Original scientific paper

Influence of irrigation and variety on the soybean grain yield and quality in the no nitrogen fertilization soil condition

Marko Josipović[1], Aleksandra Sudarić[1], Rezica Sudar[1], Hrvoje Plavšić[1], Monika Marković[2], Danijel Jug[2], Biserka Stojić[3]

[1]*Agricultural Institute Osijek, Južno predgrađe 17, 31103 Osijek, Croatia (marko.josipovic@poljinos.hr)*
[2]*University J. J. Strossmayer in Osijek, Agricultural faculty Osijek, Svačićeva 1d, Osijek 31000 Osijek, Croatia,*
[3]*Petrokemija d.d., Kutina, Aleja Vukovar 4, 44320 Kutina, Croatia*

Abstract
Soybean as wide spread crop in eastern Croatia is planted on 45888 ha with grain yield 2.0 t ha^{-1}. The treatments in the field trials were growing season (GS, main factor, A: A1=year 2010; A2= year 2011; A3= year 2012), irrigation rate (IR, sub factor, B: B1=control, no irrigation, B2= soil water content maintained from 60% to 100% of field water capacity (FWC), B3= soil water content maintained from 80% to 100% of FWC) and soybean varieties (sub sub-factor, C: C1=Lucija, C2=Vita, C3=Ika and C4=Tena, created at Agricultural Institute Osijek). The objective of this study was testing irrigation and genotype impact on grain yield, oil and protein content at the soybean in the no nitrogen fertilization soil conditions. Therefore, the nitrogen potential in three climatically different growing seasons in natural, field conditions has been tested. Mean soybean grain yields were 3436 kg ha^{-1}, 3678 and 3633 kg ha^{-1} in year 2010, 2011 and 2012, respectively. Irrigation and soybean variety had statistically significant impact on soybean grain yield, while growing season not. Growing season, irrigation and soybean variety resulted by statistical significant impact on oil content, while growing season on protein content, only.

Key words: irrigation, soybean, nitrogen fertilization, grain yield, grain quality

Introduction

Soybean is wide spread crop in eastern Croatia and in the ten years (2000-2009) mean soybean harvested area was 45888 ha with average grain yield 2.0 t ha^{-1} (Central Croatian Bureau of Statistic, 2010). Grain yields of soybean varied in close connection with amount and distribution of precipitation during the growing season (Vučić and Bošnjak, 1980; Josipović et al., 2006; Bošnjak 2008; Kovačević et al., 2010; Josipović et al. 2010) and N fertilization (Bharati et al., 1986), intensity and longings of dry period in different growing stage (Rao and Reddy, 1990; Dragović, 1994; Brevedan and Egli, 1978; Bošnjak, 2008), properties of cultivars (Sudarić et al., 1996; Sudarić et al., 2004; Sudarić et al., 2009) soil properties and performing of other agro-technical measures (Sudarić et al., 2009; Fehr, 1983 and Specht et al., 1999 according to Sudaric et al., 2004). Some general aspects of irrigation effects were shown by Mađar and Vratarić (1980); Vučić and Bošnjak (1980); Bošnjak et al. (2008); Josipović et al. (2010). Studies of Bošnjak (2008), Josipović et al. (2010) and Pejić et al. (2012) confirmed that the highest soybean grain yield was when the soil water content was maintained from 60% field water capacity (FWC) to 100% FWC. The mentioned authors also confirmed that maintenance soil water content from 80% FWC to 100% FWC resulted in same or lower grain yield on the irrigation control treatment. Vučić (1976) confirmed that

irrigation, in most cases of growing soybean, increased grain yield by 30% while Mađar and Vratarić (1980) achieved higher grain yield, from 23% to 49%. The „very dry and warm year“, 2012 are in accordance to Mađar and Vratarić results.

Irrigation is very important factor of stable soybean grain yield (Sorensen and Penas, 1978; Jurić et al., 1995; Josipović et al., 2010) and soybean cultivar are also important. Thus, Josipović et al. (2010) concluded that irrigation and N fertilization resulted in statistically significant difference in soybean grain yield in the four year investigations. The highest soybean grain yield, 4.13 t ha^{-1} achieved when soil moisture was maintained from 60% to 100% FWC and 100 kg ha^{-1} N. De Mooy et al. (1973) and Welch et al. (1973), according to Brevedan et al. (1978a), Brevedan et al. (1978b) confirmed that N fertilization effect on grain yield soybean reduced soybean grain yield. Bhangoo et al. (1972), Johnson and Hume (1972), Lyons and Earley (1972) and Mederski et al. (1958, cit. Sorensen and Penas, 1978) confirmed small increasing soybean grain yield (as influence of N fertilization). Opposite the mentioned results, Beard and Hoover (1971), Lyons and Early (1952), Mederski et al. (1958), Wagner (1962), Welch et al. (1973, cit. Sorensen and Penas, 1978), Jurić et al. (1995) confirmed that N fertilization did not result in growing soybean grain yield. Soybean protein and oil content are in close connection in total amount and usually is from 60% to 65%. It content is property of cultivar but growing season with soil properties and applied soil cultivation has considered impact on that. The objective of this study was testing irrigation and genotype impact on soybean grain yield under the no nitrogen soil fertilization. Thus will be tested nitrogen potential in three climatically different growing seasons in natural, field conditions.

Material and methods

In this paper influence of three growing seasons, irrigation rate (IR) and soybean varieties was tested on the grain yield and grain quality on no nitrogen (N) fertilization, under field conditions in Osijek (Croatia) humofluvisol, semi deep, no calcareous soil type. The soil had retention water capacity near 38.5% volume. The growing season (GS, main factor, A) were: A1=year 2010; A2=year 2011; A3=year 2012. Irrigation rate (IR) was sub factor, B: B1=control, no irrigation, B2=soil water content maintained from 60% to 100% of FWC and B3=soil water content from 80% to 100% of FWC.

Table 1. Irrigation water distribution on the irrigation treatments (B1, B2 and B3) during the investigation, 2010 - 2012

Growing season	No of IR and amount of water, mm				Rainfall mm in GS mm	Total water amount per treatment, irrigation+rainfall, mm		
	A2 treatment		A3 treatment					
	No of IR	applied water	No of IR	applied water		A1	A2	A3
2010	2	70	4	140	676	676	746	811
2011	4	140	7	245	246	246	386	491
2012	5	175	8	280	293	293	368	573
Mean	3.7	128	6.3	222	405	405	500	625

Amount of water added by IR was as follows: B1=control treatment; B2=twice by 35 mm and B3=four times by 35 mm (in year 2010); B1=control treatment; B2=4 time by 35 mm and 7 times by 35 mm (in year 2011); B1= control treatment; B2=5 time by 35 mm and 8 times by 35 mm (in year 2012, Table 1). Average total water amount in tree year was 405 mm, 500 and 625 mm, on the B1, B2 and B3 treatment, respectively. N fertilization was zero kg ha^{-1} (during the last 6 years). The 100 kg ha^{-1} P_2O_5 and 150 kg ha^{-1} K_2O were applied in form of NPK 0:20:30 fertilizers (500 kg ha^{-1} as a basic and pre sowing fertilization, split in twice).

Soybean cultivars (sub sub-factor C) were C1=Lucija, C2=Vita, C3=Ika and C4=Tena, created at Agricultural Institute Osijek.

The field trial experiments were designed as three factorial methods with randomized blocks design in three replications. Experimental basic plot of soybean cultivar (C) was 30 m^2, irrigation plot (B) 120 m^2. Self-propelled sprinkler for irrigation was used. Soybean was planted in the middle of April and harvested at the October. An Infratec 1241 Grain Analyzer at the Agricultural Institute Osijek was used for the analyses of protein, oil and starch concentrations with ready-to-use calibrations. Planned plant densities were 550 plants m^{-2}. Soybean grain yield was calculated on 13% grain moisture basis. The given data was statistically performed by SAS, model GLM, three factorial trial design. Growing season 2010 was very wet, 2011, dry and warm, 2012 very dry and very warm (Table 2). Rainfall shortage, especially during July is in close connection with low yields of spring crops in Croatia (Kovačević et al. 2010), but also wet years in soybean crop production (Josipović et al., 2011.).

Table 2 Mean air temperatures (°C) and amount of rainfall (mm) in Osijek region in growing season 2010-2012, and 30-year mean (Osijek, Weather Bureau)

Osijek	Weather Bureau: years 2010-2012 and long-term mean (LTM: 1971-2000)							
Month	Rainfall in growing season, mm				Temperature in growing season, °C			
	2010	2011	2012	LTM	2010	2011	2012	LTM
April	12.4	13.2	12.5	54.1	71	20	47	11.3
May	16.5	16.7	16.9	58.9	121	81	94	16.5
June	20.4	20.8	22.5	83.5	234	50	68	19.4
July	23.2	22.2	24.8	66.6	32	74	48	21.1
Aug.	21.7	23.1	24.1	59.6	111	5	4	20.3
Sept.	15.6	20.3	18.9	51.8	108	16	32	16.6
April-June	18.3	19.4	20.0	368.3	676	246	293	17.5

Results and discussion

Grain yield of soybean is one of the most important properties for both breeders and producers. Seed yield is comprehensive property and it consists of many components of quantitative parameters, whose genetic base is polygenic (Sudaric, 1999). Mean soybean grain yields were 3436 kg ha^{-1}, 3678 and 3633 kg ha^{-1} in year 2010, 2011 and 2012, respectively (Table 3).

Year as main factor have no statistical significant difference in only three years, in spite some investigations indicate that. But, that is expected that year 2011 was more convenient for soybean production. In very wet year, 2010 was the lowest grain yield. In spite that year 2012 was very dry and warm, soybean had moderate grain yield, which indicate that soil fertility potential is very good. These results are in close connection with Kovačević et al. (2010), Josipović et al. (2010) which proved impact of climate conditions (environment effect = clime conditions + soil conditions + agro technical practice + their interactions).

Irrigation, both treatments (B2 and B3) resulted in high statistically difference ($P \geq 0.01$), in soybean grain yield toward control treatment (B1, no irrigation, Table 3). Irrigation treatments showed statistical almost same results, that is good basis for recommend B2 treatment, well, reduced irrigation and production costs in soybean production. It is in a close connection with investigation of Mađar and Vratarić (1980), Vučić and Bošnjak (1980), but only partly with Bošnjak (2008) and Josipović et al. (2010).

Cultivar effect (C) in seed yield resulted in high statistically influence (P≥0.01). Thus variety Tena (C4) yielded 3707 kg ha^{-1}, which is better than two other cultivars, and the most widespread cultivar Ika was on the same level. Interaction effect, year and irrigation and year and cultivar were statistically high significant.

Table 3. Influence of growing season, irrigation and variety of soybean on grain yield with no nitrogen fertilization

A	B1 (control treatment)				B2 (60-100% FWC)				B3 (80-100% FWC)			
	C1	C2	C3	C4	C1	C2	C3	C4	C1	C2	C3	C4
	Soybean grain yield (kg/ha)											
A1	3505	3363	3571	3399	3470	3393	3479	3302	3595	3439	3375	3344
A2	2908	2321	2926	3145	3942	3843	4191	4462	3510	4200	4209	4477
A3	2660	3033	3183	3106	3585	4224	3786	3711	3240	4299	4357	4416
xBC	3024	2906	3227	3217	3666	3820	3819	3825	3448	3979	3980	4079

	Interaction AB				Interaction AC				Mean
	B1	B2	B3		C1	C2	C3	C4	A
A1	3460	3411	3438	A1	3523	3399	3475	3348	3436
A2	2825	4110	4099	A2	3453	3455	3775	4028	3678
A3	2996	3827	4078	A3	3162	3852	3776	3744	3633
x B	3094	3782	3872	x C	3379	3568	3675	3707	3582

Analyze of variance	A	B	C	AB	AC	BC	ABC
LSD 5%	n.s.	173	192	332	367	n.s.	n.s.
LSD 1%	n.s.	227	259	466	527	n.s.	n.s.
F test	n.s.	46.83**	5.00**	13.88**	4.52**	n.s.	n.s.

Note: growing season (A: A1=year 2010, A2=year 2011, A3=year 2012), irrigation treatment (B1=control, B2=60-100% maintenance of field water capacity, FWC, B3=80-100% FWC) and variety (C: C1=Lucija, C2=Vita, C3=Ika, C4= Tena)

Table 4. Influence of growing season, irrigation and variety on soybean oil content with no nitrogen fertilization

Influenced of on soybean grain yield												
A	B1 (control treatment)				B2 (60-100% FWC)				B3 (80-100% FWC)			
	C1	C2	C3	C4	C1	C2	C3	C4	C1	C2	C3	C4
	Soybean oil content (%)											
A1	22.0	22.0	21.6	21.3	21.7	21.2	20.8	21.0	22.0	21.3	21.1	20.8
A2	24.1	23.3	22.6	23.0	23.0	22.5	21.9	22.3	22.6	22.1	21.7	22.0
A3	23.5	23.1	22.5	22.3	23.0	23.2	22.7	22.7	23.3	22.7	22.9	22.7
xBC	23.2	22.8	22.3	22.2	22.6	22.3	21.8	22.0	22.6	22.0	21.9	21.9

	Interaction AB				Interaction AC				Mean
	B1	B2	B3		C1	C2	C3	C4	A
A1	21.7	21.2	21.3	A1	21.9	21.5	21.2	21.0	21.4
A2	23.3	22.4	22.1	A2	23.2	22.6	22.1	22.4	22.6
A3	22.9	22.9	22.9	A3	23.3	23.0	22.7	22.6	22.9
x B	22.6	22.2	22.1	x C	22.8	22.4	22.0	22.0	22.3

Analyze of variance	A	B	C	AB	AC	BC	ABC
LSD 5%	0.19	0.28	0.16	n.s.	0.30	n.s.	n.s.
LSD 1%	0.25	0.37	0.21	n.s.	0.44	n.s.	n.s.
F test	128.1**	7.81**	47.72**	n.s.	2.34*	n.s.	n.s.

Note: growing season (A: A1=year 2010, A2=year 2011, A3=year 2012), irrigation treatment (B1=control, B2=60-100% maintenance of field water capacity, FWC, B3=80-100% FWC) and variety (C: C1=Lucija, C2=Vita, C3=Ika, C4= Tena)

Mean soybean oil content in the three year trials was 21.4%, 22.6 and 22.9% in year 2010, 2011 and 2012, respectively (Table 4). Year as main factor, irrigation as sub factor and variety as sub sub-factor have had statistical significant difference in oil content in soybean grain. Mentioned results are similar to Breene et al. (1988). B2 and B3 irrigation treatment resulted by lower oil content then control treatment, which induce that rational irrigation is good solution for practice application. Variety Lucija have the highest oil content (22.8%). Interaction of year and variety also resulted by statistical significant effect of oil in soybean grain.

Protein content resulted with statistical significant impact between all tested growing seasons and was 40.5, 38.2 and 39.0% in year 2010, 2011 and 2012, respectively (Table 5). In very wet year 2010, protein content was significantly higher than other two, dry and very dry years. Irrigation treatments have no statistical significant impact to soybean grain protein content that is recommended use B2 treatment, as cheaper. Cultivars also have no statistical significant impact in three tested years what is unusual for four varieties.

Table 5. Influence of growing season, irrigation and variety on soybean protein content with no nitrogen fertilization

Influenced of on soybean grain yield												
A	B1 (control treatment)				B2 (60-100% FWC)				B3 (80-100% FWC)			
	C1	C2	C3	C4	C1	C2	C3	C4	C1	C2	C3	C4
	Soybean protein content (%)											
A1	40.5	39.9	39.9	40.0	40.6	41.0	41.0	40.3	40.6	41.0	40.4	40.6
A2	34.8	36.9	38.1	37.2	38.3	38.6	39.3	38.5	39.4	39.5	39.0	38.9
A3	39.2	39.2	39.6	40.0	39.7	38.5	38.4	38.6	39.1	38.8	38.0	38.6
xBC	38.2	38.7	39.2	39.1	39.5	39.4	39.5	39.1	39.7	39.7	39.1	39.4

	Interaction AB				Interaction AC				Mean
	B1	B2	B3		C1	C2	C3	C4	A
A1	40.1	40.7	40.6	A1	40.6	40.6	40.4	40.3	40.5
A2	36.7	38.7	39.2	A2	37.5	38.3	38.8	38.2	38.2
A3	39.5	38.8	38.6	A3	39.4	38.8	38.7	39.1	39.0
x B	38.8	39.4	39.5	x C	39.1	39.3	39.3	39.2	39.2

Analyze of variance	A	B	C	AB	AC	BC	ABC
LSD 5%	0.40	n.s.	n.s.	1.10	0.65	0.65	1.58
LSD 1%	0.53	n.s.	n.s.	1.55	0.93	0.93	2.91
F test	63.89**	n.s.	n.s.	6.19**	4.65**	3.92**	2.05*

Note: growing season (A: A1=year 2010, A2=year 2011, A3=year 2012), irrigation treatment (B1=control, B2=60-100% maintenance of field water capacity, FWC, B3=80-100% FWC) and variety (C: C1=Lucija, C2=Vita, C3=Ika, C4= Tena)

Conclusions

Year as main factor have no statistical significant difference in soybean grain yield. Irrigation, both treatments resulted in high statistically difference, in soybean grain yield toward control treatment. Cultivar effect in seed yield resulted in high statistically influence. Interaction effect, year and irrigation and year and cultivar were statistically high significant. Year as main factor, irrigation as sub factor and variety as sub sub-factor have had statistical significant difference in oil content in soybean grain. Protein content resulted with statistical significant impact between all tested growing seasons and was 40.5, 38.2 and 39.0% in year 2010, 2011 and 2012, respectively. Irrigation treatments have no statistical significant impact to soybean grain protein content that is recommended use B2 treatment, as cheaper.

Acknowledgments
We tank so much to Petrokemija d.d, Kutina, Croatia on financial support for these investigations.

References

Bharati, M.P., Whigham, D.K. and Voss, R.D. (1986): Soybean Response to Tillage and Nitrogen, Phosphorus, and Potassium Fertilization. Agronomy Journal. 78: 947-950.

Bošnjak Đ (2008): Navodnjavanje soje u redovnoj, drugoj i postrnoj sjetvi – Irrigation of soyabean in order, second crop and after cereals planting. In book Soja -Soyabean. Miladinović J., Hrustić M., Vidić M. ur. Miladinović J., Hrustić M., Vidić M. p. 512. Serbia. Institut za ratarstvo i povrtarstvo, Novi Sad. Sojaprotein Bečej.

Breene, W.M., Lin, S., Hardman, L., Orf J. (1988): Protein and oil content of soybeans from different geographic locations. Journal of the American Oil Chemists' Society vol. 65 (12) 1927-1931.

Brevedan, R.E. and Egli, D.B. (1978): Short Periods of Water Stress during Seed Filling, Leaf Senescence, and Yield of Soybean. Crop Science Society of America. 43: 2083-2088.

Brevedan, R.E.; Egli, D.B. and Leggett J.E. (1978): Influence of N Nutrition on Flower and Pod Abortion and Yield of Soybeans. Agronomy Journal. 70: 2083-2088.

Dragović, S. (1994): Uticaj suše u različitim fenofazama razvića na prinos soje i efekat navodnjavanja – Influence of soil draught in different growing stages to soybean grain yield and irrigation effect. Zbornik radova Instituta za ratarstvo i povrtarstvo. Novi Sad. Serbia. 143-152.

http://www.dzs.hr: Republic of Croatia - Central Croatian Bureau of Statistic, 2010.

Josipović, M., Plavšić, H., Sudarić, A., Vratarić, M. and Liović I. (2010): Utjecaj navodnjavanja i gnojidbe dušikom na urod zrna soje Glycine max (L.) Merr. – Irrigation and nitrogen fertilization impact on grain yield of soybean Glycine max (L.) Merr. In Proceedings and CD of 45th Croatian and 5th International symposium of agronomist (ed.) Marić, S. and Lončarić, Z. Poljoprivredni fakultet Sveučilišta Josipa Jurja Strossmayera u Osijeku. Opatija, Croatia. 751-755.

Josipović, M.; Kovačević, V.; Šoštarić, J.; Plavšić, H.; Liović, I. (2006): Influences of irrigation and fertilization on soybean properties and nitrogen leaching. Cereal Research Communications. 34 (1) 513-516.

Josipović, M., Sudarić, A., Kovačević, V., Marković, M., Plavšić, H., Liović, I. (2011): Irrigation and nitrogen fertilization influences on soybean variety (Glicine max. L. Merr.) properties. Poljoprivreda. 17 (1) 9-15.

Juric, I., Zugec, I., Knezevic, M. and Kovacevic, V. (1995): Influence of Phosphorus and Nitrogen fertilization on soybean (*Glycine max* (L.) Merr.) yields under subtropical conditions (Ethiopia). In The Proceedings, The Soil Fertility and Fertilizer Management. 9th International Symposium of CIEC. Kusadasi. Turkey. 25-30.

Kovačević, V., Josipović, M., Kaučić, D., Iljkić, D. (2010): Weather impacts on yields of maize, sugar beet, soybeans and sunflower. Proceedings of 45th Croatian ans 5th International Symposium of Agriculture. Opatija, Croatia. (ed) Marić, S. and Lončarić, Z.: Poljoprivredni fakultet Sveučilišta J.J Strosmayera u Osijeku. 796-800.

Mađar, S., and Vratarić, M. (1980): Ispitivanje reakcije sorata soje u uvjetima navodnjavanja – Testing of soybean variety in irrigation conditions. Zbornik radova Poljoprivrednog instituta Osijek (PIO): Croatia, 121-134.

Pejić, B.; Bošnjak, D.; Mačkić, K.; Rajić, M.; Josipović, M.; Jug, I.; Maksimović, L. (2012): Yield and water use efficiency of irrigated soybean in Vojvodina, Serbia. Ratarstvo i povrtarstvo. 49 (1) 80-85.

Rao, G.S.S. and Reddy, T.R. (1990): Effect of irrigation and nitrogen levels on yield components and yield of Rabi soybean. Journal of Research – APAU. 18(1): 52-53.

Sorensen, R.C., and Penas, E.J. (1978). Nitrogen Fertilization of Soybeans. Agronomy Journal. Vol. 70 (2): 213-216.

Sudarić, A., Vratarić, M., Jurković, Z. (1996): Procjena novih linija soje I grupe zriobe Poljoprivrednog instituta Osijek tijekom 1994. i 1995. godine – Evaluation of some new soybean lines of the I maturity group at the Osijek Agricultural Institute in years 1994 and 1995. Poljoprivreda 2 (1-2): 47-54.

Sudaric, Aleksandra (1999): Oplemenjivačka vrijednost kvantitativnih svojstava različitih genotipova soje (Glycine max (L.) Merill) – The breeding values of quantitative traits different soybean genotypes (Glycine max (L.) Merill). Phd Thesis. University J.J. Strossmayera u Osijeku, Agricultural faculty in Osijek. Croatia. p. 99.

Sudarić, A., Vrataric, M., Sudar, R., Duvnjak, T. (2004): Genetic advance in yield components, seed yield and seed quality of soybean OS-lines. Sjemenarstvo, 21 (3-4): 115-124.

Sudarić, A., Vratarić, M., Volenik, M., Matoša, M., Duvnjak, V. (2009): Heterozis i beltozis za komponente uroda zrna soje - Heterosis and heterobeltozis for seed yield components in soybean. Poljoprivreda 15 (2): 26-31.

Vratarić, M. and Sudarić, A. (2008): Soja Glycine max (L.) Merr. – Soybean Glycine max (L.) Merr. In book., (ed.) Vratarić. Osijek. Croatia. Poljoprivredni institut Osijek. p 460.

Vučić, N. (1976): Zalivni režim pojedinih poljoprivrednih kultura. In book "Navodnjavanje poljoprivrednih kultura". (ed) Stojanović Z. Poljoprivredni fakultet u Novom Sadu. Novi Sad. Serbia. 41-66.

Vučić, N. and Bošnjak, Đ. (1980). Potencijalna evapotranspiracija soje u klimatskim uslovima Vojvodine – Potential evapotranspiration in clime conditions of Vojvodina region. Arhiv za poljoprivredne nauke. Serbia. 41 (144): 569-575.