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EFFECTS OF CULTIVAR AND NITROGEN DOSE ON GRAIN WEIGHT IN ROMANIAN WINTER BARLEY

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ABSTRACT

During 2014-2016 at National Agricultural Research and Development Institute Fundulea three yield trials with winter barley cultivars under three levels of nitrogen fertilization were performed. The objective of this study was the evaluation of Romanian winter six and two row barley cultivars across three years, in order to analyse the effects of cultivar and fertilizer dose on yield and grain weight.

As the main source of variation, the nitrogen level influenced significant the grain yield, which registered a progressive increase according to nitrogen dose, while the grain weight decreased from the second to third nitrogen level.

Influence of grain weight on yield was different and much stronger in a few cases, comparing winter six row with two row varieties and their reaction to the nitrogen dose.

Variations in grain weight were related to the number of row/spike and at the three levels of nitrogen fertilization were highly correlated (r = 0.93* and 0.85***). The most productive winter six row varieties registered on average the lowest grain weight (Cardinal, Smarald and Lucian) and the highest yield. Winter two row variety Artemis and Gabriela presented an increased value of grain weight at 100 kg ha^{-1} nitrogen level and this quality index contributed to achieve higher yield.**

Keywords: cultivar, grain yield, grain weight, quality, nitrogen fertilizer.

INTRODUCTION

Improvement of the yield capacity is a difficult task to be achieved within a breeding programme of winter barley (Lewis et al., 2008) due the complexity of this trait, which includes agronomical, physiological and environmental characters (Öztürk et al., 2018).

Different authors showed that yield (GY) depends on both grain number and grain weight (Kesavan et al., 2013; Distelfeld et al., 2014). It seems that grain weight (GW) is the main component of yield (Passarella et al., 2005), and GW is determined by grain length and grain width (Sun et al., 2013). Grain weight, length and width are quantitative traits, controlled by polygenes or QTLs (Sun et al., 2013), influenced by environment (Walker et al., 2013), as temperature during anthesis and grain filling (Wallwork et al., 1998) and also drought stress (Royo et al., 2006).

The study made by Eshghi et al. (2010) indicated GW had a complex heredity, and that is the reason to select this trait during later breeding generations.

Mirosavljević et al. (2015) found that yield had a positive relationship with thousand kernel weight (TKW); and the same relationship between GW and GY was shown in a different study of barley (Pržulj and Momčilović, 2012) and also in drought environments (Royo et al., 2006). Three years later, when Mirosavljević et al. (2018) studied by comparison a few species of grains, they had found that there was no correlation between GY and GW, especially when they analysed six row and two row barley.

Between GW and starch content there is a positive relationship (Savin and Molina-Cano, 2002) a desirable trait for brewers with positive contribution on malt extract.

Pržulj et al. (2014) reported that cultivars with medium-sized grains, TKW from 41 to

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44 g, are more suitable for raw industry because they uptake the water faster and more uniform. On the other hand, a very large grain could have a negative impact on malt quality due to a higher quantity of water necessary to seed hydration (Fox et al., 2006).

Malting barley yield and quality can be improved considering the strategic practices for nitrogen fertilizer application (McKenzie et al., 2005; O'Donovan et al., 2011; Edney et al., 2012) and also a suitable variety selection (O'Donovan et al., 2011; Edney et al., 2012).

Other results revealed the genetic variability among five barley cultivars (six and two row) on both grain yield and yield components in response to nitrogen fertilization. When they used different nitrogen fertilization levels, Oral et al. (2018) observed the higher increments on grain yield and yield components under conditions of 40 kg/ha nitrogen fertilization level, while value of GW was the biggest without nitrogen application. Their results also indicated that grain weight was significantly affected by different nitrogen doses, years, cultivar and nitrogen x cultivar interactions. The same study of Oral et al. (2018) made on two consecutive years showed that GW decreased by increasing nitrogen doses, by different climatic data and by genetic of cultivars.

A high dose of nitrogen in barley can causes lodging, low GW, short spikes, delayed maturity and susceptibility to biotic and abiotic stresses (Alam et al., 2007), but this trait is more dependent on genetic of cultivars (Kizilgeciet al., 2016) due to genotypic variation in nitrogen translocation to the grain during the filling process (Bulman and Smith, 1994).

The objective of this study was the assessment of winter six and two row Romanian barley cultivars across three years, in terms of relations that can be established between the yield and grain weight under different nitrogen doses, applied as fertilizers.

MATERIAL AND METHODS

Eleven Romanian winter barley varieties (namely Cardinal, Smarald, Onix, Lucian, Simbol, Univers, Ametist, Dana, Artemis, Gabriela, and Andreea), released from 1992 to 2018 (eight six row and three two-row barley) were analysed. The studies were performed during a three-year period (2014-2016) at NARDI Fundulea in the barley breeding experimental field on a chernozem soil (pH 6.3-6.8, humus 3%) with peas as preceding crop. In the autumn 100 kg/ha P_2O_5 were incorporated in soil and sowing was carried out each year in October, 10-15.

A complete randomised block design with three replications was used and the plots (4 m x 1 m in size with 20 cm between rows) were sown at the rate of 400 seeds/m^2. Three identical yield trials were performed as follows: one trial without spring N fertilization, the second with 100 kg ha^{-1} spring N fertilization and the third with 200 kg ha^{-1} spring N fertilization. The crop management practices used were those recommended for large-scale winter barley production, with all necessary crop protection measures, i.e. during vegetation period a herbicide and a fungicide treatment were applied.

The plots were harvested by a Wintersteiger combine and grain yield (GY) was determined in each of the three replications with correction to 140 g kg^{-1} moisture.

After that, for assessing the grain weight (GW), from each replication a sample (of 350 g weight) was taken and the seeds were conditioned by a thresher. The seeds were counted with a Contador instrument (Pfeiffer Germany) by measuring two sets of 500 grains per replication, weighed on a Partner balance and expressed as weight of thousand grains (g).

To determine the effects of cultivar (V), nitrogen (N), and VN interaction, two-way analysis of variance (ANOVA) for grain yield data was performed and linear regression were used to analyse the experimental data. Meteorological data were provided by Weather data station from NARDI Fundulea.

RESULTS AND DISCUSSION

Winter barley cultivars were tested in 9 different environmental conditions (year x nitrogen management). The regressions between grain weight and grain yield in all studied conditions showed that the six row Cardinal, Smarald and Lucian varieties had a different behaviour as compared to the other varieties, showing in all the mentioned conditions higher yield (Figure 1). The two row varieties Artemis and Gabriela showed a higher yield and grain weight in all three studied conditions, but the two row Andreea cultivar under the third level of nitrogen fertilizer had the smallest value of grain weight.

According to this relationship between these two parameters, influence of grain weight on yield was different and much stronger in a few cases, if we compare six row with two row varieties and their reaction to the nitrogen dose.

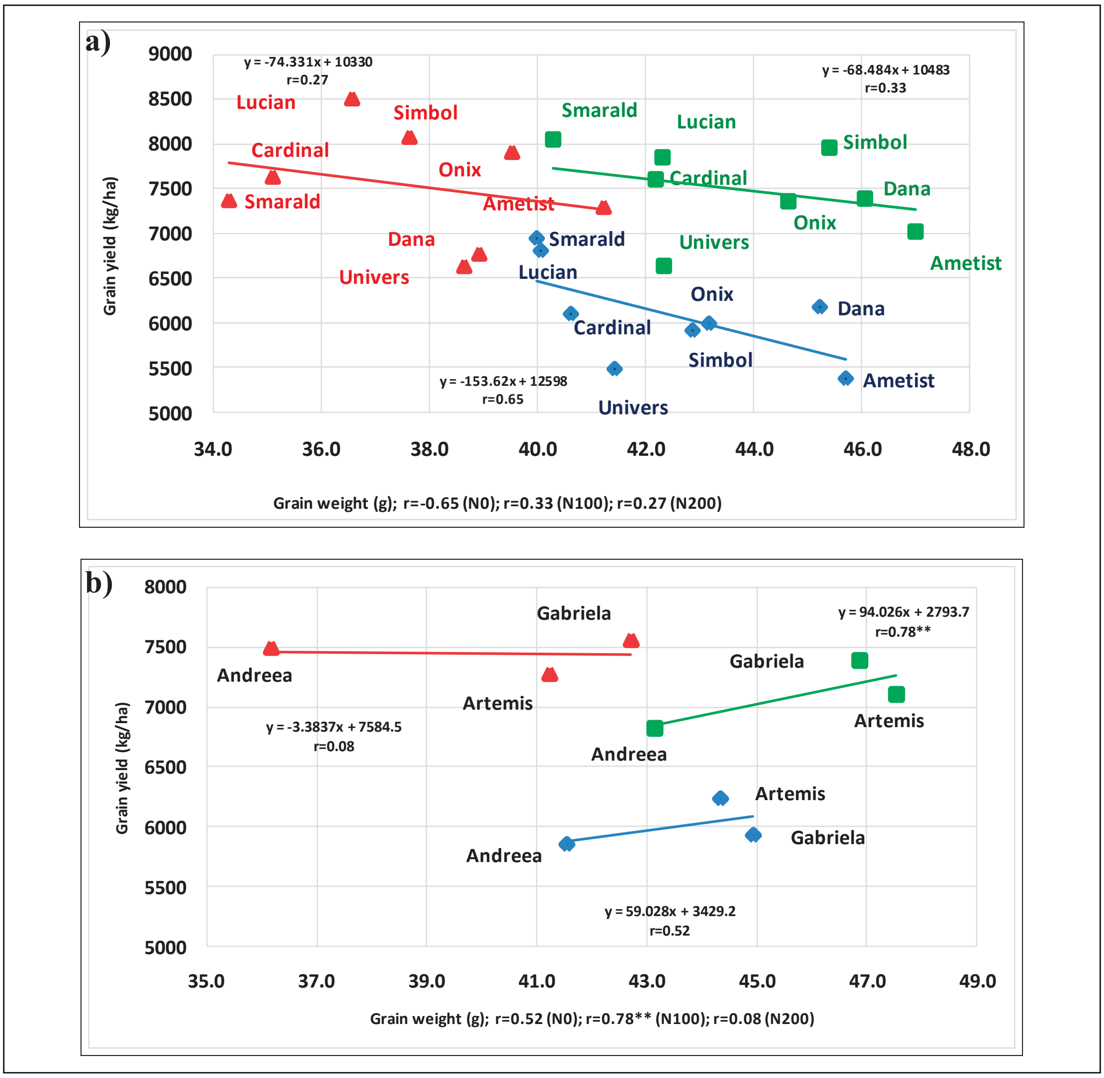

Figure 1. Relationship between grain weight and average grain yield for 11 Romanian winter barley cultivars during 2014-2016
a) six row barley without fertilizer in spring, fertilized with 100 and 200 kg ha^{-1};
b) two row barley without fertilizer in spring, fertilized with 100 and 200 kg ha^{-1}.

ANOVA of the grain yield revealed different effects of cultivar, nitrogen dose and their interaction (Table 1). Influence of cultivar, was significant in 2014 and 2016. The response of grain yield to applied nitrogen dose was similar in all three years, showing a significant nitrogen effect every year. The cultivar and nitrogen dose interaction was not significant for 2015 and 2016 years, but significant in 2014 that could be explained by the differences of rainfall distribution (quantity and uniformity), during the vegetation period.

Table 1. ANOVA for grain yield in winter barley varieties trials

Source of variation	2014		2015		2016	
	F	P-value	F	P-value	F	P-value
Cultivars (V)	13.242**	2.33E-12	0.523^{ns}	0.867	3.116**	0.002
Nitrogen dose (N)	130.914**	1.07E-23	14.438**	6.29E-06	13.911**	9.09E-06
V x N	1.939*	0.023	0.412^{ns}	0.985	1.008^{ns}	0.464

*significant at a probability level of $p<0.05$; **significant at a probability level of $p<0.01$.

Table 2. ANOVA for grain weight in winter barley varieties trials

Source of variation	2014		2015		2016	
	F	P-value	F	P-value	F	P-value
Cultivars (V)	33.847**	3.45E-22	15.756**	5.6E-14	19.997**	2.33E-16
Nitrogen(V)	4.650*	0.012	3.504*	0.035	23.226**	2.31E-08
V x N	2.531**	0.002	0.829 ^{ns}	0.670	1.550^{ns}	0.094

*significant at a probability level of $p<0.05$; **significant at a probability level of $p<0.01$.

The varieties and nitrogen dose had significant effects on grain weight in all three studied years, while the interaction between cultivar and nitrogen dose was significant only in the year 2014. These results suggest that varieties differed in grain weight, and the interaction V x N cannot always change the response of the varieties regarding grain weight (Table 2).

Table 3. Total rainfall (mm) and average temperature (°C) recorded in spring growing season (March-June), at NARDI Fundulea, during 2014-2016

Year		2014		2015		2016	
Month	Decade	Average t (^{0}C)	Average rainfall (mm)	Average t (^{0}C)	Average rainfall (mm)	Average t (^{0}C)	Average rainfall (mm)
March	1-10	5.34	36.6	4.63	24.2	9.25	23
	11-20	9.71	0.3	4.79	5.6	4.93	6
	21-30	10.19	1.2	8.09	48.9	8.51	26.9
		8.4	**38.1**	**5.8**	**78.7**	**7.6**	**55.9**
April	1-10	10.57	15.3	7.34	21.6	14.3	0
	11-20	9.76	54.8	13	15	15.36	24.8
	21-30	13.74	12.7	12.59	10.3	11.98	48.9
		11.4	**82.8**	**11.0**	**46.9**	**13.9**	**73.7**
May	1-10	13.53	21.5	17.41	8	12.61	64.9
	11-20	15.47	57.1	18.7	2.4	15.65	**2.4**
	21-30	20.06	22	18.9	19.6	18.57	13.9
		16.4	**100.6**	**18.3**	**30.0**	**15.6**	**81.2**
June	1-10	20.21	14.7	21.53	1.6	19.59	14.8
	11-20	19.4	70.9	22.04	19.2	23.34	28.5
	21-30	19.75	50.6	19.87	31.1	25.91	**0.4**
		19.8	**136.2**	**21.1**	**51.9**	**22.9**	**43.7**
Total rainfall March-June (mm)			**357.7** (82.0%)		**207.5** (59.4%)		**254.5** (58.5%)
Total rainfall during growing season (mm)			436.0		349.3		435.1

In the year 2014, 82.0% of the total rainfall during the growing season (436.0 mm) were registered in the period March-June (over 100 mm were registered in May and June) as compared with 2015 and 2016 spring growing periods, when from the total rainfall just a little bit over 58% had fallen in the same period (Table 3).

Two of three years presented limiting conditions for grain filling. The year 2014 was characterized by a high quantity of rainfall, but not uniformly distributed during the mentioned period, while in the first and the second decades of May and at the beginning of June in year 2015 rains were quite uniformly distributed. In 2016 a small amount of precipitation fell in the second decade of May (2.4 mm) and during the last 10 days of barley vegetation in June (0.4 mm). Also, the temperature averages were higher with 0.3°C in 2015 and with 3.1°C in 2016 as compared with the same month (June) of 2014.

Table 4. Means of grain weight of Romanian winter barley varieties grown at NARDI Fundulea during 2014-2016

Cultivar	No. of row	2014			2015			2016			Average 2014-2016		
		N_0	N_{100}	N_{200}	N_0	N_{100}	N_{200}	N_0	N_{100}	N_{200}	N_0	N_{100}	N_{200}
Dana	6	40.4	40.5	34.6	**53.5**	52.0	36.4	**41.8**	**45.7**	**45.7**	**45.2**	**46.1**	38.9
Cardinal	6	33.0	37.6	34.3	50.1	47.2	32.9	38.8	41.9	38.2	40.6	42.2	35.1
Univers	6	36.6	35.5	41.4	49.6	50.3	34.6	38.1	41.3	40.0	41.4	42.4	38.7
Ametist	6	**41.2**	41.1	**42.4**	51.7	52.4	34.9	**44.2**	**47.6**	**46.4**	**45.7**	**47.0**	**41.2**
Smarald	6	34.9	34.3	33.2	48.5	47.3	33.6	36.8	39.3	36.1	40.1	40.3	34.3
Simbol	6	37.7	40.6	37.2	49.9	51.0	34.6	**41.1**	**44.6**	41.1	42.9	**45.4**	37.6
Onix	6	38.1	41.5	40.8	50.7	50.2	33.7	**40.7**	42.3	**44.1**	43.2	44.7	**39.5**
Lucian	6	35.6	36.7	35.5	47.5	49.6	33.7	37.0	40.7	40.5	40.0	42.3	36.6
Six row varieties average		*37.2*	*38.5*	*37.4*	*50.2*	*50.0*	*34.3*	*39.8*	*42.9*	*41.5*	*42.4*	*43.8*	*37.7*
Andreea	2	40.5	**43.8**	41.5	50.7	51.1	33.9	33.5	34.6	33.2	41.6	43.2	36.2
Artemis	2	**46.0**	**48.5**	**47.0**	**54.6**	**54.2**	**37.5**	32.4	39.9	39.2	**44.3**	**47.5**	**41.2**
Gabriela	2	**43.4**	**43.6**	**46.8**	**56.8**	**54.6**	**38.3**	34.6	42.4	**43.1**	**44.9**	**46.9**	**42.7**
Two row varieties average		*43.3*	*45.3*	*45.1*	*54.0*	*53.3*	*36.6*	*33.5*	*39.0*	*38.5*	*43.6*	*45.9*	*40.0*
All varieties average		38.9	*40.3*	39.5	51.2	*50.9*	*34.9*	38.1	*41.8*	40.7	42.7	44.4	38.4
LSD 5%		2.2			1.8			2.4			0.9		

Bolded values of the GW are significantly superior to the average of all varieties.

The mean grain weight of all varieties showed limiting conditions for grain filling under the high nitrogen dose (200 kg ha^{-1}) in the year 2015, when the value of grain weight was just 34.9 g, lower with 4.6 g than in year 2014 and with 5.8 g in comparison with value registered in the year 2016 (Table 4). The highest grain weight averaged over all cultivars was registered under the 100 kg ha^{-1}N fertilizer, 40.3 g in 2014, 50.9 g in 2015 and 41.8 g in 2016.

Analysis of the average grain weight illustrated a large variation among six row varieties across the years and nitrogen doses (grain weight ranged between 37.2 and 50.2 g without nitrogen in years 2014 and 2015, and between 38.5 and 50.0 g with 100 kg N ha^{-1}). Regarding two row varieties, the highest variation was registered between Artemis cultivar (from 54.6 g in 2015 to 32.4 g in 2016) and Gabriela cultivar (up to 56.8 g in 2015) under conditions without nitrogen fertilizer.

During the period 2014-2016, several six row cultivars showed a high grain weight value and some of them registered a low value, especially under 100 kg ha^{-1} nitrogen fertilizer. In the case of six row cultivars, Onix, Simbol and Ametist had higher than average values (43.8 g), from 44.7-47.0 g; and cultivars Smarald, Cardinal and Lucian registered values below the average (40.3-42.3 g). The behaviour of two row varieties was different; Artemis and Gabriela had superior values in all experimental conditions (Table 4).

As depicted in Figure 2, in both cases of nitrogen fertilization during spring with levels of either 100 kg N ha^{-1} or 200 kg N ha^{-1} in comparison with the same cultivars without N fertilizers, strong linear relations between grain weights for all samples were established. For example, the grain weight obtained in conditions without fertilizer was highly correlated with grain weight of the considered cultivars when a level of 100 kg ha^{-1} nitrogen was applied (r = 0.93***).

It was noticed that all the winter barley varieties had good nitrogen utilization efficiency, for several varieties the average increase of grain weight was 9.7 g from without nitrogen condition to 100 kg ha^{-1} nitrogen fertilizer. The average decrease was 4.3 g from without nitrogen to 200 kg ha^{-1} nitrogen fertilizer.

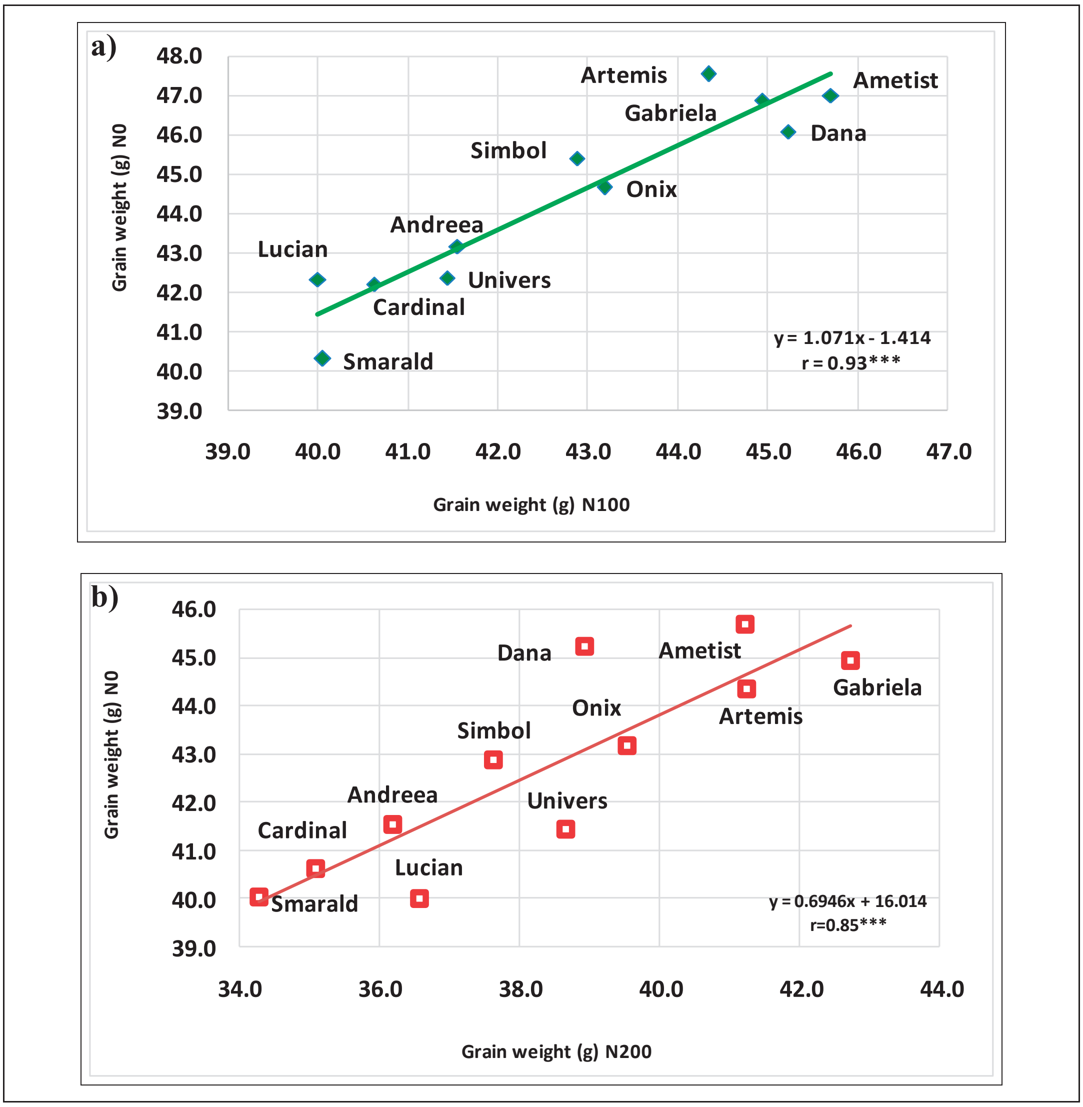

Figure 2. Relationship between grain weights for 11 Romanian winter barley varieties cultivated during 2014-2016 in plots with three nitrogen levels
a) fertilized with 100 and 0 kg ha^{-1} in spring;
b) fertilized with 200 and 0 kg ha^{-1} in spring.

CONCLUSIONS

Across the nine environmental conditions the mean yield and grain weight of 11 Romanian winter barley varieties were influenced by the nitrogen dose. According with our data, yield increased from a nitrogen dose to another. The main sources of variation were represented by nitrogen dose for grain yield and by cultivar and nitrogen dose for grain weight.

The relationship between yield and grain weight was not significant for six row barley cultivars evaluated under the first and third level of nitrogen fertilizer. But under nitrogen dose 100 kg ha^{-1} the relationship was significantly negative in winter six row barley (r = -0.65). In the case of winter two row barley the relationship was not significant, but it was significantly positive (0.78**) only under the second level of nitrogen fertilization (100 kg ha^{-1}).

Mean grain weight in all years decreased at nitrogen dose higher than 100 kg ha^{-1} for all studied winter barley cultivars, more or less, depending on cultivar.

Cultivars showed different strategies to achieve grain yield, which is based for a few varieties on the grain weight variation in trials under nitrogen dose 200 kg ha^{-1} (six row varieties Cardinal, Smarald and Lucian with a strong correlation between high grain yield and small grain weight), but for the others there is an important contribution of grain weight to achieve the yield under nitrogen dose 100 kg ha^{-1} (two row varieties Artemis and Gabriela with a strong correlation between high grain yield and big size of grain).

It is obvious that six row varieties have a different reaction compared with two row barley. According to that, it is necessary to use different nitrogen managements in order to maximize in the same time the yield and grain weight, according to the crop destination (malt, other food or feed).

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