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Assessment of the variability for some cooking quality traits in dry bean varieties

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Abstract The aim of this study was to evaluate some culinary quality traits of six Romanian bean varieties during three years, in order to find suitable genotypes for different climatic conditions and which can also be used in different programs for breeding of culinary value of dry bean. The environmental conditions of the three years have had the highest contribution on the variability of coat proportion, while the variability of hydration capacity and cooking time was affected in a low extent. The values of TGW and hydration capacity are due mainly to the effect of variety, but in the case of coat proportion the genetic component had a low contribution. The genotype x environment interaction had the highest effect on cooking time. 'Ardeleana', 'Diva' and 'Vera' varieties showed the best stability of the TGW associated with low values, below the mean. 'Star' and 'Ami' varieties showed the highest genotype x environment interaction and parallel to the favorability of weather conditions. The hydration capacity showed the highest stability for the studied varieties. Under the background of values below the mean, 'Ami', 'Ardelena' and 'Vera' varieties registered the best stability of the coat proportion. 'Avans' variety showed the best boiling capacity, associated with a superior stability. In the case of 'Ami' and 'Ardeleana' varieties, the boiling capacity was strongly influenced by the genotype x environment interaction.

Key words

Dry bean, TGW, hydration capacity, coat proportion, cooking time.

To use the rich nutritional value of dry bean, long cooking times are generally required. The cooking process is necessary for gelatinizing starch, enhancing protein digestibility, and inactivating the lectins and trypsin inhibitors [10; 20]. For the industrialization of dried grains, they must absorb as much water as possible in order that the obtained product to have the necessary fragility, which is dependent on both the genotype and used water [15]. The hydration capacity of the grains, respectively the amount of absorbed water is strongly influenced by the temperature and the rainfall during the growing period. In this sense, grains obtained in drier and warmer areas absorb a greater amount of water than those obtained in colder and wetter areas [12]. The hydrating capacity of beans can be used as a quick indirect method for screening different genotypes in terms of their cooking time [13]. The genotypes that have high hydration capacity are usually fast to cook [5], while the genotypes with lower hydration capacity have longer storage life [19].

In order to improve the culinary quality of beans, the aim is to decrease the coat proportion, meaning that the maximum permissible value should be below 6%. The improvement of coat proportion is quite difficult, especially when it is desired to obtain genotypes with large grains [14]. The size of the grains is directly correlated with the high coat proportion. As such the genotypes with a low coat proportion have small grains [2; 21]. The coat proportion is influenced by both the genotype and the environmental conditions that affect the grain filling process, changing the proportion between cotyledons and coats, as well as protein synthesis [16].

The cooking time of the grains in common bean, among others, is influenced by two phenomena: the hardness of the coat and the "boiling resistance". The hardness of the coat causes the grains to absorb a small amount of water during boiling, so that it does not soften after cooking. The main cause being a low permeability to water of the grain coat, in this respect, major differences in the size of some microstructural elements of the coat were identified [1]. In the case of boiling resistance, the grains absorb enough water but do not soften after boiling [12], this phenomenon is irreversible being favoured by long periods of storage under relative humidity and high temperatures conditions [9].

Soaking time of common bean is directly correlated with cooking time, which tends to decrease, as the grains remain immersed [17; 18]. Cooking time is affected both by grain type and storage time, considering that refrigeration is the best storage type which allows to keep the quality of bean grains up to 19 months [3]. Freshly harvested beans are able to be cooked two to four times faster than the beans stored over 6 months [8]. The efficiency of the programs for improving the culinary traits of common bean depends on the methodology used to evaluate a large number of genotypes in a short period of time [4].

The aim of this study was to evaluate some cooking quality traits of six Romanian bean varieties during three years, in order to find suitable genotypes for different climatic conditions and which can also be used in different programs for breeding of culinary value of common bean.

Material and Method

The experiments were conducted at the Faculty of Horticulture and Forestry, Banat's University of Agricultural Sciences and Veterinary Medicine Timisoara, on a black chernozem, during 2017-2019. Depending on the average temperatures and rainfall regime, 2018 was considered the most favourable year and 2019 the least favourable for cultivation of common bean. During the study a conventional cultivation practices for this crop, was applied. The experiment was organized in a randomized block design with four replications and 30 harvestable plants per plot. The biological material was composed by six Romanian varieties of common bean: 'Ami', 'Ardeleana', 'Avans', 'Diva', 'Star' and 'Vera'.

From each plot were randomly selected three samples of 100 grains in order to determine the 1000 grains weight (TGW). Subsequently, the respective grains were used to determine the other quality traits. The hydration capacity was determined by soaking the grains in distilled water for 16 hours at room temperature, using two samples of 10 grains / replication. After soaking, the hydration capacity was express as the percentage ratio between the final and the initial (before soaking) weight of the grains.

In order to establish the coat proportion of the grain, two samples of 10 g were used for each replication of a variety. After removing, the coats were dried for 24 h at 105 ^{0}C. The coat proportion was calculated as the weight ratio between coat and grain expressed in percentage.

For the determination of cooking time, two samples of 10 grains were used for each replication of a variety. The grains were placed in bowling distilled water and cooked. A grain was deemed to be cooked when its coat was split, recording the time for each grain, and after that the mean for each sample.

The analysis of variance was used to evaluate the effects of varieties, years and their interaction. The comparisons of means were performed using Multiple Range Test according to Ciulca (2006). The significances of differences were expressed using letters, considering as different the means without common letters.

Results and Discussions

Considering the data from Table 1, it was observed that both varieties and weather conditions during the experimentation had significant influences on the grain size, on the background of an insignificant heterogeneity at the level of the experimental design. The variety has had a higher effect (80.36%) on the variability of this trait compared to the effect of ecological conditions (11.51%). It was also observed that the genotype x environment interaction has had a statistically effect on TGW in 2017-2019, but considerably lower (3.45%) compared to the effects of the two factors. The results were influenced into a small extent (4.68%) by other sources of variation not included in the experimental design.

Table 1

Analysis of variance for TGW and hydration capacity of common bean varieties during 2017-2019

Source of variation	DF	TGW			Hydration capacity		
		SS	MS	F	SS	MS	F
Total	71	148112			7745.50		
Replications	3	981	327	2.18	121.66	40.55	3.80
Years	2	17049	8524	56.87**	373.36	186.68	17.49**
Erorr years	6	899	150		64.05	10.68	
Varieties	5	119030	23806	212.21**	5836.79	1167.36	63.39**
Years x Varieties	10	5105	511	4.55**	431.00	43.10	2.34*
Erorr varieties	45	5048	112		828.73	18.42	

The hydration capacity of grains was significantly influenced both by the variability of weather conditions during the period of study and by the bean variety, taking into account the existence of a uniformity values of this trait at the level of replications. The effect of variety (75.36%) was higher than the effect of climatic conditions (4.82%), while the combined effect of weather conditions and variety had a significant influence of (5.56%) on the variability of hydration capacity. Also, Katuuramu et al. (2020) found that the genotype was the major source of variation for this trait. The values of this trait were influenced to an extent of about 14% by uncontrolled sources of variation.

Table 2

Analysis of variance for TGW and hydration capacity of common bean varieties during 2017-2019

Source of variation	DF	Coat proportion			Cooking time		
		SS	MS	F	SS	MS	F
Total	71	127.65			11214.04		
Replications	3	2.31	0.77	4.07	114.28	38.09	1.35
Years	2	58.34	29.17	154.23**	292.20	146.10	5.20*
Erorr years	6	1.13	0.19		168.69	28.11	
Varieties	5	17.60	3.52	12.60**	4001.68	800.34	40.13**
Years x Varieties	10	15.70	1.57	5.62**	5739.77	573.98	28.78**
Erorr varieties	45	12.57	0.28		897.42	19.94	

In the case of the coat proportion (Table 2), it was observed that all three sources of variation had significant influences, against the background of an insignificant heterogeneity at the level of replications. Weather conditions showed a higher effect (45.70%) on the variability of coat proportion compared to the effect of genotype (13.79%) or genotype x environment interactions (12.3%).

The cooking time was influenced to a significant extent of about 90% by the unilateral and combined effects of the climatic conditions during the study and by the bean variety, taking into account the existence of uniformity values of this trait at the level of replications. The effect of the interaction between the two factors (51.18%) was higher than the effect of variety (35.68%) and weather conditions (2.61%). A large effect of genotype, followed by genotype x environment, on cooking time was also reported by several studies: Coelho et al. (2007); Katuuramu et al. (2020) and Kirchi et al 2019.

Table 3

Mean values of TGW for common bean varieties during 2017-2019

Varieties	Years			Means (g)	
	2017	2018	2019	$\bar{x} \pm s_{\bar{x}}$	$S_{\%}$
Ami	y 215.42 b	x 238.30 b	z 174.84 b	209.52±4.92 B	8.75
Ardeleana	x 185.45 c	x 196.33 d	y 158.37 c	180.05±5.31 D	10.05
Avans	y 268.68 a	x 309.63 a	y 263.29 a	280.53±2.87 A	6.68
Diva	x 197.40 c	x 190.59 d	y 161.17 bc	183.05±7.27 D	8.98
Star	y 199.35 c	x 210.09 c	z 175.92 b	195.12±8.40 C	13.89
Vera	x 152.73 d	x 152.91 e	y 140.43 d	148.69±6.02 E	11.59
$\bar{x} \pm s_{\bar{x}}$	203.17±7.63 Y	216.31±10.41 X	179.01±8.42 Z	199.49±5.39	
$S_{\%}$	18.40	23.58	23.06	22.90	

- Years	$LSD_{5\%}$=8.65 g	$LSD_{1\%}$=13.10 g	$LSD_{0,1\%}$=21.06 g (X,Y,Z)
- Varieties	$LSD_{5\%}$=8.71 g	$LSD_{1\%}$=11.63 g	$LSD_{0,1\%}$=15.22 g (A,B,C,D,E,)
- Years x Varieties	$LSD_{5\%}$=15.48 g	$LSD_{1\%}$=20.66 g	$LSD_{0,1\%}$=27.01 g (x,y,z)
- Varieties x Years	$LSD_{5\%}$=15.08 g	$LSD_{1\%}$=20.14 g	$LSD_{0,1\%}$=26.36 g (a,b,c,d,e,)

With regard to the effect of weather conditions on the TGW (Table. 3), it was observed amplitude of 37.3 g on a background of low variability. The weather conditions from 2018 were significantly higher than those of 2017 and 2019, in terms of grain size for bean varieties, allowing increases of about 6.5 to 20.8%. Also, the mean values of the trait in 2017 were significantly higher by 13.5% compared to those from 2019.

The means of the varieties for the whole period showed a variability of 22.32% for TGW, at amplitude of 131.84 g, with the limits from 148.69 g for 'Vera' up to 280.53 g for 'Avans' variety. Based on multiple comparisons it was observed that 'Avans' variety registered a significantly higher TGW than the rest, being followed by 'Ami' variety, both with values over 200 g. In the case of Star variety, the grain size was larger than at 'Diva', 'Ardeleana' and 'Vera' varieties.

Considering the effect of the weather conditions on the grain size, Ami and Star varieties registered in 2018 the highest values, significantly higher than in other two years, differentiated in favor of those from 2017. 'Ardeleana', 'Diva' and 'Vera' varieties showed a good adaptation to the conditions from 2017-2018, achieving values close of TGW and significantly higher than those from 2019. 'Avans' variety utilized at a higher level the conditions from 2018, registering a grain size significantly superior to the other years.

Table 4

Mean values of hydration capacity for common bean varieties during 2017-2019

Varieties	Years			Means (%)	
	2017	2018	2019	$\bar{x} \pm s_{\bar{x}}$	S%
Ami	x 110.76 b	x 110.12 a	x 107.85 b	109.57±2.06 B	6.54
Ardeleana	x 116.84 a	x 113.25 a	x 115.75 a	115.28±1.82 A	5.48
Avans	x 112.39 ab	x 110.75 a	x 114.65 a	112.60±1.92 AB	5.88
Diva	x 99.12 c	x 96.51 b	x 99.97 c	98.53±1.76 C	6.18
Star	x 102.84 c	x 98.90 b	x 104.16 bc	101.96±2.26 C	7.66
Vera	xy 114.71 ab	y 109.73 a	x 119.48 a	114.64±3.08 A	9.30
$\bar{x} \pm s_{\bar{x}}$	109.44±2.84 X	106.54±2.90 Y	110.31±3.20 X	108.76±1.74	
S%	12,72	13.32	14.22	13.58	

- Years	LSD $_{5\%}$=2.30	LSD $_{1\%}$=3.49	LSD $_{0,1\%}$=5.60 (X,Y,Z)
- Varieties	LSD $_{5\%}$=3.52	LSD $_{1\%}$=4.70	LSD $_{0,1\%}$=6.15 (A,B,C,D,E,)
- Years x Varieties	LSD $_{5\%}$=5.86	LSD $_{1\%}$=7.81	LSD $_{0,1\%}$=10.19 (x,y,z)
- Varieties x Years	LSD$_{5\%}$=6.09	LSD $_{1\%}$=8.14	LSD $_{0,1\%}$=10.65 (a,b,c,d,e,)

Regarding the unilateral effect of weather conditions (Table 4), the hydration capacity of bean varieties showed a low variability from one year to another, associated with amplitude of 3.77% with limits between 106.54% in 2018 and 110.31% for 2019. The conditions from 2019 and 2017 had a positive influence on the hydration capacity of the grains, registering significant increases compared to the results from 2018.

During the study, the average values of the water absorption capacity achieved by the six varieties showed amplitude of 16.75%, with the limits from 98.53% for 'Diva' to 115.28% for 'Ardeleana', on the background of a low inter-genotypic variability (6.41%). Thus, 'Ardeleana' and 'Vera' varieties achieved in this period a hydration capacity significantly higher by over 5.92% than most of the varieties. Also, 'Avans' variety showed significant increases compared to 'Diva' and 'Star' varieties.

Regarding the genotype x environment interaction, it was found that generally the hydration capacity was not significantly influenced by the variation of the weather conditions during the study. Only in the case of 'Vera' variety it was noted a significant increase of hydration capacity in 2019 compared to 2018.

Table 5

Mean values of seed coat proportion for common bean varieties during 2017-2019

Varieties	Years			Means (%)	
	2017	2018	2019	$\bar{x} \pm s_{\bar{x}}$	S%
Ami	x 7.54 a	x 7.36 a	x 7.81 d	7.57±0.12 C	5.37
Ardeleana	x 8.25 a	x 7.75 a	x 8.46 cd	8.16±0.14 B	6.11
Avans	y 7.52 a	y 7.22 a	x 9.04 bc	7.93±0.26 BC	11.20
Diva	y 8.02 a	z 7.29 a	x 10.89 a	8.74±0.48 A	19.06
Star	y 7.63 a	y 7.42 a	x 9.27 b	8.11±0.27 B	11.48
Vera	x 8.05 a	x 7.63 a	x 8.21 d	7.96±0.12 BC	5.04
$\bar{x} \pm s_{\bar{x}}$	7.83±0.09 B	7.45±0.07 C	8.95±0.22 A	8.08±0.11	
S%	5,70	4.79	12,16	11.74	

- Years	LSD $_{5\%}$=0.31	LSD $_{1\%}$=0.46	LSD $_{0,1\%}$=0.75 (X,Y,Z)
- Varieties	LSD $_{5\%}$=0.43	LSD $_{1\%}$=0.58	LSD $_{0,1\%}$=0.76 (A,B,C,D,E,)
- Years x Varieties	LSD $_{5\%}$=0.73	LSD $_{1\%}$=0.97	LSD $_{0,1\%}$=1.27 (x,y,z)
- Varieties x Years	LSD $_{5\%}$=0.75	LSD $_{1\%}$=1.00	LSD $_{0,1\%}$=1.31 (a,b,c,d,e,)

The studied varieties achieved yearly average values of coat proportion between 7.45 in 2018 and 8.95 in 2019, under a low variability from one year to another (Table 5). Against the background of the conditions from 2019, the weight of the coat was significantly higher by 1.13-2.5% to the values registered in the other two years. Also in 2018 the mean values of this trait were significantly lower compared to those of 2017.

Regarding the effect of the bean variety on the manifestation of this trait, it was found that the varieties achieved a coat proportion with values from 7.57 for Ami to 8.74 for Diva, on the background of a low inter-population variability (4.76%). Based on multiple comparisons, it was noted that 'Ami' variety recorded a lower coat proportion than 'Star', 'Ardeleana' and 'Diva' varieties. In the case of Diva variety, the coat proportion was significantly higher than the other varieties.

Considering the effect of the weather conditions on the coat proportion, 'Avans' and 'Star' varieties registered the highest values in 2019, significantly superior to other years with close values.

In the case of 'Ami', 'Ardeleana' and 'Vera' varieties, the variation of the weather conditions during the study did not significantly influence the coat proportion of grains. 'Diva' variety showed the highest interaction with the environment, achieving significantly different values of this trait from one year to another, higher in 2019 and lower in 2018, respectively.

Table 6

Mean values of cooking time for common bean varieties during 2017-2019

Varieties	Years			Means (min.)	
	2017	2018	2019	$\bar{x} \pm s_{\bar{x}}$	$S_{\%}$
Ami	z 70.46 d	y 77.62 e	x 98.03 a	82.03±3.68 CD	15.55
Ardeleana	y 86.80 abc	z 74.31 e	x 95.73 a	85.61±2.85 C	11.54
Avans	x 84.95 bc	x 85.16 d	y 67.10 c	79.07±2.70 D	11.85
Diva	y 92.31 a	x 108.47 a	y 98.34 a	99.71±2.33 A	8.10
Star	y 91.17 ab	x 100.27 b	z 81.31 b	90.92±2.62 B	9.98
Vera	xy 83.91 c	x 90.17 c	y 77.74 b	83.94±1.96 C	8.09
$\bar{x} \pm s_{\bar{x}}$	84.93±1.65 Y	89.33±2.65 X	86.38±2.56 XY	86.88±1.35	
$S_{\%}$	9.51	14.56	14.85	13.15	

- Years	$LSD_{5\%}$=4.09	$LSD_{1\%}$=6.19	$LSD_{0,1\%}$=9.95 (X,Y,Z)
- Varieties	$LSD_{5\%}$=4.01	$LSD_{1\%}$=5.35	$LSD_{0,1\%}$=7.00 (A,B,C,D,E,)
- Years x Varieties	$LSD_{5\%}$=7.17	$LSD_{1\%}$=9.56	$LSD_{0,1\%}$=12.51 (x,y,z)
- Varieties x Years	$LSD_{5\%}$=6.94	$LSD_{1\%}$=9.26	$LSD_{0,1\%}$=12.13 (a,b,c,d,e,)

Regarding the effect of weather conditions on the cooking time (Table 6), amplitude of 4.40 min was observed on the background of a low variability. In 2018, the climatic conditions were less favourable than in 2017, in terms of boiling capacity of grains in bean genotypes, causing an increase of cooking time with 5.2%.

During the study, the mean boiling time values of the six varieties showed amplitude of 20.64 min., ranging from 79.07 min. in case of 'Avans' up to 99.71 for 'Diva', under a low (8.55%) inter-genotypic variability. Thus, 'Avans' variety registered in this period a significantly higher boiling capacity than most other varieties. Also, 'Ami' variety showed a significantly shorter cooking time than 'Diva' and 'Star' varieties.

Considering the genotype x environment interaction, it was found that the six varieties showed a different reaction in terms of boiling capacity to the variability of weather conditions. Thus, Ami and Diva varieties showed a good adaptation to the conditions from 2017, achieving significantly lower values of cooking time compared to the period 2018-2019. 'Ardeleana' variety recorded the best cooking capacity in 2018, while 'Avans','Vera' and 'Star' varieties showed a good cooking time under the conditions from 2019. 'Ami' and 'Ardeleana' varieties express good cooking qualities under favorable conditions, while 'Avans' variety is recommended for less favorable conditions for common bean growing.

Conclusions

The environmental conditions of the three years have had the highest contribution on the variability of coat proportion, while the variability of hydration capacity and cooking time was affected in a low extent. The values of TGW and hydration capacity are due mainly to the effect of variety, but in the case of coat proportion the genetic component had a low contribution. The genotype x environment interaction had the highest effect on cooking time.

'Ardeleana', 'Diva' and 'Vera' varieties showed the best stability of the TGW associated with low values, below the mean. 'Star' and 'Ami' varieties showed the highest genotype x environment interaction and parallel to the favourability of weather conditions. The hydration capacity showed the highest stability for the studied varieties. Under the background of values below the mean, 'Ami', 'Ardelena' and 'Vera' varieties registered the best stability of the coat proportion. 'Avans' variety showed the best boiling capacity, associated with a superior stability. In the case of 'Ami' and 'Ardeleana' varieties, the boiling capacity was strongly influenced by the genotype x environment interaction.

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