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COMPARISON OF TWO SOIL TILLAGE TREATMENTS FOR WINTER BARLEY - SOYBEAN GROWING BASED ONLY ON RESIDUAL NITROGEN AFTER SOYBEAN

USPOREDBA DVA SUSTAVA OBRADE TLA ZA OZIMI JEČAM I SOJU S KORIŠTENJEM DUŠIKA SAMO IZ REZIDUA SOJE

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ABSTRACT

The winter barley crop growing has not been adequately researched regarding soil tillage systems, especially in crop rotation with the soybean, both crops gaining importance as food or fodder. Also, productivity of such crop rotation in low nitrogen environment is especially interesting for organic crop growing, where mineral nitrogen fertilization is not allowed. The research on two soil tillage systems, the conventional one, based on mouldboard ploughing (PLOW) and reduced soil tillage, based on discharrowing (DISC), with no other nitrogen source except symbiotic soybean bacterial fixation, was conducted at the experimental site Bokšić (Croatia), during the seasons 2004/05 and 2005/06. Results showed low but stable yields of winter barley, between 2.1 and 2.6 t ha^{-1}, where PLOW treatment recorded lower yield than DISC in 2005, and usual soybean yields (between 2.8 and 3.4 t ha^{-1}), with higher soybean grain yields for PLOW only in 2006. The absolute mass and hectolitre mass did not show any statistical differences among treatments either.

Key words: winter barley, soybean, mouldboard ploughing, discharrowing

SAŽETAK

Uzgoj ozimog ječma nije adekvatno istražen glede sustava obrade tla, posebice u plodoredu sa sojom, a oba usjeva dobivaju na važnosti kao hrana za

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ljude ili krma za životinje. Isto tako, produktivnost ovakvog plodoreda u uvjetima niske gnojidbe dušikom je osobito zanimljiva za ekološku poljoprivredu, gdje korištenje mineralnih dušičnih gnojiva nije dopušteno. Istraživanje dvaju sustava obrade tla, konvencionalnog, baziranog na oranju lemešnim plugom (PLOW), te reduciranog, baziranog na tanjuranju (DISC), bez ikakvog izvora dušika osim dušika simbiotski vezanog kvržičnim bakterijama na soji, provedeno je na pokušalištu Bokšić (Hrvatska), tijekom sezona 2004/05-2005/06. Rezultati su pokazali niske ali stabilne urode ozimog ječma, između 2.1 i 2.6 t ha^{-1}, gdje je na PLOW tretmanu zabilježen niži prinos nego na DISC tretmanu u 2005. godini, te uobičajene urode soje (između 2.8 i 3.4 t ha^{-1}), s višim urodima zrna soje na PLOW tretmanu samo u 2006. godini. Razlike apsolutne i hektolitarske mase među tretmanima nisu bile statistički opravdane.

Ključne riječi: ozimi ječam, soja, oranje, tanjuranje

INTRODUCTION

The efficiency of different soil tillage in cereal production has recently been reconsidered due to simplifications for higher sustainability of agriculture, in which the environment protection and decreases of tillage costs are especially emphasised (Karlen et al,1994). Leguminous crops, such as soybean, contributes to higher sustainability of the crop rotation in different soil tillage systems, due to nitrogen fixation through the symbiotic bacteria (Hardy and Havelka, 1975; Evans and Barber, 1997; SeiJoon et al, 2005) and better stability of the soil complex, through the improvement of soil aggregation, soil mulching, water holding capacity, humus build-up and diverse soil fauna activities (Campbell et al, 1984; Munawar et al, 1990; Vyn et al, 1998; Baumhardt and Jones, 2002). In spite the fact that various systems of reduced tillage for different main crops grown in Croatia have been already tested (Stipesevic et al,1997; Zugec et al, 2000; Filipovic et al, 2006), with main goals to decrease the costs of production, maintain agro-sustainability (Birkas et al, 2002) and to preserve high and constant grain yields despite the reduction of applied soil tillage (Jug et al, 2006), the interaction between soil tillage systems and nutrients availability have not been investigated sufficiently, especially for winter barley-soybean rotation, potentially very interesting crop rotation for the organic agriculture due to their nutritional values for human and animal consumption.

MATERIAL AND METHODS

This research was conducted near Bokšić in northeastern Croatia, on the winter barley (*Hordeum vulgare L.*) in a crop rotation after soybeans (*Glycine max L.*) for crop seasons 2004/05-2005/2006. The site soil type was determined as a eutric cambisol, with loamy clay texture, total porosity between 32.2 and 44.7%, bulk density from 1.30 to 1.70 kg dm^{-3}, neutral reaction (pH in KCl 6.8), with rather high humus content (4.1%), and with poor fertility (6.6 mg P_2O_5 and 6.8 mg K_2O per 100 g of soil, 2.8 % of $CaCO_3$) in 0-30 cm depth. The main experimental set-up was a Completely Randomised Block Design in four repetitions, with two soil tillage system treatments: PLOW=conventional tillage (autumn ploughing up to 25 cm depth, spring discharrowing, followed by seedbed preparation with rototiller and standard sowing) and DISC=autumn discharrowing up to 20 cm depth, seedbed preparation with rototiller in spring and standard sowing. Applied amounts of nutrients were the same for both soil tillage treatments in both years: phosphorus (83 kg P_2O_5 ha^{-1}) and potassium (124 kg K_2O ha^{-1}). The phosphorus and potassium amounts were determined by soil analyses and planned crop uptake recommendations. The basic experimental plot size was 5 m wide and 30 m long (total area of 150 m^2). The winter barley cultivar "Trenk" was sown, the creation of the Agricultural Institute Osijek, Croatia, in recommended plant density of 450 plants m^{-2}, within the optimal sowing dates (31.October 2004 and 20. October 2005). The soybean cultivar "Anica", also creation of the Agriculture Institute Osijek, was sown in reccomended plant density of 60 plants m^{-2} and within optimal sowing dates (6. May 2005 and 2006). The same soybean cultivar was the pre-crop in this experiment, with average yield obtained in the year 2004 (no exact data available for the particular site). During the harvest time, plots were harvested one by one and complete grain mass from each plot was weighed on portable electronic scales, whereas moisture content was determined by "Dickey John GAC 2000" grain moisture meter, from ten subsamples taken during the harvest and preserved in the plastic bags. The split-plot ANOVA was performed separately for each crop by SAS statistic package (V 8.02, SAS Institute, Cary, NC, USA, 1999) with Year as the main level, and Tillage as the sub-level. The

Fisher protected LSD means comparisons were performed for P=0.05 significance levels.

Weather data are showed in Figure 1, where it is visible that the year 2005 had a marked water surplus in comparison with average climatic conditions, especially during the summer period, where 237 mm poured down in August. Lack of precipitation during October 2005 did not affect crops due to plentiful of the soil moisture and crop generative phases (close to the full maturity), and soil moisture condition was favourable for soil tillage and autumn sowing that year. In spite of sufficient precipitation during the spring, the year 2006 had below average dry summer, especially July and September, the driest months during previous 10 years. Lack of water in that period was not necessarily bad for crops, especially for winter crops which entered maturity prior to that dry period.

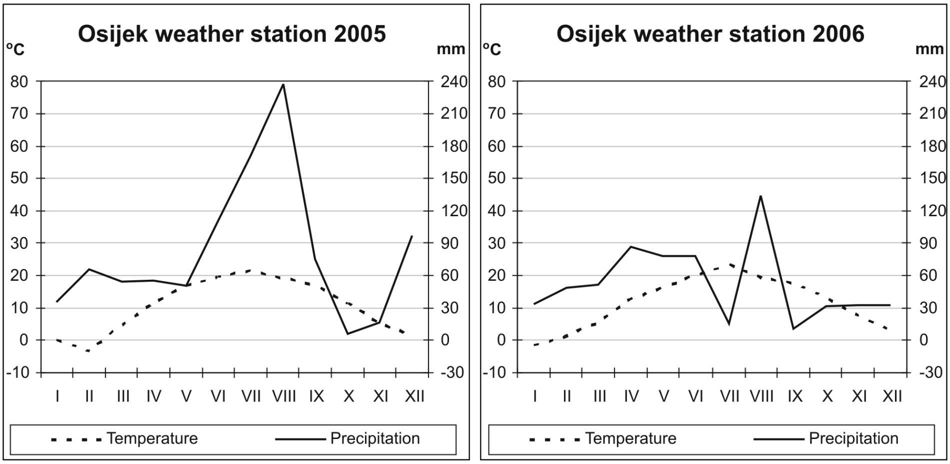

Figure 1: Weather data for Meterological station Osijek, years 2005 and 2006.

RESULTS

Results for the winter barley and soybean are presented in Table 1. The factor Year was not significantly expressed in both crops, since both years had similar weather pattern, usual for the local climate, and the year 2005 had less winter precipitation than in the year 2006. The grain yield of winter barley was in the range between 2188 kg ha^{-1} for the PLOW treatment in the year 2005 and 2576 kg ha^{-1} for the same soil tillage treatment in the year 2006. The DISC treatment was significantly better than PLOW for 375 kg ha^{-1} in the year 2005, whereas in 2006 there were no significant differences between two soil tillage treatments. As for the average soil tillage, DISC showed a higher yield by 151 kg ha^{-1}, although without statistical significance.

Regarding soybean grain yield, this experiment recorded minimum of 2926 kg ha^{-1} in the DISC treatment, and maximum of 3268 kg ha^{-1} in the PLOW treatment, with significant difference of 342 kg ha^{-1}, both in the year 2006. The soil tillage system averages showed insignificant difference of 154 kg ha^{-1} between DISC and PLOW treatments. Soybean grain yields achieved in this experiment are in the range of local farmers' average in regular years.

Table 1: Winter barley and soybean grain yields (kg ha^{-1}) as affected by different soil tillage systems (DISC and PLOW), site Bokšić, years 2005 and 2006.

	Winter barley yields (kg ha^{-1})			Soybean yields (kg ha^{-1})		
Tillage treatments	2005	2006	Till mean	2005	2006	Till mean
DISC	2563 a†	2503 a	2533 A	3000 a	2926 a	2963 A
PLOW	2188 b	2576 a	2382 A	2966 a	3268 b	3117 A
Year mean	2376 A‡	2540 A		2983 A	3097 A	

†Means labelled with the same lowercase letter are not statistically different at the $P<0.05$ significance level

‡Means labelled with the same uppercase letter are not statistically different at the $P<0.05$ significance level

Hectolitre weight is presented in the Table 2. Measures showed significantly lower values for winter barley in year 2005 in comparison with the year 2006 for almost 5 kg heavier grain hectolitre. Soil tillage systems had almost identical values in both years and soil tillage average. Soybean hectolitre weights did not differ statistically, and they were in the narrow range of 72.11-72.57 kg.

Table 2: Winter barley and soybean hectolitre weight (kg) as affected by different soil tillage systems (DISC and PLOW), site Bokšić, years 2005 and 2006.

	Winter barley hectolitre weight (kg)			Soybean hectolitre weight (kg)		
Tillage treatments	2005	2006	Till mean	2005	2006	Till mean
DISC	58.27 a†	63.50 b	60.88 A	72.10 a	72.11 a	72.11 A
PLOW	58.13 a	62.87 b	60.50 A	72.57 a	72.03 a	72.30 A
Year mean	58.20 A‡	63.18 B		72.33 A	72.07 A	

†Means labelled with the same lowercase letter are not statistically different at the $P<0.05$ significance level

‡Means labelled with the same uppercase letter are not statistically different at the $P<0.05$ significance level

The 1000 grains mass is given in the Table 3. In both years, both soil tillage treatments didn't show any statistical differences for winter barley. Regarding soybean, PLOW gave significantly higher 1000 grains weight than the DISC treatment in the year 2005, but not in 2006, and average for both soil tillage treatments stayed insignificant.

Table 3: Winter barley and soybean mass of 1000 grains (g) as affected by different soil tillage systems (DISC and PLOW), site Bokšić, years 2005 and 2006.

	Winter barley mass of 1000 grains (g)			Soybean mass of 1000 grains (g)		
Tillage treatments	2005	2006	Till mean	2005	2006	Till mean
DISC	49.47 a†	49.53 a	49.50 A	151.87 a	159.73 a	154.30 A
PLOW	50.60 a	49.48 a	50.03 A	155.60 b	157.67 a	156.63 A
Year mean	50.03 A‡	49.49 A		153.73 A	157.50 A	

†Means labelled with the same lowercase letter are not statistically different at the $P<0.05$ significance level

‡Means labelled with the same uppercase letter are not statistically different at the $P<0.05$ significance level

DISCUSSION

Rather favourable weather conditions for winter barley in both years (favourable conditions for emergence-early growth, mild winter, sufficient spring moisture without high temperature stresses) managed rather constant yields under both tillage systems. However, DISC treatment in this research tended to produce slightly higher yield in the first year. This effect was probably the result of higher concentration of incorporated soybean residues in shallower upper soil layers of DISC treatment. Presumable compensation of more available nitrogen in deeper tilled PLOW treatment soil would probably alleviate even that difference, as observed by Fertilization x Tillage interaction in other experiments involving cereal-soybean crop rotation (Stipesevic et al, 1997; Halvorson et al, 1999; Jug et al, 2006). The second year showed no differences between soil tillage systems, presumably due to more soybean's nitrogen enriched residues ploughed into the soil, as a consequence of the accumulation of two years of soybean prior to winter barley 2005/06 season. As soybean is capable of using atmospheric nitrogen through the symbiotic relationship with symbiotic bacteria (*Rhizobium* and *Bradyrhizobium sp.*), lack of nitrogen from fertilizers should not present problems to high and stable yields (Hardy and Havelka, 1975; Stanhill, 1990; Temple et al, 1994; Evans and Barber, 1997). Furthermore, soybean produced in reduced soil tillage systems in many cases gave similar or even higher yield than mouldboard ploughing (Vyn et al, 1998), as long as weed control was effective and soil loose enough to present no limits for root nodes development (Birkas et al, 2002). However, some other authors with similar soil tillage treatments recorded that usually conventional tillage had better results than reduced soil tillage systems (Varvel et al, 1989) in spite of achieved weed control and solved soil compaction. For the given climate of this experimental site (Bokšić, north-eastern Croatia) characterised by continental, semi-arid to semi-humid climate, mouldboard ploughing has always been considered the best practice for accumulation and conservation of winter moisture for summer drought, as pointed out by Zugec et al (2000). Birkas et al (2002), Campbell et al (1984) and Baumhardt and Jones (2002) furthermore pointed out the need for soil mulch coverage and presented different soil tillage operations and tools to improve soil coverage and water conservation. Obviously, more available water would provide higher soybean (and other summer crops) yields, which was the case in this research, with no differences in precipitation-rich year 2005, and somewhat drier 2006, with the lack of precipitation in July, usual in this climate.

CONCLUSION

Results of this experiment showed that production of winter barley in crop rotation with soybean without any source of nitrogen except soybean residuals gave rather low but stable yields of winter barley, whereas soybean gave the yield comparable with usual yields from surrounding area. The reduction and replacement of primary soil tillage by moldboard ploughing with discharrowing did not give statistically different yields both of winter barley and soybean, leading to the conclusion that both soil tillage systems can be utilized equally for given winter barley-soybean crop rotation

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