

Influence of Sowing Density on Yield and Quality of Soybean under Ecological and Conventional Production Systems

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Abstract: Research was conducted during 2008 under ecological and conventional systems of soybean production. The observed factors included three different seeding densities (400.000, 500.000 and 600.000 plants per ha) and three soybean varieties of different maturity groups ('Galina', 'Sava' and 'Mima'). The obtained data were processed by analysis of variance method of two factorial split-plot test (variety and seeding density). Yield and protein content were higher under conventional production than under the ecological system, while the oil content was 1.66% lower. Yield significantly depended on variety in both production systems. The effect of sowing density was non-significant in the conventional system and highly significant in the ecological system. Differences between the average values of the protein content of soybean grain were not statistically significant in terms of variety and sowing density in both production technologies. Under conventional production conditions, the variety Mima had a significantly higher oil content of grain as compared to the variety Galina. The ecological production differences were not statistically significant. Sowing density had no impact on the oil content of soybean grain in both production technologies tested. A very significant negative correlation between protein and oil content was established in both ecological and conventional production systems (-0.86** and -0.91**, respectively).

Key words: soybean, sowing density, yield, proteins, oil.

Introduction

Soybean production is aimed at high and stable yields of good quality, including a high protein and oil content. In practice, producers try to reach this

goal in different ways. One of the ways is to use different kinds of vegetation area, i.e. different row spacing. Plant number per hectare is the first yield component; if it is not optimal, all subsequent interventions towards the production of high yields prove unsuccessful. More than any other crop, soybean responds to changes in sowing density (Relić 1996.). Yield increase can be affected by an increase in sowing density and choice of soybean varieties. Soybean is used in many different processed products for human nutrition; therefore, that part of soybean production should not undergo any changes in mineral fertilisers and pesticides. According to the definition of NOBS – National Organic Standards Board in the USA (1995), organic agriculture is a system of ecological management of production which promotes and advances biodiversity, mineral cycle and biologic activity of the soil (Kovačević and Oljača 2005, Dozet *et al.* 2008).

The objective of this research was to confirm the influence of sowing density and maturity group on yield, and protein and oil content of soybean grain under ecological and conventional production systems using sowing densities of 400.000, 500.000 and 600.000 plants per ha.

Material and Method

A study on the effect of sowing density on the yield, protein and oil content of soybean grain was conducted in 2008 at a production field in Pačir, Municipality of Bačka Topola, on calcareous chernozem, with maize used as a preceding crop.

Two parallel experiments were carried out: one under conventional conditions, and the other involving ecological production. The experiment included a total of three varieties of different maturity groups created at the Institute of Field and Vegetable Crops, Novi Sad:

- ‘Galina’, an early maturing variety, belonging to maturity group 0,
- ‘Sava’, a mid-season variety, maturity group I,
- ‘Mima’, a late maturing variety, maturity group II.

In conventional soybean production, a specific quantity of mineral nutrition was applied, including NPK 15:15:15 at a rate of 137 kg ha⁻¹, totalling 11.8 kg/860m² (quantum of experiment) and NPK 8:16:24 at a rate of 242 kg ha⁻¹ or 20.8kg/860m². The pre-sowing treatment in the conventional production of soybean involved the use of 39.91kg ha⁻¹ N, 59.27 kg ha⁻¹ P₂O₅ and 78.63 kg ha⁻¹ K₂O.

The experiment was set up in a two factorial split plot design in four replications, with main plots representing varieties, and subplots representing three plant densities of 400.000; 500.000 and 600.000 plants ha⁻¹. The size of the basic plot was 17.5m² (5m x 7 rows), with two side rows serving as protection, the middle two for yield and one middle row for the samples. Manual sowing was performed on 17 April in furrows made by sweeps at a depth of 5cm. The sowing rate increased 10% due to lower seed germination. Parallel sowing was employed under conventional and organic production systems, each involving seed inoculation and use of nitrogen before sowing.

The experiment conducted under ecological production conditions was manually hoed two times (when the soybean crop had trifoliolate leaves, and before assemblage rows). Under conventional production system, chemical weed management

measures were employed, including herbicide Pivot (11/ha) during phases 1-3, Fusilade forte at a rate of 1.3 l ha^{-1} before blossom, using a backpack sprayer of 12 l capacity.

Harvest was done manually (plants were taken from two middle rows without first plants, carefully bound up in sheaves), trashing was performed using a Winterstaigner harvester at the Institute of Field and Vegetable Crops, Novi Sad. The moisture content was reduced to 13%. The protein and oil content of 13% moisture grain was determined by a Perten DA-700 FLEXI-MODE NIR/VIS spectrophotometer.

The obtained data were subjected to the split-plot analysis of variance to assess the effect of variant, and the persistence of interaction was tested using the least significant difference test (Hadživuković 1991).

Weather conditions during the study

A comparison between data on mean monthly temperatures during the growing season of 2008 and the long-term mean (1977-2007) shows a significant deviation from the long-term mean. The average temperature during the 2008 growing season was 19.5°C , being 1°C higher than the long-term mean of 18.5°C (Figure 1). Soybean requires very high temperatures until maturation but no high temperature fluctuations during day and night periods are desirable. During the period of maturation, the temperature requirements of soybean are low. The temperature during the growing season was not particularly unfavourable although the year was warmer than average.

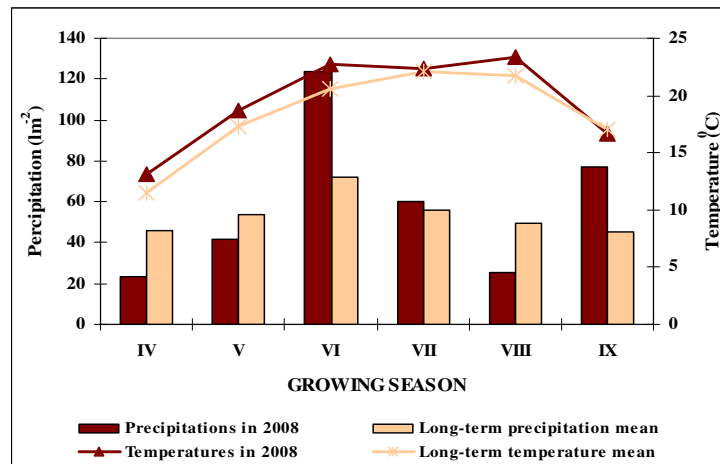


Fig. 1. Weather conditions for 2008 growing season and long-term mean

During the 2008 growing season, the total precipitation was about 9% higher than the long-term mean, showing high deviations across months due to unfavourable distribution of precipitation (Figure 1). During the seed swelling and germination periods, the amount of precipitation was lower, inducing non-uniform emergence and an adverse effect of the bacterial activity of the root which needs moisture for development. Soybean water requirements were significantly reduced during the stage of maturation. Large amounts of precipitation during the growing season, especially in September, resulted in the prolongation of the growing season.

Results and Discussion

The average yield under conventional technology production was 4.84 tha^{-1} and it was higher compared to the ecological system of soybean production yielding 4.68 tha^{-1} . The protein content of grain was 0.97 % higher in conventional production than in ecological production, while the oil content of grain was 1.66 % lower under conventional production conditions (Table 1).

Tab. 1. Yield and quality of soybean grain from conventional and ecological production systems

<i>Conventional production</i>		<i>Yield (t ha⁻¹)</i>				<i>Proteins (%)</i>				<i>Oil (%)</i>			
		<i>Varieties</i>											
<i>Density</i>		Galina	Sava	Mima	\bar{x} B	Galina	Sava	Mima	\bar{x} B	Galina	Sava	Mima	\bar{x} B
400.000		4.81	4.63	5.16	4.87	38.65	39.31	37.03	38.33	20.83	21.95	22.62	21.80
500.000		4.91	4.63	5.10	4.88	38.41	39.28	37.20	38.30	21.27	21.68	22.49	21.81
600.000		4.78	4.43	5.09	4.77	39.27	39.74	36.40	38.47	20.94	22.04	23.06	22.01
\bar{x} A		4.84	4.56	5.12	4.84	38.78	39.44	36.88	38.37	21.01	21.89	22.72	21.87
<i>Ecological production</i>		<i>Yield (tha⁻¹)</i>				<i>Proteins (%)</i>				<i>Oil (%)</i>			
		<i>Varieties</i>											
<i>Density</i>		Galina	Sava	Mima	\bar{x} B	Galina	Sava	Mima	\bar{x} B	Galina	Sava	Mima	\bar{x} B
400.000		4.55	4.15	5.01	4.57	38.76	38.86	36.55	38.06	20.78	22.16	23.29	22.08
500.000		4.99	4.52	5.06	4.86	38.69	39.66	36.30	38.22	21.49	21.89	23.25	22.21
600.000		4.71	4.23	4.87	4.60	38.38	39.14	35.67	37.73	21.33	22.20	23.75	22.43
\bar{x} A		4.75	4.30	4.98	4.68	38.61	39.22	36.17	38.00	21.20	22.08	23.43	22.24

<i>Factor</i>	<i>Conventional production</i>						<i>Ecological production</i>					
	<i>Yield</i>		<i>Proteins</i>		<i>Oil</i>		<i>Yield</i>		<i>Proteins</i>		<i>Oil</i>	
	LSD											
	1%	5%	1%	5%	1%	5%	1%	5%	1%	5%	1%	5%
A	0.47	0.31	4.17	2.76	2.56	1.70	0.46	0.30	4.74	3.13	6.17	4.08
B	0.27	0.19	1.15	0.84	0.85	0.62	0.23	0.17	1.00	0.73	0.56	0.41
A x B	0.46	0.34	1.99	1.46	1.48	1.08	0.41	0.30	1.74	1.27	0.98	0.71
B x A	0.56	0.41	4.46	3.00	2.81	1.90	0.56	0.38	4.94	3.29	6.22	4.18

Conventional production

Variety 'Mima' produced a statistically very significantly higher yield than 'Sava'. The other differences were not statistically significant. Grain yield was not significantly affected by either sowing density or the variety x density interaction. The effect of the density \times variety interaction was significant. 'Mima' had statistically significantly much higher yield than 'Sava' at a sowing density of 400.000 and 500.000 plants ha^{-1} , and statistically very significantly higher yield at 600.000 plants ha^{-1} .

Differences between the average values for the protein content of soybean grain were not statistically justified. Varga *et al.* (2008) report a somewhat higher grain protein content at an increasing plant density during a period of three years. The density x variety interaction was significant, as variety 'Sava' had a higher grain protein content than 'Mima' at a density of 600,000 plants ha⁻¹. The other differences observed were not statistically significant.

'Mima' had a significantly higher oil content of grain than 'Galina', which is in agreement with the results of Dozet *et al.* (2008). Change of sowing density did not affect the oil content of soybean grain. The variety x density interaction was not significant as opposed to the significant density x variety interaction. Due to the highest sowing density employed, 'Mima' had a statistically significantly higher percentage of oil than 'Galina'.

Ecological production

The average grain yield was statistically significantly much higher in 'Mima' than in 'Sava'. The influence of sowing density was highly significant. The sowing density of 500,000 plants ha⁻¹ resulted in significantly higher yield as compared to the other densities tested. Both interactions were significant.

Protein and oil content was not dependent upon variety and sowing density.

Tab. 2. Correlation of properties tested under conventional and ecological production systems

<i>Conventional production</i>	<i>Yield</i>	<i>Proteins</i>	<i>Oil</i>
<i>Yield</i>	1.00		
<i>Proteins</i>	0.00	1.00	
<i>Oil</i>	- 0.12	- 0.86**	1.00
<i>Ecological production</i>	<i>Yield</i>	<i>Proteins</i>	<i>Oil</i>
<i>Yield</i>	1.00		
<i>Proteins</i>	- 0.03	1.00	
<i>Oil</i>	- 0.06	- 0.91**	1.00

p < 0.05 * p < 0.01 **

In both production technologies tested in this study, a highly negative correlation between protein content and oil content in soybean grain was confirmed (Table 2), complying with the study of Brim and Burton (1979) who report that an increase in protein content leads to a decrease in oil content. The other correlations were not significant.

Conclusion

This study suggests the following:

- Yield and protein content were higher under conventional production technology than under the ecological system, whereas the oil content was 1.66 % lower in the former than in the latter system;

- Yield significantly depends on variety in both production systems. The effect of sowing density was non-significant in the conventional system and very significant in the ecological system;
- Differences between the average values of the protein content of soybean grain were not statistically justified in terms of the factors tested in the two production technologies;
- Under the conventional production system, variety 'Mima' had a significantly higher grain oil content than variety 'Galina'. Under ecological production, the differences observed were not statistically significant;
- Change of sowing density did not influence the oil content of soybean grain in the production technologies studied;
- In both technologies of soybean production, a highly negative correlation between the protein content and oil content of soybean grain was confirmed.

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UTICAJ GUSTINE SADNJE NA PRINOS I KVALITET SOJE U EKOLOŠKIM I KONVENCIONALNIM USLOVIMA PROIZVODNJE

- originalni naučni rad -

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Rezime

Ispitivanja su izvršena tokom 2008. godine u uslovima ekološke i konvencionalne proizvodnje soje. Praćeni su sledeći parametri: tri različite gustine sadnje (400.000, 500.000 i 600.000 biljaka/ha) i tri sorte soje različite grupe zrelosti (Galina, Sava i Mima). Dobijeni podaci obrađeni su analizom varijanse, po dvofaktorijalnom metodu razdeljenih parcela (sorta i gustina sadnje). Prinos i sadržaj proteina bili su viši u konvencionalnoj tehnologiji proizvodnje u odnosu na ekološku, dok je sadržaj ulja bio manji za 1,66%. Prinos je značajno zavisio od sorte u oba sistema proizvodnje. Uticaj gustine sadnje nije bio značajan u konvencionalnoj proizvodnji, za razliku od ekološke proizvodnje. Razlike između prosečnih vrednosti sadržaja proteina u zrnju soje nisu bile statistički značajne u pogledu sorti i gustine sadnje u ispitivanim tehnologijama proizvodnje. U konvencionalnoj proizvodnji, sorta 'Mima' imala je značajno veći sadržaj ulja u zrnju nego sorta 'Galina'. Gustina sadnje nije uticala na sadržaj ulja u zrnju soje u ispitivanim tehnologijama proizvodnje. Veoma značajna negativna korelacija između sadržaja proteina i ulja utvrđena je u ekološkoj i konvencionalnoj proizvodnji (-0,86**, odnosno -0,91**).