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Study on seed yield components depending on the duration of vegetation period in soybean

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Abstract

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Avoidance of drought by using varieties with rapid phenological development or displacement of critical phenological periods through the variety are effective approaches to stabilizing soybean yields under non-irrigated conditions in Bulgaria. This requires when selecting genetic resources for our breeding program, the study of seed productivity and structural yield components to be made in relation to the duration of the vegetation period. With such aim twenty-eight cultivars of different maturity groups were studied during three year in a field trial conducted in the long-plot design method on the soybean technology established for the country. According to the results presented, a high and stable performance regarding the traits determining the seed productivity could be considered in connection with the maturity group of genotypes. In selection for "large-seedness" as parental components should be used genotypes with high expression of the trait from the early-ripening or middle late-ripening group of maturity. The average values, but also the ecological dispersion of the traits number of fertile nodes and number of branches were higher in genotypes with a longer vegetation period, and also early-ripening genotypes with a high and ecologically stable expression on these traits were established in this study. Individual productivity, estimated by the number and mass of seeds obtained from a plant, has the most stable performance in Bulgarian cultivars and can be considered to be a function of the specific adaptation of genotypes. Also there is a trend for a higher yield of seed from a plant in genotypes with shorter growth period which can be associated with better seed filling.

Keywords: soybean; seed yield components; variance components

Introduction

Soybean is a culture of global importance grown mainly because of its protein, oil and nutrient content. The seeds contain 40% protein and 20% oil. Each year, it provides more protein and vegetable oil than any other culture in the world (Subramanian and Smith, 2013). Soybean is important and traditionally grown in Balkan Peninsula. One of the main factors limiting soybean production is drought (Kosturkova et al., 2014; Popovic et al., 2015; Georgiev, 2017). The sowing of soybean with seeds of accidentally imported cultivars of unsuitable maturity groups, along with non-irrigated conditions of crop cultivation, are determined as the main reasons for low yields and relatively high share of unharvested stands in our country in recent years. According to Aleksieva (2015), avoidance of drought by using varieties with rapid phenological development or displacement of critical phenological periods through the variety are effective approaches to stabilizing soybean yields under non-irrigated conditions in Bulgaria. This requires when selecting genetic resources for our breeding program, the study of seed productivity and structural yield components to be made in relation to the duration of the vegetation period. With such aim the present

study was conducted, which included modern non-GMO soybean cultivars cultivated in the countries of the Danube Region as well as Bulgarian cultivars.

Materials and Methods

Twenty-eight cultivars of different maturity groups were studied in a field trial conducted in the long-plot design method on the soybean technology established for the country. The experiment was carried out at the Soybean Experimental Station (Pavlikeni) during the period 2015-2017, on the soil type of leached chernozem. Mineral fertilization was not applied. The sowing was carried out in the second decade of April, at row-spacing of 70 cm and a sowing rate of 40 000 seeds/da. The following indicators were recorded by years: vegetation period (germination-harvesting), plant height (cm), number of branches, fertile nodes on the main stem and pods per plant, number and weight (g) of seeds per plant, absolute mass of seeds (g). Biometric measurements were determined in 10 plants of each genotype.

Dispersion analysis of structural elements of seed productivity was carried out by varieties and years and the component composition of the variation was established. The values of the ecological dispersion of the studied varieties were used for determining their stability during the different agrometeorological conditions of the experimental period.

The experiment included years with different rainfall quantities during the critical stages of reproductive development of soybean (Table 1). The first two experimental years were characterized by more favorable conditions in the flowering period - with corresponding monthly rainfalls for June of 86.4 and 67.6 mm, which were distributed uniformly by decades. In 2015 and 2016, the pod formation occurred in severe drought conditions - the rainfall sums in the second and third decade of July and the first decade of August were 20.2 and 0 mm, respectively. In 2017, the rainfall sum for the same period was considerably higher (48.9 mm).

Results and Discussion

The length of the cultivar growth cycle and seed maturity time have a complex genetic control that is regulated by temperature and photoperiod (Kurasch et al., 2017; Li et al., 2017). According to the phenological observations in the three experimental years, the cultivars included in the study under the agro-ecological conditions of Central North Bulgaria were grouped as follows: 5 very early-ripening cultivars (with a vegetation period of up to 110 days, group 00), 6 early-ripening ones (vegetation period up to 120 days, group 0), 14 middle early-ripening ones (up to 130 days, group I), and 4 middle late-ripening ones (vegetation period over 140 days, group II).

According to the variance component analysis of yield components (Table 2), more pronounced genotypic heterogeneity in the studied group of cultivars was observed by the traits of plant height, number of fertile nodes and branches, absolute mass of seeds. The variance regarding the number of pods per plant, which in broad-row cultivation of soybean correlated to the greatest extent with grain productivity (Aditya et al., 2011), was predominantly ecological. This was due to the different climatic conditions during the years, including the specific genotypic response to these conditions (Table 3). The same was observed in term of the indicators of individual productivity - number and mass of seeds per plant.

Genotypic differences were significant ($P < 0.001$) for all observed traits (Table 3). The yield components ($P < 0.001$; $P < 0.01$) were also significantly influenced by the agro-climatic conditions of the experimental years.

Table 1. Rainfall sums by months and decades of the vegetation period of soybean

	IV	V	VI	VII	VIII	IX	X
2015	39.7	66	86.4	20.4	72.3	46.8	37.4
I decade			29.3	14	14.2		
II decade			17.1	5.6	7.0		
III decade			40.0	0.4	52.0		
2016	51.4	105.9	67.6	25.4	66.9	37.1	38.4
I decade			19.6	25.4	0		
II decade			27.6	0	34.5		
III decade			28.4	0	32.4		
2017	58.5	82.4	37.8	98.9	8	21.5	117.5
I decade			18.5	50.5	0.5		
II decade			19.3	22.4	0		
III decade			0	26.0	7.5		
Average for 50-year period	48.7	67.1	58.1	58	50.8	46.8	37.4

Table 2. Average values, limit values and components of variance regarding the structural elements of yield in soybean cultivars

	Plant height, cm	Fertile nodes, number	Branches, number	Number of pods/plant	Number of seeds/plant	Seed mass/ plant	1000 seeds mass
Average	83.0	14.0	1.9	42.8	81.3	9.9	121.3
min	52.4	10.3	0.6	25.3	49.0	5.8	87.3
max	106.5	17.4	3.8	84.0	124.0	16.2	152.2
σ^2_e	100.52	3.74	1.81	461.67	1786.61	32.84	755.57
σ^2_g	114.92	2.24	0.48	51.87	146.70	4.08	199.80
σ^2_{ph}	215.44	5.98	2.29	513.54	1933.30	36.92	955.37

Table 3. Significance and extent of factorial impact

	G	η^2_G	Y	η^2_Y	G*Y	η^2_{G*Y}
Plant height, cm	P < 0.001	0.56	P < 0.001	0.12	P < 0.001	0.20
Fertile nodes, number	P < 0.001	0.42	P < 0.001	0.04	P < 0.001	0.21
Branches, number	P < 0.001	0.29	P < 0.001	0.08	P < 0.001	0.17
Number of pods/plant	P < 0.001	0.13	P < 0.001	0.04	P < 0.001	0.34
Number of seeds/plant	P < 0.001	0.15	P < 0.01	0.02	P < 0.001	0.33
Seed mass/plant	P < 0.001	0.17	P < 0.001	0.03	P < 0.001	0.35
1000 seeds mass, g	P < 0.001	0.35	P < 0.001	0.25	P < 0.001	0.13

The highest average values of plant height were recorded for the Romanian early cultivars Onix (106.5 cm) and Felix (100.1 cm) - Fig. 1a. The trait had a lower ecological dispersion (σ^2e) in cultivars with a longer vegetation period. The most stable phenotypic expression in years was observed in the middle early-ripening cultivars Pavlikeni and Isidor, and in the early-ripening cultivars PN91M10 and Felix. It was established a slight tendency to increase the value of the trait in genotypes with a longer vegetation period.

The high-growing early cultivars Felix and Onix form the largest number of fertile nodes – 17.4 and 16.5, respectively (Fig. 1b). The mean values, but also the ecological dispersion of the trait are higher in the genotypes from a middle late-ripening group.

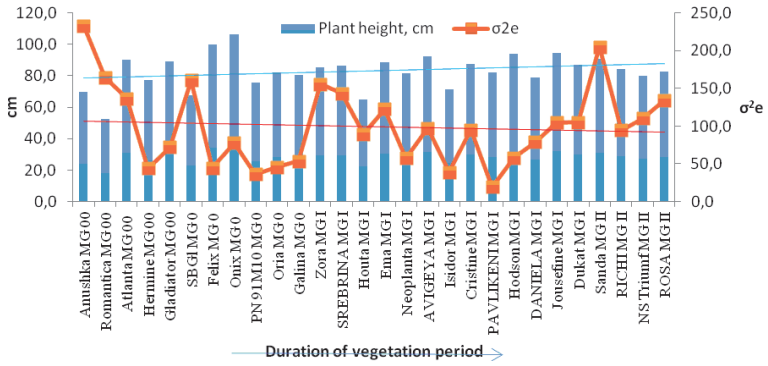
The studied cultivars formed an average of 0.6 to 3.8 branches per plant (Fig. 1c). Bulgarian cultivars Richi, Avigeya, Rosa and Daniela had the highest average values for this indicator. A high and ecologically stable performance was recorded in the ultra early-ripening Romanian cultivar Romantika. There was a clear tendency in more late-ripening genotypes to form more branches, but also a greater variation in the values of the indicator depending on the year conditions.

The average number of pods formed by a plant depending on the genotypic factor ranged from 25.3 to 84.0 (Fig. 1d). It was not established a relationship between the number of pods and the early maturing of genotypes included in the experiment. The highest values were recorded for the ultra early-ripening cv. Romantika and middle early-ripening cultivars Cristine, Avigeya and Zora. For the first two cultivars, the indicator varied greatly depending on the ecological factor, respectively the conditions by years. The Bulgarian cultivars Srebrina and Rosa were distinguished by an exceptionally stable performance regarding this trait. It was observed also a slight tendency for higher ecological dispersion of the indicator in genotypes with a longer vegetation period. According to the results of the dispersion analysis, the variance on this indicator was predominantly non-additive, due to the interaction genotype x year (Table 3).

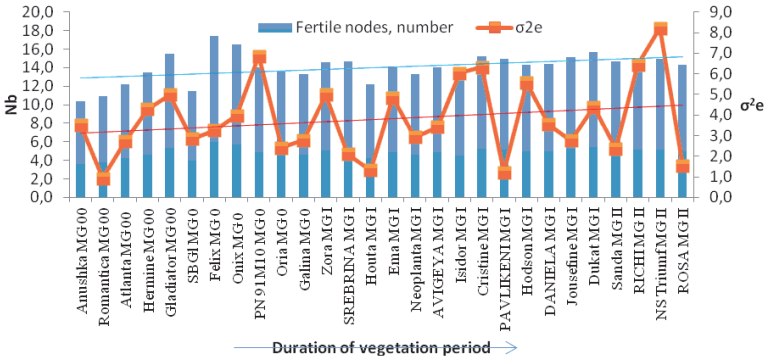
The cultivars also differed significantly in terms of the individual plant productivity traits. The number of seeds obtained from a plant ranged from 49.0 to 124.0 (Fig. 1e). High and stable values were recorded by years in the middle early-ripening cultivars Zora and Avigeya and early-ripening cv. Felix. It was not observed a tendency for an influence of the vegetation period, respectively, of the differences in the duration of the reproduction R5-R6 stages, on the number of seeds formed by a plant. Seed number differences was not related to maturity groups also according to the results of the studies of other authors (Rotundo et al., 2012; Santachiara et al., 2017).

The seed mass obtained from a plant was from 5.8 to 16.2 g (Fig. 1f). There is a significant trend for a higher yield of seed from a plant at in genotypes with shorter growth period.

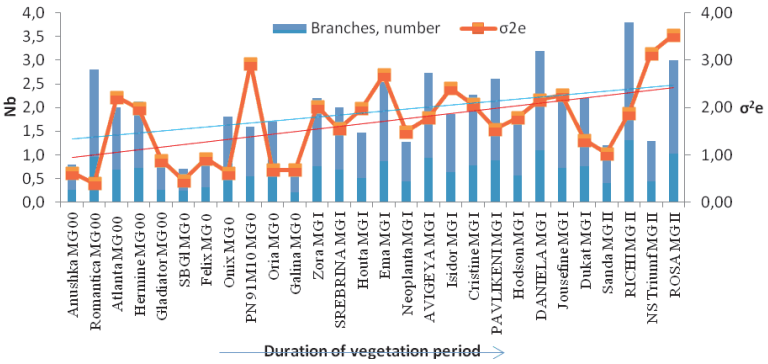
a) Plant height (cm)



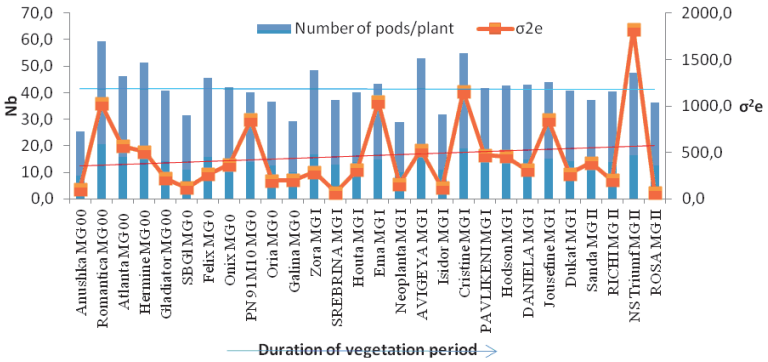
b) Number of fertile nodes

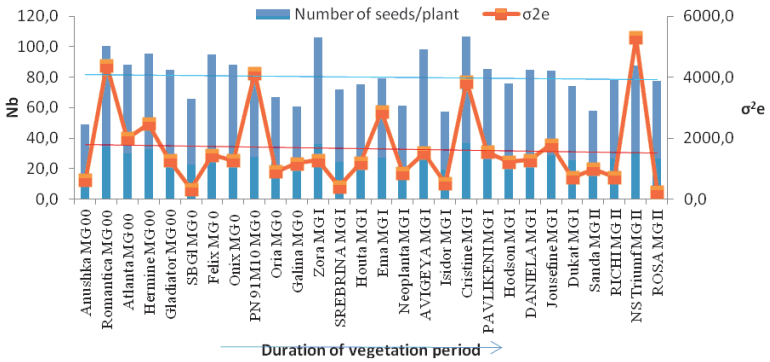


c) Number of branches formed by a plant

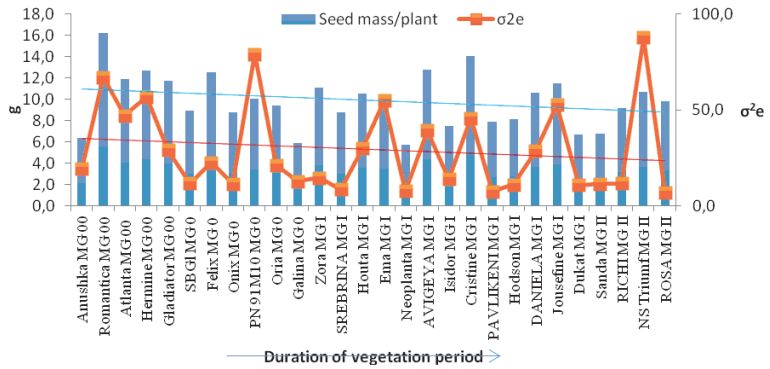


d) Number of pods per plant

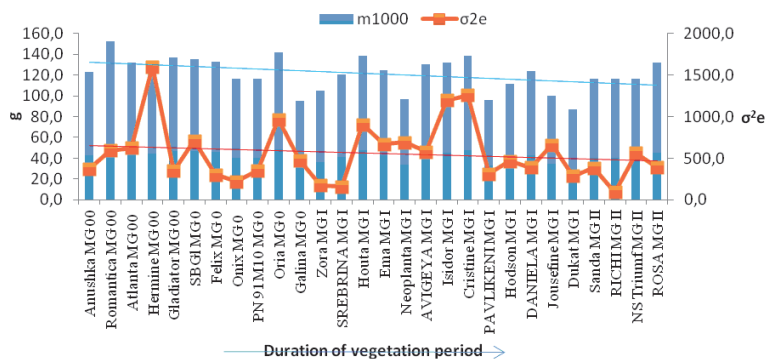




e) Number of seeds per plant



f) Seed mass per plant (g)



g) Absolute mass of seeds (g)

Fig. 1. Average values and ecological dispersion of the main traits in soybean genotypes, a-g

The highest productivity for the study period was recorded in the ultra early-ripening cv. Romantika and the middle early-ripening cv. Cristine, but the values of the indicator for both genotypes varied greatly under the influence of the ecological factor. In contrast, the Bulgarian middle early-ripening cultivars Pavlikeni and Srebrina, and the middle late-ripening cv. Rosa stood out with the lowest variation of seed productivity by years. Also, according to the trendline of ecological dispersion, the individual productivity had a more stable performance in later-ripening cultivars (Fig. 1f).

The cultivars studied also differed substantially in the absolute mass of seeds (Fig. 1g). The large-seedness had a stable phenotypic expression in Rosa and Daniela, as well as in considerably earlier-ripening cultivars Romantika and Gladiator. It is important to note that the reproductive stages R7-R8 (grain filling) in the first two genotypes occurred in the third decada of August, and in the early-ripening genotypes Romantika and Gladiator - in the second to third deca-

da of July, i.e. in both cases grain filling occurred outside the period 1-15 August, in which the drought in the region is common and the strongest. High average values were also reported for early-ripening cv. Oria and middle early-ripening cultivars Isidor and Houta, but according to the results, the well-fed seeds in these genotypes varied greatly by years.

Conclusions

According to the results presented, a high and stable performance regarding the traits determining the seed productivity could be considered in connection with the maturity group of genotypes. In selection for „large-seedness" as parental components should be used genotypes with high expression of the trait from the early-ripening or middle late-ripening group of maturity. The average values, but also the ecological dispersion of the traits of number of fertile nodes and number of branches were higher in genotypes with a longer vegetation period, and also early-ripening genotypes with a high and ecologically stable expression on these traits were established in this study. Individual productivity, estimated by the number and mass of seeds obtained from a plant, has the most stable performance in Bulgarian cultivars and can be considered to be a function of the specific adaptation of genotypes. Also there is a trend for a higher yield of seed from a plant in genotypes with shorter growth period which can be associated with better seed filling.

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