EFFECTS OF CONVENTIONAL AND REDUCED TILLAGE SYSTEMS IN WINTER WHEAT – SOYBEAN CROP ROTATION ON CROPS BIOMASS DEVELOPMENT

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Abstract
Croatian Baranja region contains soils with highly quality crop production properties, but the knowledge of the effects of reduced tillage systems is lacking. Our investigations were conducted under field conditions at Knezevo site chernozem in four replications. They included four soil tillage systems (CT: conventional tillage, with ploughing up to the 30 cm as a primary tillage; DS: diskharrowing up to the 15 cm; CH: chiselling up to the 30 cm + diskharrowing; NT: no-till seed drilling), both for winter wheat (*Triticum aestivum L.*) - soybean (*Glycine max L.*) in crop rotation during three growing seasons (2002-2004). All measured crop properties were strongly affected by different seasons, especially with the season of 2003 with extreme drought. Crop biomass in five growth stages for winter wheat showed that at the beginning DS and CH had stronger growth than CT and NT, but differences vanished toward final stages. Winter wheat grain yield achieved by reduced tillage systems was in average either higher (CH=5.59 t ha^{-1}) or not different (5.38 and 5.23 t ha^{-1} for DS and NT, respectively) than CT (5.28 t ha^{-1}). Soybean growth was consistently the most impaired at NT system, especially at the full maturity stage, where also DS and CH had lower biomass than CT. Soybean grain yield confirmed biomass results, since NT (2.11 t ha^{-1}) had always the lowest yield, when compared with other tillage systems (CT=2.88, CH=2.77 and DS=2.72 t ha^{-1}). Our conclusion is that within the Croatian Baranja environmental conditions is possible to replace soil tillage based on the ploughing for winter wheat and soybean with reduced soil tillage systems based on disking and chiselling, whereas no-till system still needs solution which will address drought-related problems.
Key words: winter wheat, soybean, ploughing, diskharrowing, chiselling, no-till

Introduction

In the Republic of Croatia, different trials of reduced tillage have been performed (Butorac et al. 1979, Juric et al. 1998, Zugec et al. 2000, Husnjak et al. 2002), with different results and conclusions, ranging from the full acceptability of certain reduced tillage systems, up to the conditional or even complete unsuitability of other systems, mostly due to the inherited soil and weather limitations. This is the main reason why the acreage under reduced tillage systems in Croatia is still very low, even at highly producible soils such are chernozems and eutric cambisols which are prevailing in Eastern Croatia, in spite the fact that scientists from different agriecological conditions confirmed possibilities of reduced tillage in more harsh environments, especially for winter wheat - soybean crop rotation (Vyn et al. 1991, Prasad 1996, Vyn et al.1998, Kelley et al. 2003), which is very interesting for Croatian farmers due to the traditional, technological and especially economical reasons, whose analyses were given very noticeably by DosSantos et al. (1997). The aim of this research was to explore replacements for soil tillage based on ploughing and their effects on winter wheat and soybean growth and grain yield in environmental conditions of Eastern Croatia.

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Materials and methods

The research was conducted near Knezevo in northern part of Croatian Baranja, at Agricultural Industrial Complex "Belje" Ltd., farm unit "Knezevo" land, for the winter wheat (*Triticum aestivum L.*) - soybeans (*Glycine max L.*) in crop rotation during period 2002-2004. The dominant soil type was determined as a chernozem. The main experimental set-up was a complete randomised block design in four replications for both crops in rotation, with four soil tillage systems for each crop: CT) Conventional Tillage: ploughing up to 30 cm depth, followed by diskharrowing, sowing preparation and sowing with no-till driller John Deere 750A; DS) Diskharrowing and sowing as for CT; CH) Chiselling on up to 30 cm depth, diskharrowing and sowing as for CT; NT) No-Tillage sowing without any primary tillage operation. The size of basic experimental plot for each individual tillage treatment was 900 m^2. The winter wheat cultivar "*Demetra*" was sown at the planned rate of 700 germinating seeds m^{-2}, at the inter-row distance of 16.5 cm. The soybean cultivar "*Tisa*" was sown at the planned rate of 55 germinating seeds m^{-2}, with inter-row distance of 33 cm, by closing every odd seeding dispenser on the no-till driller. The fertilization was uniform across treatments and years for each crop, and it consisted of 121 kg N ha^{-1} for winter wheat and 40 kg N ha^{-1} for soybean, 130 kg P_2O_5 ha^{-1} and 130 kg K_2O ha^{-1} each season. The soybean seed was inoculated with nitrate-fixing symbiotic bacteria ***Bradyrhizobium japonicum*** (trade-mark name "Biofixin-S"). The plant protection was performed uniformly for each crop by local farm manager recommendations. The winter wheat shoot biomass was collected from four 0.25 m^2 randomly collected on each experimental plot, during five growth stages: beginning of erect growth, visible flag leaf, flowering, milky ripeness and full maturity, determined by Feekes as F=4.0, F=8.0, F=10.5.1., F=11.1 and F=11.4, respectively. The soybean above ground biomass was collected by the very same procedure in first trifoliate growth stage (V3), bloom beginning (R1), full bloom (R2), full pod (R4) and full maturity (R8) growth stage. Collected biomass was dried at 65°C in three days, cut, mixed and weighed. The yield from each experimental plot was weighed at heavy duty bridge scale, grain moisture was recorded by moisture-meter "Dickey-John GAC2100" at the same time, and yield was recalculated on uniform moisture for each crop. The split-plot ANOVA was performed for all measurement results, with seasons as the main level and tillage as sub-level, and Fisher protected LSD means comparisons were performed at $P<0.05$ significance level by using SAS V8.0 (SAS Institute 2001, Cary, NC, USA).

Results and discussion

Winter wheat

As is shown in the Figure 1, the winter wheat biomass was significantly affected by different soil tillage systems mostly in first two sampled stages, beginning of wheat erect growth and during the growth of flag leaf, and fourth sampled growth stage, during the milky ripening. However, differences vanished at the end of vegetation, during the full maturity stage, presumably due to the nutrient allocation into grain. Similar development was observed also by some other authors (Busscher et al. 2000), but, results of Izumi et al. (2004) showed inconsistence of wheat shoot biomass in relation with tillage, where greater biomass was recorded for no-tillage than tilled plots in third year of their experiment.

However, the grain yield data (Table 1) showed inconsistence between biomass and final yield of winter wheat, both within each season (biomass data not shown) and in tillage yield means. In the first season, during the year 2002, with relatively favourable weather conditions for winter wheat growth, CT had the lowest yield, lower than DS and significantly lower than CH and NT. The highest yield at NT in this year could be also attributed partially toward residual effect of pre-trial soil tillage, as suggested by results of Frederick et al. (2001).
Extremely droughty spring of year 2003, with only 65 mm during period March-June 2003, instead of expected long-term average of 234 mm for the same spring period (based on 1965-1999 precipitation data for nearby weather station "Brestovac"), presented different situation, and all yields were rather low, within 1/3 of usually expected winter wheat yields. The drought-related stresses were the most expressed at NT, presumably due to the lacking of water accumulation during the winter period, and poor water conservation, since the soil surface was not covered fully with the mulch from previous crop, given it was only the second year of no-till practice. In third year, again with relatively usual precipitation pattern, but with colder spring temperatures, there was no difference between CT and other tillage systems.
Significant difference was recorded between CH, with maximal yield in this trial (7.05 t ha^{-1}) and NT, which yield was the lowest (6.49 t ha^{-1}), but not statistically different from other two tillage systems in the year 2004, CT and DS. Overall, the highest yield in average was achieved by CH, since it was the most consistent system. The second best was DS, followed by CT and NT, which were not statistically different among themselves. Lund et al. (1993) recorded also inconsistent effects of ploughing and no-tillage systems at winter wheat yields not only in winter wheat – soybean rotation, but also for monoculture and crop rotations which included winter wheat, soybean and maize. In contrast, Prasad (1996) showed no effects of tillage on winter wheat yield.

Soybean

Although constantly with the highest biomass (Fig. 2), CT was not significantly higher than DS and CH until the full maturity growth stage. Only at that growth stage, the most tilled soil under CT showed advantage over other tillage systems. The NT in all stages had significantly the lowest biomass recorded, which leads toward assumption that the soybean plant is more dependable on root proliferation within the soil in final stage than the winter wheat. Vyn et al. (1998) suggested that delayed growth and consequently lower soybean yield was a consequence of wheat residues. Problems with shallow tillage were observed also by Busscher et al. (2000), whose results suggested that deeper tillage can increase yields both for soybean and winter wheat.
The recorded biomass data were more consistent with grain yields (Table 2) in the sense of tillage treatment yield results relations (CT>CH>DS>NT), not only in grand mean, but in each year separately. In most cases CT, CH and DS were not different among themselves, all having significantly higher yield than NT. Some other authors (Lueschen et al. 1992, Prasad 1996) had not recorded dependence of tillage systems and soybean yield. Deeper tillage importance for given ecological conditions in soybean production was expressed in drought during the year 2003, when CT and CH, with soil tilled up to the 30 cm depth, accumulated and conserved winter water needed for soybean growth better than shallow DS and NT systems. At NT plots situation was even worsen, with 1/5 of planned plant population (10 instead of 55 plants m^{-2}), so poor plant stand, which stimulated stronger weed proliferation, was also to blame for final low yield.

As conclusion, the reduced soil tillage for winter wheat - soybean crop rotation grown by conventional tillage in Croatian Baranja agriclimatic conditions is equally applicable through either replacement of ploughing with diskharrowing only or diskharrowing in combination with chiselling as a primary tillage. No-till system in winter wheat production is still deprived in drought conditions, but otherwise it can replace other tillage systems without limitations. For soybean, no-till technology can show disadvantages even at highly productive soil such as chernozem, which can be additionally worsen with weather extremes. The further research is required for better no-till system adoption for soybean production.

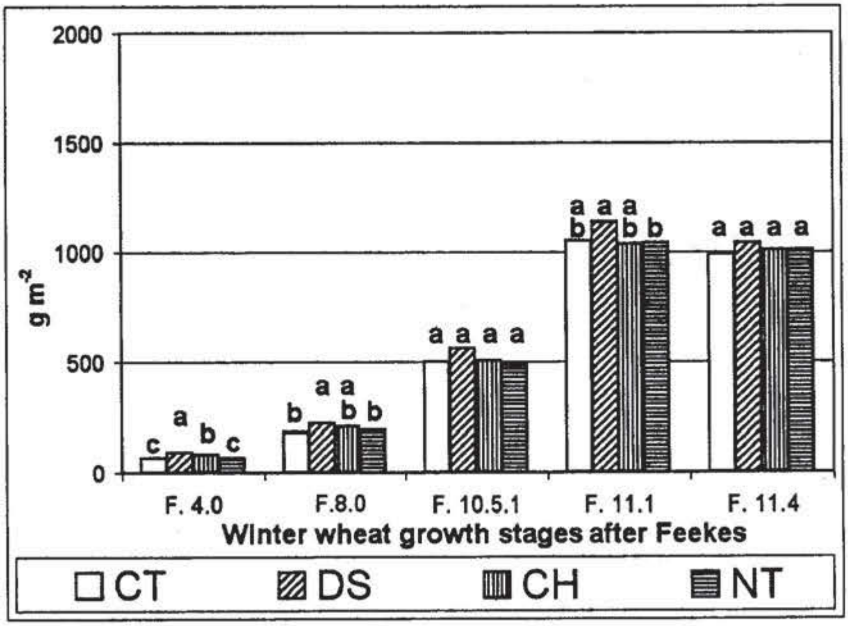

Fig. 1. The winter wheat biomass (g m^{-2}) at five growth stages (after Feekes): beginning of erect growth (F.4), flag leaf visible (F.8), flowering (F.10.5.1), milky ripe (F.11.1) and full maturity (F.11.4), Knezevo site, Croatian Baranja region, 2002-2004. The means within the same stage with the same lowercase letters are not different at P<0.05 significance level.

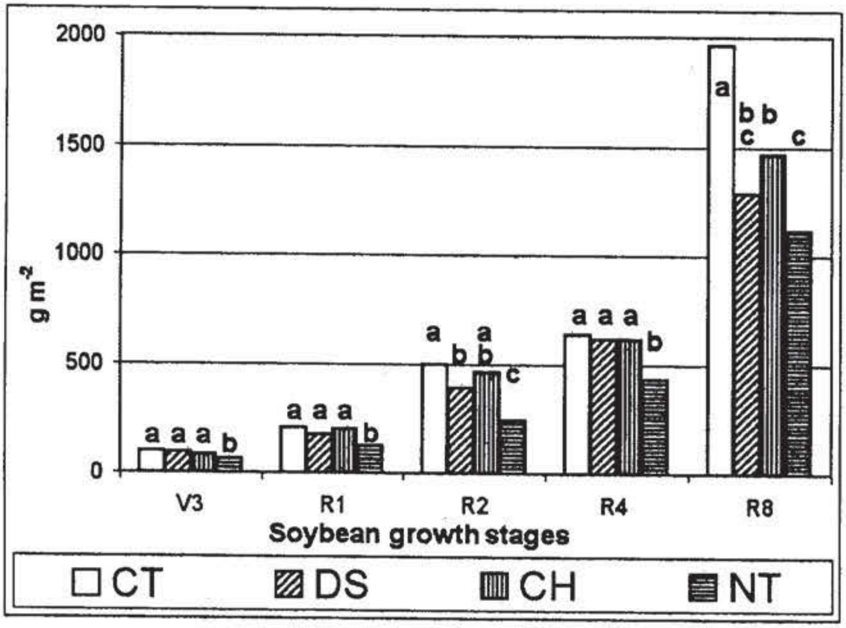

Fig. 2. The soybean biomass (g m^{-2}) at five growth stages: first trifoliate (V3), bloom beginning (R1), full bloom (R2), full pod (R4) and full maturity (R8), Knezevo site, Croatian Baranja region, 2002-2004. The means within the same stage with the same lowercase letters are not different at P<0.05 significance level.

Table 1 Influence of soil tillage system on the grain yield of winter wheat (t ha^{-1}) in Knezevo, Croatian Baranja region, for 2002-2004 period

	Year			
Soil tillage	2002	2003	2004	**Tillage mean**
1) CT	6.40b[†]	2.74a	6.69ab	5.28 B[‡]
2) DS	6.71ab	2.64a	6.80ab	5.38AB
3) CH	6.96 a	2.78a	7.05a	5.59A
4) NT	7.01 a	2.20 b	6.49 b	5.23 B

	Tillage	**Tillage|Year**	**Tillage x Year**
LSD (P<0.05)	0.20	0.41	0.46

[†] Means within the same year with the same lowercase letter(s) are not significantly different at P<0.05 level

[‡] Means with the same uppercase letter(s) are not significantly different at P<0.05 level

Table 2 Influence of soil tillage system on the grain yield of soybean (t ha^{-1}) in Knezevo, Croatian Baranja region, for 2002-2004 period

Soil tillage	Year			Tillage mean
	2002	2003	2004	
1) CT	3.27a[†]	2.40a	2.96a	2.88A[‡]
2) DS	3.24a	2.03 b	2.90a	2.72A
3) CH	3.28a	2.18ab	2.85a	2.77A
4) NT	2.90 b	1.25 c	2.17 b	2.11 B

	Tillage	Tillage|Year	Tillage x Year
LSD (P<0.05)	0.17	0.25	0.33

[†] Means within the same year with the same lowercase letter(s) are not significantly different at P<0.05 level

[‡] Means with the same uppercase letter(s) are not significantly different at P<0.05 level

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