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Weed Control and Grain Yield in Double-Cropped Soybean

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SUMMARY

The effects of different herbicide combinations: control (1), alachlor+linuron (2), and alachlor+linuron+imazethapyr (3) were investigated in double-cropped soybean grown in two row spacing variants, 38 cm and 76 cm, under conventional tillage (CT) or no-tillage (NT). In trials conducted on a sandy loam soil at Zemun Polje, high weediness had a negative effect of on the yield of double-cropped soybean, especially at the higher row spacing tested and with no-tillage.

Regression and correlation data revealed a dependence of weediness in double-cropped soybean on tillage system and herbicide combination, and dependence of soybean yield on tillage system.

Keywords: Weeds; Control; Double-cropped soybean; Tillage method; Herbicide treatment; Yield

INTRODUCTION

Coinciding with global trends, research has been also conducted in our country regarding double crop growing (Momirović, 1994; Momirović et al., 2004). Hitherto research has revealed some advantages of this method in maize and soybean growing, but certain shortcomings have surfaced as well. Growing double crops ensures maximum utilization of productive capacities per area unit, and clearly involves a high level of growing technology. However, depending on a tillage system, most double crops face the problem of weediness, especially with grasses, which results in higher application rates of herbicides (Burnside and Wicks, 1982; Kostov et al., 1992; Momirović, 1994). Problems of herbicide application to double crops are further complicated by the fact that double-crop growing is most efficient in a reduced, so-called conservation tillage system as stubbles grow on large areas of arable fields in our country (Momirović et al., 1996). Also, in systems of multiple harvests the choice of herbicides is limited due to crop rotation and a need for high efficacy of herbicides against a wide spectrum of weed species (Altieri and Liebman, 1986).

The level of weediness and competition between a crop and weeds depends on many factors, including the properties of both the weeds and crop and existing environmental conditions (Hall et al., 1992). Cultural practices such as the choice of sowing density and row spacing also affect the competition in agrophytocoenoses (Tollenaar et al., 1994; Teasdale, 1995; Simić and Stefanović, 2007). Consistent to Murphy et al. (1996), who found that smaller row spacing and higher density of maize result in lower biomass of late spring weeds, Mulugeta and Boerboom (2000) reported that soybean grown at 18 cm row spacing was more compatitive against weeds than soybean grown at 76 cm spacing. Soybean crops with smaller row spacing close canopy earlier, thus intercepting light on its way down to soil surface and modifying weed emergence and growth (Knežević et al., 2003). Soybean cultivation in a double-cropped system requires irrigation under domestic conditions, which additionally modifies the composition and structure of weed communities and affects the level of weediness (Momirović et al., 1997).

Cultural practices have immediate impact on the yield of double-cropped soybean. Row spacing, choice of a soybean cultivar based on its maturity group, and irrigation modify the level of weediness and determine the size of leaf area and light intake. Double-cropped soybean is sown after its optimal time and has lower grain yields. Lower yield is mostly associated with insufficient vegetative development and it has been established in earlier research that a soybean crop needs to intake 95% of total light required for fruiting before it starts flowering (Egli, 1988; Westgate, 1999). This is why a development of greater above-ground biomass and leaf area is directly associated with higher yield in double-cropped soybean (Board and Harville, 1993; Ball et al., 2000).

MATERIAL AND METHODS

Investigation of the effects of different tillage systems, row spacing and herbicides on the weediness and yield of double-cropped soybean was carried out on a sandy loam soil on the experimental fields of the Maize Research Institute at Zemun Polje in 1995 and 1996. Field trials were set up in a block design with four replications. Plot size was 12.16 m^2, and total trial area 1900 m^2. Fertilization was avoided because of a significant amount of available phosphorus and potassium in the top soil, confirmed in a previous chemical analysis of soil. The test cultivar was Moma (FAO maturity group 00) and sowing was completed in the first week of July in both years of investigation.

Two tillage systems were tested in the trials:

- Conventional tillage involving plowing at 20-25 cm depth + disking + spike harrowing, and
- No-tillage, sowing carried out by a John Deere planter Max Emerge-2.

Soybean was planted at two row spacings: 76 cm and 38 cm, at a density of 700000 plants/ha in both sowing variants.

The effect of these two factors was studied in combination with chemical control of weeds in the following treatments:

- alachlor 262 g l^{-1} + linuron 105 g l^{-1} (Afalon combi) at a rate of 8 l ha^{-1} after sowing, before emergence,
- alachlor 262 g l^{-1} + linuron 105 g l^{-1} (Afalon combi) at a rate of 8 l ha^{-1} after sowing, before emergence + imazethapyr 100 g l^{-1} (Pivot 100E) at a rate of 0.8 l ha^{-1} after crop emergence at the stage of 1-3 trifoliate leaves of soybean, and
- untreated controla

The crop was grown with irrigation and by monitoring moisture dynamic in soil up to 50 cm depth. Moisture degree before irrigation was 80% field capacity.

Samples for the weediness study were collected from plots of 0.25 m^2. Fresh biomass of each weed species and total fresh biomass were determined for each sample. At the end of the vegetation season, soybean grain yield was measured, and corrected for 12% moisture. The data presented here are average values recorded in both years of investigation.

Tabela 1. Meteorological data for Zemun Polje over the period of investigation
Table 1. Meteorološki uslovi u periodu izvođenja ogleda u Zemun Polju

Month – Mesec	Temperature – Temperatura (°C)			Precipitation – Padavine (mm)		
	1995	1996	1953-94	1995	1996	1953-94
April – april	12.6	12.6	11.4	61.8	52.3	48.8
May – maj	16.8	19.3	16.7	83.6	108.0	61.5
June – jun	20.5	21.9	19.9	64.7	57.1	79.7
July – jul	24.8	22.0	21.6	33.7	35.5	62.6
August – avgust	21.6	23.1	21.2	69.2	6.6	50.3
September – septembar	16.6	14.0	17.4	92.6	57.7	42.7
Average means – Prosek-suma	18.8	18.8	18.0	404.2	317.2	345.6

The data were statistically processed by linear regression and correlation method for all investigated parameters in the statistical software STATISTIKA 5.0.

Meteorological conditions differed over the experimental years even though the average monthly means for each vegetation period were the same as a long-term average. July was significantly warmer in 1995 than it was in 1996 or in the previous long-term period. In the second year of investigation, the weather was warmer throughout the months of vegetation, while the monthly mean air temperature in September was significantly below the 40-year average. Total rainfall was significantly higher in the first year than in the second, and slightly higher than the long-term average. Also, significantly higher monthly rainfall was recorded in August and September of 1995 than in the corresponding period of 1996 or the 40-year period (Table 1).

RESULTS AND DISCUSSION

The tillage system, herbicide treatment and row spacing were all found to affect weediness in the irrigated double-cropped soybean at Zemun Polje (Table 2). The table shows fresh biomass of grass weeds, broad-leaved and total weeds per variant tested. The dominant species in the experimental fields were *Sorghum halepense*, *Amaranthus retroflexus* and *Convolvulus arvensis*. The average fresh biomass of weeds in both years of investigation was lower in the variant with conventional tillage than no-tillage, especially in the control variants without herbicide treatment. Total average fresh biomass of weeds in all variants of herbicide treatment was 34.82 g m^{-2} under conventional tillage at 76 cm row spacing, and 16.21 g m^{-2} at 38 cm spacing. In no-tillage plots, the corresponding values were significantly higher, 57.63 and 50.94 g m^{-2}, respectively. The importance of tillage system for weed control in double-crops had been confirmed in earlier research as well (Momirović, 1994; Momirović et al., 1996).

Herbicide application acted towards a further decrease of weediness in double-cropped soybean. The highest efficacy was achieved by the combination Afalon combi + Pivot, which in interaction with conventional tillage caused lower weediness of grass, broad-leaved and total weeds at 76 cm row spacing (2.54, 4.55 and 7.09 g m^{-2}), while there were no broad-leaved weeds at all in the variant of 38 cm spacing. The combined herbicide treatment after sowing and before crop emergence (Afalon combi) and after emergence up to third trifoliate leaves (Pivot) demonstrated good efficacy under no-tillage system, which is very significant as higher weediness is one of the shortcomings of no-tillage (Momirović et al., 1997).

The data show that cultivation of double-cropped soybean at 38 cm row spacing resulted in a decrease in

Tabela 2. Fresh biomass of weeds (g m^{-2}) depending on a cropping system (average 1995/96)
Table 2. Sveža masa korova (g m^{-2}) u zavisnosti od sistema gajenja (prosek 1995/96. godina)

Row spacing Međ. rastojanje	Herbicide application Primena herbicida	Tillage system / Sistem obrade zemljišta					
		No-tillage Direktna setva			Conventional tillage Konvencionalna obrada		
		Grass weeds Travni	Broad-leaved weeds Širokolisni	Total Ukupno	Grass weeds Travni	Broad-leaved weeds Širokolisni	Total Ukupno
76 cm	Control Kontrola	91.23	394.00	485.23	40.47	94.94	135.41
	Alachlor + linuron	60.27	22.23	82.49	46.07	16.49	62.55
	Alachlor + linuron + imazethapyr	18.34	14.43	32.77	2.54	4.55	7.09
	Average for herbicides Prosek za herbicide	39.30	18.33	57.63	24.30	10.52	34.82
38 cm	Control Kontrola	92.77	114.37	207.13	39.03	63.09	102.12
	Alachlor + linuron	79.82	13.44	93.26	14.62	7.85	22.47
	Alachlor + linuron + imazethapyr	4.74	3.89	8.62	9.96	0.00	9.96
	Average for herbicides Prosek za herbicide	42.28	8.67	50.94	12.29	3.93	16.21

fresh biomass of all investigated groups of weeds. In the no-tillage system especially, denser sowing of soybean significantly reduced weediness with broad-leaved species (18.33 g m^{-2} at 76 cm and 8.67 g m^{-2} at 38 cm). The importance of row spacing for weed control in soybean had been found in previous investigations as well (Burnside, 1979; Mulugeta and Boerboom, 2000; Knežević et al., 2003). Knežević et al. (2003) showed that growing soybean at higher row spacing reduced the crop's tolerance of weeds in its early stages of growth and required earlier weed control measures than it was the case when soybean was grown at 38 or 19 cm spacing. Conversely, crops growing at smaller row spacing require less intensive programmes of weed control as the crop is more competitive than the weeds (Simić and Stefanović, 2007).

Soybean generally has lower yield when grown as a double crop than in a conventional cropping system (Wesley, 1999; Ball et al., 2000) (Table 3). Our results show the highest influence of tillage systems on yield. The average double-cropped soybean yield in both years of investigation was higher under conventional tillage than no-tillage in all variants of herbicide treatments and both variants of row spacing. The advantage of conventional tillage in terms of a grain yield of double-cropped soybean is especially evident at 76 cm row spacing (1256.36 kg ha^{-1} under conventional tillage and 793.64 kg ha^{-1} under no-tillage).

Row spacing affected both the level of weediness and soybean yield. The average soybean yield, especially under no-tillage, was higher in plots with the reduced row spacing of 38 cm (924.34 kg ha^{-1}) than in those with 76 cm spacing (793.64). On the average for both tillage systems and herbicide treatments, the yield of double-cropped soybean was slightly higher when sown at 38 cm row spacing (1044.40 kg ha^{-1}). In the variant without herbicide application, the difference in grain yields was even more evident between 38 cm row spacing (1081.01 kg ha^{-1}) and 76 cm spacing (873.54 kg ha^{-1}). Similar findings on the effect of reduced spacing on soybean yield under conditions of irrigation have been reported in other studies (Heatherly et al., 2001). However, most studies have shown that soybean grain yield depends under conditions of reduced row spacing on the amount of rainfall during the vegetation season and on agroecological conditions existing in a region (Devlin et al., 1995; Bowers et al., 2000).

Regarding herbicide treatments, the variant of combined application of herbicides after sowing and before emergence, and after emergence up to third trifoliate stage leaves (Afalon combi+Pivot), although achieving the best efficacy against weeds, failed to produce the highest soybean grain yield. Soybean yield in that variant was lower both compared to the control variant without herbicide application and the variant in which Afalon combi alone was applied, which may be the result of a possible negative herbicide effect in interaction with meteorological conditions.

Regression and correlation analyses of total weed biomass and tillage systems; total weed biomass and herbicides applied; and soybean grain yield and tillage systems are presented in Figures 1, 2 and 3. A model of linear regression and correlation for the investigated parameters was constructed with the weed biomass and soy-

Tabela 3. Grain yield of double-cropped soybean depending on cropping systems
Table 3. Prinos zrna postrne soje u zavisnosti od sistema gajenja

Row spacing Međ. rastojanje	Herbicide application Primena herbicida	Tillage system Sistem obrade zemljišta		
		No-tillage Direktna setva	Conventional tillage Konvencionalna obrada	Average Prosek
76 cm	Control Kontrola	721.86	1025.22	873.54
	Alachlor + linuron	907.84	1446.44	1177.14
	Alachlor + linuron + imazethapyr	679.43	1066.28	872.86
	Average for herbicides Prosek za herbicide	793.64	1256.36	1025.00
38 cm	Control/Kontrola	993.97	1168.04	1081.01
	Alachlor + linuron	947.09	1249.12	1098.11
	Alachlor + linuron + imazethapyr	901.59	1079.77	990.68
	Average for herbicides Prosek za herbicide	924.34	1164.45	1044.40

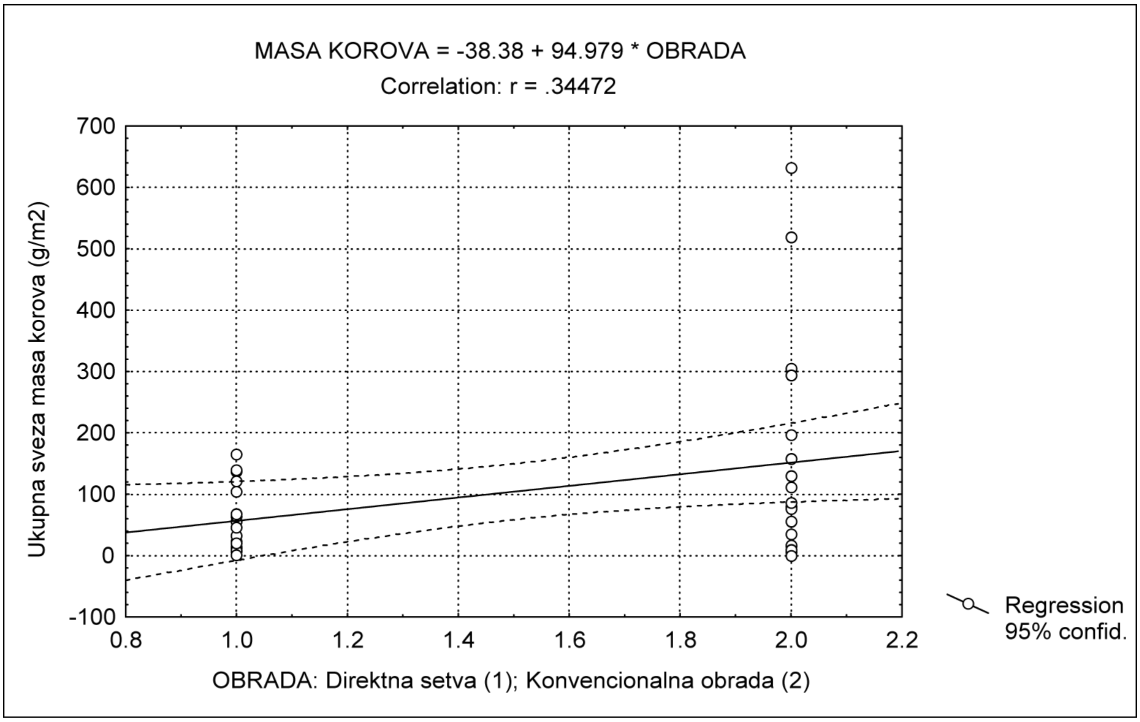

Figure 1. Dependence of fresh biomass of weeds on tillage systems
Slika1. Zavisnost sveže mase korova od sistema obrade zemljišta

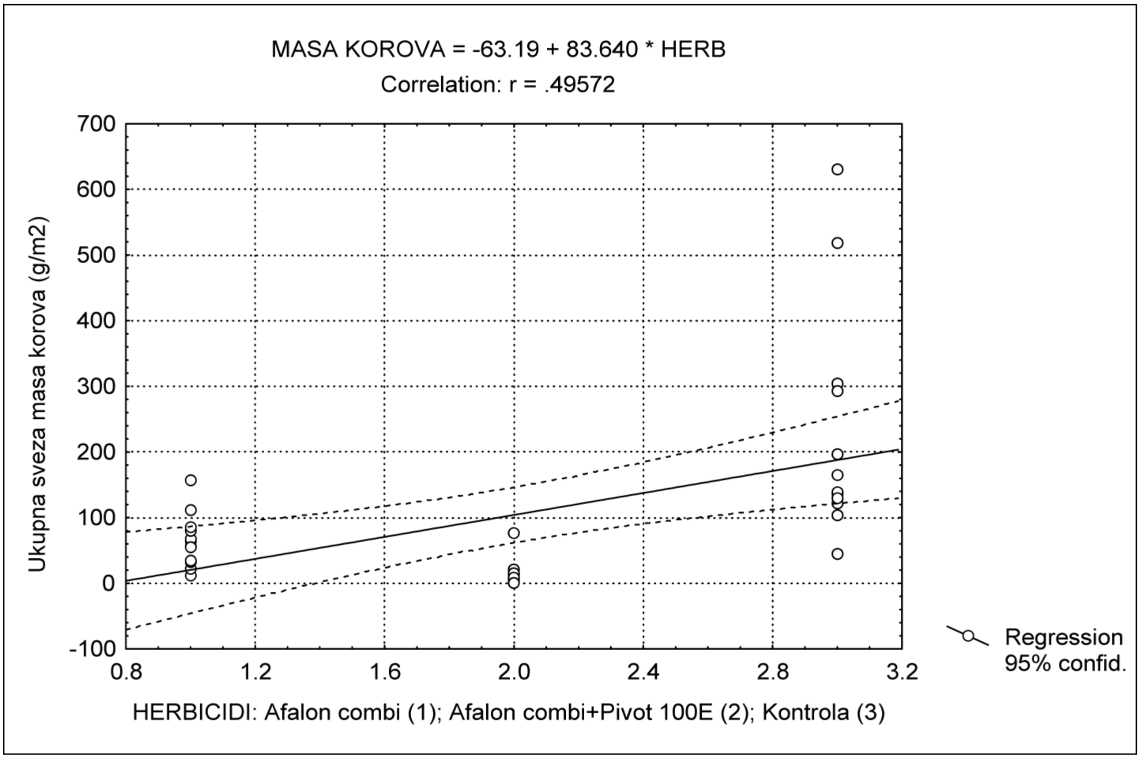

Figure 2. Dependence of fresh biomass of weeds on herbicides applied
Slika 2. Zavisnost sveže mase korova od sistema obrade zemljišta

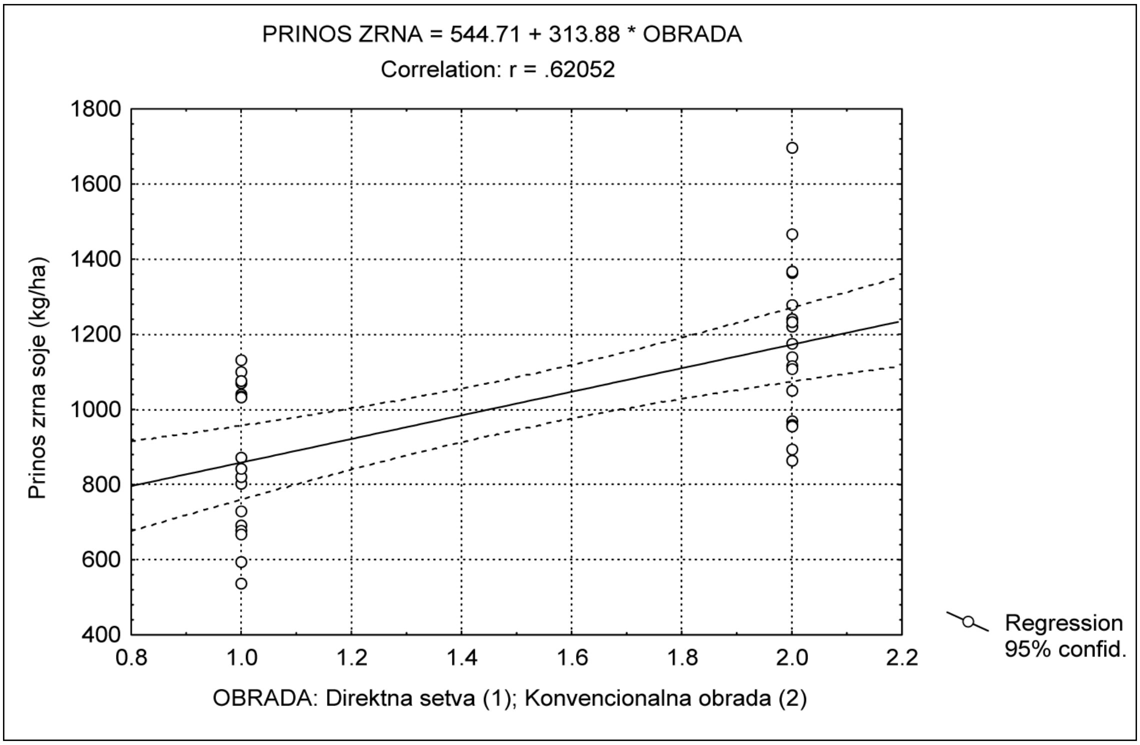

Figure 3. Dependence of soybean grain yield on tillage systems
Slika3. Zavisnost prinosa zrna soje od sistema obrade zemljišta

bean grain yield being the dependent variables, while tillage system and herbicides applied were independent variables. The analysis showed a significant dependence of total fresh biomass of weeds on the tillage system and herbicides applied, and grain yield on tillage system. The dependence of fresh weed biomass and soybean grain yield on row spacing was statistically insignificant.

The dependence of fresh weed biomass on tillage system in terms of a coefficient of correlation is 0.3447, which is a positive correlation (Figure 1). Although the coefficient of correlation is not high, a test of significance revealed statistical significance for this indicator (H_0: ρ=0; Ha: ρ≠0). The best fitted regression line also suggests that fresh weed biomass in the system of conventional tillage was nearly three times lower on the average than it was under no-tillage, which is consistent with findings reported by Momirovića et al. (1996, 1997).

When tillage was avoided in double-cropped soybean, especially under irrigation, weediness with grass weeds, as well as broad-leaved species increased significantly. The result is substantiated by the regression coefficient b from the regression equation (94.979), which means that the option of no-tillage increases weed biomass by an average 94.979 g.

Regarding the effect of the herbicides applied on total weed fresh biomass, a positive statistically significant dependence was also found based on a correlation analysis (Figure 2). The applied herbicides (Afalon combi, Afalon combi+Pivot 100E), compared to the untreated control, showed very high efficacy, which is especially evident from the regression equation ($\hat{y}_i$ = -63.19 + 83.640*Xi). The equation shows that fresh weed biomass in the control plots was 83.640 g higher on the average than the biomass in treated plots.

Analysing the effect of the investigated parameters on the grain yield of double-cropped soybean, we found it to depend significantly in statistical terms on the tillage system (Figure 3). One of the reasons of higher yield under conventional tillage is the reduced weediness, especially with perennial weeds (Kovačević et al., 1999). The average two-year grain yield of double-cropped soybean was 313.88 kg higher under conventional tillage than it was under no-tillage, which is evident from the regression equation ($\hat{y}_i$ = 544,71 + 313,88*Xi).

Based on our two-year investigation of the effects of different cropping systems (conventional tillage and no-tillage; two combinations of herbicides and a control variant without herbicide application; and row spacing at 38 cm and 76 cm) on the weediness and yield of double-cropped soybean under conditions of irrigation and a sandy loam soil at Zemun Polje, we have concluded that total fresh biomass of weeds, as well as the biomass of narrow-leaved and broad-leaved weeds in particular, decreased significantly in the variant involving conventional tillage, compared to no-tillage. The highest efficacy was achieved by the herbicide combination Afalon combi+Pivot 100E, which resulted in the lowest weediness with grass, broad-leaved and total weeds in interaction with the conventional tillage system. The double-cropped soybean sown at 38 cm spacing was more competitive against weeds than the crop sown at 76 cm spacing, which is also evident from the decreased fresh biomass of weeds.

Grain yield of double-cropped soybean grown under the conventional tillage system, compared to no-tillage, was higher in all variants of herbicide treatment and both row spacings. Also, the average two-year grain yield of double-cropped soybean achieved under conventional tillage was by 313.88 kg higher than the average yield in the no-tillage variant.

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Suzbijanje korova i prinos zrna u postrnom usevu soje

REZIME

U radu su prikazani rezultati uticaja primene različitih kombinacija herbicida: kontrola (1); alahlor+linuron (2); alahlor+linuron+imazetapir (3); u postrnom usevu soje gajenom na dva međuredna rastojanja: 38 cm; 76 cm; u konvencionalnom sistemu obrade (CT) i u direktnoj setvi (NT). Na zemljištu tipa slabokarbonatni černozerm u Zemun Polju konstatovan je negativan uticaj povećane zakorovljenosti na prinos soje u postrnoj setvi, posebno gajenjem na većem međurednom rastojanju i direktnom setvom u neobrađeno strnište.

Utvrđene su jasne regresione i korelacione zavisnosti zakorovljenosti postrnog useva soje od sistema obrade zemljišta, zakorovljenosti i kombinacije primenjenih herbicida, kao i prinosa soje od sistema obrade zemljišta.

Ključne reči: Korovi; suzbijanje; postrna soja; sistem obrade zemljišta; primena herbicida, prinos