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EFFECT OF AGROECOLOGICAL FACTORS ON VARIATIONS IN YIELD, PROTEIN AND OIL CONTENTS IN SOYBEAN GRAIN

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ABSTRACT

This paper presents the grain yields and protein and oil contents of NS soybean cultivars of 0 maturity group grown for three successive years. The average yield for all cultivars was 3,335 kg ha^{-1}. The 2010 yields were significantly higher than the three-year average yield. The cultivar Becejka had a significantly higher grain yield per unit area (3,628 kg ha^{-1}) and higher yields of proteins and oil (1,355 kg ha^{-1} and 769.50 kg ha^{-1}, respectively) than the other cultivars.

The highest protein content (40.56%) was recorded in 2008. The average protein content for all cultivars was 37.60%. The cultivar Proteinka had significantly higher three-year average protein content (38.21%) than the other cultivars, except Tara. The average oil content for all tested cultivars was 21.31%. The cultivar Afrodita had the highest average oil content 21.55%. Statistically significant differences were recorded in grain yield and protein and oil contents and yield, which were due to cultivar and test year.

Soybean yield varied according to temperature and quantities and distribution of precipitation. Yield was positively highly significantly correlated with precipitation (r=0.94), and negatively highly significantly correlated with temperature (r=-0.61**).**

Key words: soybean, ecological factors, yield, protein and oil content, yield of protein and oil.

INTRODUCTION

The economic importance of soybean [*Glycine max (*L.) Merr.] lies in the fact that it is an important raw material in the food processing industry. It is the main source of high-quality proteins and oil for millions of people. Soybean-based products do not contain cholesterol and saturated fatty acids and they exhibit dietary and preventive effects. The amount of 100 grams of soybean contains 1787 kJ, 38% of total proteins, 19% of oil and 26% of carbohydrates (Popovic, 2010). Due to a favorable composition, soybean is classified among major sources of vegetable protein and oil. Climate has a major impact on the growth and development of plants. Since climatic factors such as light, heat, air and water cannot be successfully controlled by the man, they often occur as limiting factors in crop production. The soybean has strong roots and for their proper development, particularly for the development of nodular bacteria, it is important that the soil is neither acidic nor saline, that it has good water-air properties and sufficient amounts of nutrients in the available form (Miladinovic et al., 2008). According to Hurburgh (2000), environmental conditions prevailing during the phase of growth and specific features of the cultivar are important factors that influence the chemical composition of soybean grain. High yield and quality of soybean grown under different environmental conditions are secured, in addition to optimal cultural practices, by a proper choice of cultivar. Although oil and protein contents are quantitative traits, they can be modified by breeding (Hollung et al., 2005; Vidic et al., 2010). When breeding for improved chemical composition, it is important not to reduce grain yield, since these properties are generally in a strong negative correlation, especially grain yield and protein content and protein content and oil content in soybean grain (Chung et al., 2003).

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The objective of this study was to determine the variability of yield and protein and oil contents in soybean grain depending on cultivar and year of growing.

MATERIAL AND METHODS

The reaction of cultivars of agroecological conditions was studied in the location of Pancevo, in the period 2008-2010, on the calcareous chernozem soil on the loess terrace, which had high humus content, medium carbonate content and low alkali content. We studied five early soybean cultivars (0 maturity group): Becejka, Proteinka, Alisa, Tara and Afrodita. The last cultivar served as a standard. The experiment was set up according to a modified block design in three replications. Sowing was done at an optimal time, using a planter for small-plot trials, in the row distance of 50 cm and 3-5 cm distance in the row. The size of the experimental unit was 10 m^2. The previous crops were small grains. During seedbed preparation, 200 kg/ha of NPK nutrients (15:15:15) were applied. Crop density was 500,000 plants per ha. Conventional soybean growing technology was applied in the experiment. Harvest was performed at technological maturity stage, with a harvester for small-plot trials. This study is part of continual examination of soybean cultivars. Protein and oil contents in grain were determined by infrared spectroscopy technique on Perten DA 7000 NIR/VIS spectrophotometer, applying a non-destructive method.

The obtained experimental data were analysed by descriptive and analytical statistical methods using the statistical package STATISTICA 10 for Windows. Significance of differences between the calculated mean values of the studied characteristics (year and genotype) was tested by the two-way analysis of variance (Maletic, 2005):

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

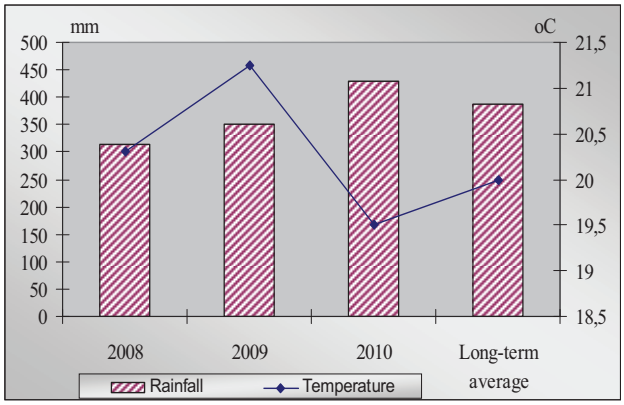
i=1,2, j=1,2,...,5, k=3

All significant values obtained in the LSD test were calculated for significance levels of 5% and 1%. 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%. Stability tested traits determined by the coefficients of variation (%). Most important characteristics are presented in tables and graphs.

Ecological conditions

Data gathered at the meteorological station of PDS Tamis Institute in Pancevo were used for the analysis of weather conditions. The experimental location has a moderate continental climate. The average air temperature for the studied period was 20.4ºC, which is 0.4ºC over the average for the period 1999-2010. The highest average annual temperature (21.25ºC) was recorded in 2009, which was 1.25ºC higher than the long-term average for the location of Pancevo, Serbia.

The average rainfall sum for the studied period was 367.5 mm, ranging from 313.2 (2008) to 429.8 mm (2010). The most favourable water regime was in 2010, which was humid, with the amount of rainfall 42.93 mm higher than the twelve-year average for this area (Graph l).



Graph 1. Average temperature and rainfall for the soybean growing season, Pancevo, Serbia

Ecological conditions in years are different (Bran et al., 2008, Malesevic et al., 2010, Popovic, 2010). The monthly distribution of rainfall was favourable in 2009 and 2010, which favourably affected the germination and growth of soybean plants. In 2008, the rainfall was below the long-term average and the monthly distribution was

unfavourable, resulting in slower plant germination and growth of soybean and lower yields of soybean.

RESULTS AND DISCUSSION

Soybean cultivars under study showed statistically significant differences in grain yield and protein and oil contents that were due to the cultivar and the year of growing. The average yield for all cultivars and the studied period amounted to 3,335 kg ha^{-1}. The yields of the cultivars varied significantly from year to year ($p<0.05$). The 2010 average yield (4,423 kg ha^{-1}) was significantly higher than the 2009 and 2008 yields (3,081 kg ha^{-1} and 2,498 kg ha^{-1}, respectively). The 2008 yields were significantly lower than those obtained in the other years. The cultivar Becejka had a significantly higher average yield per unit area (3,628 kg ha^{-1}) than the other cultivars. The cultivar Becejka had a significantly higher yield in 2010 (5,020 kg ha^{-1}). The cultivar Afrodita had the lowest average yield, which was 13.20% lower than that of the highest yielding cultivar (Table 1). Stability of yield is presented in table 6.

Table 1. Average yields (kg ha^{-1}) in soybean cultivars. Serbia, 2008-2010

Cultivar	Yield (kg/ha)			
	2008	2009	2010	Average
Becejka	2,815	3,050	5,020	3,628
Proteinka	2,515	2,891	4,230	3,188
Alisa	2,465	3,272	4,350	3,362
Tara	2,417	3,366	4,250	3,344
Afrodita	2,279	2,898	4,266	3,149
Average 2008	2,498	-	-	2,498
Average 2009	-	3,081	-	3,081
Average 2010	-	-	4,423	4,420
Average 2008/2010	-	-	-	3,335

Indicator	LSD test	Year	Genotype	Interaction
Yield	0.5	142.25	183.65	318.09
	0.1	191.57	247.32	428.38

The genotype x year interaction had a highly significant impact on the yield performance of the tested cultivars ($p<0.05$).

The protein content in soybean grain differed significantly among the cultivars and years ($p<0.05$). The average protein content for the period 2008-2010 was 37.60%. The 2008 average protein content (40.56%) was significantly higher than the 3-year average, while the 2009 average content was significantly lower than the 3-year average. Grain varieties, in the study period, the cultivar Proteinka had significantly higher protein content than the other cultivars, while the cultivar Afrodita had the lowest protein content (Table 2). The genotype x year interaction exhibited a statistically significant effect on protein content in soybean grain ($p<0.05$).

The average yield of protein in the studied period was 1,254 kg ha^{-1} (Table 3). The highest yield of proteins was achieved by the cultivar Becejka (1,355 kg ha^{-1}). The highest average yield of proteins (1,643 kg ha^{-1}) was obtained in 2010.

The average oil content for the period 2008-2010 was 21.31%. The oil content in grain differed significantly among the years ($p<0.05$).

The cultivar Proteinka had a significantly lower oil content compared to the other cultivars, except Becejka where the difference was within the statistical error.

Table 2. Protein content (%) in NS soybean cultivars. Serbia, 2008-2010

Source of variation	Protein content (%)			
Cultivar	2008	2009	2010	Average
Becejka	39.90	34.60	37.54	37.35
Proteinka	41.60	35.28	37.76	38.21
Alisa	40.30	34.87	37.44	37.54
Tara	41.10	35.30	37.35	37.92
Afrodita	39.90	35.21	35.81	36.97
Average 2008	40.56	-	-	-
Average 2009	-	35.05	-	-
Average 2010	-	-	37.18	-
Average 2008/2010	-	-	-	37.60

Indicator	LSD test	Year	Genotype	Interaction
Protein content	0.5	0.47	0.61	1.05
	0.1	0.63	0.81	1.41

Table 3. Protein yield (kg ha^{-1}) in NS soybean cultivars. Serbia, 2008-2010

Source of variation	Protein yield (kg/ha)			
Cultivar	2008	2009	2010	Average value
Becejka	1,123	1,055	1,885	1,355
Proteinka	1,046	994	1,597	1,218
Alisa	994	1,141	1,629	1,262
Tara	993	1,188	1,587	1,268
Afrodita	909	1,020	1,528	1,164
Average 2008	1,013	-	-	-
Average 2009	-	1,080	-	-
Average 2010	-	-	1,644	-
Average 2008/2010	-	-	-	1,254

Indicator	LSD test	Year	Genotype	Interaction
Protein yield	0.5	110.978	143.273	248.156
	0.1	149.457	192.948	334.196

The other cultivars did not differ significantly in oil content. The average oil content achieved in 2008 soybean was significantly higher than the contents obtained in the other test years (Table 4). The cultivar by year interaction too was statistically significant ($p<0.05$).

Table 4. Oil content (%) in NS soybean cultivars. Serbia, 2008-2010

Source of variation	Oil content (%)			
Cultivar	2008	2009	2010	Average value
Becejka	21.80	20.98	20.85	21.21
Proteinka	21.10	20.52	20.96	20.86
Alisa	21.50	21.56	21.52	21.53
Tara	21.80	21.00	21.31	21.37
Afrodita	21.90	20.68	21.71	21.55
Average 2008	21.62	-	-	-
Average 2009	-	20.95	-	-
Average 2010	-	-	21.27	-
Average 2008/2010	-	-	-	21.31

Indicator	LSD test	Year	Genotype	Interaction
Oil content	0.5	0.37	0.48	0.82
	0.1	0.50	0.64	1.11

The average oil yield for all cultivars tested in the period 2008-2010 was 710 kg ha^{-1}. The highest oil yield was achieved by the cultivar Becejka (767 kg ha^{-1}). The highest average oil yield (940 kg ha^{-1}) was obtained in 2010, the lowest (540 kg ha^{-1}) in 2008 (Table 5).

Table 5. Oil yield (kg ha^{-1}) in NS soybean cultivars. Serbia, 2008-2010

Source of variation	Oil yield (kg/ha)			
Cultivar	2008	2009	2010	Average value
Becejka	614	640	1,047	767
Proteinka	531	578	887	665
Alisa	530	705	936	724
Tara	527	707	906	714
Afrodita	499	599	926	678
Average 2008	540	-	-	-
Average 2009	-	645	-	-
Average 2010	-	-	940	-
Average 2008/2010	-	-	-	710

Indicator	LSD test	Year	Genotype	Interaction
Oil yield	0.5	37.549	48.466	83.947
	0.1	50.559	65.271	113.053

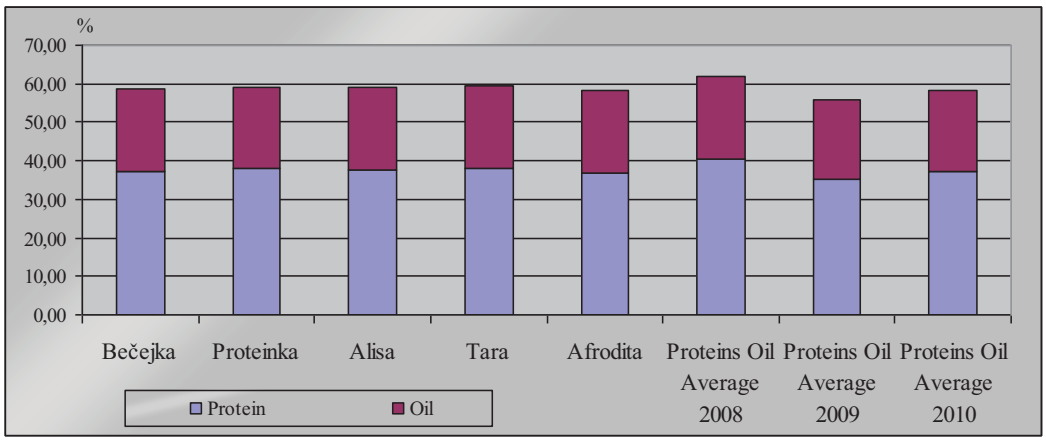
Table 6. Coefficients of variation (%) of main traits in tested cultivars during 2008-2010

Cultivar	Yield (%)	Protein content (%)	Oil content (%)
Becejka	39.80	10.06	3.15
Proteinka	38.80	10.73	2.64
Alisa	39.11	10.21	0.21
Tara	35.95	11.63	1.95
Afrodita	42.99	8.83	4.05
Average 2008	14.88	2.95	2.63
Average 2009	12.48	1.42	3.49
Average 2010	12.08	3.75	2.85
Average 2008/2010	39.35	10.30	2.23

* Coefficient of variation

Large variations were recorded in the pooled values of protein and oil contents, which ranged from 56.00% (2009) to 62.18% (2008). The average pooled content of proteins and oil for all tested soybean cultivars and for the period 2008-2010 was 58.91% (Graph 2).

The large variations in yield and contents of proteins and oil indicated that, in addition to genetic factors and applied cultural practices, these characteristics were also affected by the agroecological factors of the location. Similar results were obtained by Vidic et al. (2010) and Popovic et al. (2012).



Graph 2. Pooled protein and oil contents in NS soybean grain. Serbia, 2008-2010

Correlations between individual characteristics

Correlations are important indicators in soybean breeding programs. The significant correlations between the examined factors suggest mutual synergies between their effects ($p<0.05$).

Yield was positively highly significantly correlated with protein yield (r=0.87**), the oil yield (r=0.99**) and precipitation (r=0.94**), and positively not significantly correlated with oil content (r=0.09).

High negative significant correlations were found between yield and temperature (r=-0.61**) and a negative significant correlation was found between yield and protein content (r=-0.37*) (Table 7).

Table 7. Coefficients of correlations between of tested traits, during 2008-2010

Indicator	Yield	Protein content	Oil content	Protein yield	Oil yield	Temperature	Precipitation
Yield	-	-0.37*	0.09ns	0.87**	0.99**	-0.61**	0.94**
Protein content	-	-	-0.27ns	-0.10ns	-0.33*	-0.41*	-0.42*
Oil content	-	-	-	-0.01ns	-0.03ns	-0.25ns	0.15ns
Protein yield	-	-	-	-	0.87**	-072**	0.82**
Oil yield	-	-	-	-	-	-0.63**	0.93**

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

Soybean seed yield varied according to temperature and precipitation quantity and distribution. Many studies showed that increased soybean yields are a result of adequate and timely application of cultivation practices (Al-Ithawi et al., 1980, Miladinovic at al., 2008, Vidic et al., 2010, Popovic et al., 2011, 2012a) which can correct adverse meteorological conditions.

CONCLUSION

Following conclusions can be drawn on the basis of the three-year study:

– Genotype and year were found to cause statistically significant differences in yield, protein and oil content ($p<0.05$). Average yields were significantly higher in 2010 (4,423 kg ha^{-1}) compared to 2008 and 2009 yields. 2008 was the best year for the synthesis of proteins and oil in soybean grain, for all tested cultivars (40.56% and 21.62%, respectively), while the highest protein and oil yields were achieved in 2010 (1,644 kg ha^{-1} and 940 kg ha^{-1}, respectively).

– The interaction genotype x year had a statistically significant impact on grain yield and protein and oil contents in soybean grain ($p<0.05$).

– The cultivar Becejka had significantly higher yields of grain, oil and proteins (3,628 kg ha^{-1}, 1,355 kg ha^{-1} and 767 kg ha^{-1}, respectively) than the other cultivars. The cultivar Proteinka achieved the highest protein content and the cultivar Afrodita the highest oil content.

– Yield was positively highly significantly correlated with precipitation (r=0.94**), and negatively highly significantly correlated with temperature (r=-0.61**). Soybean yields varied according to temperature and quantities and distribution of precipitation.

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