EFFECTS OF SOIL TILLAGE AND HERBICIDES ON WEEDS AND WINTER WHEAT YIELDS

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Abstract: The effects of three tillage systems and the post-emergence chemical weed control of annual broad-leaved weeds in winter wheat were studied on lessive pseudogley soil in north-eastern Croatia from 2001 to 2006. Total weed biomass on untreated plots was the lowest in continuous mouldboard ploughing (49.8 g m^{-2}), medium in chisel ploughing (90.9 g m^{-2}) and highest in continuous disk harrowing (187.3 g m^{-2}) with statistically significant differences ($P < 0.01$). The most abundant weeds were annual broad-leaved species of *Matricaria inodora*, *Ambrosia artemisiifolia*, *Galium aparine*, and *Stellaria media*, which constituted 57, 56 and 41% of total weed biomass in mouldboard-, chisel ploughing and disk harrowing, respectively. Three herbicide mixtures of 5% iodosulfuron - methyl sodium + 15% mefenpyr-diethyl; 12% fluoroglycofene-ethyl + 6% triasulfuron and 54% 2,4-D ethylhexyl ester + 0.5% metosulam in low doses provided a successful biomass control of dominant annual broad-leaved weeds (89-100% control). Herbicide treatments gave significantly higher yields than untreated controls with an average yield increase of 3, 11 and 7% in mouldboard-, chisel ploughing and disk harrowing, respectively. The yields did not differ among herbicide mixtures. Compared to the highest yield with mouldboard ploughing (6.1 t ha^{-1}), average yield depressions with chisel ploughing and disk harrowing were 3 and 5%, respectively.

Keywords: winter wheat, soil tillage, herbicides, weed density, weed biomass, crop yields

Introduction

A recent method of plant protection from weeds based upon integrated weed management includes a combination of all cultural, mechanical, chemical and other measures for an effective and economical weed control (Swanton and Weise, 1991). Crop production, its advantages and risks according to integrated plant management has not yet been sufficiently researched in Croatia, especially for main arable crops. Previous researches suggested a possibility of high herbicide doses substitution with reduced doses in winter wheat, spring barley and maize (Knežević et al., 2003a, 2003b, 1999). Yet, as such researches are long-term, they preclude final conclusions and need to be continued. Results of reduced tillage practices for cereal crops under different conditions in Croatia (Jug et al., 2006; Kisić et al., 2006; Žugec et al., 2000; Košutić et al.,1998) demonstrated advantage of less intensive tillage systems compared to conventional deep tillage systems. This paper reports the effects of three tillage systems and application of environmentally safe herbicides in post-emergence weed control in winter wheat and crop yields.

Materials and methods

Field experiments with winter wheat (cv. Demetra) in crop rotation with soybean were conducted at Čačinci locality in the north-eastern Croatia from 2001 to 2006. Soil type was lessive pseudogley: 13-18% of clay, 1.03% of organic matter, pH in H_2O - 5.1, pH in nKCl - 4.1, 9.7 mg P_2O_5 and 18.7 mg K_2O 100g^{-1} (AL-method). The fertilisation was based on 231 kg N, 150 kg P_2O_5 and 100 kg K_2O per ha. Winter wheat was sown in the third decade of October. The annual mean air temperature (October, July) was 9.9 °C and the annual mean precipitation was 666 mm. The experimental design was a split-plot with tillage

as the main factor (T) and weed control as the sub-factor (W). Weed control plots (3.5 x 9 m) were replicated four times within each tillage plot. Tillage had been performed continuously from 1996 in three treatments: 1. CT - conventional (ploughing with mouldboard plough at 30 - 35 cm depth with standard sowing), 2. CP- loosening with a chisel plough at 15 - 20 cm depth and 3. DH-disk harrowing at 8 - 10 cm depth. Weed control included four treatments: W0 - untreated control; W1 - 5% iodosulfuron - methyl sodium + 15% mefenpyr-diethyl at 0.02 kg ha^{-1} of commercial mixture "Hussar" (Bayer Crop Science); W2 - 12% fluoroglycofene-ethyl + 6% triasulfuron at 0.02 kg ha^{-1} of commercial mixture Satis 18 WP (Syngenta) and W3 - 54% 2,4-D ethylhexyl ester + 0.5% metosulam at 1.25 L ha^{-1} of commercial mixture Sansac (Bayer Crop Science). Each year in all tillage treatments the same post-emergence herbicide mixtures were applied at the tillering stage of winter wheat corresponding to Zadoks´ scale 25-31. Herbicides were applied by knapsack-sprayer "Solo" (Lurmark AN 1.0 nozzle type) in 300 L ha^{-1} of water volume at a pressure of 300 kPa. Weed infestation was evaluated twice a year. The first evaluation was two weeks after herbicide application, and the second one was after wheat heading. This paper presents the weed data based on a second assessment. Weed density and fresh weed biomass were estimated in each sub-plot in four quadrants, each measuring 50 cm x 50 cm (16 replications totally). Weeds found in each quadrant were cut at ground level, separated by species, counted and weighed. The efficacy of herbicide was measured as a relative reduction in weed biomass for each weed species compared to untreated plots within each tillage treatment. Before the statistical analyses a square root transformation for weed density and weed biomass of annual grasses, annual broad-leaved weeds and perennial weeds had been performed. Winter wheat was harvested each year in the middle of July. The crop yields were adjusted to 14% of the moisture content. The SAS V8.1 statistical package´s Proc Mixed was used for calculating ANOVA and means were compared at $P < 0.01$ significant level.

Results and discussion

Thirty-eight weed species were recorded in winter wheat, 19 of which were species in conventional tillage with mouldboard-, (CT) and chisel ploughing (CP) and 24 species in disk harrowing (DH). Annual broad-leaved species were the dominated weeds with 22 species, compared to 14 perennials and 2 annual grass species. Neglecting the effects of tillage on untreated plots, nine species reached more than one plant per m^2. They were: annual grass of *Apera spica-venti* (L.) PB., annual broad-leaved species of *Matricaria inodora* L., *Galium aparine* L., *Stellaria media* (L.) Vill., *Ambrosia artemisiifolia* L., and perennials of *Convolvulus arvensis* L., *Equisetum arvense* L., *Calystegia sepium* (L.) R. Br., *Cirsium arvense* (L.) Scop. In the time after wheat heading, when the weeds become strong competitors with wheat (Klem and Vánová, 1999), the fore mentioned species constituted 73% and 95% of total density and total weed biomass, across all tillage treatments, respectively. *M. inodora* thrived in wet seasons of 2002, 2004 with high precipitation in April and May (> 100 mm). In extremely dry 2003 when the precipitation in April and May was only 9 mm and 14 mm, respectively, it showed a biomass depression of 62%, compared to an average of 61.9 g m^{-2} in wet spring months. With respect to tillage effects, a total weed biomass on

untreated plots was the lowest in CT tillage (49.8 g m^{-2}), medium in CP (90.9 g m^{-2}) and the highest in DH tillage (187.3 g m^{-2}). Thereby the proportion in biomass of annual broad-leaved weed groups was 57, 56 and 41%, respectively (Table 1). Biomass of annual grasses with *A. spica-venti* populations did not vary significantly between tillage treatments.

Table 1. Plant density and fresh weed biomass of weed groups on untreated plots at different tillage systems (2001-2006)

Weed groups	Weed density (plants m^{-2})			Weed biomass (g m^{-2})		
	CT	CP	DH	CT	CP	DH
Annual grasses	3.8 ns	4.8 ns	3.1 ns	17.0 ns	20.0 ns	16.4 ns
Annual broad-leaved weeds	5.5 a	8.3 ab	13.2 b	28.5 a	50.6 ab	77.6 b
Perennial weeds	0.9 a	4.7 b	6.4 b	4.0 a	21.7 b	92.9 c
Total	10.1 a	18.0 b	22.7 b	49.8 a	90.9 b	187.3 c

The means followed by the same letter within weed groups are not significantly different at P< 0.01 level.

Perennial weeds of *Cirsium arvense* was associated only with DH tillage, especially in the last year when it produced 72% of the total perennial biomass of 92.9 g m^{-2}. The tendency of biomass increase of some perennial weeds with time on continuous disk harrowed plots has been reported previously (Knežević et al., 2003b). Findings of Reisinger and Pálmai (2007) suggest that the sowing time of crop could be integrated in a strategy against some annual and perennial weeds in winter wheat. On average, applied herbicide mixtures in our trials provided a successful biomass control of main annual broad-leaved weeds such as: *M. inodora* (92-98% control), *G. aparine* (90-100%), *S. media* (89-100%) and *A. artemisiifolia* (85- 90%). Herbicide mixtures did not sufficiently control perennial weeds. Compared to the best control efficacy of all species with CT (90% control), a less but still satisfactory control efficacy of 83 and 81% was achieved with CP and DH tillage treatments, respectively.

Table 2. Grain yields of winter wheat at different tillage and herbicide treatments (2001-2006)

Weed control	CT	CP	DH	Average
Untreated control	5.9 a	5.5 b	5.5 b	5.6 b
Iodosulfuron - methyl sodium + mefenpyr-diethyl	6.1 a	6.0 a	5.8 ab	5.9 a
Fluoroglycofene-ethyl + triasulfuron	6.2 a	6.1 a	6.1 a	6.1 a
2,4-D ethylhexyl ester + metosulam	6.1 a	6.1 a	5.9 a	6.0 a
Average	6.1 a	5.9 ab	5.8 b	

The means followed by the same letter within weed control and tillage treatments are not significantly different at P< 0.01 level.

Grain yields of winter wheat were significantly influenced by year and tillage. The highest yields were obtained in the first year of study with favourable weather

conditions when yields in three tillage treatments did not significantly differ (7.1 t -7.4 t ha^{-1}). A drastic yield depression occurred in the dry season of 2003 at all tillage treatments, but the highest depression of 32% was found in DH tillage compared to 4.9 t ha^{-1} in CT. In comparison with the highest yields in CT with mouldboard ploughing (6.1 t ha^{-1}), average yield depressions in reduced CP and DH tillage treatments were 3% and 5%, respectively (Table 2). Differences in yields are statistically significant between CT and DH. Compared to untreated controls, on average, herbicide mixtures provided significantly higher yields of 3, 11 and 7% in CT, CP and DH tillage treatments, respectively. The yields did not differ between three herbicide treatments.

Conclusions

Plant density and fresh biomass of weeds varied according to year and tillage system. Significant differences between three tillage systems were observed in biomass of annual broad-leaved and perennial weeds. The proportion in biomass of annual broad-leaved weeds was 57, 56 and 41% in mouldboard-, chisel ploughing and disk harrowing, respectively, whereas the proportion of perennial weeds was 8, 24 and 50%, respectively. Applied herbicide mixtures provided a successful biomass control of dominant annual broad-leaved weeds (89-100%), and gave significantly higher yields than untreated controls with an average yield increase of 7%. Compared to the highest yield in conventional tillage with mouldboard ploughing (6.1 t ha^{-1}), a significant average yield depression by 5% occurred after disk harrowing.

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