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Moldovan soybean varieties testing in the condition of North Bulgaria

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Abstract

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Eight soybean varieties from Moldovan selection were traced in terms of productivity and its determining components in a three-year field trial. They have been compared with the Bulgarian standard variety Avigeya. The experiment was conducted in the period 2019-2021 in the condition of North Central Bulgaria at the field of Experimental station of soybean and grain crops, Pavlikeni, under non-irrigated conditions, with the standard for our country technology for growing soybeans. According to the results, in the studied group of varieties a significant genotypic diversity was observed for the selected morphological indicators during each year of experiment. The yields of soybean grain from Moldovan varieties and Bulgarian standard was greatly influenced by the weather conditions of the agricultural year. The significance of the genotypic effect in relation to environmental condition of agricultural year is less pronounced. Relatively high and stable year-round values for plant seed yield are observed for varieties Indra, Amedia and Aura. The same is observed for the indicated varieties with regard to the indicators harvest index and seed yield per decare. In general even in the condition of dry summer in non-irrigated cropping in Bulgaria and Republic of Moldova possess a great soybean cropping potential and could increase it.

Keywords: soybean; variety testing; Moldovan soybean selection; genotype; environmental conditions
Abbreviations: qs-quality seeds

Introduction

Legumes are widespread throughout the world, providing more than 69% of the protein as well as 30% of the fats/oils needed for the human diet (Ge et al., 2016). Pea (*Pisum sativum*), soybean (*Glycine max*), common bean (*Phaseolus vulgaris*) and beans (*Vicia faba*) are the main sources of protein, with a content of 20% to 40% depending on the genotype and environment. Very important for the widespread use of these crops is the fact that legumes require minimal amounts of mineral fertilizers, because they possesses the unique ability to absorb nitrogen from the air through a symbiotic interaction with nitrogen-fixing soil bacteria from genera *Rhizobium* and *Bradyrhizobium*. This determines them as a one of the global sources of nutrition for the human population, providing sustainable friendly agriculture (Iantcheva & Naydenova, 2020). Soybean is a crop which produces cheap and high quality vegetable protein. It contains 3 to 4 times more protein and essential amino acids than some basic crops such as wheat, corn and barley and 1.5 to 2 times more protein than other cereals. Modern soybean production requires new soybean varieties, in addition to the formation of high and stable yields, to have a set of economic qualities, among which the content of crude protein and crude oil in the grain are the two components of greatest economic value. Worldwide research investigations are aimed at increasing the yield and quality of soybean vegetable protein. The published studies concern soybean varieties developed in other countries according to the specific climatic requirements and needs of agriculture (Mandic et al., 2020; Zajac et al., 2017).

Among the countries of the Danube region, Bulgaria and Moldova have the greatest similarities in terms of ecological and production conditions for soybean cultivation. The natural soil and climatic conditions, heat and light regime of both countries are suitable for the crop, as the main factor limiting its production are the strong summer droughts in the periods of pod formation and grain filling. In this regard, the breeding programs for soybean in both countries can be defined as similar, and their most important aims are adaptability and phenotypic stability of yield in conditions of insufficient moisture. Northern Bulgaria and Moldova are comparable in terms of agricultural land suitable for soybean cultivation, but soybean production in Moldova is many times higher. The number of Moldovan varieties registered and distributed in the last decade is also significantly higher (Dima, 2015). The above emphasizes the importance of regional breeding programs for the efficiency and capacity of production. It is also a reason for interest of the introduction of Moldovan soybeans, varieties for the purpose of breeding programs as genetic sources for the combinative selection of the crop carried out in Bulgaria. From 16-18 June, 2021 delegation leaded by Mr. Viorel Gherciu, Director of Donau Soja Organization in Moldova visited Experimental Station of Soybean and grain crops, Agricultural Academy in Pavlikeni, Bulgaria. Considering that between the research institutions from Republic of Moldova and Bulgaria there was an exchange of soybean genetic material, the purpose of the visit was to know how the Moldovan varieties are manifested in the climate conditions of Bulgaria. Moldovan varieties were presented at the breeding fields of Soybean Experimental Station in Pavlikeni and therefore the study of the performance of genetic traits and resistance to biotic and abiotic factors is very important for researchers in Moldova. There was also an exchange of views, methods of improvement and good practice during the visit on demonstration fields.

The present study aims to investigate the field performance of Moldovan varietis based on selected morphological indicators in the conditions of North Central Bulgaria and indentify the genotypes of Moldovan selection with stable grain yield and its determining components under the conditions of Northern Bulgaria.

Materials and Methods

Plant material and experimental conditions

The study was conducted at the Experimental Station for Soybeans and grain crops, Pavlikeni situated in North Central Bulgaria, (43°23'N, 25°32'E, 144 m above sea level). The soil subtype is moderately leached chernozem, with a humus horizon thickness of 40-50 cm. In the experimental work the following Moldovan varieties, established at the Research Institute of Field Crops "Selectia" in Bălți, Moldova were used: Amedia, Aura, Veronia, Deia, Indra, Magia, Horboveanca and S-4-04. These varieties, together with the Bulgarian medium-early standard variety Avigeya, have been traced for three consecutive years (2019-2021), in a field in non-irrigated conditions by the method of long plots with the country's standard soybean cultivation technology. Sowing is regular, with a row spacing of 70 cm and a sowing rate of 40 000 qs/da[1]

Each experimental year, during the phenophase R8, for each variety a biometric characteristic was performed on the following indicators: plant height (cm), number of branches, fertile nodes on the main stem, number of seeds per plant, total yield of aboveground plant biomass, stems and branches, without leaves – BMY, g), seed yield from plant (SY, g), absolute mass of seeds (m 1000 g), yield of seeds per decare.

Statistical analysis

The significance of the genotypic variance by years and on average for the experimental period was established by one-factor and two-factor analysis of variance. Multiple comparison of the average values of the varieties on the observed indicators was performed by Duncan's test at a significance level of 5%. The stability of the phenotypic expression of the tested genotypes under the different agrometeorological conditions of the experimental years was determined by the values of the ecological variance (σ^2_x).

Results and Discussion

The first experimental year (2019) was characterized with very favorable conditions in the periods of flowering and pod formation. The formation of pods and grain filling in 2020 took place in conditions of very severe drought. The worst agro-meteorological conditions were detected at 2021. During the period April-September, 281.8 mm rainfalls fell. In April they were 8 mm above the norm, in May they were above the norm by 34 mm, and in the remaining 4 months they were much below the norm, especially in July – 10.1 mm (Table 1). The period R1-R8 (beginning of flowering – ripening), critical in terms of water availability, took place with very low moisture supply, which had an extremely unfavorable effect on the yield. Rainfall in September had no effect, as soybeans were in the phenophase beginning of ripening. According to the water availability for the period IV-VIII, 2021 is characterized as extreamly dry, with precipitation much below the norm and with unfavorable distribution by months. In the three years experimental period, 2021 was the second dry year together with 2020.

[1] 1 da = 1000 m^2

Table 1. Rainfall sums by months during the vegetation period of soybean for three experimental years 2019-2021

Months Years	IV	V	VI	VII	VIII	IX
2019	94.4	41.8	149.0	77.8	8.6	2.4
2020	20.2	47.3	99.1	6.4	36.4	22.4
2021	51.8	104.2	65.7	10.1	26.4	23.6
Average for 50-Year period	48.7	67.1	58.1	58	50.8	46.8

According to the study of Dima (2015) in the past decade in the Republic of Moldova the Research Institute of Field Crops "Selectia" from Balti registered soybean varieties very early Harboveanca and Deia and early Indra, Magia, Aura, Veronia and S-4-04. The Institute of Genetics and Plant Physiology from Kishinev registered early variety, Amedia. The length of the growing season and the ripening period varied at the agrometeriological conditions during three consecutive years of experiment in the condition of North Central Bulgaria. The Moldovan varieties included in the test are grouped as follows during the most dry year 2021: very early, with a growing season of up to 110 days were the varieties Deia, Magia, early, with a growing season of up to 120 days – Indra, Horboveanca and S-4-04 and medium early with a growing season of up to 130 days – Amedia, Aura, Veronia (Figure 1).

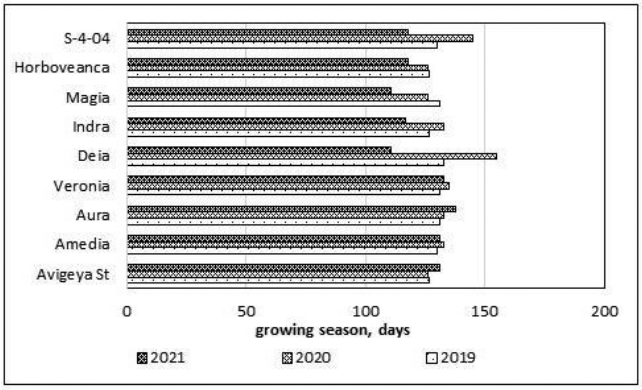

Fig. 1. Lenth of the growing season during three years field experiment

According to the results of the analysis of variance, genotypic differences by year are significant ($P < 0.01$, $P < 0.001$) for the following traits plant height, number of branches, seed yield per plant for 2019 and 2021, weight per 1000 seeds and harvest index for 2019 and 2021. The highest average values for plant height are reported for the varieties: Aura (110.8 cm) followed by the standard Avigeya, Habroveanka, Indra (Table 2, Figure 2A). The varieties Deya and Magia are low-growing. High and ecologically stable performance on the basis of plant height is reported for the Aura variety. The number of the formed branches of a plant, depends on the genotypic factor, varies in the range from 0 to 4.7 and the Bulgarian standard variety Avigeya is distinguished by the highest average values on this indicator (Figure 2B). The number of branches per plant varies greatly depending on the environmental factor. In the varieties S-4-04 and Aura it possesses the lowest values, varying slightly during the years. The most stable manifestation of the trait in the competitive conditions of the agrocenosis is reported for the high-growing variety Aura.

Moldovan varieties also differ significantly in terms of individual plant productivity. The number of seeds obtained per plant varies ranged from 63.1 to 84.9, which is significantly less than the standard variety 117.9 (Figure 2C). The highest and stable values are reported for the varieties Aura, Amedia, S-4-04. The mass of seeds obtained per plant varies from 7 to 11.7 g again the highest values were reported for the varieties Amedia, Aura and S-4-04 (Figure 2D). The specific weights of the seeds – mass of 1000 seeds are high in the varieties Aura, Indra, S-4-04, and Harboveanka, even higher than the standard. The varieties Aura and Amedia are equal to the standard variety both in average values and in the stability of the phenotypic manifestation in relation to the absolute mass of the seeds (Figure 2E).

Relatively high and stable year-round values for plant seed yield are observed for Indra, Amedia and Aura. The same is observed for the indicated varieties with regard to the indicators harvest index and seed yield per decare (Figure 2F and Figure 3). Despite its strong genetic determination, the absolute mass of seeds is significantly influenced by environmental factors (Krisnawati & Adie, 2015). According to our results from a comparative variety test (Naidenova & Georgieva, 2019), genotypically determined trait large-seed possess a phenotypic realization when the reproductive phases of grain filling took place outside the period 1-15 August, when drought in Bulgaria is most frequent and highly pronounced. As a consequence, high and stable large-seeded expression is observed in very early (MG 000-00) and medium-late varieties (MGII).

The harvest index and the absolute mass of the seeds are important traits of soybean productivity. The harvest index is indicative of the plant's ability to distribute assimilates in the reproductive organs and is an indicator of productivity in grain crops. On this basis, it can be used to assess the adaptability and stability of genotypes. New results underscore the importance of a stable and high harvest index performance to

Table 2. Structural analysis of seed yield by years and average for the period

Plant height,cm	Avigeya St	Amedia	Aura	Veronia	Deia	Indra	Magia	Hor-boveanca	S-4-04	$LSD_{0.05}$	Significane of genotypic variance
2019	106.4	103.6	110.8	90.0	80.8	102.8	79.4	102.0	92.8	14.2	P < 0.001
2020	94.8	81.2	92.8	74.2	60.0	85.2	59.8	91.4	81.4	7.4	P < 0.001
2021	86.7	78.3	96.0	67.3	72.7	77.7	40.7	79.0	74.7	3.1	P < 0.001
Mean	96.0^{ab}	87.7^{bc}	99.9^{a}	77.2^{de}	71.2^{e}	88.6^{bc}	60.0^{f}	90.8^{bc}	83.0^{cd}		
Branchs-number	Avigeya	Amedia	Aura	Veronia	Deia	Indra	Magia	Hor-boveanca	S-4-04		
2019	4,0	0.4	0.2	0.6	0.8	0.0	1.0	0.0	1.2	1.1	P < 0.001
2020	4.2	2.8	2.4	2.4	2.4	2.0	3.8	2.6	0.6	1.5	P < 0.01
2021	4.7	2.0	1.3	2.3	3.0	2.7	4.3	3.0	2.0	1.0	P < 0.001
Mean	4.3^{a}	1.7^{c}	1.3^{c}	1.8^{c}	2.1^{bc}	1.6^{c}	3.0^{b}	1.9^{c}	1.3^{c}		
Number seeds/ plant	Avigeya	Amedia	Aura	Veronia	Deia	Indra	Magia	Hor-boveanca	S-4-04		
2019	128.8	75.0	76.0	56.2	94.4	60.8	93.2	96.6	102.8	46.1	NS
2020	149.8	103.8	114.8	74.0	88.2	85.2	95.2	81.4	68.0	50.1	NS
2021	75.0	66.0	55.7	59.0	67.3	81.0	66.3	60.3	74.7	13.8	P < 0.05
Mean	117.9^{a}	81.6^{b}	82.2^{b}	63.1^{b}	83.3^{b}	75.7^{b}	84.9^{b}	79.4^{b}	81.8^{b}		
SY, g	Avigeya	Amedia	Aura	Veronia	Deia	Indra	Magia	Hor-boveanca	S-4-04		
2019	17.2	10.0	11.1	6.3	11.2	8.7	9.0	13.1	16.2	5.8	P < 0.01
2020	17.4	15.0	17.2	9.1	13.2	13.6	11.2	12.4	11.1	7.3	NS
2021	10.6	7.0	6.8	5.6	4.5	6.9	3.4	6.1	6.5	1.8	P < 0.001
Mean	15.1^{a}	10.7^{bcd}	11.7^{ab}	7.0^{d}	9.7^{bcd}	9.7^{bcd}	7.8^{cd}	10.6^{bcd}	11.3^{abc}		
m 1000, g	Avigeya	Amedia	Aura	Veronia	Deia	Indra	Magia	Hor-boveanca	S-4-04		
2019	135.1	137.5	145.6	112.9	119.7	144.8	99.4	142.6	154.5	23.8	P < 0.001
2020	113.0	142.4	150.5	117.2	149.3	161.6	117.1	152.1	164.1	25.6	P < 0.001
2021	139.6	106.7	122.7	94.9	67.1	89.4	50.7	97.7	89.1	17.7	P < 0.001
Mean	129.2^{abc}	128.9^{abc}	139.6^{a}	108.3^{cd}	112.0^{bc}	131.9^{ab}	89.1^{d}	130.8^{ab}	135.9^{a}		
HI, %	Avigeya	Amedia	Aura	Veronia	Deia	Indra	Magia	Hor-boveanca	S-4-04		
2019	30.7	43.3	41.7	35.2	49.4	43.8	37.3	43.0	47.7	6.4	P < 0.001
2020	33	42.2	40.7	33.6	40.0	42.4	41.0	42.6	42.1	7.4	P = 0.05
2021	46.3	37.9	36.0	36.4	30.1	37.4	25.7	30.2	35.4	3.7	P < 0.001
Mean	36.6^{bcd}	41.1^{ab}	39.5^{abcd}	35.1^{cd}	39.9^{abc}	41.2^{ab}	34.7^{d}	38.6^{abcd}	41.7^{a}		

improve soybean productivity (Cui & Yu, 2005; Todeschini et al., 2019).

The yields of soybean grain from Moldovan varieties and Bulgarian standard was greatly influenced by the weather conditions of the agricultural year. The most favorable year was 2019, when the yield for Avigeya reached 312.7 kg/da and from foreign varietis the highest yeald was detected for Deia and Indra 273.2 kg/da, 267.9 kg/da for Veronia and 262.9 kg/da for S-4-04. In the second year 2020, which was less favorable in agro-meteorogical condition the grain productivity drop down: Avigeya 245.0 kg/da almost equal to Aura for Indra 228.9 kg/da; Deia 199.6 kg/da and 137.7 kg/da for S-4-04? In the most unfavorable year 2021 the grain yield decreases significantly. Surprisingly the Moldovian variety Amedia (139.0 kg/da) outrun Bulgarian standard Avigeya 137.5 kg/da followed by Aura-118.0 kg/da and drop down significantly for Indra 98.5 kg/da, Deia 92.5 kg/da and S-4-04 71.0 kg/da (Table 3, Figure 3). Despite the unfavorable weather conditions in the summer, Bulgaria and the Republic of Moldova have favorable climatic conditions for soybean cultivation. Two factors agro-meteriological condition of the year and genotype are

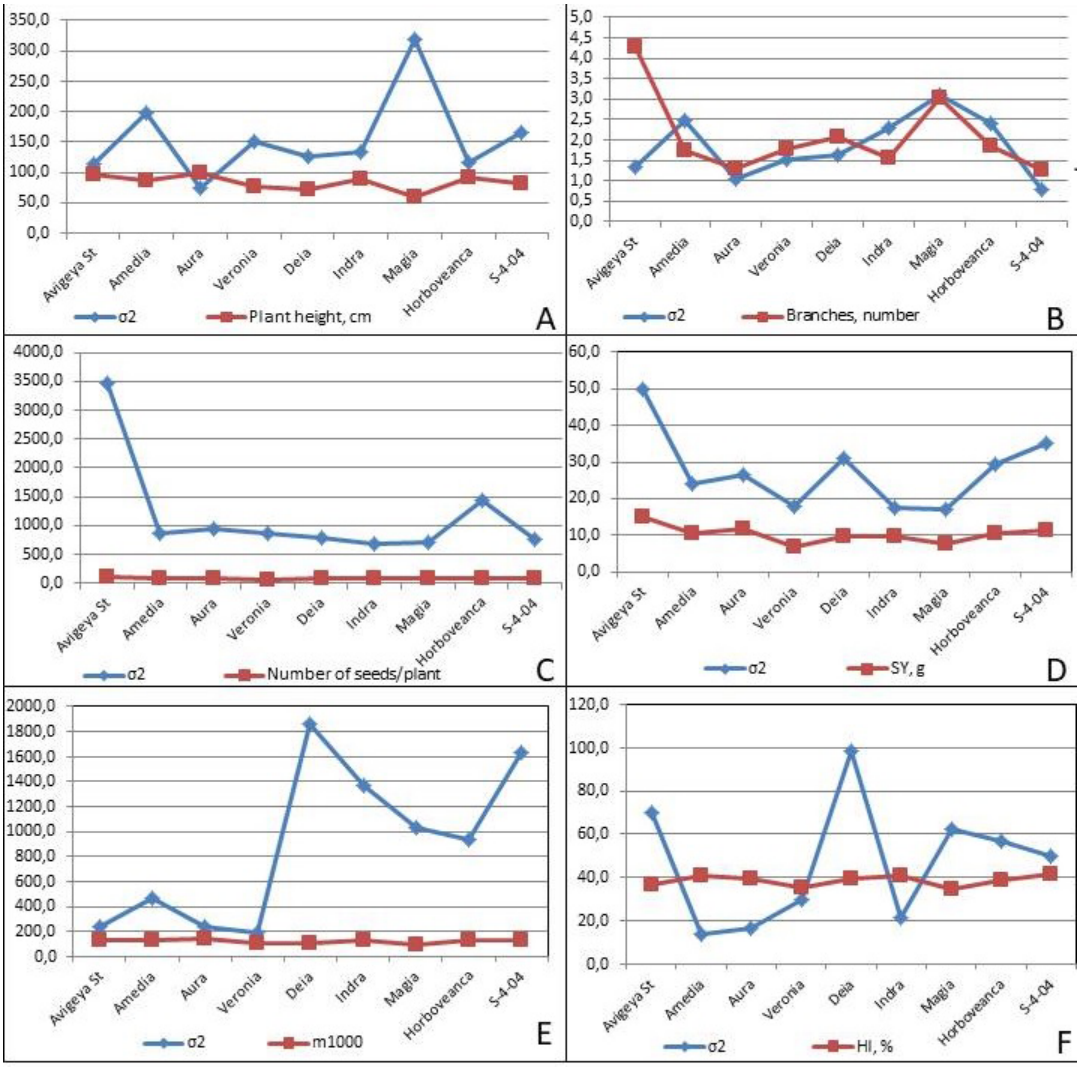

Fig. 2. Manifestation of genotypes in relation to the average values of the selected indicators and the ecological variance (σ^2_x) of the trait during three years experiment:

A – plant heitgh; B – number of branches; C – number of seeds per plant; D – seed yield; E- mass of 1000 seeds; F – harvest index

with significant importance for the filed performance of each variety. The highest influence of the manifestation of varieties on the field possesses factor environmental potential of agricultural year, followed by genotype. Interaction of both factors is significant ($P < 0.05$) during the three years experiment.

In the past decade Europe is facing a major deficit on soy protein. The grain legume crops accounted for only about 3% of the annually cropped area of the European Union in 2019, compared with 17% world-wide (FAOSTAT, 2021). In the case of certified non-GM soy protein EU counts for 0.4% of worldwide soybeans acreage. Soybean imports – grain equivalent – represent 95% of the European annual consumption of 38 million tons. The countries from the Danube region provide new opportunities to increase the area occupied by soybeans and the region is known for very favorable conditions for this crop. Bulgaria and the Republic of Moldova took an important place of conventional soybeans breeding and growth potential. In these two countries breeding and cropping of soybeans possess a 100 of year's history. Both countries followed a long time tradition in soybean breeding and well adapted agro-technology

Table 3. Grain productivity, kg/da

	Avigeya St	Amedia	Aura	Veronia	Deia	Indra	Magia	Hor-boveanca	S-4-04	$LSD_{0.05}$	Signifi-cance of genotypic variance
2019	312.7	253.6	253.6	267.9	273.2	273.2	230.4	248.2	262.5	74.6	ns
2020	245.0	167.3	243.2	175.2	199.6	228.9	180.9	194.8	137.7	42.1	P < 0.01
2021	137.5	139.0	118.8	87.5	92.5	98.8	43.5	92.0	71.0	13.9	P < 0.001
Mean	232[a]	187[b]	205[b]	177[c]	188[b]	200[b]	152[c]	178[c]	157[c]	26,1	P < 0.001

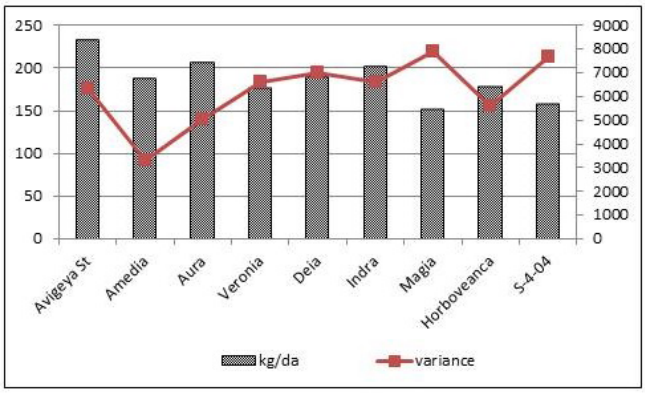

Fig. 3. Distribution of genotypes according to the average values of grain yield and the ecological variance (σ^2_x) of the trait

to local cropping conditions. Last ten years, a growing interest of the farmers in the region to increase the soybeans area could be observed. Bulgaria and the Republic of Moldova possess a great soybean cropping potential and could increase it.

Conclusion

The performed three years field trial test of Moldovan varieties in the condition of North Central Bulgaria showed that the values of selected morphological indicators are less compared to the Bulgarian standard. Significant genotypic diversity was observed for the selected indicators during each year of experiment. The yields of soybean grain from Moldovan varieties and Bulgarian standard was greatly influenced by the weather conditions during the agricultural year. Environmental factor possesses the highest influence of the manifestation of Moldovan varieties in Bulgaria followed by genotype.

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