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PRODUCTIVE CHARACTERISTICS OF SOYBEAN IN AGROECOLOGICAL CONDITIONS OF SREMSKA MITROVICA, SERBIA

ABSTRACT

The objective of this paper was to examine and present the results of soybean grain yield and oil content during a two-year period in agro-ecological conditions of Sremska Mitrovica, Serbia. Data were statistically analysed by analysis of variance, using the method of two factorial trials (variety, year). LSD was used to compare means for significant differences.

Significantly higher yields were recorded in 2010 compared to 2009. Average yield amounted to 4,409 kg ha^{-1} for analysed soybean varieties, and ranged from 3,697 kg ha^{-1} (2009) to 5,121 kg ha^{-1} (2010). The average highest yield was found in Victoria variety (4,520 kg ha^{-1}). The year 2009 was favourable for oil synthesis. The tested soybean varieties had average oil content of 21.07%. Statistically significantly higher oil content was recorded in 2009 compared to 2010 ($p < 0.05$). The average highest oil content was found in Vojvođanka variety (21.42%). The tested soybean varieties had average oil yield of 927 kg ha^{-1}. The average highest oil yield was found in varieties Vojvođanka and Victoria (957 kg ha^{-1}, 942 kg ha^{-1}). During the analysed period varieties Vojvođanka and Victoria higher average oil yield compared to Trijumf variety.

Yield in soybean grain, 2009-2010, was statistically highly significantly positively correlated with oil yield and precipitation (r= 0.94**, r= 0.92**). Yield in soybean grain, 2009-2010, was negatively correlated with oil content (r= 0.37) and statistically highly significantly negatively correlated with temperature (r= 0.93**).

Key words: grain yield, oil content, oil yield, correlations, soybeans, variety

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INTRODUCTION

Regarding the favourable grain composition, soybean (*Glycine Max.* (L.) Merr.) has been classified into the group of the most important plant protein and oil sources in the world. Soybeans have multi-purpose: human and animal nutrition, proteins, oil and bio-diesel production. In recent years, 90% of the world production has been concentrated in a few countries (USA, Brazil, Argentina, China, India, etc.). Areas and yields have had a growing tendency (and hence higher production) in recent years, in our country and abroad (Popović 2010).

Soybean selection at the Institute of Field and Vegetable Crops has so far focused the most on the increase of yield and its stability and developing varieties adaptable to different growing conditions (Miladinović et al., 2008; Popović et al., 2013, 2014).

However the Institute is soybean program also makes sure to take into account the preferences of its customers and the processing industry and to adapt to the demands of the market. In addition to this, the discerning market of the West has a preference for a good balance between the oil and protein contents in order to use soybean for manufacturing products for human nutrition as well as for certain levels of amino acids containing sulphur, a balance between the levels of oligosaccharides and polysaccharides for the purposes of fish food production (Hollung et al., 2005) and improved nutritional and medicinal properties of soybean (Miladinović et al., 2008, Glamočlija et al., 2015).

The total fatty acid content and composition are another essential component of soybean breeding for a modified chemical composition of the grain. The dominant fatty acid fraction comprises linoleic acid (18:2) with about 55% conntribution and oleic acid (18:1) with about 20%. Linolenic (18:3, approx. 8%), palmitic (16:0, approx. 10%) and stearic (18:0, approx.4%) are also present. The general trend in breeding for fatty acid composition is to reduce the levels of polyunsaturated fatty acids and increase the oleic acid content. Reducing the levels of polyunsaturated fatty acids increases the oxidative stability of soybean oil and also reduces the need for the catalytic hydrogenation of polyunsaturated lipids during the processing of soybean oil. The use of soybean cultivars with an altered fatty acid composition is not only advantageous from the technological point of view but is also beneficial health-wise. Oleic acid is known to be the most desirable fatty acid from the point of view of human nutrition, so the increase of oleic acid levels has a positive effect on the quality of products obtained from high-oleic cultivars (Miladinović et al., 2008).

The climate has a major effect on plant growth and development, and often represents a limiting production factor. Very important factors that influence the chemical composition of soybean grains are the prevailing environmental conditions during the growth phase, as well as specificities of a variety, in accordance with the results of Hurburgh (2000). Proper variety selection, besides the best cultivation technology use, has major influence on the

yield increase and soybean grain quality in different environmental conditions (Miladinović et al., 2008; Popović et al., 2012, Kolarić et al., 2014).

The aim of this study was to determine the productivity soybean grain of varieties of Novi Sad in the region of Sremska Mitrovica, in agro-climatic divergent years.

MATERIALS AND METHODS

Yield and oil content of soybean grain were analysed in this two-year trial (2009-2010) in Sremska Mitrovica, Serbia. The trials were set up as randomized block design in three replicates with three NS soybean cultivars of different maturity groups (I and II). 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. 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 I maturity group cultivars was 450,000 grain ha^{-1} and for II maturity group 400,000 grain ha^{-1}. Variety Victoria (I MG), Trijumf (Popović et al., 2014, 2015) and Vojvođanka (II MG). Before planting, soybean seeds were inoculated with microbiological preparation NS Nitragin which is produced by Institute of Field and Vegetable Crops, Novi Sad. 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 1 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 content in grain. Total oil content in grain was determined by infrared spectroscopy technique on the apparatus Perten DA 7000, (NIR/VIS Spectro-photometer) employing non-destructive method.

Experimental data were processed using descriptive and analytical statistics of Statistica 12 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.

Agro-meteorological conditions

Meteorological data were taken from the Meteorological station in Sremska Mitrovica. Meteorological data in year is different (Bran et al., 2008; Popović 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 Fig. 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).

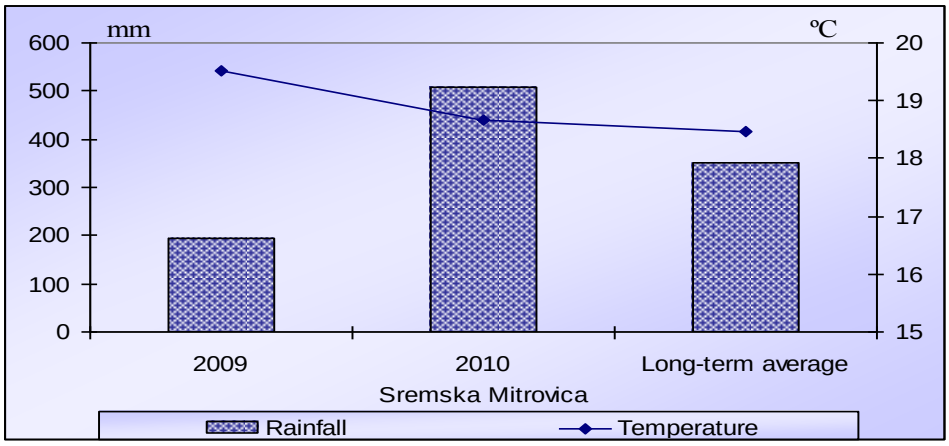

Fig. 1. Precipitation sum (mm) and temperature (°C), Sremska Mitrovica, Serbia, 2009-2010.

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 (Fig. 1 and Tab. 2). The increase of production was also affected by weather conditions (Popovic et al., 2013). 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

Soybean grain yield. Analysed year had a statistically significant effect ($p < 0.01$) on soybean grain yield. In 2010 yields were significantly higher (5,121 kg ha^{-1}) compared to the yields in 2009 (3,697 kg ha^{-1}), Table 1. Since the studied years were agro-meteorological divergent, 2009 relatively arid and 2010 humid, large fluctuations in the yields were recorded. Pejić et al. (2012) reported that soybean yields are projected to significantly increase under irrigation.

All the tested varieties achieved high yield. The average highest yield was found in Victoria variety (4,520 kg ha^{-1}). The average yield for all soybean tested varieties in the two-year period was 4,409 kg ha^{-1} (Table 1, 2). Yields ranged from 4,280 kg ha^{-1} (Trijumf) to 4,520 kg ha^{-1} (Victoria).

Average yield of the II maturity group varieties (4,354 kg ha^{-1}) was lower compared to the maturity group I varieties (4,520 kg ha^{-1}) by 166 kg ha^{-1}, i.e. by 3,81 % (Tab. 1). The higher yield in 2009 was achieved by Victoria variety (3,933 kg ha^{-1}), as shown in Tables 1 and 2. Victoria (3933 kg ha^{-1}) and Vojvođanka (3713 kg ha^{-1}) yield higher in 2009 compared to the Trijumf (3447

kg ha^{-1}). Year and year x variety interactions had a statistically significant effect ($p < 0.05$, $p < 0.01$) on soybean grain yield (Table 1 and Table 2).

Table 1. Soybean yield (kg ha^{-1}) in Sremska Mitrovica, Serbia, 2009-2010

Variety	**MG**	**Grain yield,** kg ha^{-1}		
		2009	**2010**	**2009-2010**
Victoria*	I	3933	5107	4520
Trijumf	II	3447	5112	4280
Vojvođanka	II	3713	5144	4429
Average I MG		3933	5107	4520
Average II MG		3580	5128	4354
Average 2009		**3697**	-	-
Average 2010		-	**5121**	-
Average, 2009-2010		-	-	**4409**

*Popovic et al, 2014

LSD test	**Variety**	**Year**	**V x Y**
0.05	362.41	295.91	512.52
0.01	510.19	414.57	721.51

Table 2. Analysis of variance for yield

Effect	SS	Deg. of Fr.	MS	F	P
Intercept	349942331	1	349942331	4251.815	0.000000
Variety	176567	2	88284	1.073	0.372747
Year	9119297	1	9119297	110.800	0.000000
Variety x Year	181170	2	90585	1.101	0.364026
Error	987651	12	82304		

Oil content. Year had a statistically significant effect ($p<0.01$), on the oil content in soybean grain.

Table 3. Oil content (%) of soybean in Sremska Mitrovica, Serbia, 2009-2010

Variety	**MG**	**Oil content, %**		
		2009	**2010**	**2009-2010**
Victoria*	I	21.53	20.44	20.99
Trijumf	II	21.57	20.04	20.81
Vojvođanka	II	21.79	21.04	21.42
Average I MG		21.53	20.44	20.99
Average II MG		21.68	20.54	21.11
Average 2009		**21.63**	-	-
Average 2010		-	**20.51**	-
Average, 2009-2010		-	-	**21.07**

*Popovic et al, 2014

LSD test	**Variety**	**Year**	**V x Y**
0.05	0.705	0.575	0.995
0.01	0.992	0.810	1.401

The year 2009 was favourable for oil synthesis. Statistically significantly higher oil content was recorded in 2009 (21.63%), compared to 2010 (20.51%), Tables 3 and 4. The tested soybean varieties had average oil content of 21.07%. The average highest oil content was found in Vojvođanka variety (21.42%), Table 3. During the analysed period Vojvođanka variety (21.42%) higher average oil content compared to Victoria and Trijumf varieties, $p < 0.05$.

Table 4. Analysis of variance of oil content

Effect	SS	Deg. of Fr.	MS	F	P
Intercept	7989.323	1	7989.323	25742.94	0.000000
Variety	1.184	2	0.592	1.91	0.190820
Year	5.645	1	5.645	18.19	0.001098
Variety x Year	0.455	2	0.228	0.73	0.500459
Error	3.724	12	0.310		

The average oil content in 2009-2010 of I maturity group varieties (20.9%) was lower compared to the maturity group II varieties (21.1%), Table 3. Year and variety x year interaction had a statistically significant effect ($p<0.05$) on the oil content in soybean grain, Table 3.1.

Among the currently grown NS cultivars of soybean, the variety Vojvođanka has a high oil content of the grain. Although Vojvođanka performs the best yield – wise in optimal growing conditions, it also produces stable yields in unfavorable, droughty conditions, which is not typical of a genotype with a long growth period. Cultivar Vojvođanka has been released in Serbia, as well as Italy, Romania and Kazakstan. Trijumf cultivar has been released in Serbia, as well as Romania and cultivar Victoria variety has been released in Serbia, as well as Ukraine and Russian Federation.

Oil yield. Year had a statistically significant effect ($p<0.01$), on the oil yield in soybean grain. Statistically significantly higher oil yield was recorded in 2010 (1055 kg ha^{-1}), compared to 2009 (799 kg ha^{-1}), Table 5.

Table 5. Oil yield kg ha^{-1} of soybean in Sremska Mitrovica, Serbia, 2009-2010

Variety	**MG**	**Oil yield,** kg ha^{-1}		
		2009	**2010**	**2009-2010**
Victoria*	I	847	1038	942
Trijumf	II	742	1024	883
Vojvođanka	II	809	1104	957
Average I MG		847	1038	942
Average II MG		776	1064	920
Average 2009		**799**	**-**	**-**
Average 2010		**-**	**1055**	**-**
Average, 2009-2010		**-**	**-**	**927**

*Popovic et al, 2014

LSD test	**Variety**	**Year**	**V x Y**
0.05	118.74	96.95	167.92
0.01	167.16	136.48	236.40

The tested soybean varieties had average oil yield of 927 kg ha^{-1}. The average highest oil yield was found in varieties Vojvođanka and Victoria (957 kg ha^{-1}, 942 kg ha^{-1}), Table 5. During the analysed period varieties Vojvođanka and Victoria higher average oil yield compared to Trijumf variety.

Year and variety x year interaction had a statistically significant effect ($p<0.05$), on the oil yield in soybean grain, Table 6.

Table 6. Analysis of variance of oil yield

Effect	SS	Deg. of Fr.	MS	F	P
Intercept	349942331	1	349942331	4251.815	0.000000
Variety	176567	2	88284	1.073	0.372747
Year	9119297	1	9119297	110.800	0.000000
Variety x Year	181170	2	90585	1.101	0.364026
Error	987651	12	82304		

The average oil yield in 2009-2010 of II maturity group varieties (920 kg ha^{-1}), was lower compared to the maturity group I varieties (942 kg ha^{-1}), Table 5.

The interdependence of the traits. Yield in soybean grain in 2009 and 2010 was statistically highly significantly positively correlated with oil yield (r = 0.98**, r = 0.78**), Table 7.

Yield in soybean grain was positively correlated with oil content (r = 0.06) in 2009 and less negatively correlated in 2010 (r = 0.28), Table 7.

The oil content in soybean grain was less significantly negatively correlated with oil yield (r= -0.23) in 2010 and less significantly positively correlated in 2009 (r= 0.25), Table 7.

Table 7. Correlations between yield, oil yield and oil content in soybean grain (2009-2010), Correlation parameters for 2009 above diagonal and for 2010 below diagonal

Parameter	**Yield**	**Oil content**	**Oil yield**
Yield	1.00	-0.06 ^{ns}	0.98**
Oil content	-0.28 ^{ns}	1.00	0.25^{ns}
Oil yield	0.79**	-0.23 ^{ns}	1.00

^{ns} – not significant; ** - significant at $p<0.01$

Table 8. Total correlations between of investigated traits, 2009-2010

Parameter	**Yield**	**Oil content**	**Oil yield**	**Temperature**	**Precipitation**
Yield	1.00	-0.37 ^{ns}	0.94**	-0.93**	0.92**
Oil content	-	1.00	-0.63*	0.72**	-0.71**
Oil yield	-	-	1.00	-0.83**	0.82**

^{ns} – not significant; * and ** - significant at $p<0.05$, $p<0.01$

Yield in soybean grain, 2009-2010, was statistically highly significantly positively correlated with oil yield and precipitation (r= 0.94**, r= 0.92**). Yield

in soybean grain, 2009-2010, was negatively correlated with oil content (r= 0.37) and statistically highly significantly negatively correlated with temperature (r= 0.93**), Table 8. The results of positive correlation of yield and oil yield in soybean grain were in accordance with the results of authors Popović et al., 2013. The interaction of the analysed factors, year x variety, exerts a statistically significant effect on the correlations among protein and oil content.

CONCLUSIONS

Based on annual research and variety influence on productivity of soybean grain, the following conclusions can be drawn:

–Average yield amounted to 4,409 kg ha^{-1} for analysed soybean varieties, and ranged from 3,697 kg ha^{-1} (2009) to 5,121 kg ha^{-1} (2010).

–The average highest yield was found in Victoria variety (4,520 kg ha^{-1}).

–The year 2009 was favourable for oil synthesis. Statistically significantly higher oil content was recorded in 2009 compared to 2010 ($p < 0.05$).

–The tested soybean varieties had average oil content of 21.07%. The average highest oil content was found in Vojvođanka variety (21.42%).

–Statistically significantly higher oil yield was recorded in 2010 compared to 2009.

–The tested soybean varieties had average oil yield of 927 kg ha^{-1}. The average highest oil yield was found in varieties Vojvođanka and Victoria.

–Yield in soybean grain in 2009 and 2010 was statistically highly significantly positively correlated with oil yield (r = 0.98**, r = 0.78**).

–Large fluctuations in yield, oil yield and oil contents show that, besides genetic factors, analysed traits largely depend on the amount and distribution of precipitation and temperature conditions.

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