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GENOTYPIC SPECIFICITY OF SOYBEAN [*GLYCINE MAX.* (L) MERR.] UNDER CONDITIONS OF FOLIAR FERTILIZATION

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ABSTRACT

Knowledge of genetic traits that affect yield and chemical composition of soybean grain is vital for the organization of an effective soybean breeding program. Two-year trials (2009-2010) were carried out at the Rimski Sancevi Experiment Field of the Institute of Field and Vegetable Crops in three replications. We assessed the impact of foliar fertilization with a complex liquid fertilizer that combined macroelements (N, P, K - 12:4:6, respectively) and microelements (Fe, Mn, Cu, B, Zn) on yield and grain chemical compositions of NS soybean cultivars of different maturity groups. The following traits were monitored: 1000-grain weight (g), soybean grain yield (kg/ha), and total protein and oil contents and protein and oil yield in soybean grain. All traits varied significantly depending on variety and year. On average, all cultivars had higher yield and 1000-grain weight in the variant with foliar fertilization than in the control. The highest yield in the control variant was achieved by the cultivar Victoria (5273 kg ha^{-1}) in 2009, while the highest yield in the variant with foliar fertilization was achieved by the cultivar Tea (5333 kg ha^{-1}) in 2010. The average weight of 1000 grains was significantly higher in 2010 (161.2 g) than in 2009 (132.4 g). The lowest average 1000-grain weight was registered for the cultivar Galina (140 g). The cultivar Victoria had the highest protein content in the control variant, while the cultivar Tea had the highest oil content (21.73%). In the variant of foliar fertilization, the cultivar Tea had significantly higher contents of proteins and oil than the other tested varieties.

The values of the coefficient of correlation between the studied traits in the variant of foliar fertilization were similar to the values in the control variant. The oil content was significantly and negatively correlated with 1000-grain weight (r=-0.86, r=-0.80**) and negatively correlated with protein content in soybean (r=-0.42, r=-0.04) in both the control variant and the variant with foliar fertilization. The yield was negatively correlated with protein content (r=-0.36, r=-0.05) in the control variant and the variant with foliar fertilization.**

The obtained results indicate that the yield, protein and oil content in soybean is a cultivar characteristic, but it is also strongly affected by the environment and affected by the foliar fertilization.

Key words: *Glycine max*, yield, 1000-grain weight, protein and oil content, foliar fertilization.

INTRODUCTION

Soybean (*Glycine max.* (L.) Merr.) is one of the most important crops in the world. In order for the genetic potential of a variety to be realized to as great an extent as possible, it is necessary to select the right varieties for any specific set of growing conditions (Popović, 2010). If we accept that genotype response to differences among locations can be defined as adaptability and genotype response to differences between years as stability, it then follows that success in the spread of a variety depends on its adaptability (Miladinović et al., 2011). Soybean growing aims to achieve high and stable yields per unit area and to produce yields that are of good quality, i.e. that have high oil and protein contents. On average, soybean seeds are 35-42% protein and 19-22% oil. The protein and oil components of mature soy beans account for 56 to 62% of their total dry weight (Popović et al., 2011). Soy proteins contain almost all of the essential amino acids and are the most similar to animal proteins. Soybean grains contain the following amino

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acids: lysine (6-7%), tryptophan (2%), methionine (1%), histidine (3%), arginine (12-13%), threonine (4-5%), phenylalanine (5%), serine (5-6%), glutamine (20%), proline (4-5%), glycine (4%), leucine (8%), tyrosine (4%), alanine (5%), isoleucine (5%), valine (4-5%), methionine (1%), and cysteine (1%), as well as about 400 free amino acids in addition to that (Miladinović et al., 2011, citation: Lescenko et al., 1987). Soybean oil is about 20% oleic acid (18:1), 10% palmitic, 3% stearic (18:0), 55% linoleic (18:2), and 7-8% linolenic one (18:3) (Miladinović et al. 2011, citation: SWERN, 1972). Such favourable chemical composition makes soybean one of the most important cultivated crops in existence.

Although oil and protein contents are quantitative traits, both can be altered by breeding. Soybean breeding for increased yields and oil and protein levels has been the subject of many studies (Vidić et al., 2010; Miladinović et al., 2011). Modern breeding focuses not only on yield but also on the continual improvement of technological quality and increases of the oil and protein contents of soybean grain. The main problem hampering soy breeding for increased protein content is the presence of a negative correlation between yield and protein content (Chung et al., 2003).

Crop production is aimed at achieving as high a yield as possible while at the same time reducing mineral fertilizer use to the highest possible extent. Sensible use of mineral fertilizers in agriculture requires that soil fertility should be tested on the plot on which a particular crop is to be grown. Of particular importance in crop production is nitrogen. Nitrogen is the key element of yield and most often represents a limiting factor in trying to achieve high yields. Nitrogen fertilization is specific in that, on the one hand, mineral nitrogen is susceptible to losses caused by leaching due to its mobility in the soil and denitrification, whereas, on the other hand, the element also has a tendency to increase its presence in the soil due to the mineralization of soil organic matter (Malešević et al., 2005). The total amount of nitrogen and even the amount of residual nitrogen created in the spring are both variable and depend on soil fertility, the amount of harvest residues turned under, the amount of organic matter present in the soil, the preceding crop along with its yield and nitrogen fertilization level, primary fertilization, and climatic factors, meaning that nitrogen levels will always vary from one plot to another. The uptake of mineral nutrients from the soil and the extent of their utilization by the soybean plant depend on weather conditions during the growing season of this crop (Prijić et al., 1996).

Foliar dressing is supplemental to the existing mineral nutrition of a plant and has a direct effect on cell metabolism (Kovačević, 2003). Peele (1997) reported that the foliar uptake of macronutrients increased the yield of soybean grains by 30 to 400 kg/ha. In a study by Oko et al. (2003), the foliar application of urea in an early reproductive stage (R2-R3) increased the grain yields of soybean by 6-68%. In Ranđelović et al. (2006), mineral nutrients had a positive effect on soybean yield levels. The differences in grain yield were statistically significant, with an average increase of 540 to 1690 kg/ha (20-62.22%) relative to the treatment in which no mineral nutrients were added. Popović et al. (2011) reported obtaining significantly higher yields of soy grain as a result of foliar dressing with an increased nitrogen fertilizer rate. According to the same authors, increased soybean yields are a result of an improved balance between the macro- and micro-nutrients necessary for proper plant metabolism, i.e. for enzymatic processes affecting the formation of yield and grain quality in the crop.

The objectives of this paper were to investigate the effects of foliar dressing on soybean yields, 1000-grain weight, and oil and protein contents and to determine which varieties respond better to foliar nutrition, all with the aim of obtaining high yields of good-quality soy beans.

MATERIAL AND METHODS

A trial was set up in 2009 and 2010 at the Rimski Šančevi Experiment Field of the Institute of Field and Vegetable Crops in Novi Sad with the aim to investigate how foliar nutrition during the growing season using complex liquid fertilizers containing macro- and micro-nutrients affected the yields and chemical composition of soy beans. The trial used a split-plot design with three replications, and three NS soybean varieties from different maturity groups were used: Galina (MG 0), Victoria and Tea (MG I). The soil on which the trial was carried out was a medium-calcareous, weakly alkaline chernozem. Sugar beet and wheat were the preceding crops, while the plant population in the trial depended on the variety (500,000 plants for Galina and 450,000 for Victoria and Tea). The soybeans were planted on April 19 in 2009 and April 26 in 2010. The size of the experimental unit was 8 m^2, and the row-to-row spacing was 50 cm. Just prior to planting, the seeds were inoculated with the biofertilizer Nitragin. The foliar mineral fertilizer used is environmentally-friendly and contains all the essential macro- and micro-nutrients. The treatments with foliar nutrition in the trial were treated with a 0.30% liquid fertilizer Fitofert liquid solution of the following composition: 12% N, 4% P_2O_5, 6% K_2O, 0.013% Mn, 0.010% Fe, 0.008% B, 0.006% Cu, and 0.005% Zn. The 30% solution was applied twice to each of the basic experimental plots. The first treatment of the soybean plants was carried out when they were 15 cm tall, while the second was applied just before flowering in 2009, whereas in 2010 the second treatment was performed at the reproductive stage R2, i.e. at full flowering. The standard agronomic practices for soybean were applied during the growing season. The trial was machine-harvested. After the harvest, the samples were weighed and grain moisture content was determined. The yield was calculated on a per unit area basis and adjusted to 14% moisture.

Experimental data were analysed by descriptive and analytical statistics using the statistics software package STATISTICA 10 for Windows. The significance of differences among the mean values of the different factors studied in the paper (year, genotype, nutritional treatment) was tested using three-way ANOVA (Maletić, 2005):

$$y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_l + (\alpha\beta)_{ij} + (\alpha\gamma)_{il} + (\beta\gamma)_{jl} + \varepsilon_{ijlk}$$

i=1, 2 j=1, 2 l=1, 2, 3, 4 k=3

All evaluations of significance were made on the basis of the LSD test at 5% and 1% significance levels. Relative dependence was defined through correlation analysis (Pearson's correlation coefficient), and the coefficients that were obtained were tested using the t-test at the 5% and 1% levels of significance. The results were presented in tabular and graphic form.

Weather conditions. The temperature and rainfall data were collected from the weather station at Rimski Sancevi, near Novi Sad, Serbia.

During the 2009 and 2010 growing seasons, the mean monthly air temperatures exceeded the long-term average for the Rimski Šančevi site (17.90°C) by 1.70 and 0.50°C, respectively (Figure 1).

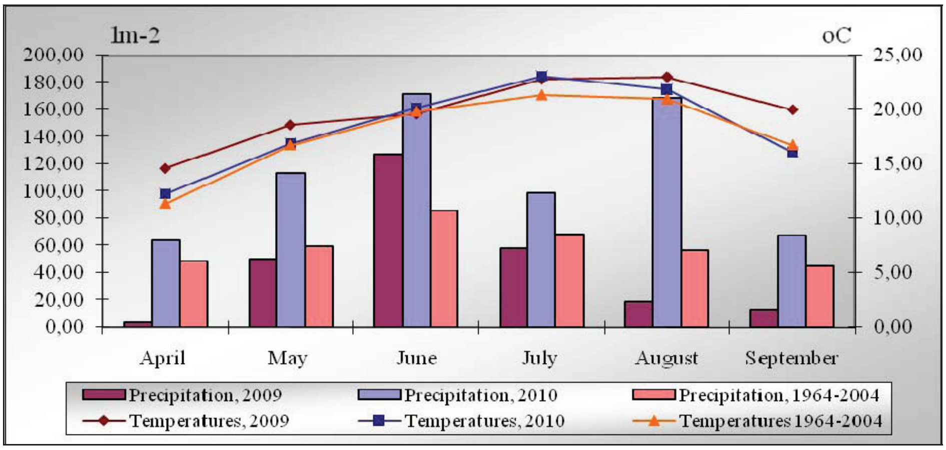

Figure 1. Average monthly temperature (°C) and precipitation sum (mm), Serbia, 2009-2010

Since soybean is planted early, yield levels will be significantly affected by temperatures and abundance and/or a good distribution of rainfall. In the present study, the sum of growing season precipitation ranged from 271.5 (2009) to 683.6 mm (2010).

In 2009, this sum was lower than the long-term average by 93 mm (364.3 mm), whereas in 2010 it was higher by 319.4 mm (Figure 1). Environmental conditions for seed production in a given area cannot be predicted with certainty. Because of this, it is very important that the variation of environmental factors is monitored and that the effects these factors have on physiological processes determining seed quality are known (Hollung et al., 2005; Popović, 2010).

RESULTS AND DISCUSSION

The year 2010 was characterized by good weather conditions. The start of the 2009 growing season of soybean was accompanied by favourable weather conditions. Despite the fact that a soil water deficit occurred in mid- and late July and August of 2009, record yields of soybean were obtained (Figure 1).

Yield and 1000-grain mass of NS soybean. Tables 1 and 2 present a descriptive statistical analysis of the soybean grain characteristics studied for both years of the experiment.

Table 1. Yields and 1000-grain weight of soybean in 2009-2010

Year	Variant	Genotype	Yield (kg ha^{-1})	1000-grain mass (g)
2009	Control	Galina	5 115	126
		Victoria	5 274	122
		Tea	5 099	122
	Average		5 165	124
2009	Foliar fertilization	Galina	5 338	121
		Victoria	4 976	122
		Tea	5 322	133
	Average		5 129	125
Total average 2009		Average	5 147	125
2010	Control	Galina	4 996	156
		Victoria	4 811	171
		Tea	4 877	153
	Average		4 895	160
2010	Foliar fertilization	Galina	5 101	154
		Victoria	5 219	162
		Tea	5 344	166
	Average		5 221	161
Total average 2010			*5 058*	*160*
Total average Control 2009-2010			5 030	141
Total average Foliar fertilization 2009-2010			5 175	143
Total average 2009-2010			5 184	143

Indicator	LSD - Test	Year	Genotype	Variant	AxBxC
Yield – control	0.05	223	274	223	388
	0.01	314	384	314	544
Yield – foliar fertilization	0.05	324	396	324	560
	0.01	454	555	454	786
1000-grain mass – control	0.05	8	10	8	14
	0.01	12	14	12	20
1000-grain mass – foliar fertilization	0.05	5	6	5	9
	0.01	7	9	7	12

On average, the yield and 1000-grain weight were higher in the treatments with foliar nutrition than in the check treatments with all the varieties under study. The difference between the foliar treatments and the checks were not statistically significant.

*Table 2***.** LSD values for yield and 1000-grain mass (2009-2010)

Parameter	Genotype		Year		Variant		GxY		YxV		GxV		GxYxV	
LSD Test	0.5	0.1	0.5	0.1	0.5	0.1	0.5	0.1	0.5	0.1	0.5	0.1	0.5	0.1
Yield	192	313	156	256	156	256	271	443	221	362	271	443	383	627
1000-grain mass	4.7	7.7	3.8	6.3	3.8	6.3	6.7	10.9	5.4	8.9	6.7	10.9	9.4	15.4

Genotype (G), Year (Y), Variant (V)

The average yield of soybeans was higher in 2009 (5147 kg ha^{-1}) than in 2010 (5058 kg ha^{-1}), but this difference was not statistically significant ($p>0.05$) either (Table 1). The highest yield among the checks was produced by the variety Victoria (5273 kg ha^{-1}) in 2009, with the difference relative to the yield of the same variety in 2010 (4811 kg ha^{-1}) being statistically significant (Tables 4 and 5). Among the treatments with foliar nutrition, the highest yield was obtained with the variety Tea in 2010 (5344 kg ha^{-1}), and the difference relative to the other varieties was statistically significant. In 2010, the average yield in the foliar treatments was higher by 327 kg ha^{-1}, or 6.7%, than in the control treatments. The highest difference in yield levels was recorded in the variety Tea. With this variety, the differences in grain yield levels between the check and foliar treatments ranged from 222 kg ha^{-1} in 2009 to 467 kg ha^{-1} in 2010, or from 4.4 to 9.6% in favour of the foliar treatments (Table 1, Figure 2). Foliar nutrition has proven to be a successful method, as it increased the yield of soybeans relative to the control.

The interactions among the studied factors were statistically significant ($p<0.05$) (Tables 1, 3 and 5). In cooler conditions, according to the findings of Osborn and Riedell (2006), the incorporation of 16 kg ha^{-1} of nitrogen prior to planting increased the seed yield by 6% as a result of an increased rate of initial growth in the plant.

Table 3. LSD test for soybean yield according to genotype and treatment

Cell No.	LSD Test; variable yield Probabilities for Post Hoc Tests Error; Between MS = 75184; df = 24.000							
	Genotype	Variant	(1) 5055.2	(2) 5212.5	(3) 5042.5	(4) 5097.8	(5) 4987.8	(6) 5332.8
1	Galina	1		0.309586	0.936890	0.789835	0.674384	0.092198
2	Galina	2	0.309586		0.274601	0.449659	0.156333	0.480957
3	Victoria	1	0.936890	0.274601		0.729739	0.732862	0.079086
4	Victoria	2	0.789835	0.449659	0.729739		0.493822	0.150705
5	Tea	1	0.674384	0.156333	0.732862	0.493822		0.039354
6	Tea	2	0.092198	0.480957	0.079086	0.150705	0.039354	

Table 4. LSD test for yield of soybean genotypes and years

Cell No.	LSD Test; variable yield Probabilities for Post Hoc Tests Error; Between MS = 75184; df = 24.000					
	Variant	Year	(1) 5162.4	(2) 5212.0	(3) 4894.6	(4) 5221.4
1	2009	1		0.704808	0.049123	0.652168
2	2009	2	0.704808		0.021673	0.942358
3	2010	1	0.049123	0.021673		0.018424
4	2010	2	0.652168	0.942358	0.018424	

Table 5. LSD test for yield according to soybean genotypes, variant and years

No.	LSD Test; variable yield Probabilities for Post Hoc Tests Error; Between MS = 75184; df = 24.000														
	Genotype	Year	Variant	(1) 5114.7	(2) 5338.0	(3) 4995.7	(4) 5101.0	(5) 5273.7	(6) 4976.3	(7) 4811.3	(8) 5219.3	(9) 5099.0	(10) 5321.7	(11) 4876.7	(12) 5344.0
1	Galina	2009	1		0.328	0.600	0.951	0.484	0.542	0.188	0.644	0.945	0.364	0.298	0.316
2	Galina	2009	2	0.338		0.139	0.300	0.776	0.119	0.027	0.601	0.296	0.942	0.050	0.979
3	Galina	2010	1	0.600	0.139		0.642	0.226	0.931	0.418	0.328	0.648	0.158	0.600	0.133
4	Galina	2010	2	0.952	0.300	0.642		0.448	0.583	0.208	0.602	0.993	0.334	0.326	0.288
5	Victoria	2009	1	0.484	0.776	0.226	0.448		0.197	0.050	0.810	0.443	0.832	0.089	0.756
6	Victoria	2009	2	0.542	0.119	0.932	0.583	0.197		0.468	0.288	0.589	0.136	0.660	0.113
7	Victoria	2010	1	0.188	0.027	0.418	0.208	0.050	0.468		0.081	0.211	0.032	0.773	0.026
8	Victoria	2010	2	0.644	0.601	0.328	0.602	0.810	0.288	0.081		0.596	0.652	0.139	0.583
9	Tea	2009	1	0.945	0.296	0.648	0.992	0.442	0.589	0.211	0.596		0.330	0.330	0.284
10	Tea	2009	2	0.365	0.942	0.158	0.334	0.832	0.136	0.032	0.652	0.330		0.058	0.921
11	Tea	2010	1	0.298	0.050	0.600	0.326	0.089	0.660	0.773	0.139	0.330	0.058		0.048
12	Tea	2010	2	0.316	0.979	0.133	0.288	0.756	0.113	0.026	0.583	0.285	0.921	0.047	

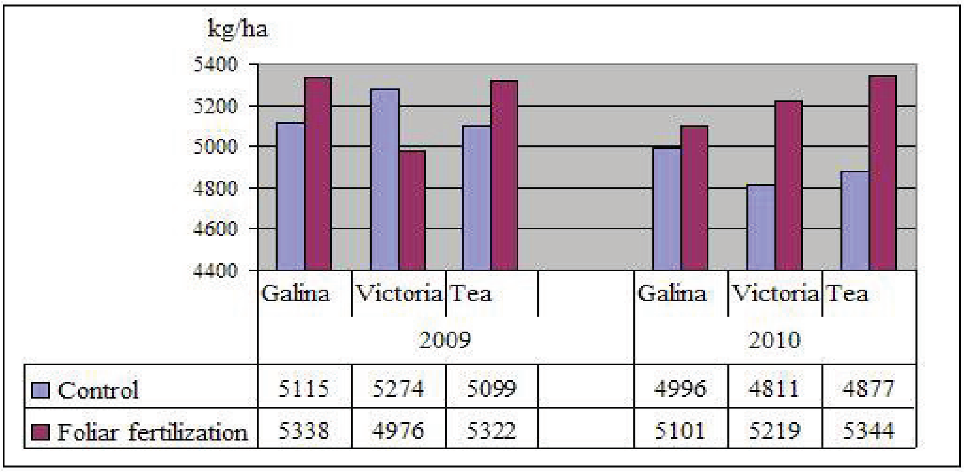

Figure 2. Variation of soybean grain yield in the control and foliar treatments (2009-2010)

The variations of the group treatments were very significant across the varieties as well as years. The average 1000-grain weight was significantly higher (by 28.2%) in 2010 (160 g) than in 2009 (125 g). The largest 1000-grain weight among the controls was observed with the variety Victoria (171 g) in 2010, with the difference relative to the other varieties being statistically significant. In both study years, the varieties Galina and Victoria had higher 1000-grain weights in the control treatments.

Among the foliar treatments, the largest 1000-grain weight was recorded in the variety Tea in 2010 (166 g), while the smallest was found in Galina in 2009 (Tables 1, 6 and 7; Figure 3). The variety Tea had a significantly larger 1000-grain weight in the check treatments than in the foliar ones (by 8.7% in 2009 and by 8.5% in 2010).

A prolonged period of grain development in 2010 resulted in larger-sized grains, an increased protein content, and a decreased oil content.

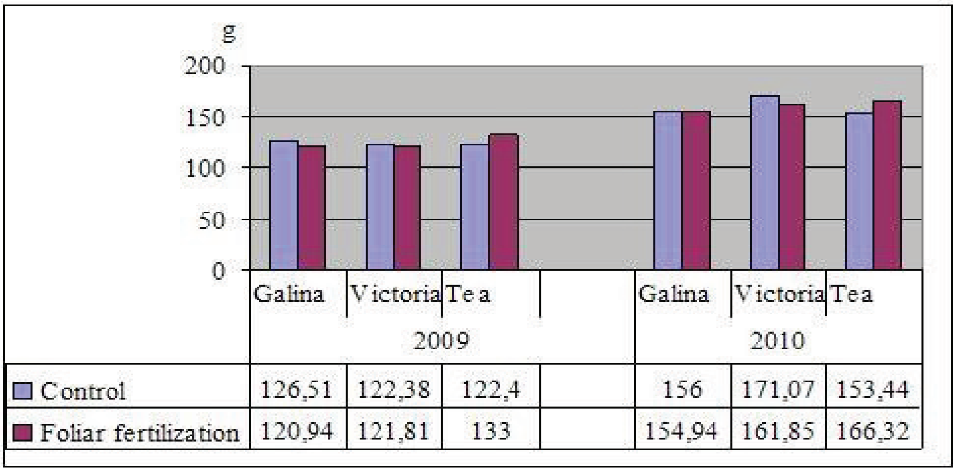

Figure 3. 1000-grain weight in the control and foliar treatments (2009-2010)

Interactions among the factors had no significant effect on grain protein content (Table 2). The year 2010 was more favourable for grain protein synthesis in soybean than 2009, but the difference in protein content was not statistically significant. The difference in protein content between the check and foliar treatments was not statistically significant (p>0.05) (Table 2).

Table 6. LSD test for 1000 grain mass according to soybean genotype and treatment

Cell No.	LSD Test; variable yield Probabilities for Post Hoc Tests Error; Between MS = 45.282; df = 24.000							
	Genotype	Variant	(1) 141.26	(2) 137.94	(3) 146.73	(4) 141.83	(5) 137.91	(6) 149.52
1	Galina	1		0.401250	0.171968	0.884248	0.397766	0.043981
2	Galina	2	0.401250		0.032997	0.326484	0.994919	0.006498
3	Victoria	1	0.171969	0.032997		0.219499	0.032547	0.479609
4	Victoria	2	0.884248	0.326484	0.219499		0.323449	0.059408
5	Victoria	1	0.397766	0.994919	0.032547	0.323449		0.006399
6	Tea	2	0.043981	0.006498	0.479609	0.059408	0.006399	

Table 7. LSD test for 1000 grain mass according to soybean genotypes and years

Cell No.	LSD – Test; variable yield Probabilities for Post Hoc Tests Error; Between MS = 45.282; df = 24.000					
	Variant	Year	(1) 123.76	(2) 125.15	(3) 160.17	(4) 161.03
1	2009	1		0.664168	0.000000	0.000000
2	2009	2	0.664168		0.000000	0.000000
3	2010	1	0.000000	0.000000		0.787827
4	2010	2	0.000000	0.000000	0.787827	

Protein and oil content. The highest protein content and protein yield was produced by genotype Galina among the checks, 2009-2010, and by genotype Tea among the foliar treatments, but the differences were not significant in statistical terms (Table 8, Figure 4).

Interactions among the factors did significantly affect grain protein and oil content (p<0.01) (Tables 9, 10, 11 and 12).

Table 8. Grain protein contents and protein yield (2009-2010)

Year	Treatment	Genotype	Protein content (%)	Protein yield (kg/ha)
2009	Control	Galina	37.24	1905
		Victoria	36.90	1946
		Tea	37.22	1898
	Average		37.12	1922
2009	Foliar fertilization	Galina	36.65	1956
		Victoria	36.90	1836
		Tea	37.93	1976
	Average		37.16	1906
Total Average 2009		Average	37.14	1912
2010	Control	Galina	37.52	1874
		Victoria	37.37	1798
		Tea	37.22	1815
	Average		37.37	1822
2010	Foliar fertilization	Galina	37.35	1905
		Victoria	37.78	1972
		Tea	37.55	2007
	Average		37.56	1895
Total average 2010			37.47	1895
Total average Control 2009-2010			37.25	1874
Total average Foliar fertilization 2009-2010			37.36	1933
Total average 2009-2010			37.31	1934

Indicator	LSD - Test	Genotype	Year	Variant	GxYxV
Protein content, PC - control	0.05%	0.5823	0.4755	0.4755	0.8236
	0.01%	0.8168	0.6668	0.6668	11.551
PC - Foliar fertilization	0.05%	0.5448	0.4448	0.4448	0.7704
	0.01%	0.7641	0.6239	0.6239	10.806

Table 9. LSD values for protein content, Genotype (G), Year (Y), Variant (V), in 2009-2010

Parameter	Genotype		Year		Variant		GxY		YxV		GxV		GxYxV	
LSD - Test	0.5	0.1	0.5	0.1	0.5	0.1	0.5	0.1	0.5	0.1	0.5	0.1	0.5	0.1
Protein content	0.31	0.49	0.25	0.41	0.25	0.41	0.43	0.70	0.35	0.57	0.43	0.70	0.81	1.32

Table 10. LSD test for protein content between soybean genotypes, variant and years

No.	LSD Test; variable yield Probabilities for Post Hoc Tests Error; Between MS = 18974; df = 24.000														
	Genotype	Year	Variant	(1) 36.613	(2) 36.879	(3) 37.347	(4) 37.127	(5) 36.720	(6) 37.200	(7) 37.497	(8) 37.450	(9) 37.307	(10) 37.817	(11) 36.827	(12) 37.107
1	Galina	2009	1		0.472	0.050	0.162	0.767	0.112	0.020	0.027	0.063	0.002	0.554	0.178
2	Galina	2009	2	0.472		0.196	0.483	0.670	0.367	0.092	0.118	0.235	0.014	0.897	0.518
3	Galina	2010	1	0.050	0.196		0.542	0.091	0.683	0.677	0.774	0.911	0.199	0.157	0.506
4	Galina	2010	2	0.016	0.483	0.542		0.264	0.838	0.308	0.372	0.617	0.064	0.407	0.956
5	Victoria	2009	1	0.767	0.670	0.091	0.264		0.190	0.039	0.051	0.112	0.005	0.767	0.288
6	Victoria	2009	2	0.112	0.367	0.684	0.838	0.190		0.412	0.489	0.767	0.096	0.304	0.795
7	Victoria	2010	1	0.020	0.092	0.677	0.308	0.039	0.412		0.897	0.598	0.377	0.072	0.284
8	Victoria	2010	2	0.027	0.118	0.774	0.372	0.051	0.489	0.897		0.690	0.313	0.092	0.344
9	Tea	2009	1	0.063	0.234	0.911	0.617	0.112	0.767	0.598	0.690		0.164	0.190	0.579
10	Tea	2009	2	0.002	0.014	0.199	0.064	0.005	0.096	0.377	0.313	0.164		0.010	0.057
11	Tea	2010	1	0.554	0.897	0.157	0.407	0.767	0.304	0.071	0.092	0.190	0.010		0.439
12	Tea	2010	2	0.178	0.518	0.506	0.956	0.288	0.795	0.284	0.344	0.579	0.057	0.439	

Table 11. Grain oil contents and oil yield (2009-2010)

Year	Variant	Genotype	Oil content (%)	Oil yield (kg/ha)
2009	Control	Galina	21.51	1100
		Victoria	21.98	1159
		Tea	23.30	1188
	Average		22.26	1149
2009	Foliar fertilization	Galina	21.91	1169
		Victoria	22.19	1104
		Tea	22.97	1222
	Average		22.36	1146
Total average 2009			22.31	1148
2010	Control	Galina	19.29	964
		Victoria	19.26	927
		Tea	20.37	994
	Average		19.64	961
2010	Foliar fertilization	Galina	19.33	986
		Victoria	18.76	979
		Tea	20.30	1070
	Average		19.37	1011
Total average 2010			19.51	986
Total average Control 2009-2010			20.95	1054
Total average Foliar fertilization 2009-2010			20.87	1080
Total average 2009-2010			20.91	1084

Indicator	LSD - Test	Genotype	Year	Variant	GxYxV
Oil content, (OC)-control	0.05%	0.4031	0.3291	0.3219	0.5700
	0.01%	0.5653	0.4612	0.4612	0.7995
OC- Foliar fertilization	0.05%	0.3605	0.2944	0.2944	0.5099
	0.01%	0.5057	0.4129	0.4129	0.7152

Table 12. LSD Test of oil content (2009-2010)

Parameter	Genotype		Year		Variant		GxY		YxV		GxV		GxYxV	
LSD Test	0.5	0.1	0.5	0.1	0.5	0.1	0.5	0.1	0.5	0.1	0.5	0.1	0.5	0.1
Oil content	0.21	0.35	0.17	0.28	0.17	0.28	0.30	0.49	0.25	0.40	0.25	0.40	0.43	0.70

Genotype (G), Year (Y), Variant (V).

The year 2009 was significantly more favourable for oil synthesis than 2010 (Table 13). In 2009, the grain oil content of soybean was significantly higher than in 2010 ($p<0.01$). The difference in oil content between the check and foliar treatments was not statistically significant ($p>0.05$). On average, the highest oil content and oil yield, both in the check and foliar treatments, was recorded in the variety Tea (21.7% and 1146 kg ha^{-1}). The same variety also had significantly higher oil content as compared to the other varieties, both in the foliar treatments and in the checks (Tables 11 and 14; Figure 4).

The use of foliar nutrition resulted in a higher average grain protein content relative to the check, but the difference was not statistically significant.

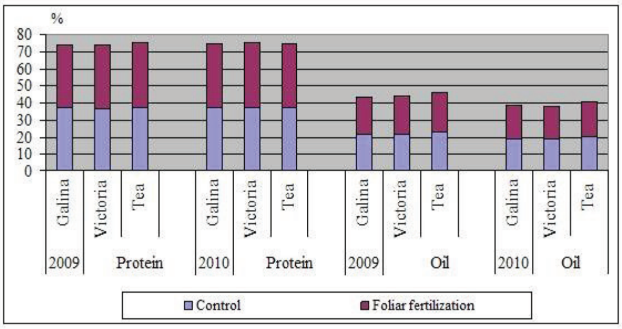

Figure 4. Protein and oil content in soybean in the control and with foliar fertilization (2009-2010)

Table 13. LSD test for oil content of soybean genotypes and years

Cell No.	LSDTest; variable yield Probabilities for Post Hoc Tests Error; Between MS = .09280; df = 24.000							
	Genotype	Year	(1) 22.062	(2) 19.325	(3) 22.103	(4) 19.018	(5) 23.083	(6) 20.222
1	Galina	2009		0. 000000	0. 814743	0. 000000	0. 000005	0. 000000
2	Galina	2010	0. 000000		0. 000000	0.094027	0. 000000	0. 000032
3	Victoria	2009	0.814743	0. 000000		0. 000000	0. 000010	0. 000000
4	Victoria	2010	0.000000	0.094027	0. 000000		0. 000000	0. 000000
5	Tea	2009	0.000005	0. 000000	0. 000010	0. 000000		0. 000000
6	Tea	2010	0.000000	0. 000032	0. 000000	0. 000000	0. 000000	

Table 14. LSD test for oil content of soybean genotypes and treatments

Cell No.	LSD – Test; variable yield Probabilities for Post Hoc Tests Error; Between MS = .09280; df = 24.000							
	Genotype	Variant	(1) 20.865	(2) 20.522	(3) 20.720	(4) 20.402	(5) 21.725	(6) 21.580
1	Galina	1		0.062691	0.417820	0.014528	0.000055	0.000447
2	Galina	2	0.062691		0.270614	0.501596	0.000000	0.000003
3	Victoria	1	0.417820	0.270614		0.082847	0.000007	0.000055
4	Victoria	2	0.014528	0.501596	0.082847		0.000000	0.000001
5	Tea	1	0.000055	0.000000	0.000007	0.000000		0.417820
6	Tea	2	0.000447	0.000003	0.000055	0.000001	0.417820	

Interactions among factors significantly affected the total oil and protein content of soybeans. Looking at the varieties on average, the year 2009 (59.5%) was more favourable for the synthesis of total oil and proteins in the grain than the year 2010 (56.9%).

The total level of these two parameters was 58.2%, ranging from 57.0% (2010) to 59.4% (2009) in the check treatments and from 56.9% (2010) to 59.5% (2009) in the foliar treatments (Figure 5). In both the check and foliar treatments, the highest average total levels of oil and protein were produced by the variety Tea, both in 2009 and 2010 (60.5 and 60.9%, respectively) (Figure 5).

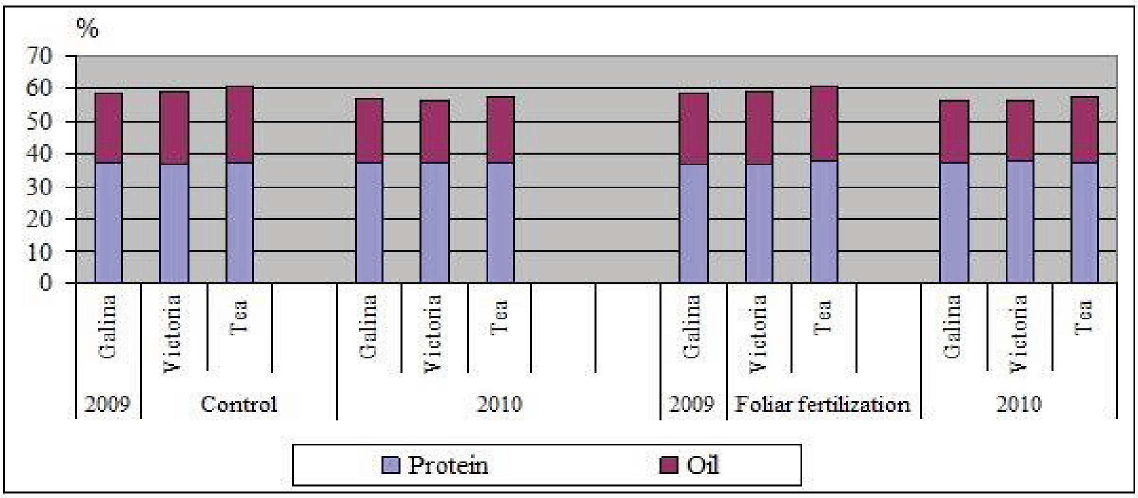

Figure 5. Total protein and oil contents in soybean (2009-2010)

Correlations between the analysed traits. The values of the coefficients of correlation among the studied traits did not differ significantly between the foliar treatments and the checks. In the checks, there was a significant positive correlation between yield and oil content (r=0.53*) and a not significant positive correlation between protein content and 1000-grain weight (r=0.46). A highly significant negative correlation was observed between oil content and 1000-grain weight (r=-0.86**). Between yield and protein content (r=-0.36) and yield and 1000-grain weight (r=-0.37) a not significant negative correlations was found. A not significant negative correlation was also observed between oil content and protein content (r=-0.42) (Table 15).

The use of foliar nutrition produced not significant positive correlations between yield and oil content (r=0.21) and protein content and 1000-grain weight (r=0.09). However, there was also a highly significant negative correlation between oil content and 1000-grain weight (r=-0.80**). A very weak negative correlation was observed between yield and protein content (r=-0.09) as well as between yield and 1000-grain weight (r=-0.14) in the mineral nutrition treatments. A weak negative correlation was found between oil content and protein content (r=-0.04) in the foliar nutrition treatments (Table 16).

Table 15. Coefficients of correlation in the control treatment (no fertilization)

Control variant	Yield	1000-grain mass	Protein content	Oil content
Yield	-	-0.37^{ns}	-0.36^{ns}	0.53^{*}
1000-grain mass	-	-	0.46^{ns}	-0.86^{**}
Protein content	-	-		-0.42^{ns}

^{ns}non significant; *significant at 0.05; **significan at 0.01.

Table 16. Coefficients of correlation in treatments with foliar fertilization

Foliar fertilization	Yield	1000-grain mass	Protein content	Oil content
Yield	-	-0.14^{ns}	-0.09^{ns}	0.21^{*}
1000-grain mass	-	-	0.09^{ns}	-0.80^{**}
Protein content	-	-		-0.04^{ns}

^{ns}non significant; *significant at 0.05; **significan at 0.01.

Chung et al. (2003) reported finding a negative correlation between grain yield and protein content as well as between oil content and protein content. The obtained results indicate that the protein and oil content in soybean is a cultivar characteristic, but it is also strongly affected by the environment, which is consistent with the results of other researchers (Perić et al., 2009; Miladinović et al., 2011; Popović et al., 2012, 2012a).

CONCLUSIONS

The results obtained in the present study have led to the following conclusions:

All the studied traits varied significantly depending on variety and from one year to the other. In all the varieties studied, yield and 1000-grain weight were on average higher in the treatments with foliar nutrition than in checks. In the treatment with foliar nutrition, the variety Tea produced a significantly higher level of protein and oil content and protein and oil yield than the other varieties.

The values of the coefficients of correlation among the studied traits did not differ significantly between the foliar treatments and the checks. In both the foliar treatments and the controls, yield was negatively correlated with protein contents (r=-0.36, r=-0.05). In the foliar treatments, yield was in a not significant positive correlation with oil content (r=0.21), whereas in the checks this correlation was statistically significant (r=0.53*). In the checks as well as in foliar treatments, oil content was negatively correlated with protein content (r=-0.42, r=-0.04) and significantly negatively correlated with 1000-grain weight (r=-0.86**, r=-0.80**).

The studied traits were significantly influenced only by the year and genotype, which had a statistically significant effect. The application of the foliar fertilizer achieved higher yields, compared with the control variant, but the difference was not statistically significant. The obtained results indicate that the yield, protein and oil content in soybean is a cultivar characteristic, but it is also strongly affected by the environment.

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