality seed parameter, the stability was better under SR2 than under SR1, opposite to the trends of all the others studied parameters.

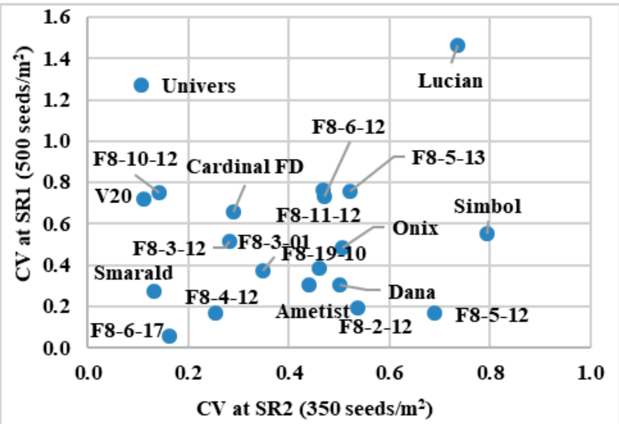

Figure 8. Starch content coefficient of variation (CV) under SR1 and SR2, as mean of 3 years

The sowing rate SR2 improved significant the grain yield, grain weight, protein and starch content (Table 3).

The average yield effect of the SR2 compared to SR1 varied between 145 kg/ha (F 8-2-12 line) and 1328 kg/ha for advanced line F 8-10-12. The higher grain yield increase at SR2 was registered also by the Simbol and Cardinal FD variety with 1169 kg/ha and 1316 kg/ha respectively.

All the winter barley varieties, respectively Dana, Cardinal FD, Univers, Ametist, Smarald, Simbol, Lucian and Onix, at SR2 achieved a grain yield over the classical seed rate (500 seeds/m^2), the difference being between 371 and 1316 kg/ha. Also, the seed quality parameters were slight improved at SR2 but in a characteristic manner of each genotype. Thus, the grain weight increased at SR2 with 1.3-6.1 g and the protein and starch content varied from -0.6 to +0.3% and from -0.1 to +0.6% respectively. In none of the analyzed cases, the values of seed quality parameters do not decrease under the raw industry requests (9.5-11.5% for protein content and over the 60% for starch content).

Table 3. Sowing rate (SR2) effect to the grain yield (+kg), grain weight (+g), protein and starch content (plus/minus %), as mean of 3 years

Variety/line	GY (kg)	GW (g)	P (%)	S (%)
Dana	**+934**	**+1.3**	+0.2	**-0.1**
Cardinal FD	**+1316**	+3.6	+0.2	+0.3
Univers	**+374**	+2.9	-0.3	+0.4
Ametist	**+717**	+3.3	**-0.6**	+0.2
Smarald	**+622**	**+6.1**	-0.1	+0.3
Simbol	**+1169**	+3.4	+0.2	+0.3
F8-19-10	+429	+4.2	-0.1	**+0.6**
Lucian	**+371**	+3.3	**+0.3**	+0.4
Onix	**+922**	+3.5	-0.2	+0.3
F8-2-12	**+145**	+3.6	-0.1	+0.1
F8-3-01	+490	+3.0	**-0.6**	**+0.6**
F8-3-12	+245	+3.5	-0.2	+0.2
F8-4-12	+338	+4.1	-0.1	+0.2
F8-5-12	+713	+4.3	-0.5	+0.2
F8-6-12	+587	+2.5	-0.4	-0.1
F8-10-12	**+1328**	+3.7	+0.1	+0.3
F8-11-12	+224	+2.7	+0.2	**-0.1**
F8-5-13	+512	+2.8	+0.1	+0.4
F8-6-17	+284	+2.8	+0.1	+0.0
V 20	+291	+4.1	-0.1	+0.5
min	**145**	**1.3**	**-0.6**	**-0.1**
mean	**601**	**3.4**	**-0.1**	**0.3**
max	**1328**	**6.1**	**0.3**	**0.6**

Correlation coefficients among the winter barley analyzed parameters (Table 4) indicated that under the SR1 there was no correlations between grain yield and other parameters. Grain weight was positively correlated (r = 0.66***) with protein content and negatively correlated (r = -0.67^{ooo}) with starch content under SR1.

Under the SR2 (Table 5), grain yield was significantly negatively associated with protein content (r = -0.57^{ooo}) and positively correlated with starch content (r = 0.46**). In the case of SR2, the grain weight was negatively correlated with starch content (r = -0.48^{oo}).

Under both seed rates (Tables 4 and 5), protein content was strongly negatively correlated (r = -0.78^{ooo} and r = -0.84^{ooo} respectively) with starch content.

Table 4. Correlations between the winter barley analyzed parameters (grain yield - GY, grain weight - GW, protein - P and starch - S content) under SR1

Parameter	GY	GW	P	S
GY	1	-0.12	-0.39	0.06
GW		1	0.66***	-0.67^{OOO}
P			1	0.78^{OOO}
S				1

Table 5. Correlations between the winter barley analyzed parameters (grain yield - GY, grain weight - GW, protein - P and starch - S content) under SR2

Parameter	GY	GW	P	S
GY	1	-0.03	-0.57^{OOO}	0.46**
GW		1	0.32	-0.48^{OO}
P			1	-0.84^{OOO}
S				1

CONCLUSIONS

There were registered large variations among the winter barley varieties and advanced lines regarding the agronomic performances related to the grain yield. Barley grain yield positively responded and had increased when seed rate decreased from 500 seeds/m² to 350 seeds/m², this being associated with a slight increase of grain quality parameters.

This study revealed that using a winter barley low seed rate which fits for every variety is necessary to enhance not only grain yield but also the grain quality which leads to specific recommendation for each barley variety. Therefore, farmers from the south-east of Romania producing winter barley should use a low sowing rate for all Romanian varieties for having an enhanced productivity. However, in order to use the seed rate of 350 seeds/m² as a standard sowing density, the main condition is to have a seedbed well prepared and enough moisture in the soil as to obtain a fast emergence of the barley plants.

REFERENCES

Ceapoiu, N. (1968). *Metode statistice aplicate în experienţele agricole şi biologice*. Editura Agro-Silvică, Bucureşti.

Gozukirmizi, N., Karlik, E. (2017). Barley (*Hordeum vulgare* L.) Improvement Past, Present and Future. In Makoto Kanauchi (Ed.), Brewing Technology (49–78), IntechOpen.

Mathre, D.E. (1997). Compendium of barley disseases, 2nd ed. APS Press, St. Paul, Minnesota, 90 pp.

O'Donovan, J.T., Turkington, T.K., Edney, M.J., Clayton, G.W., McKenzie, R.H., Juskiw, P.E., Lafond, G.P., Grant, C.A., Brandt, S., Harker, K.N., Johnson, E.N., May, W.E. (2011). Seeding rate, nitrogen rate, and cultivar effects on malting barley production. *Agronomy Journal*, *130*(3), 709–716.

Paynter, B., Hills, A., Malik, R. (2016). How much does seed rate (changing from 50 to 400 plants/m²) influence barley's performance? Grain Research Development Corporation, project number: DAW00224, Department of Agriculture and Food Western Australia, Northam, Esperance and Katanning.

Paynter, B.H., Hills, A.L. (2009). Barley and rigid rye grass (*Lolium rigidum*) competition is influenced by crop cultivar and density. *Weed technology*, *23*, 40–48.

Trainor, G., Paynter, B. (2017). What is the optimum plant density for your barley variety? https://www.agric.wa.gov.au.

Singh, A.K., Singh, B., Thakral, S.K. (2019). Effect of sowing time, seed rates and row spacing on yield of barley (*Hordeum vulgare* L.). In Haryana. *Int. J. Pure App. Biosci.*, *7*(2), 509–512.

Wade, A., Froment, M.A. (2003). Barley quality and grain size homogeneity for malting. Vol. I. Agronomic effects on varieties. Project Report # 320. Home Grown Cereals Authority, Stoneleigh Park, Kenilworth, Warwickshire, UK.

***Brewing and Malting Barley Research Institute (2010). Quality factors in malting barley. A Brewing and Malting Barley Research Publication 1510. BMBRI, Winnipeg, http://www.bmbri.ca/quality.

***FAO database, http://www.fao.org/faostat/en.