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THE REACTION OF SOME WINTER BARLEY GENOTYPES TO THE NORTH-WEST PEDOCLIMATIC CONDITIONS OF ROMANIA

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Abstract

This paper is aimed to evaluate the behaviour of 25 winter barley genotypes, tested on the acid soils at ARDS Livada, during the 2016-2018 period, in two ways of sowing: one at a distance of 12.5 cm between the rows and the other one at the distance of 25cm. The variance analysis led to the fact that the sowing distance (D), as a variation source, does not significantly influence the yield. On the other hand, the variety (S) and the interaction of distance and years between the barley varieties, had a significant influence on the yield. The regression analysis and the variation coefficient led to the identification of the most productive, stable and adaptable genotypes, specific to this area (Ametist, Cardinal, Artemis, Smarald). The larger sowing distance positively influenced the thousand grain weight, the hectolitre mass and the number and weight of the barley grains/ears. The attacks of the pathogen agents have been reduced (with 3-6%) and the resistance to lodging has been increased (with over 30%).

***Key words**: barley genotypes, acid soil, sowing distance, yield, stability.*

INTRODUCTION

The barley's importance in the cultivation's structure is given by its multiple uses: fodder, human food and as raw material in the food industry. According to the statistics (FAO.STAT) the areas cultivated with barley in Romania have been stable in the last ten years fluctuating between 450-500 thousand hectares. The results obtained through breeding programs that have taken place at NARDI Fundulea and in other research centres have led to the introduction of some efficient genotypes regarding the production capacity, stability and quality, in the crop production. Thus, it has been found a growing tendency of the average yield from the surface unit, from 2148 kg/ha in 2008 to an average yield of 4424 kg/ha in 2018.

Barley yield is always influenced by the variable climate conditions, which is why it is important that the barley varieties be adaptive to the various growing conditions (Vasilescu et al., 2017). One of the most important causes of crop decline is represented by the abiotic stress factors which produce a decrease yield that can sometimes reach till the 70% level (Săulescu et al., 1996, quoted by Petcu et al., 2007). The limitative environmental factors of yield vary in intensity from year to year. Harsh winter conditions, frequent drought, high temperatures during the growing season of barley grains, rain during the harvest time or the technological mistakes that limit potential productions that can be obtained through normal growing conditions (Mustăţea et al., 2008). A safe way to reduce these losses is creating varieties resistant to unfavourable environmental factors. Regarding these aspects, the winter barley breeding programs that have taken place at NARDI Fundulea have had as a main objective the improving of resistance to the biotic and abiotic stress due to some significant genetic progress concerning the technological quality (Bude and Vasilescu, 2007). The yield stability is given by the resistance sum of the soil to the unfavourable environmental conditions (Săulescu, 1984) and by the interaction of traits with a compensatory effect (Timariu, 1975). The use of genetic diversity on a territorial level, through the growing of multiple different varieties in each zone, represents the simplest and most accessible way of reducing the crop's fluctuations (Săulescu et al., 1980). Also, the growing of varieties with high adaptability to contrasting environmental conditions may reduce the risks of yield loss in the unfavourable years (Mustățea et al., 2008).

In the North-West part of Romania beside the climate change consisting of annual average rising temperatures and high fluctuations of the water regime, a specific characteristic is given by the acid soils. The testing of different crop species genotypes in this area offers pertinent information to the breeders and farmers regarding their stability and adaptability.

This paper is aimed to evaluate the behaviour of 25 winter barley genotypes created at NARDI Fundulea and tested at the ARDS Livada both in the pedo-climatic conditions that are specific to this area but also under two different testing conditions (different sowing distances).

MATERIALS AND METHODS

The 25 winter barley and two row barley genotypes, created at NARDI Fundulea were tested in comparative crops at the ARDS Livada between 2016-2018 period with different features concerning both the thermal and pluviometric regime, in two technological ways of sowing: one at a distance of 12.5 cm row wide and the other one at the distance of 25 cm wide. The climate data was registered at the Weather Station of ARDS Livada. The sowing was realised with the seeding machine for the experimental parcels Wintersteiger in rows of 12 m^2 of which 10 m^2 on a harvestable area. The preceeding plant of the crop rotation was the field pea. The area's winter barley recommended technology was applied. The genotypes characterization took into account the following: grain yield, resistance to disease, resistance to lodging, morpho-productive features and quality. The experiments were conducted in a typical reddish preluvosol (the brown-red soils) which is part of the argiloiluvial soil class. The main characteristics of this soil are: the B horizon presence, more or less developed with a clay content between 30-35%; decreased levels of hydraulic conductivity which determine the surface water stagnation during the heavy rainfall periods; the pH situated in the weak acid and acid soil, the trend being in the acidification direction; low hummus content; as a tendency of the organic matter content evolution it is noticed a quantitative and qualitative setback; and last but not least the presence of aluminum ions, due to the potential acidity actualization. All of these impose an urgent periodical amending.

The acid soil, poorly provided with nutritious elements represent another stress factor alongside the known climate ones, biotic and abiotic. The obtained experimental results were processed through the analysis of variance (N.A. Săulescu, N.N. Săulescu, 1967), as a series of experiences in the same location with 25 genotypes, 2 sowing distances (D1=12.5 cm and D2=25 cm between rows) in three years of testing: 2016, 2017, 2018. The high fluctuation of the production's stability, appreciated through the variation coefficient (CV%), was determined by the genotypes different answer to the climate conditions from the testing period. Each genotypes's reaction to the environmental conditions was determined through the regression analysis of each variety in the three environmental conditions as opposed to the average yield of all the varieties. Keim and Kronstad 1979, (quoted by P. Mustățea et al., 2008) suggested that by using the regression analysis method a variety which is adapted to unfavourable environmental conditions when $b< 1$ and a (the regression's constant) has high values; adapted to favorable environmental conditions when $b>1$; largely adapted to different environmental conditions when $b> 1$ and a has high values. Moldovan et al. 2003, (quoted by Racz et al., 2014) suggests that the use of the coefficient of determination (r^2) instead of the deviation from regression, offers direct information related to the predictability of genotypes behaviour in different environmental conditions. The main productivity elements were determined from samples of 25 barley spikes harvested each year from both of the sowing options, resistance to disease and lodging through observations in the field during the vegetation period.

RESULTS AND DISCUSSIONS

Due to the relatively short vegetation period as well as to other physiological features, barley adapts well to natural climate conditions and to soil from different geographical areas. In general, the winter barley's most favourable climate is the one with a prolonged autumn, with not so harsh winter conditions and with a thickly enough layer of snow (Drăghici, 1975). From a geographical point of view, the ARDS Livada is situated on the following coordinates: 47º51' North latitude, 23º08' East longitude. In the North-West of Romania, the annual average temperature is of 9.7-9.8ºC. In relation to this value it has been noticed that in recent years, average temperatures go beyond 11-12ºC. The rainfall regime is extremely fluctuant from year to year and from month to month during the vegetation period. The thermal and rainfall regime from the three years of testing (crop years) is shown in figure 1. Warm autumns, mild winters, extremely high temperatures beginning with March, extremely hot in May-June and unevenly distributed rainfall during the vegetation period are the main characteristics of the experimenting period.

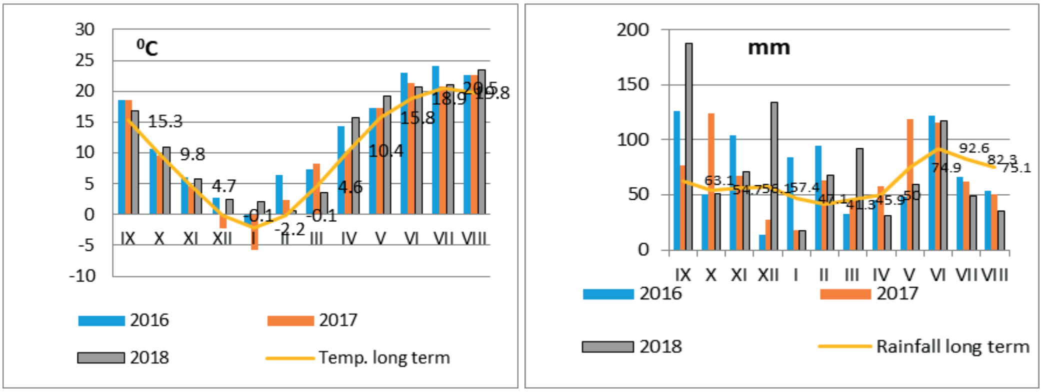

Figure 1. Average temperatures (ºC) and rainfall distribution (mm) during winter barley vegetation, ARDS Livada, 2016-2018

Reported to this diversity of climate conditions, the average level of yield was high in 2016, 2017 and quite low in 2018 (Figure 2 and 3). In 2016 year, the yield was fluctuating between 33,19 q/ha (six row barley line F8-3-01) and 54,73 q/ha (two row barley line DH 375-4), in 2017 to a few varieties and lines, the yield exceeded 60,0 q/ha, the highest being 68,37 q/ha for the Smarald variety. With a mean of 40,95 q/ha experience in 2018, were registered the lowest yields, the main cause being the lack of water during the ear development, flowering and grain filling period. Under the 25 cm distance between the rows condition, yields fluctuated between 35,01 q/ha (two row barley line DH 375-4) and 58,76 q/ha (Ametist variety). The lack of water during the maximum consumption, signalled in 2018, determined the registration of some modest yield and in this variant of sowing with a minimum of 23,2 q/ha (Standard 1) and a maximum of 47,84 q/ha (Artemis variety).

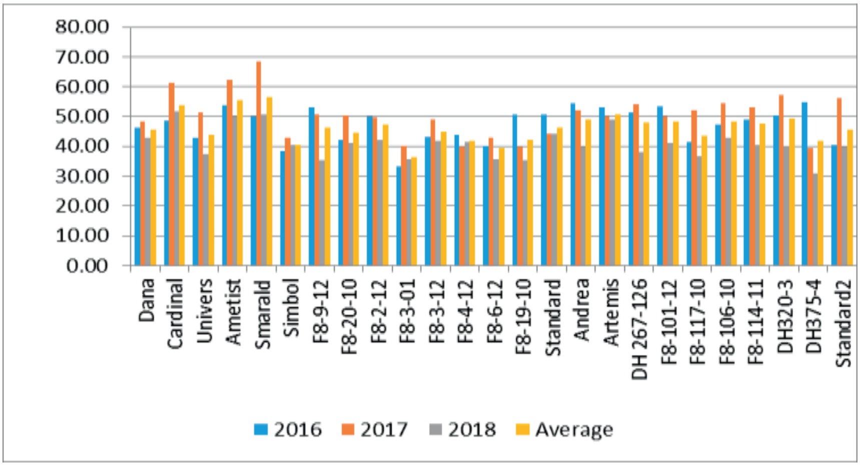

Figure 2. Annual and average yields of barley genotypes sown at 12.5 cm (q/ha), ARDS Livada, 2016-2018

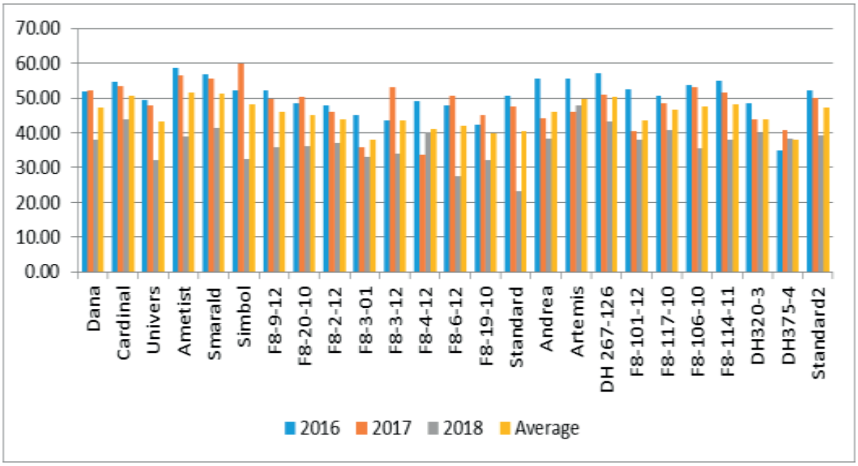

Figure 3. Annual and average yields of barley genotypes sown at 25 cm (q/ha), ARDS Livada, 2016-2018

The constancy of the obtained yield was rated upon the base of variation coefficients (Figure 4 and 5). Varieties like Ametist, Cardinal and Artemis, are characterised by high yields, more than 50q/ha and good stability, with a coefficient of variation of 11-12 %. Smarald, the variety with the highest yield (56,31 q/ha) represents a medium stability (17%). With good stability but low yield, below 45 q/ha are the following genotypes: Dana, Simbol and barley lines F8-3-12 and F8-20-10 (Figure 4).

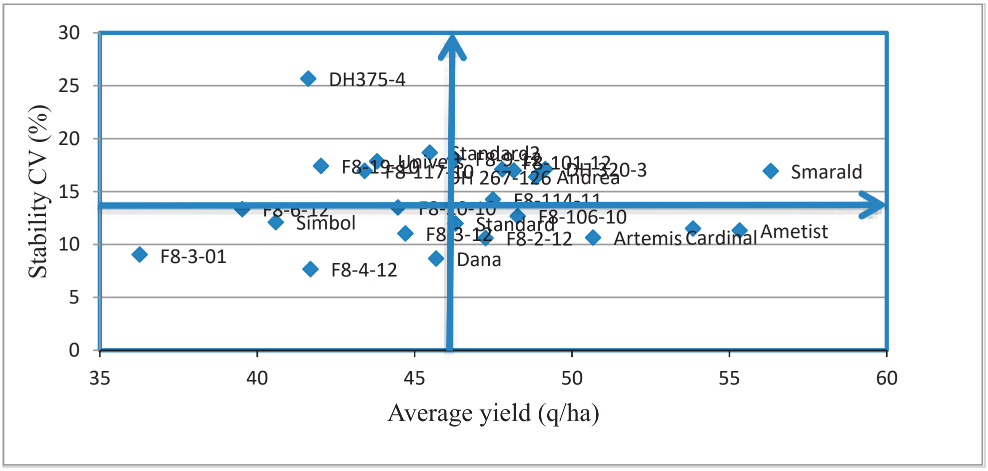

Figure 4. Relation between grain yield (q/ha) and CV/% to 25 barley genotypes sown in regular rows of 12.5 cm, ARDS Livada, 2016-2018

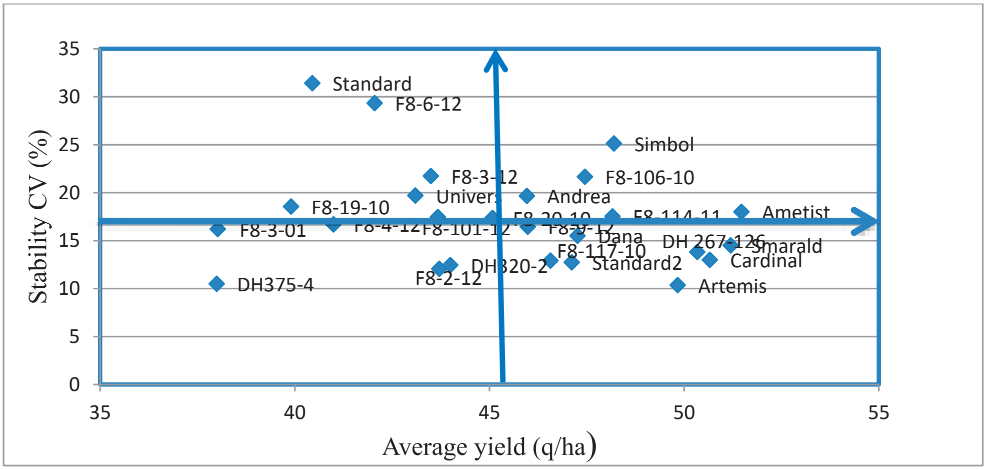

Figure 5. Relation between grain yield (q/ha) and CV/% to 25 barley genotypes sown in rare rows of 25 cm, ARDS Livada, 2016-2018

Artemis, Cardinal and Smarald varieties and two row line DH 267-126 confirm a great yield capacity but also a good stability under the North-West conditions of Romania and in the variant of sowing in rare rows (Figure 5).
The subunitar regression slope and the high value of parameter „a” suggest a good adaptation to less favourable conditions for the majority of tested genotypes (Table 1), conditions which are met in the North-West part of the country as a consequence of the evolution of climate factors but also due to specific acid soils.

Table 1. Yield stability parameters (b, a, r^2) of 25 winter barley genotypes (varieties and lines) sown to D1 (12.5 cm) and D2 (25 cm), ARDS Livada, 2016-2018

No.	Variety/line	Average grain yield - D1 (q/ha)	b	a	r^2	Average grain yield - D2 (q/ha)	b	a	r^2
1	Dana	45.68	0.57	20.14	0.34	47.26	0.72	11.21	0.79
2	Cardinal	**53.84**	0.31	29.45	0.24	**50.66**	0.67	11.33	0.55
3	Univers	43.80	0.35	30.79	0.49	43.10	0.65	17.38	0.85
4	Ametist	**55.32**	0.47	20.40	0.56	**51.47**	0.61	13.75	0.90
5	Smarald	**56.31**	0.27	31.06	0.42	**51.19**	0.75	7.02	0.86
6	Simbol	40.59	0.10	**42.07**	0.02	48.20	0.43	**24.75**	0.76
7	F8-9-12	46.27	0.39	28.03	0.71	45.98	0.75	10.87	0.90
8	F8-20-10	44.47	0.36	30.23	0.30	45.08	0.59	18.79	0.59
9	F8-2-12	47.25	0.53	21.11	0.46	43.71	1.00	1.59	0.77
10	F8-3-01	36.26	0.51	27.69	0.18	38.02	0.65	20.52	0.45
11	F8-3-12	44.71	0.43	**27.01**	0.29	43.49	0.41	**27.64**	0.41
12	F8-4-12	41.69	-0.15	**52.46**	0.01	40.99	0.21	**36.72**	0.06
13	F8-6-12	39.52	0.53	25.15	0.41	42.05	0.39	28.78	0.66
14	F8-19-10	42.02	0.22	36.91	0.17	39.90	0.57	22.75	0.49
15	Standard 1	46.30	0.06	**43.21**	0.01	40.45	0.45	27.03	0.92
16	Andrea	48.86	0.35	29.21	0.50	45.96	0.45	24.71	0.46
17	Artemis	**50.67**	0.09	**41.66**	0.01	49.83	0.45	22.73	0.15
18	DH 267-126	47.78	0.40	26.86	0.71	**50.33**	0.67	11.74	0.61
19	F8-101-12	48.15	0.28	**32.48**	0.30	43.67	0.48	**24.19**	0.38
20	F8-117-10	43.41	0.43	27.54	0.66	46.57	0.69	13.06	0.49
21	F8-106-10	48.27	0.48	23.23	0.55	47.45	0.47	23.02	0.66
22	F8-114-11	47.49	0.45	24.93	0.59	48.16	0.61	16.04	0.74
23	DH 320-3	49.15	0.39	27.03	0.71	43.99	0.65	16.88	0.35
24	DH 375-4	41.62	0.18	**38.62**	0.25	37.99	-0.20	**52.86**	0.02
25	Standard 2	45.48	0.32	31.42	0.49	47.11	0.94	1.19	0.88

The analysis of variance highlighted the fact that the sowing distance (D1 and D2) as a variation source does not significantly influence the yield, instead the genotype (G) and the interactions GxY, GxD and GxDxY had a significant influence on the yield level (Table 2).

Table 2. ANOVA for grain yield of 25 winter barley genotypes under different distance between rows

Source of variation	SS	df	MS	F
Years (Y)	10353.51	2		
Replication	540.71	6		
Distance (D)	89.3	1	89.3	1.10 (5.99)
Distance x Years (DxY)	1091.12	2	545.56	6.72 (5.14) *
Error (a)	487.18	6	81.20	
Genotype (G)	7247.67	24	301.99	13.9**(1.57;1.88)
Genotype x Years (GxY)	3206.39	48	66.80	3.07** (1.42;1.62)
Genotype x Distance (GxD)	1100.26	24	45.84	2.10 **(1.57;1.88)
GxDxY	3457.37	48	72.03	3.31** (1.42;1.62)
Error (b)	6263.40	288	21.75	

As experiment average, registered genotypes averages yield between the two technological variants of sowing are very close, and as it has been revealed by ANOVA (Table 2) there haven't been any significant differences registered (Table 3).

Table 3. The influence the sowing distance on the genotypes average yield, ARDS Livada, 2016-2018

No.	Distance	q/ha	the difference +;-	significance
1	D1 = 12.5 cm	46.20	-	-
2	D2 = 25.0 cm	45.31	-0.89	-

LSD (p 5%) = 2.08 q/ha

Cardinal, Ametist and Smarald winter barley varieties registered the highest yield in both sowing conditions, but with a significant plus to the standard sowing at 12.5 cm between rows.

A similar behaviour has been noticed in the case of two rows winter barley varieties Andrea and Artemis (Table 4).

Table 4. The sowing distance influence on grain yield, ARDS Livada, 2016-2018

Genotype	Average grain yield D1 (q/ha)	Difference +,- (q/ha) *	Average grain yield D2 (q/ha)	Difference +,- (q/ha) *	Difference D1-D2 (q/ha)	Genotype classification according yield difference**
Dana	45.68	0.52	**47.26**	1.95	-1.58	25 cm
Cardinal	53.84	7.64*	50.66	5.35*	3.18	12.5 cm
Univers	43.80	-2.4	43.10	-2.21	0.71	12.5/25 cm
Ametist	55.32	9.12*	51.47	6.16*	3.85	12.5 cm
Smarald	56.31	10.11*	51.19	5.88*	5.12	12.5 cm
Simbol	40.59	-5.61^0	**48.20**	2.89	-7.61	25 cm
F8-9-12	46.27	0.07	45.98	0.67	0.29	12.5/25 cm
F8-20-10	44.47	-1.73	45.08	-0.23	-0.61	12.5/25 cm
F8-2-12	47.25	1.05	43.71	-1.6	3.54	12.5 cm
F8-3-01	36.26	-9.94^0	**38.02**	-7.29^0	-1.76	25 cm
F8-3-12	44.71	-1.49	43.49	-1.82	1.21	12.5 cm
F8-4-12	41.69	-4.51^0	40.99	-4.32^0	0.70	12.5/25 cm
F8-6-12	39.52	-6.68^0	**42.05**	-3.26^0	-2.53	25 cm
F8-19-10	42.02	-4.18^0	39.90	-5.41^0	2.12	12.5 cm
Standard 1	46.30	0.1	40.45	-4.86^0	5.85	12.5 cm
Andrea	48.86	2.66	45.96	0.65	2.90	12.5 cm
Artemis	50.67	4.47*	49.83	4.52*	0.83	12.5/25 cm
DH 267-126	47.78	1.58	**50.33**	5.02*	-2.55	25 cm
F8-101-12	48.15	1.95	43.67	-1.64	4.47	12.5 cm
F8-117-10	43.41	-2.79	**46.57**	1.26	-3.16	25 cm
F8-106-10	48.27	2.07	47.45	2.14	0.82	12.5/25 cm
F8-114-11	47.49	1.29	48.16	2.85	-0.67	12.5/25 cm
DH 320-3	49.15	2.95	43.99	-1.32	5.15	12.5 cm
DH 375-4	41.62	-4.58^0	37.99	-7.32^0	3.63	12.5 cm
Standard 2	45.48	-0.72	**47.11**	1.8	-1.63	25 cm
	LSD (p 5%) = 3.05		LSD (p 5%) = 3.05			
Average	**46.20**		**45.31**			

^{0} – not significant, * - significant, ** - recommended distance to growing.

Dana and Simbol winter barley varieties, alongside with F8-3-01, F8-6-12, F8-117-10 lines, registered on average superior yields in the rare sowing distances. Univers, Artemis winter barley varieties and F8-9-12, F8-20-10, F8-4-12, F8-106-10 and F8-114-11 lines stand out through a neutral reaction (Table 4) to the change of the sowing distance between rows, average yields obtained during the 2016-2018 period being almost similar. The importance of this approach is that it allows barley farmers, depending on their ultimate goal, grain yield for malt (for an increase of TKW) or fodder, to opt for the cultivation of the most suitable genotypes. The choice of these genotypes that react well to the sowing distance of 25 cm allows the reduction of the quantity of seed used for sowing to the surface units with real chances of obtaining very good grain yield.

The wider sowing distance positively influenced the main elements of productivity: the hectolitre weight (HW), thousand kernel weight (TKW), the number of grains per spike (NG/S), grain weight per spike (GW/S), with significant differences concerning the thousand kernel weight which is in average 47.2 g in the case of sowing to 25 cm (Table 5). The grain weight of barley, expressed usually as thousand kernel weight, is one of the most important components of production (Hadjichristodoulou, 1990 quoted by Vasilescu et al., 2014).

Table 5. The influence of the sowing distance to some yield elements, ARDS Livada, 2016-2018
(genotypes average of the two sowing condition)

No.	Distance	HW (kg/hl)	Dif. +;- (kg/hl)	S*	TKW (g)	Dif. +;- (g)	S*	NG/S	Dif. +;-	S*	GW/S (g)	Dif. +;-	S*
1	D1=12.5 cm	57.7	-	-	42.9	-	-	25.3	-	-	1.19	-	-
2	D2=25.0 cm	59.0	1,3	ns.	47.2	4.3	*	28.4	3.1	ns.	2.33	1.14	ns.

S = significance; ns – not significant; * - significant LSD (p 5%) = 4.19

The attack of leaf pathogens on the barley field is manifested differently from year to year determining significant losses of harvest.

The study and knowledge of the barley genotypes reaction as opposed to multiple causes that determine more and more damage have a great importance in the present too due to the growing number of physiological strains of pathogenic agents.

The process of pathogenesis in plants, in general, is influenced both by their special resistance and by the climate and crop conditions (Goga and Bănățeanu, 2006). For the determining of the foliar pathogens attack incidence of winter barley crop observations were made concerning the level of attack, expressed through the degree of attack (DA%), to the main pathogens which manifest under the ARDS Livada conditions: powdery mildew (*Blumeria graminis* D.C. f.s.p. hordei March), leaf scald (*Rhynchosporium secalis* Davis), net blotch (*Pyrenophora teres* drechs. F.c. *Helminthosporium teres* Sacc), root rot (*Helminthosporium sativum* (Pam. King et Bakke), barley brown rust (*Puccinia hordei*), leaf spot of barley (*Ramularia collo-cygni*). The degree of attack produced by the leaf pathogens was different from year to year being influenced by the rainfall level, thermal regime registered during the vegetation period as well as by the tolerance of the used genotypes.

Both in the variant of regular sowing and in the rare rows, the highest average degree of attack, of the complex of barley pathogens, was registered during the conditions of 2017 while in 2018 were the lowest. During each of these three experimental years, the degree of attack was higher in the standard variant of sowing – 12.5 cm (Figure 6).

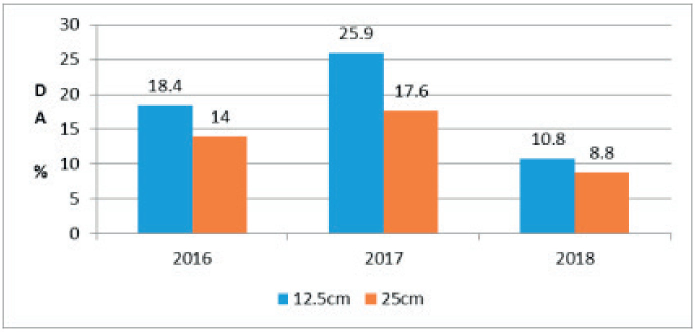

Figure 6. Average degree of attack (DA%), complex barley pathogen, ARDS Livada, 2016-2018

The difference between these two sowing variants regarding the average degree of pathogens attack specific to barley is situated in the significant limit for the 5% threshold being 4.9% (Table 6).

Table 6. The influence the sowing distance has on DA% (pathogen complex)
and of the lodging resistance (% fallen plants)

No.	Distance	DA %	Diference +;-	Significance	Lodging %	Diference +;-	Significance
1	D1=12.5 cm	18.4	-	-	72	-	-
2	D2=25.0 cm	13.5	4.9	*	41	31	*

* - significant

A factor not to be neglected which influences both the yield level and its quality is represented by the plants lodging.
The resistance to lodging is influenced both by the genetic characteristics of each genotype and by the climate conditions and the used technology. The necessity of using varieties with a good resistance to lodging in crops is given by the importance of obtaining a relatively good crop, with corresponding indices.
Crop losses registered by the lodging phenomenon can sometimes higher, especially when it takes place earlier, before ear development (Drăghici et al., 1975).
The average percentage of lodged plants fluctuated between 20-60% in the case of sowing at 25 cm while in the case of sowing in regular rows the lodging percentage has risen, the average values being in the range of 60 and 100%. On average, the percentage at the lodging plants during the 2016-2018 period was 41% for the rare sowing distance and it got to 72% for the standard sowing, the difference being significant (Table 6).
We must be aware of the fact that a great part of quality features are complex hereditary aspects, polygenic conditioned. However, it is not to be neglected that the variation of climate conditions during the vegetation period has a great impact on them.

CONCLUSIONS

Winter barley genotypes created at NARDI Fundulea are characterized by a good yield capacity, but most of all by adaptability and stability during the less favourable environmental conditions from the North-West of Romania, an area known for its acid soils.
The subunitar regression slope *(b)* and the high value of the „a” parameter suggest that has been a good adaptability to less favourable conditions for the majority of tested genotypes.
Ametist, Cardinal (six row) and Artemis (two-row) winter varieties are distinguished by a higher yield, over 50q/ha and good stability.
Artemis (two-row), Cardinal (six-row), Smarald (six-row) and DH 267-126 (two-row) line confirm a high yield capacity but also a good stability under the conditions from the North-West of the country and in the rare sowing rows.
Although there are no significant differences between them, sowing at a distance of 12.5 and 25.0 cm between rows allows the highlight of some genotypes that have similar grain yield under both growing distances: Univers, Artemis and a few advanced barley lines (F8-9-12, F8-20-10, F8-106-10, F8-114-11). These represent a good alternative for farmers, which allows them to obtain the same production performances with a cost decrease through the use of a smaller seed quantity for sowing per hectar.
Sowing in rare rows positively influenced TKW, HW and the number and weight of grains on the spike, elements of productivity influenced a lot by climate conditions.
A decrease in the degree of attack towards the main pathogenic agents specific to barley has been registered in the north-west area under rare sowing rows, which contributes to the obtaining of qualitative grain yield.

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