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Original scientific paper

VARIABILITY AND CORRELATIONS BETWEEN YIELD COMPONENTS OF SOYBEAN [*GLYCINE MAX* (L.) MERR.]

Vera POPOVIĆ[1], Miloš VIDIĆ[1], Đorđe JOCKOVIĆ[1], Jela IKANOVIĆ[2], Snežana JAKŠIĆ[1], Gorica CVIJANOVIĆ[3]

[1]Institute of Field and Vegetable Crops, Novi Sad, Serbia
[2] University of Belgrade, Faculty of Agricultural Sciences and Food, Zemun, Serbia
[3]Megatrend University Belgrade, Faculty of Biofarming, Bačka Topola, Serbia

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NS soybean cultivars were assessed for variability of and correlations between yield components and the effect of genotype - environment interaction on yield, yield component and morphological characteristics. Experiments were carried out at Rimski Šančevi experiment field in 2009 and 2010. The following characteristics were evaluated: plant height (cm), height of first pod (cm), 1000-grain weight (g), grain yield (kg/ha) and the combined content of oil and protein in grain (%). Combined contents of oil and protein in grain soybean were determined by a non-

Corresponding author: Vera Popović, Institute of Field and Vegetable Crops, Novi Sad. Phone: +381 21 4898 481; cell phone: +381 64 820 5733; e-mail: vera.popovic@ifvcns.ns.ac.rs

destructive method of near infrared spectroscopy on PERTEN DA 7000 (NIR/VIS Spectrophotometer).

The studied characteristics varied significantly depending on genotype and year. The highest yield of 5273 kg/ha was obtained in 2009 with the genotype Victoria. Highest 1000-grain weights, 2009-2010, were achieved with the genotypes Valjevka and Victoria (149.27 g and 147.23 g). Maximum heights of first pod (19.40 cm) were recorded for the genotype Victoria, 2009-2010. Highest protein contents were obtained with the genotypes Valjevka and Victoria, 2009-2010, were and highest oil contents (21.73%) with the genotype Tea. Protein content was positively significantly correlated with 1000-grain weight and negatively significantly correlated with oil content, and negatively correlated with yield and the height of first pod. Oil content was positively correlated with the height of first pod. Thousand-grain weight was negatively highly significantly correlated with oil content in grain and negatively significantly correlated the height of first pod.

The results of this study should facilitate further soybean breeding for improved seed yield and protein and oil contents.

Key words: content of proteins and oil, correlations, morphological characteristics, soybean, yield

INTRODUCTION

Soybean - *Glycine max (*L.) Merr. is a major protein plant and the main source of plant proteins. It is grown in Europe since the 18th century, as a source of proteins and oil. Depending on cultivar and growing conditions soybeans contain about 38% proteins, 19% oil and 26% carbohydrates (POPOVIĆ, 2010).

In soybean breeding, emphasis is placed on yield and stability improvement, i.e., the development of cultivars adapted to different agroecological conditions (MILADINOVIĆ *et al*., 2011). Correct choice of soybean cultivars is essential for obtaining high and stable yields (POPOVIĆ, 2010). Seed yield and quality are characteristics that are generally inherited quantitatively (polygenes) and they are highly dependent on environmental conditions. This is why the heritability for these characteristics is relatively low (MILADINOVIĆ *et al.,* 2011). Therefore, in soybean breeding, similarly to the breeding of other crops, special attention is paid to yield components which usually have a simpler genetic basis and are always more or less correlated with yield. Soybean breeders place emphasis on the development of cultivars that combine high and stable yield with high protein and oil contents (HOLLUNG *et al.,* 2005; MILADINOVIĆ *et al*., 2011). In addition to individual yield components, the protein/oil ratio is important for soybean processing.

Since yield and quality are negatively correlated, it is necessary to make certain that improved chemical composition does not reduce seed yield (CHUNG *et al*. 2003; BOROOMANDAN *et al.* 2009).

The objective of this study was to determine the productivity of and correlations between yield components, and the effect of genotype-environment interaction on yield components in four NS soybean cultivars.

MATERIALS AND METHODS

Four NS soybean cultivars differing in maturity period were studied. Galina and Valjevka are early cultivars, in the maturity group 0. Victoria and Tea are medium cultivars, in the maturity group I. Experiments were carried out at Rimski Šančevi experiment Field of Institute of Field and Vegetable Crops, in 2009 and 2010, in three replications. The experiment was established on a medium calcareous and slightly alkaline chernozem soil.

Soybeans were sown on 19 April 2009 and 26 April 2010. The size of experimental unit was 8 m^2. Each plot included 4 rows which were 5 m long. The plant densities were 50 x 4 cm (500,000 plants ha^{-1}) for Galina and Valjevka, and 50 x 4.4 cm (450,000 plants ha^{-1}) for Victoria and Tea. Directly before sowing, soybean seed was inoculated with a microbial preparation NS-Nitragin (produced at Institute of Field and Vegetable Crops in Novi Sad, which contains a mixture of strains of *Bradyrhizobium japonicum* symbiotic bacterium). Conventional technology for soybean production was applied during growing season.

The following plant characteristics were studied: plant height (cm), height of first pod (cm), 1000-grain weight (g), grain yield (kg/ha at 14% seed moisture) and the combined content of oil and protein. Plant height and height of first pod were determined by measuring 10 plants from each replication. Thousand-seed weight and grain yield were determined after harvest. To determine protein and oil contents in seed, average samples were made from each replication in the experiment. Combined contents of oil and proteins in seed were determined by a non-destructive method of near infrared spectroscopy on PERTEN DA 7000 (NIR/VIS Spectrophotometer). Meteorological data for the soybean growing seasons were obtained from the meteorological station at Rimski Šančevi.

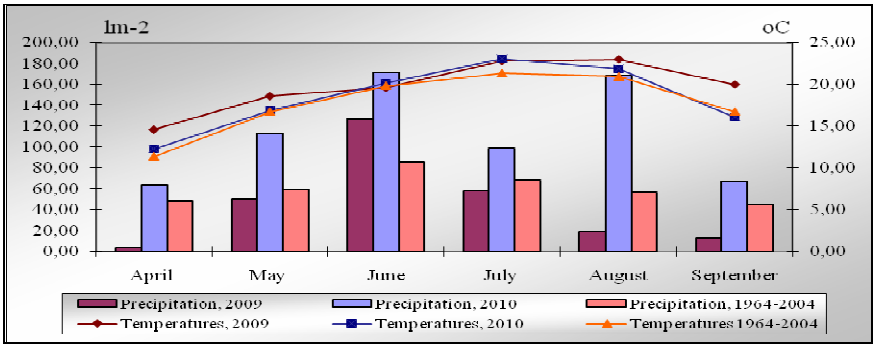
The obtained experimental data were analyzed by analytical and descriptive statistics using the statistical package STATISTICA for Windows 8. Significance of differences between the calculated mean values of the studied characteristics (year and genotype) was tested by the two-way analysis of variance (MALETIĆ, 2005):

$$y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk}, \qquad \text{i=1,2,} \qquad \text{j=1,2,...,5,} \qquad \text{k=3}$$

All significant values obtained in the LSD test were calculated for significance levels of 5% and 1%. Stability tested traits determined by the coefficients of variation (%). Relationships between yield and yield components and yield on one side and protein and oil contents on the other were determined by the correlation analysis method and the obtained coefficients were tested by the t-test for significance levels of 5% and 1%.

Meteorological conditions

In the 2009 growing season, the mean monthly air temperature was 19.60°C or 1.20°C higher than the 2010 and 1.70°C higher than the long-term average. In 2010, the mean monthly temperature was 18.40°C or 0.50°C higher than the long-term average for the location of Rimski Šančevi (Graph 1).



Graph 1. Rainfall sums (lm^{-2}) and average monthly temperatures (^oC) in 2009-2010 growing seasons, Rimski Šančevi

The rainfall in the period April - September 2009 was 271.5 lm^{-2} or 412.1 lm^{-2} below the 2010 and or 92.8 lm^{-2} below the long-term average (364.3 lm^{-2}) for Rimski Šančevi. In the 2010 growing season, the rainfall was 683.6 lm^{-2} or 319.4 lm^{-2} above the long-term average for Rimski Šančevi (Graph 1). Dry periods affected the plant growth and seed yield in the first trial year, which is in accordance with MILADINOVIĆ *et al.,* 2006, MALEŠEVIĆ *et al.* (2010) and POPOVIĆ *et al.* (2011).

RESULTS AND DISCUSSION

The weather conditions in the two study years were different and they significantly affected the growth, development, yield and seed characteristics of soybean (Graph 1 and Table 1). The distribution of rainfall was more favorable in 2010, which resulted in increased yields and high seed quality. In the studied location, the amount and distribution of rainfall during growing season exert the decisive influence on soybean yield and seed quality (POPOVIĆ, 2010).

Grain yield of NS soybean. Within the study period, the yields of the tested genotypes ranged from 4988 kg/ha (Tea) to 5043 kg/ha, 5046 kg/ha and 5060 kg/ha (Victoria, Valjevka and Galina) (Table 1, Graph 2). The yields obtained of the tested genotypes in the two years were not significantly different ($p>0.05$). The yield of the genotype Victoria was significantly higher in 2009 than in 2010 (5273 kg/ha

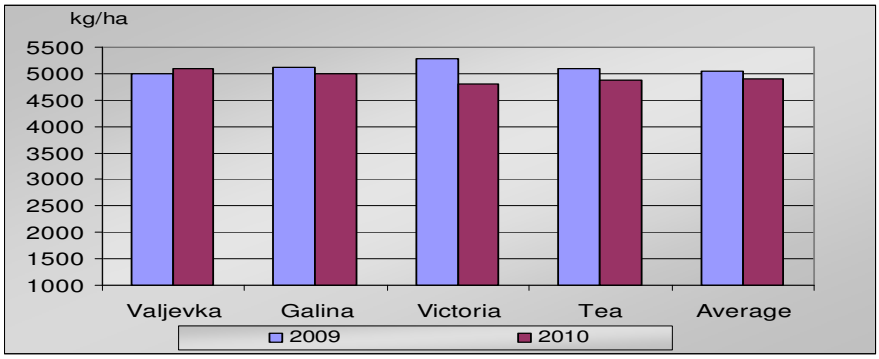
and 4811 kg/ha, respectively). The yields of the other soybean genotypes did not differ significantly (Table 1).

Table 1. Yield (kg/ha), yield component (g) and plants height of NS soybean (cm), 2009-2010

Year	Genotype	Yield (kg/ha)	1000-grain weight (g)	First pod height (cm)	Plant height (cm)
2009	Valjevka	4988.33	131.10	10.50	108.83
		(5.75)	(5.64)	(7.44)	(7.27)
	Galina	5114.67	126.51	15.07	113.97
		(7.56)	(0.56)	(2.68)	(0.64)
	Victoria	5273.67	123.38	22.77	125.00
		(3.12)	(4.55)	(4.86)	(3.49)
	Tea	5099.00	130.60	18.97	103.83
		(2.35)	(0.43)	(5.01)	(4.10)
Average		5118.92	127.89	16.83	112.98
2010	Valjevka	5104.33	167.43	10.60	117.37
		(11.20)	(3.11)	(4.36)	(7.30)
	Galina	5005.67	156.00	16.43	111.43
		(2.30)	(3.59)	(2.74)	(3.81)
	Victoria	4811.33	171.07	16.03	134.40
		(3.01)	(9.68)	(8.85)	(5.97)
	Tea	4876.67	153.44	13.03	106.83
		(5.01)	(4.78)	(9.59)	(1.09)
Average		4949.50	161.99	14.02	117.51
Total Average 2009-2010		5034.21	144.94	15.42	115.25

Indicator	LSD-test	Year	Genotype	Interaction
Yield	0.05	359.502	360.795	510.242
	0.01	495.815	497.598	703.711
1000-grain weight	0.05	6.6620	9.4215	13.3241
	0.01	9.1881	12.9939	18.3762
First pod height	0.05	0.8039	1.1369	1.6079
	0.01	1.1088	1.5681	2.2176
Plant height	0.05	4.9126	6.9475	9.8252
	0.01	6.7753	9.5817	13.5506

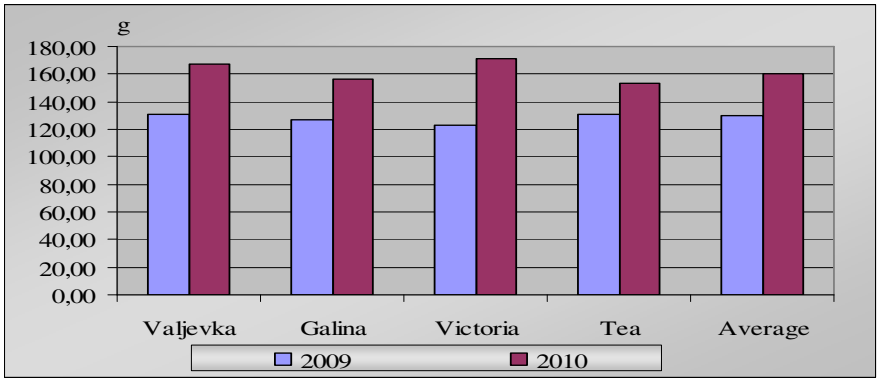
All of tested genotypes showed high stability of yield. The highest average stability of yield in 2009 and 2010 was found in genotype Victoria (3.12 % and 3.01%) as compared to other tested genotypes (Table 1).



Graph 2. Yield (kg/ha) of NS soybean genotypes in 2009-2010

The tested genotypes brought very high yields. These genotypes are the latest generation genotypes developed at Institute of Field and Vegetable Crops, which showed exceedingly high yield potentials in previous studies (MILADINOVIĆ *et al.,* 2011).

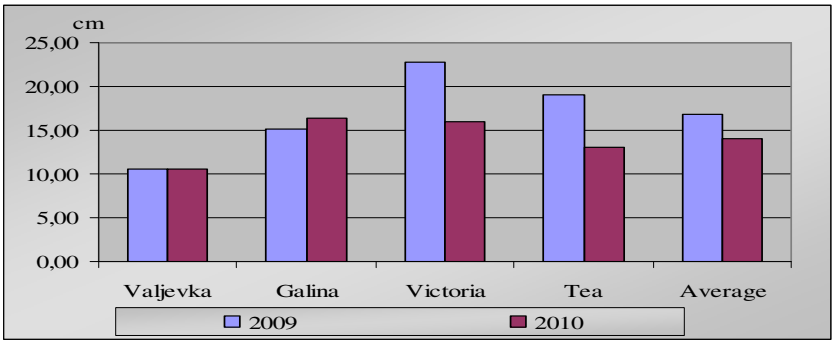
1000-grain weight. This characteristic is a major yield component. The 1000-grain weight for all genotypes and both years (2009-2010), ranged between 141.26 g (Galina) and 149.27 g (Valjevka) (Graph 3). The 1000-grain weight obtained in 2009 was significantly lower than the 2010 value, 127.90 g and 161.99 g, respectively (Table 1). This was the result of favorable weather conditions in 2010, especially the higher rainfall. The tested genotypes did not differ statistically in 1000-grain weight ($p>0.05$) (Table 1).



Graph 3. 1000-grain weight (g) of NS soybean genotypes in 2009-2010

All the tested genotypes showed high stability of 1000 grain weight. The highest stability of 1000 grain weight in 2009 was found in genotypes Tea and Galina (0.43% and 0.56%), in 2010 was found in genotype Valjevka (3.11%) as compared to other tested cultivars (Table 1).

First pod height. The height of first pod differed significantly between the years as well as among the genotypes ($p < 0.01$; Table 1). The genotype Victoria had the highest first pod (19.36 cm), the genotype Valjevka the lowest (10.55 cm). All differences in the height of first pod were significant except the difference between the genotypes Galina and Tea (Table 1, Graph 4).

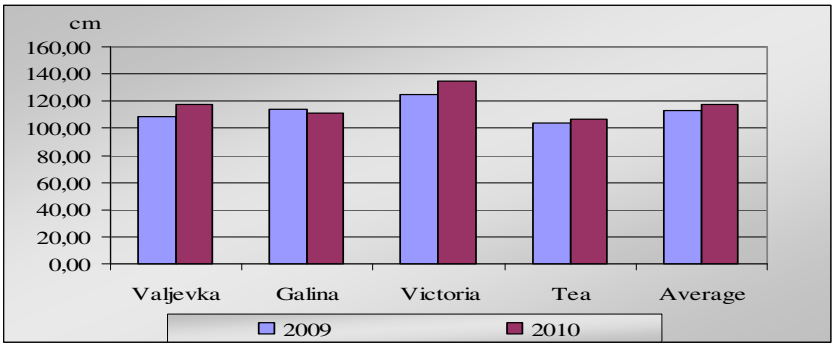


Graph 4. Height of first pod of NS soybean genotypes in 2009-2010

There was a high stability of first pod height in all of the tested genotypes in the trial period. The highest stability of the first pod height was found in genotype Galina (Table 1).

Plant height. The soybean genotypes did not significantly differ in height from year to year ($p>0.05$), but statistically significant differences were registered among the genotypes ($p<0.05$). The genotype Victoria was significantly taller than all other genotypes ($p<0.01$). The genotype Victoria had tallest plants in both years (125.00 and 134.40 cm). The genotype Tea had shortest plant in both years (103.83 and 106.83cm) (Table 1, Graph 5).

All the tested genotypes showed high stability of plant height. The highest stability of plant height in 2009 and 2010 was found in genotype Galina (0.64% and 3.81%) as compared to other tested genotypes (Table 1).

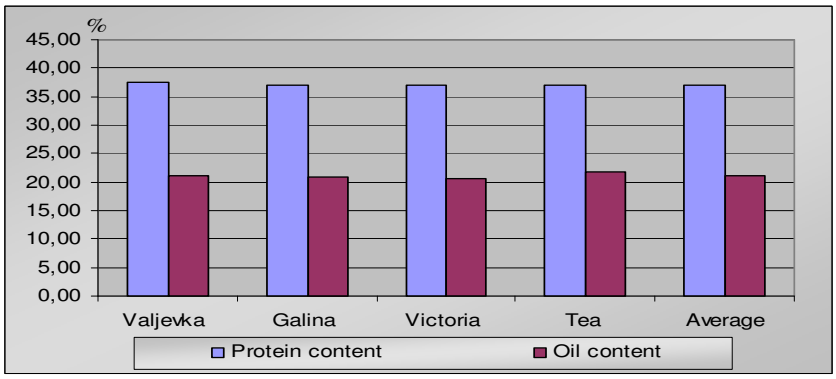


Graph 5. Plant height of NS soybean genotypes in 2009-2010

Protein content in soybean grain. Environmental factors had a statistically significant effect on the protein content in soybean seed. The protein content in grain differed significantly between the years ($p<0.05$) (Table 2).

All the tested genotypes in 2009 and 2010 showed high stability of protein content (Table 2). The protein content on average for all genotypes was higher in 2010 than in 2009. The genotypes Tea had the highest protein content in 2009, the genotypes Valjevka and Victoria in 2010 (Graph 6).

The obtained results indicate that the protein content in soybean is a varietal characteristic, but it is also strongly affected by the environment, which is consistent with the results of other researchers (PESIĆ *et al.*, 2005; POYSA *et al.,* 2006; PERIĆ *et al*., 2009; POPOVIĆ *et al.*, 2012; TAŠKI-AJDUKOVIĆ *et al.,* 2010).



Graph 6. Average protein and oil content (%) in NS soybean grain, 2009-2010

Table 2. Protein and oil content in NS soybean grain, 2009-2010

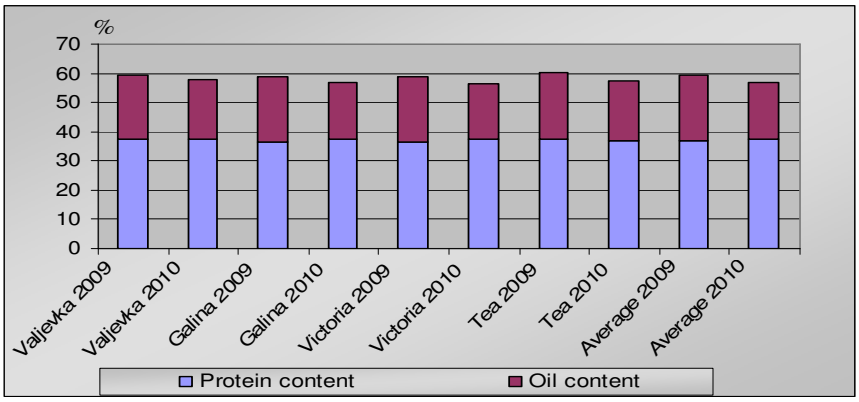
Year	Genotype	Protein content %	Oil content %
2009	Valjevka	37.20 (0.71)	22.01 (2.78)
	Galina	36.68 (0.81)	22.24 (0.66)
	Victoria	36.65 (0.94)	22.31 (2.18)
	Tea	37.31 (1.97)	23.16 (1.05)
Average		36.96	22.43
2010	Valjevka	37.66 (1.09)	20.00 (1.16)
	Galina	37.35 (0.87)	19.48 (2.22)
	Victoria	37.50 (1.39)	19.13 (1.24)
	Tea	36.83 (1.08)	20.29 (1.15)
Average		37.34	19.73
Total Average, 2009-2010		37.15	21,08

Indicator	LSD-test	Year	Genotype	Interaction
Protein content	0.05	0.3781	0.5348	0.7563
	0.01	0.5215	0.7375	1.0430
Oil content	0.05	0.2739	0.3874	0.5478
	0.01	0.3777	0.5343	0.7555

Oil content in soybean grain. The average oil content in soybean grain was significantly higher in 2009 than in 2010 (22.43% and 19.73%, respectively). The genotype Tea had a significantly higher oil content than other tested genotypes. All the tested genotypes in 2009-2010 showed high stability of oil content (Table 2). The differences in oil content in the other varieties were significant, except between the genotypes Victoria, Valjevka and Galina (Table 2, Graph 6)

The combined protein and oil content was 58.23%. The genotype Tea was significantly higher total protein and oil content (60.47%), than other tested genotypes. The average combined protein and oil content in soybean grain was significantly higher in 2009 than in 2010 (59.39% and 58.23%, respectively) (Graph 7).

Our study showed that the genotypes with the longer maturity period had higher oil content in seed, while the earlier genotypes had a higher protein content. The chemical composition of seed indicated that both genotype and environment were important for the formation of that characteristic. Our results are in agreement with those of HURBURGH (2000).



Graph 7. Average combined contents of protein and oil (%) in soybean grain in 2009-2010

Correlations between individual characteristics

The significant interactions of the examined factors suggest that the factors mutually synergized their effects ($p<0.05$). Yield was positively correlated with oil content (0.37), the height of first pod (0.22) and the plant height (0.07) and negatively correlated with protein content (-0.34) and the 1000-grain weight (-0.27), (Table 3).

Table 3. Coefficients of correlations between of investigated traits, 2009-2010

	Protein content	Oil content	1000-seed weight	First pod height	Plant height
Yield	-0.34^{ns}	0.37^{ns}	-0.27^{ns}	0.22^{ns}	0.07^{ns}
Protein content	-	-0.45*	0.47*	-0.26^{ns}	0.13^{ns}
Oil content		-	-0.85**	0.34^{ns}	-0.40^{ns}
1000-grain weight			-	-0.42*	0.35^{ns}
First pod height				-	0.22^{ns}

ns – not significant; * and ** - significant at $p<0.05$ and $p<0.01$

Protein content was positively significantly correlated with 1000-grain weight (0.47*) and negatively significantly correlated with oil content (-0.45*) and negatively correlated with the height of first pod (-0.26) (Table 3).

Oil content was positively correlated with the height of first pod (0.34). 1000-grain weight was negatively highly significantly correlated with oil content in seed (-0.85**) and negatively significantly correlated with the height of first pod (-0.42*), and positively correlated with plant height (0.35). The interaction of the studied factors (year x genotype) also exhibited a statistically significant effect on the height of first pod (Table 3).

The negative correlation between protein and oil contents in grain corroborates the results of CHUNG *et al.* (2003). There was significant correlation between plant height and first pod height of the examined cultivars.

CONCLUSION

The studied characteristics varied significantly depending on genotype and year.

- The genotypes Galina, Valjevka and Victoria had relatively uniform yields.
- The 1000-grain weight for all genotypes was higher in 2010 than in 2009.
- Highest 1000-grain weights (149.27 g and 147.23) were achieved with the genotypes Valjevka and Victoria.
- The genotype Victoria had the highest first pod. The genotype Valjevka had lowest first pods.
- The average protein content for all genotypes was lower in 2009 than in 2010.
- The oil content was significantly higher in 2009 than in 2010, 22.43% and 19.73%, respectively. The highest oil content of 23.16% was brought by the genotype Tea in 2009.
- Yield was positively correlated with oil content, 0.37, the height of first pod, 0.22, and the plant height, 0.07, and negatively correlated with protein content, -0.34 and the 1000-grain weight, -0.27.
- There was a highly significant positive correlation between 1000-grain weight and protein content, 0.47*. Highly significant negative correlations were found between 1000-grain weight and oil content in grain, -0.85**, and significant negative correlations between protein and oil contents, 0.45*. A negative correlation was found between the height of first pod and protein content, -0.26. The height of first pod was positively correlated with oil content, 0.34.
- A significant genotype x year interaction was found for 1000-grain weight. The interactions genotype x year and genotype x genotype for the height of first pod were significant in both years.

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VARIJABILNOST I MEĐUZAVISNOST KOMPONENTI PRINOSA SOJE *GLYCINE MAX* (L.) MERR.

Vera POPOVIĆ[1], Miloš VIDIĆ[1], Đorđe JOCKOVIĆ[1], Jela IKANOVIĆ[2], Snežana JAKŠIĆ[1], Gorica CVIJANOVIĆ[3]

[1]Institut za ratarstvo i povrtarstvo, Novi Sad, Srbija
[2] Univerzitet u Beogradu, Poljoprivredni fakultet, Zemun, Srbija
[3]Megatrend Univerzitet Beograd, Fakultet za Biofarming, Bačka Topola, Srbija

I z v o d

U radu je proučavana varijabilnost i međuzavisnost komponenti prinosa i interakcija genotip spoljna sredina kod NS sorti soje. Istraživanje je izvedeno na Oglednom polju u Rimskim Šančevima tokom 2009. i 2010. godine. Ispitivana su sledeća svojstva: visina biljaka (cm) i visina prve mahune (cm), masa 1000 zrna (g) i prinos zrna soje (kg/ha) i sadržaj ukupnih proteina i ulja u zrnu (%). Sadržaj ukupnih proteina i ulja u zrnu soje određen je metodom infracrvene spektroskopije na aparatu PERTEN DA 7000, (NIR/VIS Spektrofotometar) nedestruktivnom metodom, na principu NIR (Near Infra Red) tehnike.

Sva proučavana svojstva signifikantno su varirala u zavisnosti od genotipa i godine. Najveći prinos 5.273 kg/ha u 2009.oj godini dao je genotip Victoria. Najveću masu 1000 zrna imali su genotipovi Valjevka i Victoria (149,27 gr i 147,23 gr) u obe godine. Najveću visinu prve mahune imao je genotip Victoria (19,40 cm), 2009.-2010. Najveći sadržaj proteina imali su genotipovi Valjevka i Victoria, dok je najveći sadržaj ulja imao genotip Tea (21,73 %). Sadržaj proteina bio je u pozitivnoj statistički značajnoj korelaciji sa masom 1000 zrna, a u negativnoj statistički značajnoj korelaciji sa sadržajem ulja, i negativnoj sa prinosom i visinom prve mahune. Sadržaj ulja bio je u pozitivnoj korelaciji sa visinom prve mahune, a u negativnoj ali statistički visoko značajnoj korelaciji sa masom 1000 zrna. Masa 1000 zrna bila je u negativnoj statistički značajnoj korelaciji sa visinom prve mahune.

Ova istraživanja predstavljaju osnov za dalje oplemenjivanje soje, poboljšanog prinosa semena i sadržaja proteina i ulja.

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