TILLAGE AND NITROGEN EFFECTS ON WINTER WHEAT YIELD AND SELECTED SOIL PHYSICAL PROPERTIES ON HYPOGLEY OF EASTERN CROATIA

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Abstract
The field research was conducted on hypogley in Vrbanja, Croatia, during four growing seasons from 1992/1993 to 1995/1996. They included five soil tillage systems and three nitrogen fertilization levels in four replications for winter wheat (*Triticum aestivum L.*) after soybeans (*Glycine max L.*) as a preceding crop. Tillage treatments were: PL=conventional tillage (ploughing to 20 cm depth, diskharrowing and standard sowing); DS=diskharrowing and standard sowing; MC=tillage by multitiller and chisel, standard sowing; RS=soil tillage and sowing by RAU-Rotosem; PR=ploughing to the depth of 20 cm + RS. Nitrogen fertilization treatments were 140 (N1), 170 (N2) and 200 kg N ha^{-1} (N3). Wheat grain yields effects by tillage were as follows: 6.00 (PL), 5.79 (DS), 5.65 (MC), 5.61 (RS) and 5.90 t ha^{-1} (PR). Significant differences of yields were found only in the first year of testing. Nitrogen fertilization resulted by non-significant differences of yields as follows: 5.56 t ha^{-1} (N1), 5.85 t ha^{-1} (N2) and 5.96 t ha^{-1} (N3). The conclusion is that under certain environmental conditions it is possible to apply reduced soil tillage and moderate N fertilization.
Key words: conventional tillage, ploughing, diskharrowing, rotosem, multitiller, winter wheat.

Introduction

The soil tillage systems for winter wheat production had been reconsidered during the last decade. This process is a result of worldwide trends and research results about tillage simplifications for higher sustainability of the agriculture, in which the environment protection and decrease of tillage costs is especially emphasised (Karlen *et al.*, 1994). In the eastern part of Slavonia, the most agricultural region of the Republic of Croatia, various systems of reduced tillage have been already tested (Butorac *et al.*, 1979, Juric *et al.*, 1998, Stipesevic *et al.*, 2000), with main goals to decrease the costs of production, maintain agrosphere sustainability and to preserve high yield (characteristic for this region) despite the reduction of applied agritechnics. 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.

Materials and methods

This research was conducted near Vrbanja in Eastern Croatia, for the winter wheat (*Triticum aestivum L.*) in a crop rotation after soybeans (*Glycine max L.*) for period 1992/93-1995/96. The site's soil type was determined as a hypogley, with loamy clay texture, total porosity between 32.2-44.7%, bulk density from 1.30 to 1.70 kg dm^{-3}, slightly acid reaction (pH in KCl between 5.6-5.8), with low to moderate content of humus (1.6-2.3%), and with good fertility (16.61-18.28 mg P_2O_5 and 15.60-19.64 mg K_2O per 100 g of soil, 1.04-1.87 % of

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mg P_2O_5 and 15.60-19.64 mg K_2O per 100 g of soil, 1.04-1.87 % of $CaCO_3$) in 0-30 cm depth. The main experimental set-up was a split-plot design in four repetitions, where the main treatment was soil tillage with five steps: PL=conventional tillage (ploughing to 20 cm depth, diskharrowing and standard sowing); DS=diskharrowing and standard sowing; MC=tillage by Multitiller and chisel, standard sowing; RS=soil tillage and sowing by RAU-Rotosem; PR=ploughing to the depth of 20 cm + RS. The sub-treatment of N fertilization consisted of three steps: N1=140, N2=170 and N3=200 kg N ha^{-1}, with the same amount of phosphorus (150 kg P_2O_5 ha^{-1}) and potassium (100 kg K_2O ha^{-1}) each season. The basic experimental plot size was 1336 m^2. In harvest time, plots were harvested one by one and complete grain masses from each plot were weighted on large bridge-scales in vicinity, whereas moisture contents were measured and recorded by automated probe. Ten subsamples per each plot were taken after weighing yield, and weight of 1000 kernels were determined for each subsample. Soil cone penetrologger "Eikelkamp" model SN with cone diameter 2.00 cm and 60° cone angle was used for recoding soil resilience up to 30 cm depth in 10 cm steps. The split-split-plot ANOVA was performed with seasons as the main level, tillage as sub-level and added N as sub-sub-level, and Fisher protected LSD means comparisons were performed for P=0.05 significance levels.

Results and discussion

Lower depth of soil disturbance by reduced tillage (Table 1) was clearly notable through higher compaction already at 10-20 cm depth for all tillage systems not based on ploughing, i.e. DS, MC and RS. Higher soil compaction for these tillage systems was even more expressed at 20-30 cm. Harsher environment for winter wheat roots on these treatments probably contributed toward lower grain yield of these treatments (Table 2) as noted for winter wheat by Izumi *et al.* (2004).

Table 1: Influence of soil tillage (T) on soil resilience (MPa) in Vrbanja, Croatia, mean for 1992/93-1995/96 period.

	Depth (D)			
	D1	D2	D3	
Soil tillage (T)	0-10 cm	10-20 cm	20-30 cm	Mean (T)
PL) Conventional tillage	1.99 a†	3.44 a	5.65 a	3.69 A‡
DS) Diskharrowing	2.86 a	5.45 b	6.65 ab	4.99 B
MC) Multitiller + chisel	3.09 a	5.85 b	7.38 bc	5.44 BC
RS) Rotosem	3.48 a	5.92 b	8.68 c	6.02 C
PR) Ploughing + Rotosem	2.21 a	3.00 a	5.43 a	3.55 A
Mean (D)	2.73 D	4.73 E	6.76 F	4.74
	T	D	T|D	D|T, TxD
LSD(P<0.05)	1.29	0.97	1.43	1.51

†Tillage means with the same lowercase letter(s) for given depth 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

The PL treatment gave the highest grain yield (Table 2, 6.00 t ha^{-1}), followed by PR (5.90 t ha^{-1}) and DS (DS=5.79 t ha^{-1}). Significantly lower than PL and PR were MC (5.65 t ha^{-1}) and RS (5.61 t ha^{-1}). These results were in accordance with some authors whose trials included ploughing and continuous diskharrowing (Angebag and Maree, 1988; Schmidt *et al.*, 1994; Varvel *et al.*, 1989; Birkas *et al.*, 2002), although some other authors, under favorable agriecological conditions, Along with the increase of N amount, the yield also significantly increased, from 5.56 t ha^{-1} on N1 level of N fertilizer (140 kg N ha^{-1}) to 5.85 t ha^{-1} (N2=170 kg N ha^{-1}) and 5.96 t ha^{-1} on N3 level (200 kg N ha^{-1}), with better crop reaction between N1 and N2 (for 290 kg/ha or 5.2%), then N2 and N3 added nitrogen fertilizers (for 110 kg ha^{-1} or 1.9%).

Table 2: Influence of soil tillage (T) and nitrogen fertilization (N) on the grain yield of winter wheat (t ha^{-1}) in Vrbanja, Croatia, for 1992/93-1995/96 period

Soil tillage (T)	Nitrogen (N)			Mean (T)
	N1) 140 kg N ha^{-1}	N2) 170 kg N ha^{-1}	N3) 200 kg N ha^{-1}	
PL) Conventional tillage	5.81 bcd†	6.08 de	6.12 e	6.00 B‡
DS) Diskharrowing	5.56 b	5.94 de	5.87 cde	5.79 AB
MC) Multitiller + chisel	5.58 bc	5.55 b	5.81 bcd	5.65 A
RS) Rotosem	5.24 a	5.72 bcd	5.88 cde	5.61 A
PR) Ploughing + Rotosem	5.63 bc	5.95 de	6.11 e	5.90 B
Mean (N)	5.56 D	5.85 E	5.96 F	5.79
	T	N	T|N	N|T, TxN
LSD(P<0.05)	0.225	0.102	0.248	0.297

†Tillage means with the same lowercase letter(s) for given Nitrogen level 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

For all tillage treatments, except MC, significantly higher yields were recorded at N2 than N1 nitrogen level, whereas further significant differences were not achieved by additional N amount from N2 to N3 nitrogen level.

Some other authors (Kopke and Baeumer, 1985; Varvel *et al.*, 1989) reported that different placement and higher amount of nitrogen could alleviate negative effects of reduced tillage and thus unfavourable soil preparation for winter wheat growth at the yield level achieved with the conventional tillage based on ploughing. This was partially confirmed with this research, too, where level DS and RS tillage treatments at N3 nitrogen were not statistically different from PL and PR tillage systems, based on ploughing as a primary tillage.

Table 3: Influence of soil tillage (T) and nitrogen fertilization (N) on the winter wheat 1000 kernels weight (g) in Vrbanja, Croatia, for 1992/93-1995/96 period

Soil tillage (T)	Nitrogen (N)			Mean (T)
	N1) 140 kg N ha^{-1}	N2) 170 kg N ha^{-1}	N3) 200 kg N ha^{-1}	
PL) Conventional tillage	45.03 a†	45.48 a	44.68 a	45.06 AB‡
DS) Diskharrowing	46.28 a	45.45 a	46.05 a	45.93 C
MC) Multitiller + chisel	45.30 a	45.30 a	45.78 a	45.46 BC
RS) Rotosem	45.18 a	44.15 a	45.03 a	44.78 A
PR) Ploughing + Rotosem	45.03 a	45.45 a	45.25 a	45.24 AB
Mean (N)	45.36 D	45.16 D	45.36 D	45.29
	T	N	T|N	N|T, TxN
LSD(P<0.05)	0.64	0.59	1.32	6.17

†The Tillage means with the same lowercase letter(s) for given Nitrogen level 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

The weight of 1000 kernels (Table 3) confirms relations found in grain yields, and, what is especially interesting, also confirms that RS tillage treatment is not recommendable due to smaller kernels contain smaller amount of starch in endosperm, thus more unfavourable ratio of starch and rest of kernel for flour processing. However, Sabo *et al.* (2004) did not found that reducing tillage would reduce rheological quality of flour, except maximal viscosity of flour, which leads toward assumption that flour produced from winter wheat from RS treatment would have lower baking quality than other treatments.

Conclusion

The reduced soil tillage for winter wheat after soybean grown by conventional tillage in eastern Croatia and similar agriclimatic conditions is equally applicable through either omission of ploughing and replacement of ploughing with diskharrowing as a primary tillage, or replacement of diskharrowing with the Rotosem sowing. In spite of the highest yield at the highest nitrogen fertilization level of 200 kg N ha^{-1}, there is not statistically supported rationale for nitrogen fertilization higher than rate of 170 kg N ha^{-1}.

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