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Influence of Different Soil Tillage Systems on Soybean Yield and Yield Components

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Abstract: The soybean (*Glicine max L.*) in crop rotation after winter barley (*Hordeum sativum L.*) is not adequately investigated regarding soil tillage systems, both crops gaining importance as an animal feed. The research at experimental site Bokšić (Croatia), during the years 2005 and 2006, used the stationary experiment for soybean-winter barley crop rotation in split-plot experimental design in four repetitions with two soil tillage treatments (CT – conventional soil tillage, based on mouldboard ploughing; and DH –diskharrowing soil tillage) as a main factor, in combination with six combinations of fertilization as a sub-factor (added nitrogen fertilization in quantities of 0, 40 and 80 kg ha^{-1} in combinations with N-fixing inoculants - with and without *Bradhyrhizobium japonicum*). The CT treatment had higher yields than DH at N40 and N80 nitrogen fertilization levels, regardless the inoculation status. The highest yield has been achieved by CT-N80-B0 (3.61 t ha^{-1}).

Key words: Soybean, Ploughing, Diskharrowing, Nitrogen, Inoculation

INTRODUCTION

The soil tillage systems for soybean production had been reconsidered during the last decade, especially in the light of the Croatian needs for more affordable and high quality protein and oil source. This process is a result of worldwide trends and research results about the soil tillage reductions for higher sustainability of the agriculture, in which the environment protection and decreases of tillage costs is especially emphasised (Karlen et al., 1994). In the Slavonia, the most agricultural region of the Republic of Croatia, various systems of reduced tillage for different crops have been already tested (Stipešević et al., 1997, 2000; Žugec et al., 2000; Zimmer et al., 2000; Kosutić et al., 2005; Filipović et al., 2006; Jug et al., 2006a and 2006b), with main goals to decrease the costs of production, maintain agrosphere sustainability and to preserve high yield, characteristic for given region, despite the reduction of applied crop production system.

Along with the introduction of reduced tillage systems, the awareness has been raised of different approach toward fertilization, soil compaction, weed control and other problems connected with lesser soil agitation. The simplified soil tillage particularly raised the question of efficiency of fertilizers, especially nitrogen, in interaction with the tillage systems and other yield improvement techniques, such as inoculation of soybean seed with symbiotic bacteria, for enhancement of nitrogen fixation.

MATERIALS AND METHODS

This research was conducted near Bokšić in Eastern Croatia, for the soybeans (*Glycine max L.*) in a crop rotation after winter barley (*Hordeum vulgare L.*) for crop seasons 2004/05-2005/2006. The site's soil type was determined as a eutric cambisol, with loamy clay texture, total porosity between 32.2-44.7%, bulk density from 1.30 to 1.70 kg dm^{-3}, neutral reaction (pH in KCl 6.8), with rather high content of humus (4.%), 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 split-split-plot design in three repetitions, where the main treatment was the Soil Tillage with two steps: CT=conventional tillage (autumn ploughing up to 25 cm depth, spring diskharrowing, followed by seedbed preparation with rototiller and standard sowing) and DS=autumn diskharrowing up to 20 cm depth, seedbed preparation with rototiller in spring and standard sowing. The sub-treatment of the

Nitrogen Fertilization consisted of three steps of nitrogen fertilization: N1=0, N2=40 and N3=80 kg N ha^{-1} (see Table 1 for the nitrogen fertilization distribution), with the same amount of phosphorus (83 kg P_2O_5 ha^{-1}) and potassium (124 kg K_2O ha^{-1}) each season. The phosphorus and potassium amounts were determined by soil analyses and planned crop uptake recommendations. The sub-sub treatment of the Symbiotic Inoculant was B0=no additional inoculation; and B1=inoculation by Biofixin S (spores of bacteria *Bradhyrhizobium japonicum*) in amount of 100g 100 kg^{-1} of seed.

The basic experimental plot size was 5 m wide and 30 m long (total area of 150 m^2). The soybean cultivar "Anica" was sown, the creation of the Agricultural Institute Osijek, Croatia, in recommended plant density of 60 plants m^{-2}, within the optimal sowing dates (6. May of 2005 and 2006). During the harvest time, plots were harvested one by one and complete grain mass from each plot was weighted on portable electronic scale, 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-split-plot ANOVA was performed by SAS statistic package (V 8.02, SAS Institute, Cary, NC, USA, 1999) with Year as the main level, Tillage as sub-level, N fertilizer as sub-sub-level and Inoculation as sub-sub-sub-level for the soybean yields, and with Year as the main level, Tillage as the sub-level and Depth as the sub-sub-level for the soil resilience. The Fisher protected LSD means comparisons were performed for P=0.05 significance levels.

Table 1: The scheme of fertilization application for soybean, Bokšić, years 2005 and 2006.

Treatments	Incorporated by soil tillage		Side-dressing
	0PK 0:20:30	NPK 8:22:33	KAN 27% N
N1 B0	550	-	-
N1 B1	550	-	-
N2 B0	-	500.0	-
N2 B1	-	500.0	-
N3 B0	-	500.0	150
N3 B1	-	500.0	150

RESEARCH RESULTS

Weather data are showed in Figure 1 and Figure 2, 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 rained 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, which could influence somewhat on lower soybean and other summer crops yields due to limited water availability during the fertilization and grain filling stages.

Results of the soybean grain yields are shown in the Table 2. Statistically, the only significant difference occurred between soil tillage systems, where CT gave significantly higher yield than DH. Differences between years, nitrogen rates and inoculants application were not statistically different.
Also, from the TxNxB means it is visible that CT soil tillage system benefited from additional N amounts, whereas DH showed trend of decreasing grain yield for increasing N fertilization levels.

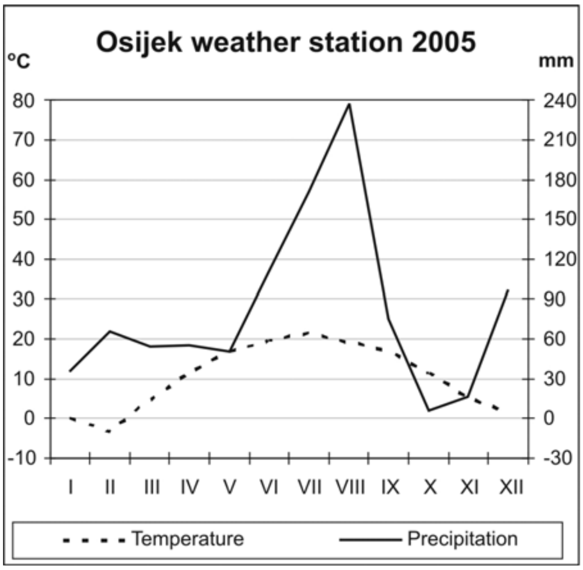

Figure 1: Weather data for Meterological station Osijek, year 2005.

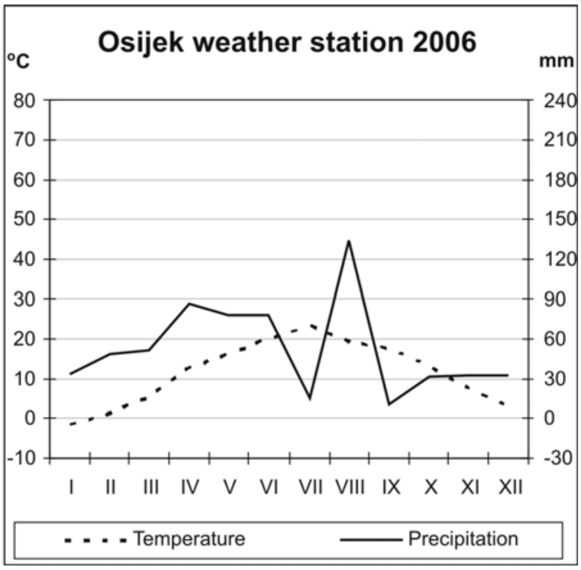

Figure 2: Weather data for Meterological station Osijek, year 2006.

DISCUSSION

The achieved results in this research were in accordance with usual soybean grain yields production level in given area, with necessary comment that the surplus of rain and water in soil during year 2005 probably affected rooting and later root uptake functions, thus resulting with somewhat lower yields for the CT, where autumn mouldboard ploughing, usually necessary for winter water accumulation in given climate, characterized with dry summers. But, it was observed that water logging was more frequent on CT than on DH plots, partially due to induced plough pan (Stipesevic et al., 2007), and partially because surface runoff from DH to deeper tilled CT furrows. Similar results of soybean yield in CT and DH soil tillage systems were also observed by Jug et al. (2006b) in years 2000 (droughty) and 2001 (wet), where in wet year 2001 soybean produced by DH had higher yield than CT. However, in this research, DH had similar yields with CT only at N00 level in more humid year 2005. Since soybean is capable of using atmospheric nitrogen through the symbiotic relationships with symbiotic bacteria (*Rhizobium and Bradyrhizobium sp.*), the lack of nitrogen from fertilizers is usually not the problem to high and stabile yields (Hardy and Havelka, 1975; Stanhill, 1990; Temple et all, 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 all, 1998), as long as weed control is effective and soil is loose enough to present no limits for root nodes development (Birkas et all, 2002).

Table 2: Soybean grain yields (kg ha^{-1}) as affected by different Soil Tillage systems (T: CT and DH), Nitrogen level (N: 0, 40 and 80 kg N ha^{-1}) and Inoculation (B: B0-without and B1-with inoculation), site Bokšić, years (Y) 2005 and 2006.

		2005		2006		Mean TxN		Mean TxNxB
		B0	B1	B0	B1	B0	B1	
CT	N00	3005 bc†	2926 ab	3249 ab	3287 ab	3127 bc	3107 ab	3117 ab
	N40	3130 b	3225 a	3479 a	3470 a	3304 ab	3348 a	3326 a
	N80	3639 a	2762bc	3589 a	3357 ab	3614 a	3060 abc	3337 a
DH	N00	3055 bc	2945 ab	2826 c	3026 bc	2941 c	2986 bc	2963 bc
	N40	2702 c	2693 bc	2901 bc	2874 c	2802 cd	2784 c	2793 c
	N80	2332 d	2523 c	2647 c	2897 c	2489 d	2710 c	2600 c

Y mean	T mean	N mean	B mean
2005: 2912 A‡	CT: 3260 C	N00: 3040 D	B0: 3046 E
2006: 3134 A	DH: 2785 B	N40: 3059 D	B1: 2999 E
		N80: 2968 D	

†Means in the same column 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

But, for this research, on higher N fertilization levels, CT showed higher soybean yields, showing probably advantageous soil structure and its influence on root proliferation and easier nutrient uptake, which can be beneficial also for symbiotic nodulation (Izumi et al., 2004), although nitrogen fixation can be lower or omitted if N is available by uptake (SeiJoon et al., 2005).

Campbell et all (1984), Munawar et al. (1990), Birkas et all (2002) and Baumhardt and Jones (2002) furthermore pointed out need for soil mulch coverage in droughty summer conditions, which, although was somewhat achieved by lesser incorporated crop residues in DH, did not preserved as much water as it was available on CT tillage.

It is interesting to point out statistical ineffectiveness of applied symbiotic inoculant, since in most cases there were no differences between B0 and B1 treatments. The main reason is that this inoculant has been widely used on given field a few years before, which was confirmed by checking root nodulation on both B treatments.

CONCLUSIONS

For given agroecological conditions and observed cultivar of soybean after winter barley in crop rotation, the conventional soil tillage, based on mouldboard ploughing, is more yielding system than reduced soil tillage, based on diskharrowing, especially in more drought seasons.

Although the most productive nitrogen fertilization has been achieved by 80 kg N ha^{-1}, statistically there is no need for more than 40 kg N ha^{-1} for soybean grain yield, preferably in combination with some symbiotic nitrogen fixation inoculant.

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