EFFECT OF IRRIGATION ON SOYBEAN YIELD AND QUALITY DEPENDING ON CULTIVATION PRACTICES

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Field trials with and without irrigation were carried out in 2005 and 2006 to study two very early soybean genotypes grown conventionally and in a double cropping system following the harvest of spring barley as the preceding crop.

In the two study years, which differed from the point of view of soybean production, the effects of weather conditions and planting date on yield and quality (oil and protein contents) of soybean grain were analyzed.

According to the obtained results, the yield of main crop soybeans depended mainly on the amount and distribution of rainfall, whereas the yield of double cropped soybeans depended to a great extent on the temperature sum during the growing period. The soybean yields decreased in proportion with the decreases in rainfall amount and temperature sum. In an average year, double cropped soybean produces a considerably lower yield than the main crop soybean, however, in dry years the former may out yield the latter when no irrigation is used. In rainy years, the yield of irrigated main crop soybean may be lower than that of non-irrigated soybean, whereas in a typical year the use of irrigation increases the yield of soybean significantly.

Keywords*: soybean, irrigation, standard sowing dates, double cropping, weather conditions, grain yield, oil and protein contents.*

The soybean acreage keeps increasing in our country and worldwide. Soybean performance is greatly affected by the genotype and agroecological conditions. As the latter change from year to year, soybean yield and quality tend to vary accordingly. Weather conditions, especially rainfall amount, rainfall distribution and drought, may significantly reduce soybean yield and quality (Dragović, 1993). These effects are effectively countermanded by irrigation. Under the local conditions, early soybean genotypes may be successfully double cropped providing that irrigation is applied. The profits in respect to the inputs are 3.1% in rainfed production and 18.4% in irrigation. Clearly, irrigation practice brings increases in yield level, production volume and the profitability of production (Babović and Milić, 2006).

In the period 1986-1990 at Rimski Šančevi experiment field, the average yield of grain of double cropped soybean was 2.38 $t \cdot ha^{-1}$ (Bošnjak and Dragović, 1998). Mađar et al. (1984) reported the yields from 1.2 to 2.0 t/ha, while Vučić

(1981) obtained 2.64 to 3.04 t·ha^{-1}. The early soybean cultivars developed at Institute of Field and Vegetable Crops in Novi Sad (maturity groups 00 and 000), make it possible for double cropped soybeans to achieve yield (Maksimović et al., 2001) and quality levels (Milić et al., 2005) of soybeans grown as the main crop.

The objectives of this investigation were to assess the effects of irrigation, weather conditions and planting date on soybean yield and quality.

MATERIAL AND METHOD

Experiments were conducted at Rimski Šančevi experiment field of Institute of Field and Vegetable Crops in Novi Sad, on the calcareous chernozem soil. Two early soybean genotypes (maturity group 000) developed at the Institute, the cultivar Gracia and the line NS-L-200181, were examined in the course of 2005 and 2006. The experiments included two planting dates. The main crop soybean was planted in mid-April and harvested at the end of August. The double cropped soybean was planted in the first 10 days of July, after barley harvest, and it was harvested in October. The main crop soybean involved variants:

- Pre-irrigation soil moisture of 60-65% FWC,
- Control, non-irrigated.

As irrigation is obligatory in double cropping, the non-irrigated control was omitted in the double cropped soybean. Sprinkling irrigation was used. Irrigation was scheduled on the basis of soil moisture dynamics monitored in the zone of active rhizosphere, in 10-20 cm layers to the depth of 60 cm. Soil moisture was determined gravimetrically, by drying soil samples at 105–110^{0}C till constant weight.

The experimental plots received conventional cultivation practices for soybeans. Stand density and yield were determined after plant maturation, in three replications. After harvest, moisture, oil and protein contents in grain were measured. The moisture content was then calculated on 14 % moisture basis. Experimental results were processed by the analysis of variance and shown in tables.

RESULTS AND CONCLUSSIONS

Weather conditions during the experimental period

In the period 2005-2006, the weather conditions were favorable for crop production. The sum of rainfall in the growing season of the main crop soybean was 144 mm above the long-term average (45%) in 2005 and 52 mm (16%) above the long-term average in 2006 (Table 1). Because of that it was not necessary to irrigate the main crop soybeans frequently. In 2005, one irrigation with 45 mm of water was performed. In 2006, the irrigation norm was 165 mm and it was added in 3 irrigations. Air temperatures were on the level of the average values in 2005, and somewhat above the average in 2006.

In the period of double cropped soybean's growing season, i.e., from 8 July to 26 October 2005, the rainfall was 279 lm^{-2}, which is much above the long term average. The rainfall pattern in June, July and August considerably aggravated the production conditions (Table 1). In 2005, only two irrigations were performed with a total irrigation norm of 90 lm^{-2}. In 2006, in the period from 3 July to 27 October, the rainfall was 196 lm^{-2} and the irrigation norm was 250 lm^{-2}. The latter norm was

in agreement with the estimate of irrigation norm for double cropped soybean (60-265 lm^{-2}) made by Bošnjak and Dragović (1998).

Table 1

Precipitation sum (lm^{-2}) and mean daily temperatures (^oC) during soybean growing season

Month	Precipitation (lm^{-2})				Temperature (^oC)				Average 1964-2000		
	2005		2006		2005		2006		Prec. (lm^{-2})		Temp ^oC
	I	II	I	II	I	II*	I	II*	I	II*	I
April	33		41		11.7		12.7		47		11.3
May	38		70		17.0		16.6		59		16.7
June	135		104		19.3		19.7		84		19.7
July	123	71	31	31	21.4	516	23.6	579	70	70	21.3
August	134	134	125	125	19.4	602	19.6	609	59	59	20.8
Septembar		67		24	16.7	518	17.4	538		41	16.8
Octobar		7		16	11.6	319	13.3	376		43	11.6
Sum	**463**	**279**	**371**	**196**		**1955**		**2102**	**319**	**213**	
I main crop ; II double crop					II* Montlhy bioclimatic sums						

The sums of active temperatures in 2005 and 2006 were 1955 and 2102°C, respectively. These values meet the temperature requirement of early soybeans (maturity group 000). Vučić (1981) estimated that early soybeans require the sum of bioclimatic temperatures between 2000 and 2200°C. Maksimović and Dragović (1993) estimated the temperature sum for double cropped soybeans (planted on 3 July) to be between 2053 and 2166°C.

Yield and quality

Soybean line NS-L-200181 had a significant grain yield compared with the cultivar Gracia in 2005, and a highly significantly yield in 2006 (Table 2).

Highly significant differences among the tested genotypes were registered both, in irrigation and the non-irrigated control. In this study, there were no significant differences in the double cropped variants. In the main crop variants, a highly significant effect of irrigation (24%) was registered in relation to the non-irrigated variants and the yield was increased by 77% in relation to double cropping. In favorable years such as 2006, yield level in double cropping reaches that achieved by non-irrigated main crop soybean (2.80 $t \cdot ha^{-1}$). In an 18-year study, Bošnjak (1996) obtained the average yield of non-irrigated main crop soybean of 2.70 $t \cdot ha^{-1}$. In extremely dry years such as 2000, early Novi Sad cultivars (maturity group 000) yielded between 2.57 and 2.85 $t \cdot ha^{-1}$ in double cropping (Maksimović et al., 2001).

The highest protein content, 42.78%, was achieved in 2005 in the irrigated variant of main crop soybean. Protein content was significantly higher in 2005 than in 2006 in all variants and in both genotypes. This was due to better climatic conditions in the period of protein synthesis in 2005. Ambient conditions during protein synthesis and specific characteristics of the cultivar are essential factors

determining the chemical composition of soybean grain (Hrustić et al., 1988; Hurburgh, 2000) (Table 3).

Table 2

Yields of main crop and double cropped soybeans

Treatments **(B)**	Variety **(A)**	Year C		Average **(AB)**
		2005	2006	
Non. Irrigated	Gracia	3443	2381	*2912*
	NS-L-200181	4108	2868	*3488*
	Average **(BC)**	***3776***	***2624***	***(B) 3200***
Irrigated	Gracia	3347	3906	*3626*
	NS-L-200181	4095	4512	*4303*
	Average **(BC)**	***3721***	***4209***	***(B) 3965***
Post harvest	Gracia	1876	*2670*	*2273*
	NS-L-200181	1463	*2930*	*2196*
	Average **(BC)**	***1670***	***2800***	***(B) 2235***
Average **(AC)**	Gracia	*2889*	*2986*	*(A) 2937*
	NS-L-200181	*3222*	*3437*	*(A) 3329*
Average (C)		***3056***	***3211***	***(ABC) 3133***

LSD	**A**	**B**	**C**	***AB***	***AC***	***BC***	***ABC***
0.05	144	212	154	336	234	310	570
0.01	197	297	210	510	336	469	1046

Table 3

Protein content (%) in grain of main crop and double cropped soybeans

Treatments **(B)**	Variety ***(A)***	Year C		Average **(AB)**
		2005	2006	
Non-irrigated	Gracia	42.80	41.18	*41.99*
	NS-L-200181	42.65	40.09	*41.37*
	Average **(BC)**	***42.72***	***40.64***	***(B) 41.68***
Irrigated	Gracia	42.60	41.07	*41.84*
	NS-L-200181	42.96	41.13	*42.05*
	Average **(BC)**	***42.78***	***41.10***	***(B) 41.94***
Post harvest	Gracia	42.56	*42.02*	*42.29*
	NS-L-200181	42.14	*40.73*	*41.44*
	Average **(BC)**	***42.35***	***41.38***	***(B) 41.86***
Average **(AC)**	Gracia	*42.65*	*41.42*	*(A) 42.04*
	NS-L-200181	*42.58*	*40.65*	*(A) 41.62*
Average (C)		***42.62***	***41.04***	***(ABC) 41.83***

LSD	**A**	**B**	**C**	***AB***	***AC***	***BC***	***ABC***
0.05	0.22	0.25	0.30	0.40	0.46	0.61	1.13
0.01	0.30	0.35	0.42	0.60	0.66	0.93	2.07

Protein content was significantly increased in the irrigated variants compared with non-irrigated ones. Bošnjak and Dragović (1998) also reported that irrigation tended to increase protein content by 2.5%. The protein content in double cropped soybean (41.86%) was at the level of that obtained in main crop soybean, confirming the results of Đorđević et al. (2005). Our results are also in good

agreement with 5-year results of Maksimović et al. (1993) who obtained high protein contents (42 to 43.4%) in catch cropping and double cropping.

Soybean cultivar Gracia had a highly significant protein content in relation to that of the line NS-L-200181.

Oil contents of both genotypes were significantly higher in 2006 than in 2005. Irrigation practice did not affect oil content of main crop soybean, contrary to the findings of Maksimović et al. (2004). The double cropped soybeans had a significantly lower oil content than the non-irrigated and irrigated main crop soybeans, 17.91%, 19.37% and 19.18%, respectively. Same results achieved Đukić et al. (2007) which explains lower level of oil content in double cropped soybeans due to unfavorable temperature condition. Soybean line NS-L-200181 had highly significant oil content in relation to the cultivar Gracia (Table 4).

Table 4

Oil content (%) in grain of main crop and double cropped soybeans

Treatments **(B)**	Variety ***(A)***	Year (C)		Average **(AB)**
		2005	2006	
Non-irrigated	Gracia	18.69	19.55	*19.12*
	NS-L-200181	18.91	20.33	*19.62*
	Average **(BC)**	***18.80***	***19.94***	***(B) 19.37***
Irrigated	Gracia	18.57	19.48	*19.03*
	NS-L-200181	19.24	19.40	*19.32*
	Average **(BC)**	***18.90***	***19.44***	***(B) 19.18***
Post harvest	Gracia	17.23	*17.12*	*17.18*
	NS-L-200181	18.92	*18.36*	*18.64*
	Average **(BC)**	***18.08***	***17.74***	***(B) 17.91***
Average **(AC)**	Gracia	*18.16*	*18.72*	*(A) 18.44*
	NS-L-200181	*19.02*	*19.36*	*(A) 19.19*
Average (C)		***18.59***	***19.04***	***(ABC) 18.82***

LSD	**A**	**B**	**C**	***AB***	***AC***	***BC***	***ABC***
0.05	0.20.	0.45	0.22	0.72	0.34	0.45	0.82
0.01	0.28	0.63	0.30	1.09	0.48	0.67	1.50

In 2005 compared with 2006, the main crop soybeans had higher protein content and lower oil content.

The cultivar Gracia had significant protein content and reduced oil content in grain while the line NS-L-200181 had significant oil content and a reduced protein content. These results confirm the negative correlation between protein and oil contents in soybean grain reported by Đorđević et al. (2005), Milić et al. (2005), etc.

CONCLUSION

The following conclusions were drawn on the basis of the obtained results:

- The early soybean genotypes from the maturity group 000, the cultivar Gracia and the line NS-L-200181, may be successfully grown as a main crop and as a double crop after small grains.

- In unfavorable years, irrigation practice considerably increased the yield of the examined genotypes, average values ranging from 3626 to 4303 $kgha^{-1}$.

- Double cropped soybean may achieve the yield level of non-irrigated main crop soybean.

- The line NS-L-200181 had significantly higher grain yield and oil content but a lower protein content than the cultivar Gracia.

- Correct choice of soybean genotypes and irrigation rates may bring a high grain yield and good grain quality (protein and oil contents), and it may increase the profitability of irrigation systems.

LITERATURE

1. Babović, J., Milić, S. (2006): Irrigation Effects in Plant Production in Serbia and Montenegro, BALWOIS – Conference on Water Observation and Information System for Decision Support, Ohrid, Republic of Macedonia, CD.
2. Bošnjak, Đ. (1996): Potreba za vodom i realizacija racionalnog zalivnog režima soje. Vodoprivreda 28: 55-65.
3. Bošnjak, Đ., Dragović, S. (1998): Navodnjavanje soje. Monografija Soja pod redakcijom Hrustić Milice i sar., Novi Sad - Bečej, 227-252.
4. Dragović, S. (1993): Uticaj suše u različitim fazama organogeneze (R1-R8) na prinos i kvalitet soje. "Korišćenje i održavanje melioracionih sistema", Posebna publikacija, JDON-a i JDPZ, Beograd, 131-138.
5. Đorđević, V., Balešević-Tubić,S., Hrustić, M., Vidić, M., Tatić,M. (2005): Stabilnost genotipova soje u pogledu sadržaja proteina i ulja. Zbornik radova Naučni institut za ratarstvo i povrtarstvo Novi Sad, Sv.41. 445-450.
6. Đukić, V., Miladinović, J., Balešević-Tubić Svetlana, Đorđević, V., Tatić, M., Hrustić Milica, Vidić, M. (2007): Mogućnost povećanja proizvodnje ulja postrnom setvom soje. Proizvodnja i prerada uljarica, Zbornik radova, 48. Savetovanje industrije ulja, 11-16. juna 2007., Herceg Novi, 69-74.
7. Hrustić, M., Vidić, M., Jocković,Đ., Soja, Novi Sad- Bečej (1988).
8. Hurburgh, C.R.(2000): Quality of the 2000 soybean crop from the United States.American.
9. Mađar, S., Kovačević, V., Jurić, I. (1984): Postrne kulture – proizvodnja i korišćenje. NIRO – Zadrugar, Sarajevo, 145.

10. Maksimović, Livija, Dragović, S. (1993): Korišćenje sistema za navodnjavanje gajenjem soje u drugoj i postrnoj setvi. "Korišćenje i održavanje melioracionih sistema", Posebna publikacija, JDON-a i JDPZ, Beograd, 149-154.
11. Maksimović, Livija, Dragović, S., Tatić, M. (2001): Unapređenje proizvodnje soje postrnom setvom u navodnjavanju. Zbornik radova Naučni institut za ratarstvo i povrtarstvo Novi Sad, Sv. 35, 425-434.
12. Maksimović, Livija, Vujaković, Milka, Balešević-Tubić, Svetlana, Tatić, M. (2004): Proizvodnja semenske soje u uslovima sa i bez navodnjavanja. Tematski zbornik radova "Poljoprivreda između suša i poplava", Poljoprivredni fakultet Novi Sad, Departman za uređenje voda, 102-108.
13. Milić, S., Đukić V., Marinković Jelena (2005): Effectiveness of irrigation and inoculation in double cropped soybeans, The VIIIth International Symposium " Young people and multidisciplinary research" CD, Resita, Rumunija.
14. Vučić, N. (1981): Navodnjavanje i dve žetve godišnje. Nišro "Dnevnik", Novi Sad, str. 148.