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Effect of preceding crop, soil tillage and herbicide application on weed and winter wheat yield

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Abstract. This article describes results obtained in three years of experiments (2001–2003) carried out at farm Dobele Agra SIA located in the Dobele region of Latvia. Trials were established in two different crop rotations (Factor A): 1. winter wheat sown after winter wheat, 2. winter wheat sown after winter rape. Three different soil tillage and sowing methods were compared (Factor B): 1. – minimal conservation soil tillage in 10–15 cm deep with mixing of soil; 2. – direct sowing into stubble without any previous soil cultivation; 3. – traditional soil tillage with ploughing on 25 cm with cultivation before sowing. Additionally we compared the impact of those soil tillage methods on weed infestation in winter wheat (Factor C): 1. - using herbicide Secator 0.3 kg ha^{-1}, 2. – without herbicide treatment. A significantly smaller total number of weeds was observed in treatments where winter wheat was grown in recurrent sowing, primarily caused by differences in numbers of oil seed rape in this treatment. A significantly smaller number of weeds was also observed after traditional soil tillage with ploughing. Data analysis shows significant linear negative correlation between winter wheat yield and the number of total weed infestation and several weed species – *Stellaria media* (L.) Vill., *Sinapis arvensis* L., *Matricaria perforata* Merat. and *Lamium purpureum* L. The highest impact on changes of winter wheat grain yield was made by herbicide use – 64.1%.

Key words: winter wheat, minimal soil tillage, direct drilling, ploughing, weed infestation

INTRODUCTION

Weed infestation in cereals remains one of the problems for growers despite many tools and possible methods both chemical and non-chemical to control them. *Weed population shifts* is a term that refers to the changes in the kinds of troublesome weeds that occur with a change in tillage systems. When tillage is reduced the environment of weed seeds and underground parts of perennial weeds is altered. These environmental alterations affect weed species differently (OMAF, 2002).

Conventional ploughing at the depth of 22–24 cm is expensive and labour–intensive work. In the world's soil tillage practice, attempts have been made to replace ploughing by subsurface cultivation, rototilling, and chisel ploughing as well as by reduced ploughing depth (Rubenis et al., 1995). The major advantage of reduced soil tillage is saving resources and working time. In Rot Amsted research farm (UK) it was demonstrated that working time for growing cereals can decrease two times using reduced tillage methods, but using direct sowing – 3–4 times (Cannel, 1985). Reduced soil tillage not only reduces costs and resources, but also reduces negative influence on soil and the environment. It positively affects structure, physical and biological processes in the soil (Monsanto 2002).

Nevertheless, changing tillage practices can result in marked shifts in weed species over time that may pose problems for producers (Blackshaw, 1996). The changes of soil tillage systems also affect many other agronomical factors which are important for yield formation; weed infestation is one. Farmers' experience indicates that herbicide use may increase during a 3- to 5-year transition period from conventional to conservation tillage. Growers then report that their herbicide use often declines in zero tillage systems. This may be due to greater weed seed mortality when seeds remain on the soil surface due to predation by rodents, birds and insects, attack by fungi and bacteria, and desiccation over the winter period. Timing of herbicide use may change with conservation tillage with reduced emphasis on in-crop herbicides and increased use of herbicides in fall or before crop seeding to control winter annuals and early germinating summer annuals (Blackshaw, 1996). The aim of the experiments was to investigate the influence of different factors on weed infestation in winter wheat grown in different crop rotations and tillage systems.

MATERIALS AND METHODS

The three years of experiments (2001–2003) were carried out at farm Dobele Agra SIA located in the Dobele region of Latvia in heavy clay soil. Trials were established in two different crop rotations (Factor A): 1. winter wheat sown after winter wheat, 2. winter wheat sown after winter rape. Three different soil tillage and sowing methods were compared (Factor B): 1. – minimal conservation soil tillage in 10–15 cm deep with mixing of soil, 2. – direct sowing into stubble with previous no soil cultivation. and 3. – traditional soil tillage with ploughing on 25 cm with cultivation before sowing. Additionally compared was the impact of those soil tillage methods on weed infestation in winter wheat (Factor C): 1. - using herbicide Secator 0.3 kg ha^{-1}, 2. – without herbicide treatment.

The winter wheat variety 'Zentos' was sown using pneumatic seed driller Vaderstad Rapid 600P. Soil ploughing used 6-furrow conventional plough Kwerneland; cultivation was done with Vaderstad Rexius equipment. Minimal soil tillage was carried out with heavy disc harrows Simba Discs 34C 4.6 together with press Simba double press 4.6. Herbicide Secator with rate 0.3 kg ha^{-1} was used during the tillering stage of winter wheat. The yield was harvested with Claas combine harvester and adjusted to 100% purity and 86% dry matter content.

The trial was arranged in a large area – factor A arranged in 90 x 100 m plots, factor B – 30 x 100 m plots, factor C – 30 x 18 m plots. The yield was harvested in 6 x 2.5 m plots in 5 replications. Weed assessments were made before spraying and before harvesting in 0.25 m^2 big square in 20 replications.

There were variable weather conditions with large differences from lengthy time averages during the experiments, resulting in large differences in results among the three years; various factors had different impacts on outcomes.

Autumn 2000 was long and warm with significant amounts of precipitation, conditions favourable for active growth and development of crops and weeds. In the variant in which winter wheat was sown after winter rape, using minimal soil tillage and direct sowing, there was a significant invasion of winter safety weeds like *Matricaria perforata* Merat. Those conditions affected the growth and development of winter wheat because of high weed competitiveness. In the spring, the weeds were already large and the effectiveness of the herbicide was low. Also, high precipitation during June and July of 2001 (115 and 118 mm, SIA Dobele Agra weather station data) caused additional active growth of weeds which affected productivity of winter wheat yield results.

The trials of the second year were established under high soil moisture, caused by a high amount of precipitation during summer 2001 (309 mm, SIA Dobele Agra weather station data). Those conditions were not favourable for the quality of soil tillage works, compared with the previous year. The winter wheat crop growth and development differed from the previous year.

Spring 2002 was favourable for winter wheat crop growth and development, but summer months were sunny and very dry (June 37 mm, July 30 mm, August 0 mm, Dobele Agra weather station data). In those conditions the efficiency of herbicides was high in those variants which used traditional soil cultivation with ploughing.

The third year experiments in 2002 were established under very dry soil conditions; the drought period lasted 60 days. Under such conditions it was difficult to do qualitative direct sowing. The cold winter with a wide range of temperatures negatively affected winter hardiness of winter wheat. Hot temperatures in July and heavy rainfall in August affected harvesting results. Such variable weather conditions provided broad experience in using different soil tillage methods in different weather and soil conditions.

Data analysis for significance used three-factor ANOVA. Interactions between factors are calculated using correlation-regression analyses.

RESULTS AND DISCUSSION

The average of three years' results shows that the significantly highest yields of winter wheat were grown in crop rotation after winter rape (1^{st} wheat). Herbicide use in both cases of crop rotation gave significant yield increase as compared with the untreated case (Fig. 1).

In trials of the 2^{nd} wheat crop (wheat after wheat in crop rotation) together with herbicide use the highest yield was in the variant with minimal soil tillage, which was significantly higher than the yield in variants with direct drilling and traditional soil tillage. Similar results were obtained in experiments carried out by F. B Ellis and J. G. Elliot (1979) and F. Pollard and J. G. Elliot (1981).

Highest winter wheat yield in variants without herbicide use was seen in the case of traditional soil tillage. Yield differences with minimal tillage and direct drilling were lower than critical difference.

The highest yield of 1^{st} wheat together with herbicide use was in the variant with traditional soil tillage; the yield was significantly higher than that in the remaining variants. The same tendencies were seen in the variants without herbicide use. The lowest winter wheat yield was seen in variants that used direct drilling. In the case of herbicide use it was significantly lower; without herbicide – not significantly. These results coincide with those obtained in a trial carried out by S. M. Knight (2004).

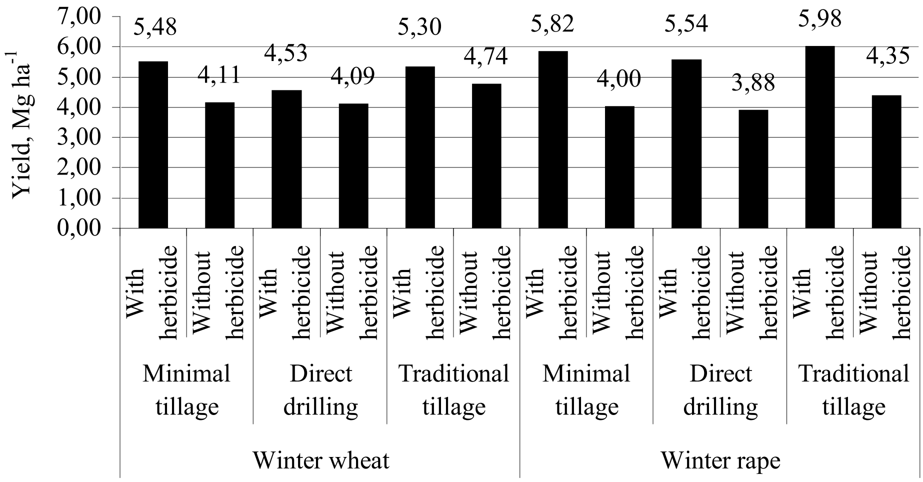

Fig. 1. The yield of winter wheat depending on preceding crop, soil tillage and weed control technologies in years 2001–2003: $\gamma^{A}_{0.05} = 0.130$; $\gamma^{B}_{0.05} = 0.159$; $\gamma^{C}_{0.05} = 0.130$.

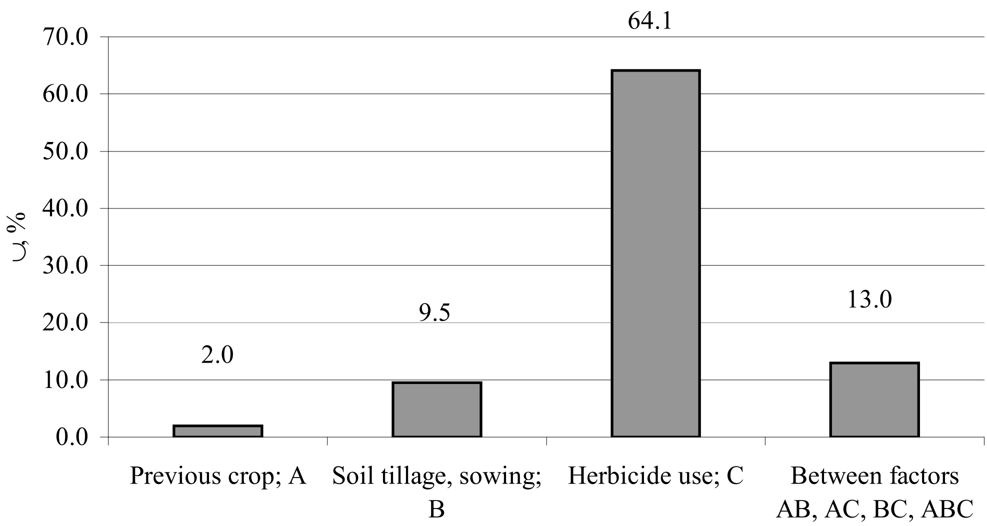

Fig. 2. Impact of different factors on winter wheat yield, on average 2001–2003.

When comparing the influence of different factors on the yield of winter wheat (Fig. 2) we show that the highest impact was from herbicide use – 64.1%. Impact from soil tillage was 9.5%, but from previous crops just 2.0%. That advocates for on demand use of different weed control methods and technologies when using different soil tillage technologies, because the noxious effect of weeds has the greatest impact on the formation of the winter wheat yield. The previous statement certifies a strong correlation between number of weeds per square meter and winter wheat grain yield (Fig. 3).

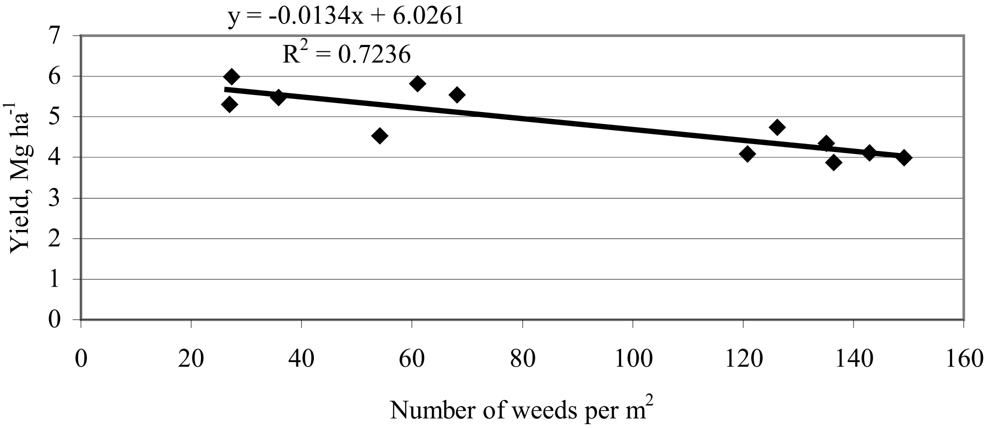

Fig. 3. Coherence between number of weeds per m^2 and winter wheat yield, on average 2001–2003.

Analysing the impact of different factors to separate weed species we can find that herbicide application has a significant effect against all dominant species. Especially high impact was observed for total weed infestation in winter wheat – 80.8% (Table 1). The distribution of oil seed rape as weed mainly was affected by the previous crop.

We will exclude herbicide application as a factor in the next calculation because it is the main factor in changes in weed flora. Soil tillage has shown a higher impact on weed infestation in winter wheat compared to the previous crop. R. E. Blackshaw (1996) reached the same conclusions. Such coherence was observed for the total number of weeds and for *Sinapis arvensis* L., *Matricaria perforata* Merat. and other weed species that were observed in the trial. Soil tillage had a higher impact on changes in the number of *Galium aparine* L. and *Lamium purpureum* L. compared to the effect of the previous crop, but this impact was insignificant at 95% probability level (Table 2).

Table 1. Impact of different factors to changes of number of some weed species (on average 2001–2003), η

Weed species	Factors						
	previous crop (A)	Soil tillage (B)	Herbicide application (C)	Interaction between factors			
				AB	AC	BC	ABC
Oil seed rape	37.7	10.3	6.5	11.5	3.0	0.5*	1.0*
Stellaria media (L.) Vill.	2.3	0.3*	41.7	1.9*	0.8*	2.5*	0.7*
Sinapis arvensis L.	0.0*	3.4	59.4	0.4*	0.1*	3.8	1.9
Galium aparine L.	0.2*	0.2*	34.2	2.7*	1.6*	4.9	0.1*
Matricaria perforata Merat.	0.3*	5.5	34.5	1.4*	0.5*	3.2	1.7*
Lamium purpureum L.	0.0*	1.5*	51.8	0.7*	0.4*	1.6*	2.3*
Others	0.0*	5.1	41.0	2.3*	0.5*	5.5	1.3*
All weed species	1.4	2.7	80.8	0.3*	0.0*	2.5	0.3*

* - impact is not significant at 95% probability level

Table 3. Number of some weed species growing winter wheat in recurrent sowing (on average 2001–2003), p m^{-2}

Soil tillage, sowing	Oil seed rape	*Stellaria media* (L.) Vill.	*Sinapis arvensis* L.	*Galium aparine* L.	*Matricaria perforata* Merat.	*Lamium purpureum* L.	Others	Total
Minimal tillage	0.93a [x]	13.27a	15.53a	8.80b	11.33a	17.73a	16.27a	89.40a
Direct drilling	1.20a	16.80a	9.53b	9.93ab	13.27a	16.40a	11.72b	87.45a
Traditional tillage	1.53a	16.20a	10.78b	12.77a	9.33a	12.27b	8.80c	76.55b

[x] - Means in each column followed by the same letter are not significantly different at P=95 % level according to ANOVA.

Table 2. Impact of previous crop and soil tillage to number of weeds per m^2 (on average 2001–2003), η

Weed species	Previous crop (A)	Soil tillage (B)	Interaction (AB)
Oil seed rape	49.9	13.7	15.2
Stellaria media (L.) Vill.	7.1	1.1*	6.1*
Sinapis arvensis L.	0.0*	19.1	2.2*
Galium aparine L.	0.4*	0.6*	7.9*
Matricaria perforata Merat.	0.7*	11.8	3.1*
Lamium purpureum L.	0.1*	7.6*	3.7*
Others	0.0*	16.9	7.6*
All weed species	11.7	22.7	2.1*

* - impact is not significant at 95% probability level

A significantly smaller total number of weeds was observed in treatments where winter wheat was grown in recurrent sowing. The main cause was the differences in number of oil seed rape in these treatments: many rape seeds were left on the surface of the soil in treatments with reduced soil tillage after winter rape. That mainly caused significant differences between soil tillage treatments: there was a significantly smaller number of weeds after traditional soil tillage with ploughing. The previous crop also had significant impact on the number of *Stellaria media* (L.) Vill. (Table 3).

A smaller number of this weed was observed in treatments after winter rape (Table 4).

Data analysis show significant linear negative correlation between winter wheat yield and the number of some weed species. There are no significant differences for coefficient b_1 among separate weed species and total weed infestation. Coefficient b_0 are significantly smaller for total number of weeds at 95% confidence level. That means slopes describing this coherence are flatter than others and weed species that had insignificant correlation with winter wheat grain yield caused these changes in the layout of the slopes. Equations describing significant coherences between winter wheat yield and separate weed species are the same at 95% confidence level (Table 5).

Table 4. Number of some weed species growing winter wheat after winter rape (on average 2001–2003), p m^{-2}

Soil tillage, sowing	Oil seed rape	*Stellaria media* (L.) Vill.	*Sinapis arvensis* L.	*Galium aparine* L.	*Matricaria perforata* Merat.	*Lamium purpureum* L.
Minimal tillage	21.60a	13.60a	14.07a	11.20a	9.40b	15.87a
Direct drilling	22.60a	8.53b	9.47b	9.73a	17.33a	16.33a
Traditional tillage	4.87b	12.73ab	12.87a	8.67a	10.73b	15.07a

^{x} - Means in each column followed by the same letter are not significantly different at P=95 % level according to ANOVA.

Table 5 Equations of regression between winter wheat yield and number of some weed species

Weed species	$y = b_0x + b_1$	b_0 95% confidence interval		b_1 95% confidence interval	
		Upper limit	Lower limit	Upper limit	Lower limit
Stellaria media (L.) Vill.	y = -0.0634x + 5.676	-0.0267	-0.1002	6.2719	5.0802
Sinapis arvensis L.	y = -0.06 x + 5.5409	-0.0277	-0.0923	6.0410	5.0407
Matricaria perforata Merat.	y = -0.0813x + 5.785	-0.0353	-0.1273	6.4213	5.1492
Lamium purpureum L.	y = -0.067x + 5.865	-0.0303	-0.1038	6.5205	5.2093
All weed species	y = -0.0134x + 6.026	-0.0076	-0.0192	6.6182	5.4341

CONCLUSIONS

1. A significantly smaller total number of weeds was observed in treatments where winter wheat was grown in recurrent sowing.

2. A significantly smaller number of weeds was observed after traditional soil tillage with ploughing compared to minimal soil tillage or direct sowing.

3. Data analysis show significant linear negative correlation between winter wheat yield and number of several weed species - *Stellaria media* (L.) Vill., *Sinapis arvensis* L., *Matricaria perforata* Merat. and *Lamium purpureum* L. and total weed infestation.

4. The highest impact on changes of winter wheat grain yield occurred with herbicide use.

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