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Effects of soil tillage and post-emergence herbicides on weed control and yield of winter wheat

Mira Knežević[1], Renata Baličević[1], Marija Ravlić[1], Ivana Ravlić[1,2]

[1]*Faculty of Agriculture, University of J.J. Strossmayer in Osijek, Kralja Petra Svačića 1d, Osijek, Croatia (Mira.Knezevic@pfos.hr)*
[2]*Student, Graduate study*

Abstract

Field trials were conducted in winter wheat during 2008-2011 in north-eastern Croatia to evaluate the effects of two continuous tillage systems (conventional with mouldboard ploughing-CT & reduced with disk harrowing-RT)) and post-emergence chemical weed control upon species composition, weed density and crop yield. In both tillage systems the main weeds were annual species, grass of *Apera spica-venti* (L.) PB. and broad-leaved weeds of *Matricaria inodora* L., *Papaver rhoeas* L. and *Viola arvensis* Murray. Weed density on untreated plots was lower in CT tillage (26.4 plants m^{-2}) than in RT tillage (40.2 plants m^{-2}). The best total weed control was achieved with iodsulfuron-methylsodium (97.3%), followed by the herbicide combinations of prosulfocarb plus triasulfuron (96.7%), triasulfuron plus pinoxaden (95.3%), standard tank mixture of triasulfuron + chlortoluron (93.8%) and prosulfocarb (88.3%). Compared to the highest yield with disk harrowing (6659 kg ha^{-1}) average percent yield depression with mouldboard ploughing was 5%. Among the herbicide variants, significant yield depression (3%) was observed only when prosulfocarb was applied alone.

Key words: soil tillage, weed density, chemical weed control, crop yield

Introduction

In recent years there has been an increasing interest in the research of the rational tillage systems such as reduced, minimum or no-tillage for cereal crops in Croatia as an alternative to conventional soil tillage because of environmental and economic reasons (Jug et al., 2006, Košutić et al., 1998). Reduced soil tillage systems have a major impact on the weed species composition and the density of weed populations (Arshad et al., 1994, Froud-Williams et al., 1981) and generally favor greater weed infestation in winter wheat (Knežević, 2003, 2012). Weed control programs developed under conventional tillage systems are seldom appropriate for reduced tillage systems. Therefore, introducing reduced soil tillage systems in cereal cropping, weed control programs must be accommodated to tillage systems (Pallut & Bennewitz, 1996). Rational tillage systems and usage of environmentally safe herbicides in post-emergence weed control are compatible with an integrated weed management (Swanton & Weise, 1991), which has been inplemented in Croatia because of its favorable ecological and economic implications. Effects of crop production, its advantages and risks according to integrated weed management, have not yet been sufficiently researched in Croatia, especially regarding the main arable crops.

The objective of this study was to determine the effects of two tillage systems (conventional with mouldboard ploughing and reduced with disk harrowing) and some post-emergence herbicide combinations particularly with lower than recommended rates upon species composition, weed density and crop yield of winter wheat.

Material and methods

Field experiments with winter wheat (cv. *Matea)* were conducted on lessive pseudogley soil at Zdenci locality in north-eastern Croatia during 2008-2011. In all three years, the previous crop was soybean. Winter wheat was sown in the second decade (2009, 2010) or in the last decade of October (2008). Weather conditions during the winter wheat growing seasons are presented in Table 1.

Table 1. Weather conditions during winter wheat growing season (2008-2011)

Growing seasons		Months										Total Mean
		X	XI	XII	I	II	III	IV	V	VI	VII	
2008-	P*	50	53	45	69	32	37	25	94	84	28	517
2009	T†	13.6	7.5	4.1	-1.3	2.8	7.5	14.0	18.3	19.7	23.0	10.9
2009-	P	74	91	118	87	84	53	70	183	239	47	1046
2010	T	12.1	8.1	3.0	-2.0	0.9	7.4	11.9	16.7	20.0	23.2	10.1
2010-	P	85	65	72	19	26	36	17	48	76	132	576
2011	T	9.1	9.2	0.9	1.6	1.5	6.9	13.8	16.4	21.4	22.7	10.3

*P= precipitation (mm), †T= temperature (°C); Source: Meteorological Station of Čačinci located near the experimental site

The experiment was conducted as a randomized complete block design with split-plot arrangement and four replications. Tillage system was taken as the main plot and weed control management as the subplot. The size of the subplots was 3 x 9.3 m. Continuous tillage systems were conventional tillage (CT) – ploughing with a mouldboard plough at 30-35 cm depth; and reduced tillage (RT) – with disk harrowing at 15 cm depth. Weed management included untreated control and five herbicide treatments: 1) iodsulfuron-methyl sodium 5% & mefenpyr-diethyl 15% (10 + 30 g a.i. h^{-1}); 2) triasulfuron 0.75% & chlortoluron 79% (9.75 + 1027 g a.i. h^{-1}); 3) prosulfocarb (N) 80% (2400 g a.i. h^{-1}); 4) prosulfocarb (N) 80% + triasulfuron 20% (2400 + 7.4 g a.i. h^{-1}); 5) triasulfuron 20% + pinoxaden 5% (8 + 30 g a.i. h^{-1}). All herbicides and their combinations were applied post-emergence in the spring when the winter wheat was at the tillering stage corresponding to Zadoks' scale 25-29, while the weeds were in the 2-4 leaf stages. The herbicides were applied by a knapsack-sprayer Solo (Lurmark AN 1.0 nozzle type) in 300 l ha^{-1} of water volume at a pressure of 300 kPa.

The weed density m^{-2} was recorded first time 3-4 weeks after the herbicide application and again in June when the weeds were cut at above ground level from 0.25 m^2, replicated 16 times within each treatment including untreated controls and treated plots with the tested herbicides. The efficacy of herbicides is shown according to weed density in relation to the weedy control plots. Phytotoxic effects of herbicides at crop plants were estimated using the EWRS (1-9) scale. Winter wheat was mechanically harvested from each subplot in all three years in the middle of July. The grain yield data was recorded and adjusted to 14% of the moisture content.

The data on weed density, percentage of weed control and crop yield in all tillage and weed management treatments as well as their interactions were subjected to an analysis of variance and tested by F-test (Fisher's Protected LSD test), using Microsoft Excel and Statgraf program.

Results and discussion

During the experiment, a total of 22 weed species were recorded in winter wheat, 17 of which were annual broad-leaved species, 4 perennials and one annual grass species. In a three-year average in both tillage systems, four weed species reached more than one plant m^{-2} on untreated plots. They were: annual grass of *Apera spica-venti* (L.) PB. (20.6 – 32.2 shoots m^{-2}) and annual broad-leaved species of *Papaver rhoeas* L. (1.2 – 1.9 plants m^{-2}),

Tripleurospermum inodorum (L.) C.H.Schultz (1.2 plants m^{-2}), and *Viola arvensis* Murray (0.8 – 1.2 plants m^{-2}). The weed density differed significantly among years and tillage systems (Table 2). The greatest average weed density on untreated plots was in 2009-2010 and it reached 42.3 plants m^{-2}. The probable reason for these differences could be the extremely high rainfall in 2009-2010 which was 529 and 470 mm higher compared to 2008-2009 and 2010-2011, respectively (Table 1). With respect to tillage, the average weed density in RT tillage was 53% greater compared to 26.3 plants m^{-2} in CT tillage system.

Table 2. Weed density (plants m^{-2}) on untreated plots in winter wheat affected by year and tillage

Tillage	2008-2009	2009-2010	2010-2011	Average of tillage
Conventional tillage	22.5 b	37.8 b	18.8 b	26.3 b
Reduced tillage	40.8 a	46.8 a	33.1 a	40.2 a
Average of year	31.6 B	42.3 A	24.9 C	

Means followed by the same letter within the column (lower case letters) or in rows (capital letters) are not significantly different at P<0.05.

The annual grass of *A. spica-venti* was the most abundant weed on untreated plots in both tillage systems and its population constituted 78% and 80% of total weed density in CT and RT tillage systems, respectively. Plant densities of three main annual broad-leaved species constituted 16% and 11% of total weed density in CT and RT tillage systems, respectively. In our previous experiments (Knežević et al., 2003, 2008) and other researches (Ozpinar, 2006) the average plant density of annual broad-leaved species was lower in CT tillage than in some reduced tillage systems, although annual broadleaf species according to some authors (Froud-Williams et al., 1981, Streit et al., 2003) tend to adapt better to frequently disturbed habitats and are more abundant in conventional tillage systems. The perennial weeds of *Calystegia sepium* (L.) R.Br., *Cirsium arvense* (L.) Scop., *Convolvulus arvensis* L. and *Ranunculus repens* L. were associated only to RT tillage system. An increase of perennial weeds in reduced or no-tillage systems was documented by Tørresen et al. (2003). The herbicide efficacy significantly varied among years and ranged from 93.4 to 95.2%, on average. Although herbicide efficacy in RT was significantly lower (93.6%) than in CT (95%), herbicide combinations ensured good annual weed control. An earlier study showed that herbicides in reduced tillage systems can provide equally high weed control as well as in conventional tillage systems (Knežević et al., 2012).

Across years and tillage systems, the best total weed control was achieved with iodsulfuron-methyl sodium (97.3%), followed by prosulfocarb + triasulfuron (96.7%) and triasulfuron + pinoxaden (95.3%). The application of triasulfuron + chlortoluron mixture ensured 93.8% of weed control, while prosulfocarb herbicide applied alone controlled 88.3% of the weed plants. The application of triasulfuron & chlortoluron tank mixture in the trials with reduced doses (one-half and one-quarter) can also provide good weed control in winter wheat (Knežević et al., 2003).

All herbicide treatments gave good control of *A. spica-venti* (92-97%). The best grass control was achieved with iodsulfuron-methyl sodium (97%), followed by herbicide combinations of prosulfocarb + triasulfuron (96%) and triasulfuron + pinoxaden (95%). High activity of prosulfocarb and pinoxaden herbicides against *A. spica-venti* was observed by Adamczewski et al. (2009) and Kiehloch et al. (2006). In our experiments, when prosulfocarb was applied alone, it brought a low control of *P. rhoeas* (70-77%), *V. arvensis* (66-77%) and *M. inodora* (58-71%) across two tillage systems. The unsatisfactory efficacy of prosulfocarb on aforementioned weeds was also reported by Tomczak et al. (2007) for Polish conditions. All herbicides used in the experiments were selective for winter wheat and caused no crop injury.

Table 3. Effects of year, tillage system and weed management on grain yield (kg ha^{-1}) of winter wheat

Weed control treatment	2008-2009		2009-2010		2010-2011		Mean		
	CT	RT	CT	RT	CT	RT	CT	RT	Mean
Untreated control	7179	7765	4369	4502	6261	6103	5936	6123	6030c
1	7769	8155	4880	5188	6790	7072	6480	6805	6642a
2	7501	8175	4913	5136	6879	7018	6431	6776	6603a
3	7409	8186	4646	4925	6602	6831	6219	6647	6433b
4	7599	8370	4982	5187	6757	7095	6446	6884	6665a
5	7602	8213	4837	5000	6655	6943	6364	6718	6540ab
Mean of tillage	7510 B	8144 A	4771 B	4989 A	6657 B	6844 A	6312 B	6659 A	
Mean of year	7827 A		4880 C		6750 B				

Means followed by the same letter within the column (lower case letters) or in rows (capital letters) are not significantly different at P<0.05.

The winter wheat grain yields significantly varied among years and tillage systems (Table 3). The lowest yields were in the unfavourable 2009-2010 with an average yield depression of 38% in comparison to the highest yields obtained in 2008-2009. The average yields from disk harrowed plots were 5% higher than the yields from ploughed plots. This coincides with the finding by Ozpinar (2006) that the reduction of tillage does not always correlate with a significant crop yield reduction. On the contrary, Butorac et al. (1986) reported for Croatian conditions, that the yields were always highest in the conventional tillage system than in the reduced tillage systems. The average yields from herbicide treated plots were 6388 kg ha $^{-1}$ in CT tillage and 6766 kg ha^{-1} in RT tillage, while the yields from the weedy control were 7–10% lower in comparison with the yields of herbicide treatments. Among herbicide treatments, significantly lower yields were obtained only with prosulfocarb with a yield depression of 3% on average, compared to the highest yields with herbicide combinations.

Conclusions

The results showed a clear effect of the year on the changes in plant density of the main weeds and the total weeds. Regarding the tillage, the average total weed density of annual weeds with mouldboard ploughing was 33% lower than with disk harrowing. In both tillage systems, all herbicide treatments provided a good level of weed control (93.8-97.3%), except prosulfocarb (88.3%), when applied alone. An average crop yield of 6659 kg ha^{-1} was for 5% higher with disk harrowing compared to the yields with mouldboard ploughing. The average yield increase ensured by herbicides was 8% in CT and 11 % in RT tillage systems compared to the yields from weedy control plots.

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