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VARIABILITY AND CORRELATIONS BETWEEN SOYBEAN YIELD AND QUALITY COMPONENTS

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ABSTRACT

The aim of this research was to determine variability and correlations between yield, protein content and oil content in soybean cultivars. The research was carried out on ten NS soybean cultivars in 2008, 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 Proteinka (4,947 kg ha^{-1}) which was significantly higher than that of cultivars Becejka, Tara, Afrodita and Diva. The highest average yield in 2010 was found in cultivars Irina (5,590 kg ha^{-1}) and Bečejka (5,340 kg ha^{-1}). The highest protein content was found in cultivars Afrodita and Galina, while the highest oil content was found in cultivars Alisa, Valjevka and Alisa. Significantly higher yield were obtained in 2010, while significantly higher protein and oil content was recorded in 2008.

Yield was insignificantly positively correlated with oil content both in 2008, 2009 and 2010 (0.06, 0.31 and 0.17, respectively), and negatively but not significantly correlated with protein content (-0.06, -0.12 and -0.19, respectively). Oil content was significantly negatively correlated with protein content (-0.47*) in 2009, while in 2008 and 2010 this correlation was insignificant (-0.25, -0.11).

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 content, oil content, correlations.

INTRODUCTION

Soybean (*Glycine max* (L.) Merr.) is the most important legume crop (*Fabaceae*) and one of the most important protein crops in the world. Primary gene centre of soybean origin is north-eastern China (Popovic, 2010). In Serbia, soybean is mostly grown in Vojvodina. Depending on cultivar and growing conditions, soybean contains circa 35-41% protein and 19-22% oil. Due to this composition, soybean grain is the main nutritive component for millions of people worldwide (Popovic et al., 2011, 2013).

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, i.e. developing cultivars that are well-adapted to various growing conditions. Grain yield and quality are metric traits which are generally quantitatively inherited (polygenetic) and 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; Vidic et al., 2010).

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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., 2011). The aim of this research was to determine productivity and interdependence between yield and quality components of soybean cultivars, as well as interaction G x E in ten NS soybean cultivars.

MATERIAL AND METHODS

Yield and chemical composition of soybean grain were analysed in this three - year trial (2008-2010) in Sremska Mitrovica, in the village of Kukujevci (Slatine) in 2009 and in the village of Lacarak (Zabran) in 2008 and 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 2008 and 2010 trial was carried out on marshy black soil low in humus, highly calcareous, moderately alkaline, moderate in P_2O_5 and in 2010 high in K_2O (Table 1).Soybean was planted on April 17, 2008, 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 x 4 cm (500,000 plants ha^{-1}) and for I maturity group 50 x 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 2-3 well-developed leaf blades with herbicides: Pulsar40 1 l/ha + Harmony 8 g/ha in 2008 and 2009, and Acetogal 1.8 l/ha + Mistral 0.35 kg/ha in 2010. Crops were harvested mechanically on September 7, 2008, September 4, 2009 and September 24, 2010.

Table 1. Agrochemical soil analysis, Sremska Mitrovica, Serbia, 2008-2010

Year	Humus (%)	pH (KC1)	pH (H_2O)	$CaCO_3$ %	P_2O_5 mg/100 g	K_2O mg/100g
2008	2.7	7.3	8.3	8.4	12.3	21.5
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

*Popovic et al, 2013.

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 8 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 was calculated based on LSD test for probability levels 5% and 1%. Relative dependence was defined by method of correlation analysis, and the coefficients were t-tested for probability levels 5% and 1%.

Meteorological conditions

Meteorological data were taken from the Meteorological station in Sremska Mitrovica. Meteorological data in year is different (Bran et al, 2008). Mean monthly temperature in 2008 and 2010 was 18.51°C and 18.64°C, which exceeded long-term average by 0.03°C

and 0.19°C. During growing period in 2009 mean monthly temperature was 19.51°C which exceeded average 2008 and 2010 by 1°C and 0.88°C and which exceeded long-term average by 1.03°C for Sremska Mitrovica (18.48°C) as shown in Figure 1.

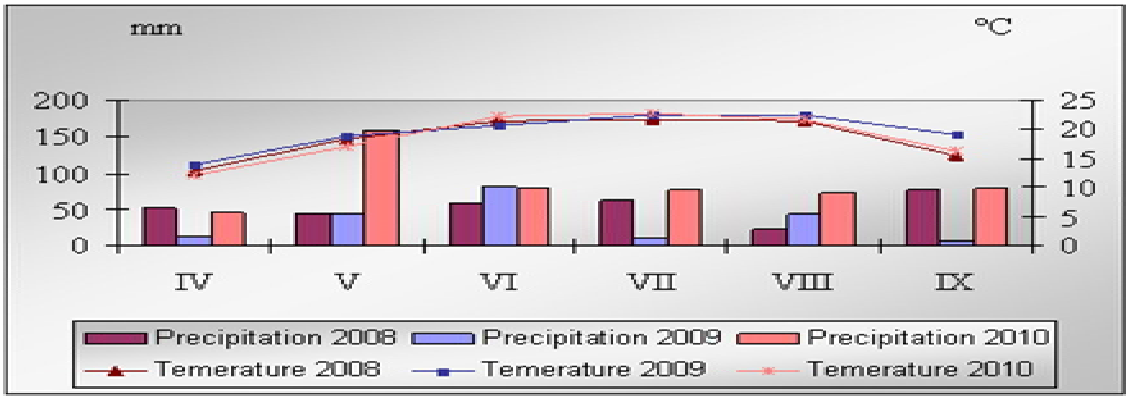

Figure 1. Precipitation sum (mm) and average monthly temperature (°C), Sremska Mitrovica, Serbia, 2008-2010

Precipitation quantity during soybean growing period in 2008 was 313.1 mm. 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).

RESULTS AND DISCUSSION

Weather conditions in three 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.

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 differed significantly among the analysed cultivars ($p<0.01$). In the analysed period, average yield for all analysed cultivars was 4,661 kg ha^{-1}, ranging from 4,354 (Afrodita) to 4, 947 (Proteinka) as shown in Table 2.

Table 2. Seed grain yield (kg ha^{-1}) of NS soybean, 2008-2010

No.	Genotype	Yield, 2008 (kg ha^{-1})	Yield, 2009* (kg ha^{-1})	Yield, 2010* (kg ha^{-1})	Yield, Average (kg ha^{-1})
1.	Galina	4,503	4,240	4,290	4,678
2.	Valjevka	4,621	4,551	5,230	4,801
3.	Bečejka	4,774	3,694	5,340	4,603
4.	Tara	4,556	3,725	5,220	4,500
5.	Alisa	5,086	3,769	5,280	4,712
6.	Proteinka	5,111	4,511	5,220	4,947
7.	Afrodita	4,936	3,74	4,360	4,345
8.	Irina	5,199	3,336	5,590	4,708
9.	Diva	4,758	4,015	5,010	4,594
10.	Balkan	5,256	3,653	5,240	4,716
Average		4,880	3,923	5,178	4,661

*Popovic et al, 2013.

Indicator	LSD-test	Year	Genotype	Interaction
Yield	0.05	178.198	325.340	563.512
	0.01	234.004	432.708	749.471

Table 2a. ANOVA for yield

Univariete Tests of Significance for yield, Sigma-restricted parameterization Effective hypotesis decomposition					
	SS	Degree of freedom	MS	F	p
Intercept	1,954795E+09	1	1,954795E+09	16415,84	0,000000
Genotype	2,1686540E+06	9	2,409600E+05	2,02	0,051970
Year	2,577981E+07	2	1,288990E+07	108,25	0,000000
Genotype x Year	6,888782E+06	18	3,827101E+05	3,21	0,000354
Error	7,144791E+06	60	1,190799E+05		

Average yields between years differed significantly ($p<0.01$). Yield in 2010 (5,178 kg ha^{-1}) was significantly higher than in 2008 (4,880 kg ha^{-1}) and was significantly very higher than in 2009 (3,923 kg ha^{-1}) as shown in Tables 2 and 2a.

A great effect of environmental factors on yield was also determined by Aremu and Ojo (2005), Akande et al. (2009) and Popovic (2010).

Interactions between the analysed factors (year x genotype) show statistically significant effect on yield ($p<0.01$).

Protein content

Protein content significantly differed between years ($p<0.01$), and was on average significantly higher in 2008 than in 2009 and 2010. Environmental factors show significant effect on alterations of protein content in soybean grain.

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, Irina, Diva and Balkan (Tables 3 and 3a).

Table 3. Protein content (%) of NS soybean, 2008-2010

No.	Genotype	Protein content. 2008, (%)	Protein content* 2009, (%)	Protein content* 2010, (%)	Protein content. Average, (%)
1.	Galina	38.40	37.99	37.70	38.03
2.	Valjevka	38.30	37.03	37.26	37.53
3.	Bečejka	38.30	36.97	37.78	37.68
4.	Tara	38.80	37.33	37.46	37.86
5.	Alisa	38.80	36.99	36.92	37.57
6.	Proteinka	38.90	36.84	37.48	37.74
7.	Afrodita	38.80	38.01	37.71	38.17
8.	Irina	38.20	36.75	37.33	37.43
9.	Diva	38.00	36.61	37.03	37.21
10.	Balkan	38.40	36.48	37.16	37.35
Average		38.49	37.10	37.38	37.66

*Popovic et al, 2013.

Indicator	LSD-test	Year	Genotype	Interaction
Protein content	0.05	0.2601	0.4749	0.8225
	0.01	0.3459	0.6316	1.0938

Table 3a. ANOVA for protein

Univariete Tests of Significance for protein, Sigma-restricted parameterization Effective hypotesis decomposition					
	SS	Degree of freedom	MS	F	p
Intercept	127732,9	1	127732,9	503535,4	0,000000
Genotype	7,9	9	0,9	3,5	0,001651
Year	33,8	2	16,9	66,5	0,000000
Genotype x Year	4,7	18	0,3	1	0,450335
Error	15,2	60	0,3		

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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).

Interactions between the analysed factors (year x genotype) showed statistically significant effect on protein content ($p<0.01$).

Oil content

Oil content in soybean grain was significantly different between years ($p<0.01$).

In 2008 and 2009 oil content (22.34%, 22.15%) was significantly higher than in 2010 (20.41%) (Table 4).

Cultivars Proteinka, Alisa and Valjevka showed significantly higher oil content than cultivars Galina and Balkan. Differences in oil content between other analysed cultivars were statistically insignificant ($p>0.05$). Cultivars Galina and Balkan showed the lowest oil content which was significantly lower than in cultivar Alisa, Proteinka and Valjevka (Tables 4 and 4a).

Table 4. Oil content (%) of NS soybean, 2008-2010

No.	Genotype	Oil content. 2008, (%)	Oil content* 2009, (%)	Oil content* 2010, (%)	Oil content. Average, (%)
1.	Galina	21.10	21.73	20.28	21.37
2.	Valjevka	22.50	22.56	20.29	21.78
3.	Bečejka	22.40	22.37	20.33	21.70
4.	Tara	22.00	21.85	20.62	21.49
5.	Alisa	22.20	22.72	20.43	21.78
6.	Proteinka	22.60	22.65	20.14	21.80
7.	Afrodita	22.60	21.54	20.65	21.60
8.	Irina	22.30	22.13	20.78	21.74
9.	Diva	22.40	22.17	20.38	21.65
10.	Balkan	22.30	21.82	20.07	21.40
Average		22.34	22.15	20.40	21.63

*Popovic et al, 2013.

Indicator	LSD-test	Year	Genotype	Interaction
Oil content	0.05	0.1972	0.3599	0.6234
	0.01	0.2622	0.4787	0.8229

Table 4a. ANOVA for oil

Univariete Tests of significance for oil, sigma-restricted parameterization, effective hypotesis decomposition					
	SS	Degree of freedom	MS	F	p
Intercept	42139,57	1	42139,57	289111,3	0,000000
Genotype	2,1	9	0,23	1,6	0,134731
Year	69,91	2	34,96	239,8	0,000000
Genotype x Year	4,92	18	0,27	1,9	0,036035
Error	8,75	60	0,15		

Interactions between the analysed factors (year x genotype) showed statistically significant effect on oil content ($p<0.01$).

Protein and oil synthesis was more favourable in 2008 (60.83 %) than in 2009 and 2010 (59.27% and 57.78%). Total protein and oil content for all analysed cultivars in 2008-2010 was 59.29%, ranging from 58.74% (Balkan) to 59.77% (Afrodita). The highest total protein and oil content was found in cultivar Afrodita and Proteinka (61.40 %, 61.50%) in 2008 (Tables 3 and 4, Figure 1). Significant interactions between the analysed factors were determined, which shows that the analysed factors jointly increase their effect ($p<0.05$).

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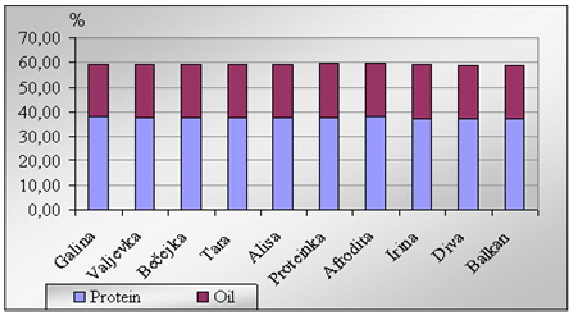

*Fig.1.*Total protein and oil content (%) in soybean grain, 2008-2010

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), but correlations were not significant. Protein content in 2009 was significantly correlated negatively with oil content (-0.47*) as shown in Table 6. Correlations between analysed traits in 2008 and 2010 were not statistically significant. Soybean yield was positively correlated with oil content (0.06, 0.17). Yield was negatively correlated with protein content (-0.06, -0.19) and protein content was negatively correlated with oil content (-0.25, -0.11) as shown in Tables 5 and 7.

Table 5. Correlations between grain yield and contents of protein and oil in soybean grain, 2008

Parameter	Yield	Protein	Oil
Yield	-	-0.06^{ns}	0.06^{ns}
Protein		-	-0.25^{ns}

^{ns} non significant;

Table 6. Correlations between grain yield and contents of protein and oil in soybean grain, 2009

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

^{ns} non significant; *significant at 0.05.

Table 7. Correlations between grain yield and contents of protein and oil in soybean grain, 2010

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

^{ns} non significant.

The results of negative correlations between yield and protein content, as well as between protein content and oil content are in accordance with the results of other authors (Chung et al., 2003; Miladinovic et al., 2006; Popovic et al., 2011, 2012).

CONCLUSIONS

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

- Interaction between the analysed factors (year x genotype) showed statistically significant effect on yield, protein content and oil content in soybean grain, which showed that the analysed factors jointly increase their impact ($p<0.05$). In humid 2010 average yield was significantly higher, while in 2008 protein and oil content was significantly higher.
- The highest average yields were gained by cultivars Irina (5,590 kg ha^{-1}) and Becejka (5,340 kg ha^{-1}) in 2010, and cultivars Proteinka and Valjevka in 2009-2010 (4,947 kg ha^{-1} and 4,801 kg ha^{-1}).
- 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 2008 and 2010 were not statistically significant.
- 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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