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Stability of soybean yield and quality components

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Varieties of testing are very important so we could evaluate which varieties are the best solution for the specific growing region. The aim of this research was to determine stability and correlations between yield, protein content and oil content in soybean cultivars. The research was carried out on ten NS soybean cultivars in 2009 and 2010. All of the analysed traits significantly varied depending on cultivar and year. The highest yield in the analysed period was found in cultivar Valjevka which was significantly higher than that of cultivars Afrodita and Balkan. The highest average yield in 2010 was found in cultivars Irina and Becejka. The highest protein content was found in cultivars Afrodita and Galina, while the highest oil content was found in cultivar Alisa. Significantly higher yield and protein content were gained in 2010, while significantly higher oil content was gained in 2009. Yield was insignificantly positively correlated with oil content both in 2009 and 2010, and negatively correlated with protein content. Oil content was significantly negatively correlated with protein content in 2009, while in 2010 this correlation was insignificant. This research is a basis for further breeding of soybeans with improved grain yield and content of protein and oil.

Key words: soybean, yield, protein and oil content, correlations, stability.

INTRODUCTION

Soybean (*Glycine max*. (L.) Merr.) has been present in Yugoslav and Serbian field crops production since the start of the 20th century, but the area sown to the crops has varied a lot (Miladinovic et al., 2011). Soybean (*Glycine max.* (L.) Merr.) is the most important legume crop and is one of the most important industrial plants in Serbia. Primary gene centre of soybean origin is north-eastern China. In Serbia, soybean is mostly grown in Vojvodina (Popovic, 2010). The chemical composition of soybean seed is one of the most important factor for processing industry (Zilic et al., 2009). The importance of this crop is primarily due to its chemical grain composition – circa 40% protein and 20% oil, amounting to more than 60% of nutrients. Yield grain, protein and oil content in soybean seed are determinate by genetic and environmental factors (Popovic, 2010, Miladinovic et al., 2011). During soybean seed development the four main stages can be observed: morphogenesis and cell division, cellenlargement, seed maturation, and ultimately the release of moisture and period of seed dormancy. Synthesis of proteins and oilstakes place during the growth phase of seed cells (Blamusa et al., 2000).

Adequate choice of soybean cultivar is of great importance for attaining high and stable yields (Popovic, 2010). An important feature of contemporary agriculture is growing high-yielding cultivars and hybrids that are resistant to diseases, pests and other adverse environmental conditions. These cultivars have been created primarily by using plant breeding methods based on selection of favourable genotypes and gene recombination in crossing and reselection. In soybean breeding, the focus of attention has been on yield increase and stability, that is, developing cultivars that are well-adapted to various growing conditions. Grain

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Table 1. Agrochemical soil analysis, Sremska Mitrovica, Serbia, 2009-2010.

Year	Humus (%)	pH in KCl	pH in H_2O	$CaCO_3$ (%)	P_2O_5 (mg/100 g)	K_2O (mg/100 g)
2009	2.8	7.4	8.2	8.6	12.5	21.7
2010	2.5	7.4	8.2	9.2	10.7	23.2

yield and quality are metric traits which are generally quantitatively inherited (polygenetic) and are strongly dependant on environmental conditions. For this reason, heritability for these traits is relatively low (Miladinovic et al., 2011), which is why in plant breeding attention is given to yield components which are mostly of simpler genetic base and are always more or less correlated with yield. In soybean breeding, special attention is given to developing cultivars with high contents of protein and oil, apart from high and stable yields (Hollung et al., 2005). Besides individual soybean grain components, processing industry finds the ratio between protein and oil content in soybean grain equally significant (Miladinovic et al., 2011). Since the mentioned traits are negatively correlated, the improvement of chemical composition must not decrease grain yield (Boroomandan et al., 2009; Popovic et al., 2012).

The perspectives of Soybean Department of Institute of Field and Vegetable Crops, Novi Sad lay in a successfully planned NS soybean seed production, based on contemporary cultivation practices, high cultivar yield potential equal to that of cultivars from other countries much more developed in agriculture, science and economy (Popovic et al., 2011).

The aim of this research was to determine productivity and interdependence between yield and quality components of soybean cultivars, as well as interaction GxE in ten NS soybean cultivars.

MATERIALS AND METHODS

Yield and chemical composition of soybean grain were analysed in this two-year trial (2009-2010) in Serbia, in Sremska Mitrovica, in the village of Kukujevci in 2009 and in the village of Lacarak in 2010. The trials were set up as randomized block design in three replicates with ten NS soybean cultivars of different maturity groups (0 and I). The 2009 trial was carried out on meadow black soil low in humus, calcareous and moderately alkaline, moderate in P_2O_5 and rich in K_2O. The 2010 trial was carried out on marshy black soil low in humus, highly calcareous, moderately alkaline, moderate in P_2O_5 and high in K_2O (Table 1).

Soybean was planted on April 14, 2009 and April 25, 2010 on a basic plot size of 10 m^2 with maize as the preceding crop. Plant density for 0 maturity group cultivars was 50 × 4 cm (500,000 plants ha^{-1}) and for I maturity group 50 × 4.4 cm (450,000 plants ha^{-1}). Before planting, soybean seeds were inoculated with microbiological preparation NS Nitragin which is produced by Institute of Field and Vegetable Crops, Novi Sad. NS Nitragin contains mixture of symbiotic bacterium strains *Bradyrhizobium japonicum*. During growing period, standard soybean cultivation practices were applied. In order to prevent negative effects of weeds, the trials were treated in the phase of 2 to 3 well-developed leaf blades with herbicides: Pulsar 40 L/ha + Harmony 8 g/ha in 2009, and Acetogal 1.8 L/ha + Mistral 0.35 kg/ha in 2010. Crops were harvested mechanically on September 4, 2009 and September 24, 2010.

Yield was measured after harvest and average samples were taken from each trial replicate to determine oil and protein content in grain. Total oil and protein content in grain was determined by infrared spectroscopy technique on the apparatus PERTEN DA 7000, (NIR/VIS Spectrophotometer) employing non-destructive method.

Experimental data were processed using descriptive and analytical statistics of STATISTICA 10 for Windows. Significance of differences between the calculated mean values of the analysed factors (year and genotype) was tested by two-factor analysis of variance (Maletic, 2005):

$$y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk},$$

I =1,2; j =1,2,...,5; k=3.

Significance assessment was calculated based on LSD test for probability levels 0.05% and 0.01%. Relative dependence was defined by method of correlation analysis, and the coefficients were t-tested for probability levels 0.05 and 0.01%. Stability tested traits evaluated on the basis of the relative increase in value in a more favorable compared to the less favorable year (%).

Weather conditions

Meteorological data were taken from the Meteorological station in Sremska Mitrovica. Meteorological data in year is different (Bran et al., 2008; Popovic et al., 2013). Mean monthly temperature in 2010 was 18.67°C, which exceeded long-term average by 0.19°C. During growing period in 2009 mean monthly temperature was 19.51°C which exceeded long-term average by 1.03°C for Sremska Mitrovica (18.48°C) as shown in Figure 1.

Precipitation quantity during soybean growing period in 2009 was 194.5 mm, which is by 154 mm less than long-term average for Sremska Mitrovica. In humid 2010 precipitation quantity was 509.5 mm, which exceeded long-term average by 160 mm for Sremska Mitrovica (Figure 1). The increase of production was also affected by weather conditions (Popovic et al., 2011). Weather conditions in both analysed years were different, which greatly affected soybean grain growth, development, yield and traits. Precipitation quantity and distribution were more favourable in 2010, resulting in higher yields and good grain quality (Figure 1 and Table 2). According to Popovic (2010), precipitation quantity and distribution during growing period in our conditions have the highest effect on yield and grain quality.

RESULTS AND DISCUSSION

Grain yield

The analysed soybean cultivars developed by Institute of Field and Vegetable Crops have extremely high yield potential and give very high yields in trials. The yields

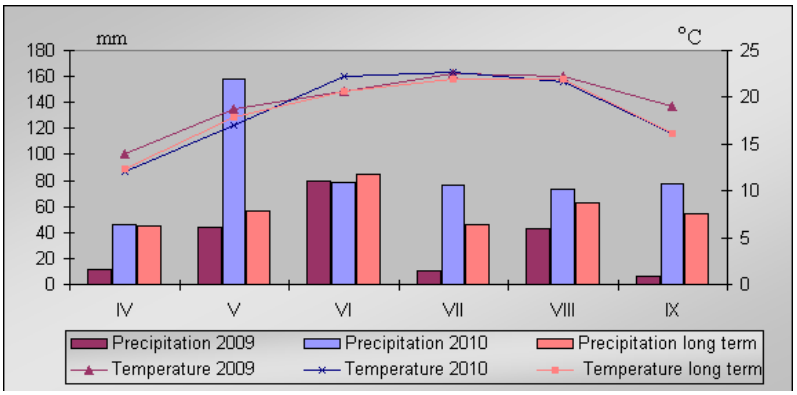

Figure 1. Precipitation sum (mm) and average monthly temperature (°C), Sremska Mitrovica, Serbia, 2009-2010.

Table 2. Yield (kg/ha) of NS soybean seed, Serbia, 2009-2010.

No.	Genotype	Yield, 2009 (t/ha)	Yield, 2010 (t/ha)	Stability (%)
1.	Galina	4240	5290	23.07
2.	Valjevka	4551	5230	16.00
3.	Bečejka	3694	5340	44.56
4.	Tara	3725	5220	40.13
5.	Alisa	3769	5280	40.09
6.	Proteinka	4511	5220	15.72
7.	Afrodita	3740	4360	16.58
8.	Irina	3336	5590	67.56
9.	Diva	4015	5010	24.78
10.	Balkan	3653	5240	43.44
Average		3923	5178	31.99

Indicator	LSD-test	Year	Genotype	Interaction
Yield	0.05	191.70	428.62	606.20
	0.01	256.48	573.51	811.07

differed significantly among the analysed cultivars ($p<0.01$). In the analysed period, average yield for all analysed cultivars was 4,551 kg/ha, ranging from 4,050 kg/ha (Afrodita) to 4,891 Kg/ha (Valjevka) as shown in Table 2.

All of tested genotypes showed high variability of yield. The highest average stability of yield in 2009-2010 was found in cultivars Proteinka, Valjevka and Afrodita (15.72, 16.00 and 16.58%) as compared to other tested cultivars (Table 2).

Average yields between years differed significantly ($p<0.01$). Yield in 2010 (5,177 kg/ha) was significantly higher than in 2009 (3,923 kg/ha) as shown in Figure 2. A great effect of environmental factors on yield was also determined by Aremu and Ojo (2005), Akande et al. (2009) and Popovic (2010).

Protein content

Environmental factors show significant effect on alterations of protein content in soybean grain. Protein content significantly differed between years ($p<0.01$), and was on average higher in 2010 than in 2009. Differences between cultivars were statistically significant ($p<0.01$). The highest protein content was found in cultivars Afrodita and Galina, which was significantly higher than in cultivars Valjevka, Proteinka, Irina, Diva and Balkan (Table 3 and Figure 3).

The results show that protein content is a cultivar-specific trait in soybean and is also strongly dependent on environmental factors, which is in accordance with the results of Vidic et al. (2010), Popovic (2012) and Poysa et al. (2006).

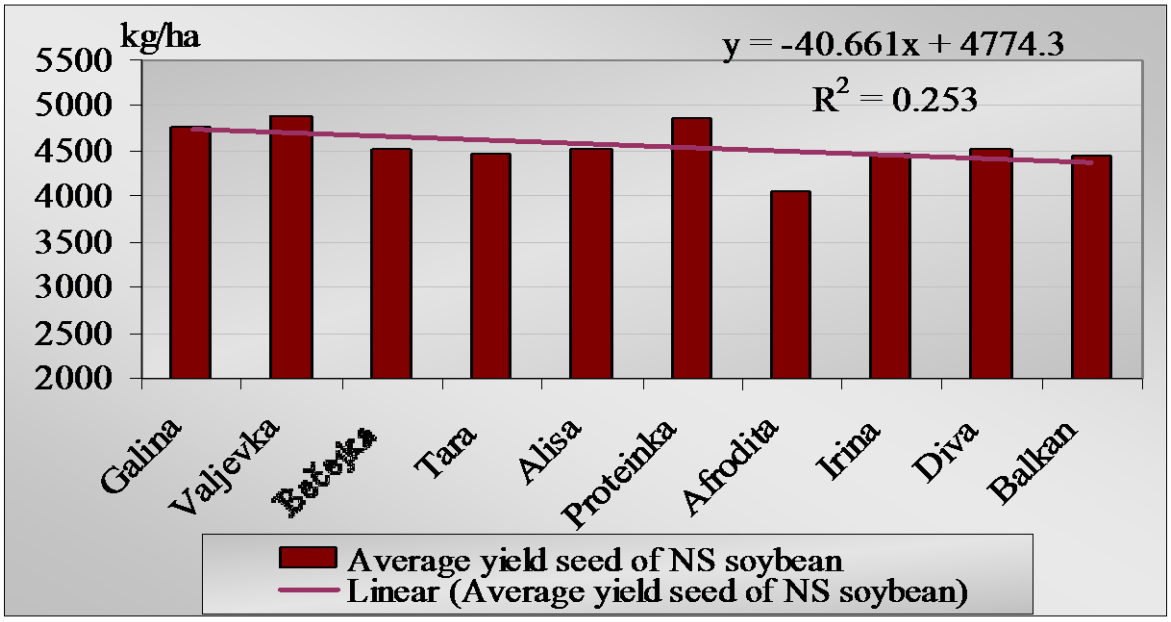

Figure 2. NS soybean seed yield (kg/ha), Serbia, 2009-2010.

Table 3. Protein content (%) of NS soybean seed, Serbia, 2009-2010.

S/N	Genotype	Protein content, 2009 (%)	Protein content, 2010 (%)	Stability (%)
1.	Galina	37.99	37.70	0.76
2.	Valjevka	37.03	37.26	0.62
3.	Bečejka	36.97	37.78	2.19
4.	Tara	37.33	37.46	0.35
5.	Alisa	36.99	36.92	0.19
6.	Proteinka	36.84	37.48	1.74
7.	Afrodita	38.01	37.71	0.79
8.	Irina	36.75	37.33	1.58
9.	Diva	36.61	37.03	1.86
10.	Balkan	36.48	37.16	0.75
Average		37.10	37.38	0.75

Indicator	LSD-test	Year	Genotype	Interaction
Protein	0.05	0.2887	0.6456	0.9129
Content	0.01	0.3863	0.8637	1.2215

All of tested genotypes showed high stability of protein content. The highest average stability of protein content in 2009-2010 was found in cultivars Alisa, Tara and Valjevka (0.15, 0.35 and 0.62%) (Table 3).

Oil content

Oil content in soybean grain was significantly different between years ($p<0.01$). In 2009 oil content was significantly higher (22.15%) than in 2010 (20.41%). All of tested genotypes showed variability of oil content. The highest average stability of oil content in 2009-2010 was found in cultivar Afrodita (4.31%) as compared to other tested cultivars (Table 1).

Cultivar Alisa showed significantly higher oil content (21.67%) than cultivars Galina, Afrodita and Balkan. Differences in oil content between other analysed cultivars were statistically insignificant ($p>0.05$). Cultivar Balkan showed the lowest oil content (20.95%) which

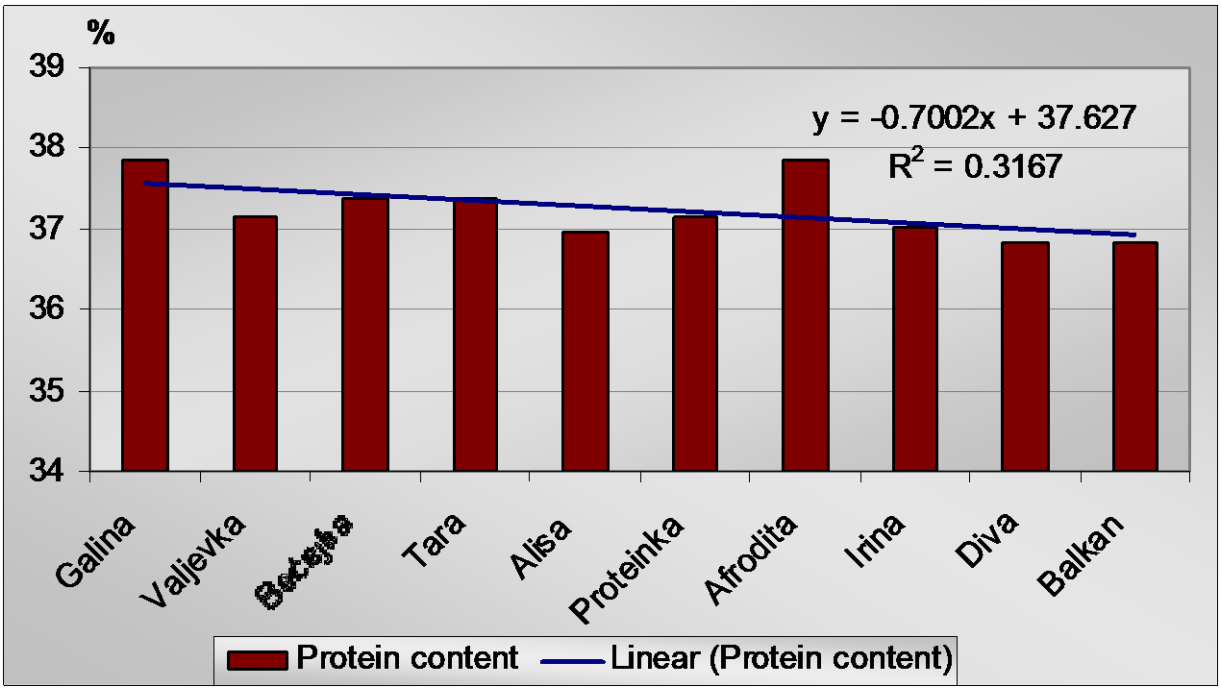

Figure 3. Average protein content (%) in NS soybean seed, Serbia, 2009-2010.

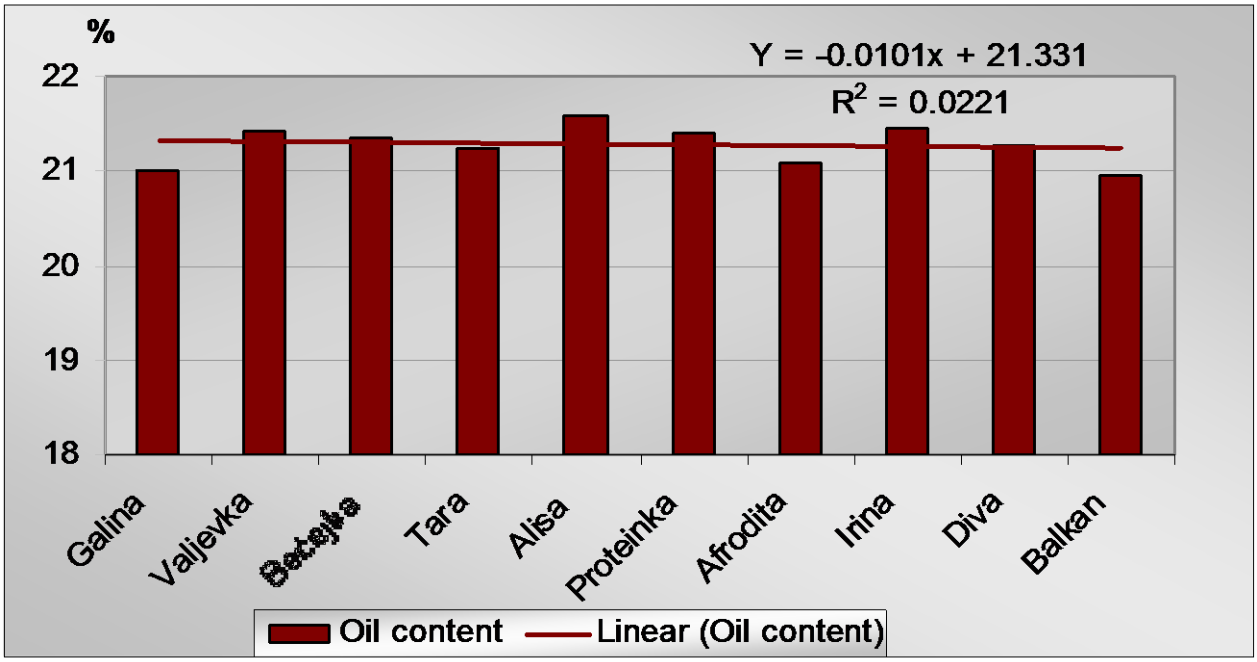

Figure 4. Average oil content (%) in NS soybean seed, Serbia, 2009-2010.

was significantly lower than in cultivar Alisa (Figure 4).

Protein and oil synthesis was more favourable in 2009 (59.27%) than in 2010 (57.78%). Total protein and oil content for all analysed cultivars in 2009-2010 was 58.52%, ranging from 57.77% (Balkan) to 59.0% (Afrodita). The highest total protein and oil content was found in cultivar Galina (59.73%) in 2009 (Tables 3 and 4 and Figure 5). Significant interactions between the

Table 4. Oil content (%) of NS soybean seed, Serbia, 2009-2010.

S/N	Genotype	Oil content, 2009 (%)	Oil content, 2010 (%)	Stability (%)
1.	Galina	21.73	20.28	7.15
2.	Valjevka	22.56	20.29	11.19
3.	Bečejka	22.37	20.33	10.03
4.	Tara	21.85	20.62	5.97
5.	Alisa	22.72	20.43	11.21
6.	Proteinka	22.65	20.14	12.46
7.	Afrodita	21.54	20.65	4.31
8.	Irina	22.13	20.78	6.50
9.	Diva	22.17	20.38	8.78
10.	Balkan	21.82	20.07	8.72
Average		22.15	20.40	8.58

Indicator	LSD-test	Year	Genotype	Interaction
Oil content	0.05	0.2227	0.4979	0.7043
	0.01	0.2979	0.6663	0.9423

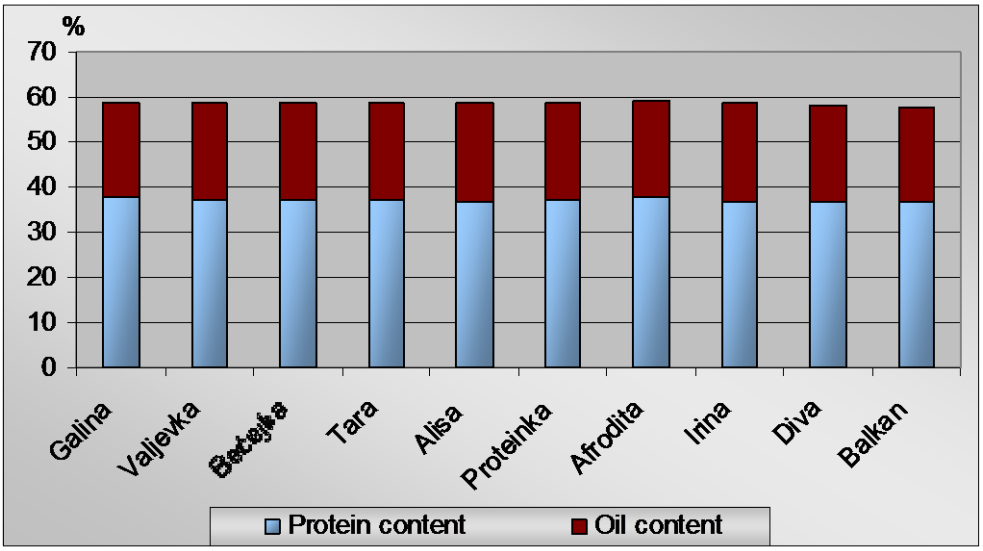

Figure 5. Total protein and oil content (%) in soybean grain, Serbia, 2009-2010.

analysed factors were determined, which shows that the analysed factors jointly increase their effect ($p<0.05$).

Grain chemical composition results show that, besides cultivar, growing conditions are also very important, which is in accordance with the results of Hurburgh (2000).

Correlations between the analysed traits

Soybean yield in 2009 was positively correlated with oil content (0.31) and negatively correlated with protein content (-0.12). Protein content was negatively but significantly correlated with oil content (-0.47*) as shown in Table 5.

Correlations between analysed traits in 2010 were not statistically significant. Soybean yield was positively correlated with oil content (0.17). Yield was negatively correlated with protein content (-0.19) and protein content was negatively correlated with oil content (-0.11) as shown in Table 6.

Interactions between the analysed factors (year x genotype) show statistically significant effect on protein and oil content (Tables 3 and 4). The results of negative correlations between yield and protein content, as well as between protein content and oil content are in accordance

Table 5. Correlations between grain yield and contents of protein and oil in soybean grain, 2009.

Parameter	Yield	Protein content	Oil content
Yield	-	-0.12^{ns}	0.31^{ns}
Protein content		-	-0.47*

^{Ns}Non significant; *significant at 0.05.

Table 6. Correlations between grain yield and contents of protein and oil in soybean grain, 2010.

Parameter	Yield	Protein content	Oil content
Yield	-	-0.19^{ns}	0.17^{ns}
Protein content		-	-0.11^{ns}

^{ns}Non significant.

with the results of other authors (Chung et al., 2003; Popovic et al., 2013).

Conclusions

Based on the results, the following conclusions can be drawn:

1. Interaction between the analysed factors (year x genotype) shows statistically significant effect on yield, protein content and oil content in soybean grain, which shows that the analysed factors jointly increase their impact ($p<0.05$). In humid 2010 average yield was significantly higher, while in 2009 oil content was significantly higher.
2. The highest average yields were gained by cultivars Irina (5,590 kg/ha) and Bečejka (5,340 kg/ha) in 2010,and cultivar Valjevka in 2009-2010 (4,891 kg/ha).
3. In 2009 a positive correlation was found between yield and oil content (0.31) as well as a significant negative correlation between protein content and oil content (0.47*), while these correlations in 2010 were not statistically significant.
4. Analysis of cultivar performance is a basis for further breeding of soybeans with increased yield potential and seed yield, as well as grain protein content and oil content.

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