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Harrowing timing for winter wheat and spring barley under organically growing conditions

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Abstract. Field trials were conducted over the period of 2005–2007 at the Lithuanian Institute of Agriculture to test the efficacy of harrowing on weeds at different growth stages of ecologically grown winter wheat and spring barley. The main weeds in winter wheat were: *Lamium sp.*, *Chenopodium album, Tripleurospermum inodorum, Capsella bursa-pastoris* and in spring barley *Ch.album, Sinapis arvensis, Stellaria media, T. inodorum.* The weeds most vulnerable to harrowing in winter wheat were: *Veronica* sp., *Chenopodium album* and *Capsella bursa pastoris*. *Chenopodium album* and *Sinapis arvensis* were vulnerable to harrowing in spring barley. Early harrowing pre-emergence followed with harrowing at the 3–4 leave stage of spring barley was the most optimal.

Winter wheat grain yield reduction tendencies were obtained in plots harrowed three times. No statistical difference in spring barley grain yield was found among the treatments. The decrease in weed number and mass depended on harrowing timing and frequency, meteorological conditions and weed species composition.

Key words: spring barley, winter wheat, harrowing, weeds, yield

INTRODUCTION

Harrowing is a traditional form of mechanical weed control for dealing with annual weeds but is ineffective against perennial and established deep-rooted weeds. In cereals, 'blind' or pre-emergent harrowing may be carried out after drilling but before crop emergence in order to kill the first flush of small emerging weeds (Rasmussen & Ascard, 1995). Dry weather is critical to the success of early harrowing operations but adequate soil moisture is needed initially to encourage early weed emergence. Blind harrowing has little effect if few weeds have emerged, and may sometimes delay crop emergence (Heard, 1993). The advantage of harrowing is that the tines control both intra-row and inter-row weeds. Harrowing had a greater effect on smaller weeds, on loose sandy soil; plant sensitivity to uprooting decreases rapidly after plant emergence (Kurstjens et al., 2000). Direct non-chemical weed control measures need to be linked with cultural measures that maintain the weed population at a manageable level (Bond & Grundy, 2001). Harrowing selectivity tests showed that higher yielding cultivars with a high leaf area index tended to be less tolerant to post-emergence weed harrowing than shorter and lower yielding cultivars (Rasmussen et al., 2004, 2008) In Lithuania, the most common spread broadleaved weed species in winter wheat crop are: *Tripleurospermum inodorum, Galium aparine, Lamium purpureum, Capsella bursa pastoris, Stellaria media*and *Viola* *arvensis* (Auškalnis et al., 2007). Selectivity with rigid and flexible tines could be improved when the crop has a size advantage over the weeds (Rasmussen & Svenningsen, 1995) and the effect on the weeds depends on the species (Welsh at al. 1997). Increased harrowing speed from 2 to 8 km per hour in winter barley did not showed higher weed control efficacy (Cirujeda et al., 2003). Time and frequency of harrowing had more of an effect than type of harrows (Rasmussen, 2004). The most vulnerable species to harrowing in spring barley were: *Chenopodium album, Stellaria media* and *Viola arvensis* (Auškalnienė & Lukošiūnas, 2003; Auškalnis & Auškalnienė, 2006).

The aim of the present work was to estimate the efficacy of harrowing at different growth stages of spring barley and winter wheat.

MATERIALS AND METHODS

Six field experiments were conducted in organically grown spring barley and winter wheat during 2005–2007 to investigate the influence of pre and post-emergence harrowing on weed number and weed mass. The preceding crop for spring barley was winter wheat and, for winter wheat, black fallow. The spring barley variety ‛Luokė' and winter wheat 'Širvinta' were grown; conventional soil tillage was used. The soil of the experimental site is an *Endocalcary-Endohypogleyic Cambisol*, loam. Spring barley was harrowed with a flex-tine harrow according to the following scheme:1) control (not harrowed); 2) harrowed at spring barley pre-emergence stage; 3) harrowed twice: at spring barley pre-emergence stage and at 3–4 leaf stage; 4) harrowed three times: at spring barley pre-emergence stage, at 3–4 leaf stage and at stem elongation stage; 5) harrowed at 3–4 leaf stage of spring barley, and 6) harrowed at spring barley 3–4 leaves stage and at spring barley stem elongation stage. Winter wheat was harrowed by the same harrows in spring according to the following scheme: 1) control (not harrowed); 2) harrowed at BBCH 23-25 growth stage one pass; 3) harrowed at BBCH 23-25 growth stage 2 passes; four) harrowed at winter wheat BBCH 23-25 and BBCH 31 growth stage. 5) harrowed 3 times at BBCH 23-25, BBCH 31 and BBCH 35 growth stages of winter wheat. Plot size was 3.0 by 10.0 m. The plots were replicated four times and arranged randomly. In all treatments harrowing speed was 6 km h^{-1} along the crop sowing direction to a depth of 1.5–2.5 cm. The grain yield of crops was harvested with a combine "Sampo" and adjusted to 15% moisture.

Meteorological conditions. Mean air temperature over the growing season was close to the long term mean in all three years. Amounts of precipitation in 2005-2007 were different. The driest year was 2006. In April -51%, in May 86% and in June -11% precipitation of the long term mean. The most precipitation was in 2007; in May 187 % and in June 100% of the perennial mean.

Five weeks after the last harrowing weeds were removed from each plot's four $0.25m^{-2}$ subplots and counted, green mass of weeds was measured for each weed species. All data were analyzed using ANOVA from the package SELEKCIJA (Tarakanovas, Raudonius, 2003). To achieve homogeneity of variance, the weed biomass data were Sqr(X+1) transformed.

RESULTS AND DISCUSSION

Short-lived broadleaved weed species dominated in the winter wheat crop. Each year 2–3 weed species occupied from 60 to 80 percent of all weeds presented in winter wheat (Table 1). In winter wheat *Tripleurospermum inodorum*, *Lamium* sp. and *Veronica* sp. were prevalent in 2005, *Chenopodium album* and *Viola arvensis* in 2006 and *Thlaspi arvense*, *Viola arvensis* and *Veronica* sp. in year 2007.

Table 1. The weed mass g m^{-2} in winter wheat crop at BBCH 65 growth stage without harrowing in years 2005–2007.

Weed species	2005		2006		2007	
	g m^{-2}	u m^{-2}	g m^{-2}	u m^{-2}	g m^{-2}	u m^{-2}
Chenopodium album L.	0.0	0.0	36.3	88.0	0.0	0.0
Thlaspi arvense L.	0.6	0.3	0.0	1.0	3.7	10.3
Galium aparine L.	3.9	0.5	0.0	0.5	0.0	0.0
Lamium sp.	41.8	14.8	0.0	0.0	2.0	1.5
Viola arvensis Murr.	5.3	3.8	12.0	15.3	4.2	8.5
Tripleurospermum inodorum Sch. Bip.	39.1	16.3	11.4	2.8	0.8	0.3
Capsella bursa – pastoris L.	5.1	4.8	3.8	4.8	0.1	0.5
Veronica sp.	21.0	17.5	0.2	1.5	4.3	6.8
Papaver rhoeas L.	4.7	3.3	0.0	0.0	0.0	0.0
Polygonum aviculare L.	0.0	0.0	0.6	4.3	0.0	0.0
Stellaria media (L.) Vill.	0.1	1.0	0.0	2.5	9.5	1.8
Cerastium arvense L.	0.0	0.0	0.4	2.3	4.1	2.8
Other weeds	3.9	2.0	8.4	8.1	3.1	8.1
Total	125.4	67.5	73.1	131.9	31.8	40.6

In the spring barley crop stand the dominant weed species two put of the three years was *Chenopodium album,* and one year the perennial weed *Sonchus arvensis* dominated (Table 2). Plant biodiversity in spring barley was lower compared to winter wheat. In winter wheat these were from eight to 11 and in spring barley from six to nine weed species (Tables 1–2).

Table 2. Weed mass g m^{-2} and number u m^{-2} in non-harrowed spring barley stand at BBCH 65 growth stage. Dotnuva, 2005–2007.

Weed species	Weed mass g m^{-2} and number u m^{-2}					
	2005		2006		2007	
	g m^{-2}	u m^{-2}	g m^{-2}	u m^{-2}	g m^{-2}	u m^{-2}
Chenopodium album L.	27.4	39.3	1.4	6.5	14.9	56.8
Euphorbia helioscopia L.	0.0	0.0	0.1	0.3	0.0	0.0
Sinapis arvensis L.	8.2	5.2	0.0	0.0	0.0	0.0
Lamium sp.	0.1	0.8	0.1	1.0	0.5	0.0
Viola arvensis Murr.	0.0	0.0	0.1	0.3	0.8	3.0
Fallopia convolvulus (L.) Löwe	0.3	0.3	0.0	0.5	0.3	1.5
Tripleurospermum inodorum Sch. Bip.	0.0	0.8	0.3	0.0	0.5	0.3
Sonchus arvensis L.	0.0	0.0	44.8	25.0	0.0	0.0
Other weeds	3.2	5.4	9.7	6.3	1.6	10.0
Total	39.2	51.8	56.5	39.8	18.1	71.6

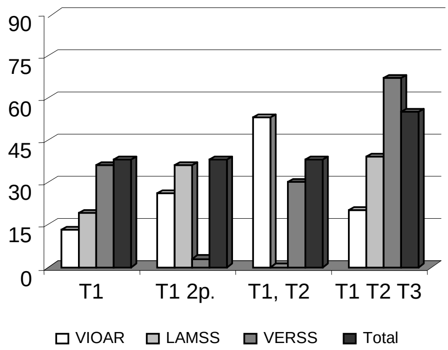


Fig. 1. Weed mass reduction % in winter wheat in year 2005.

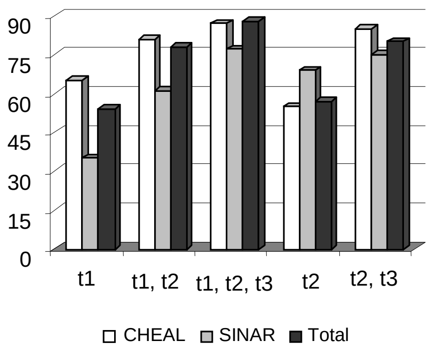


Fig. 2. Weed mass reduction % in spring barley in year 2005.

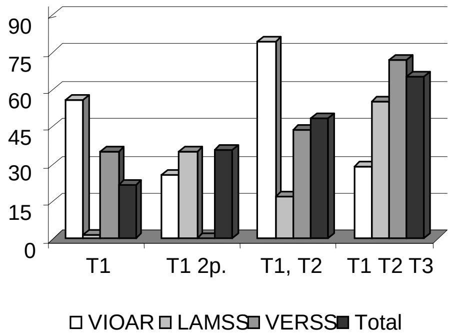


Fig. 3. Weed number reduction % in winter wheat in year 2005.

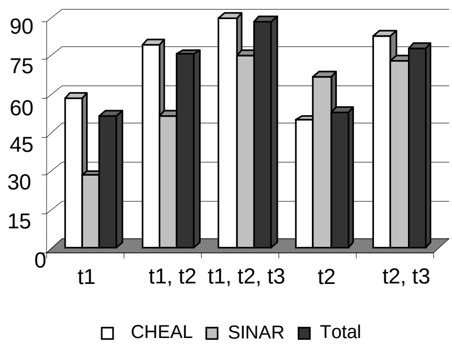


Fig. 4. Weed number reduction % in spring barley in year 2005.

Efficacy of harrowing in the first year of the experiment on weed biomass and number in winter wheat depended on timing and frequency. The highest weed decrease at BBCH 65 stage was found in plots that had been harrowed three times (Figs 1 & 3). In spring barley the efficacy of harrowing on weed biomass was higher compared to winter wheat. Harrowing two and three times showed higher efficacy compared to one harrowing at pre-emergence or post emergence of spring barley (Figs 2 & 4).

In the year 2006 the total harrowing efficacy on weeds in winter wheat was high. The effect on *Chenopodium album* biomass did not depend on harrowing intensity (Figs 5 & 7). In spring barley the lowest weeds total and *Chenopodium album* biomass reduction was when harrowing was done at the 3–4 leaves stage of spring barley. Early harrowing and harrowing two or three times was most effective in controlling the amount of total weeds (Figs 6 & 8). The reason for this high efficacy was the dry weather conditions after harrowing. In June 2006 there was only 6.8 mm of rain, which is 11% of the long-term mean. No new weed germination occurred after harrowing.

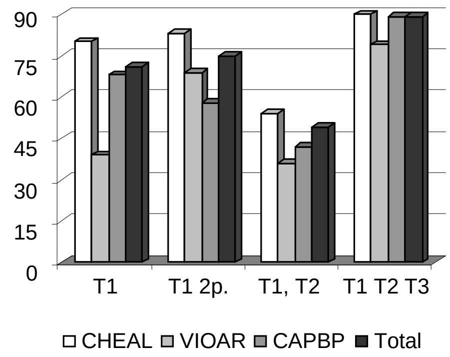


Fig. 5. Weed mass reduction % in winter wheat in year 2006

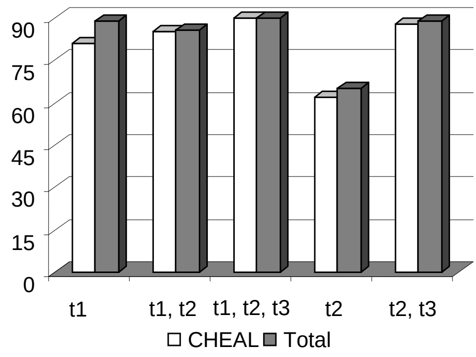


Fig. 6. Weed mass reduction % in spring barley in year 2006

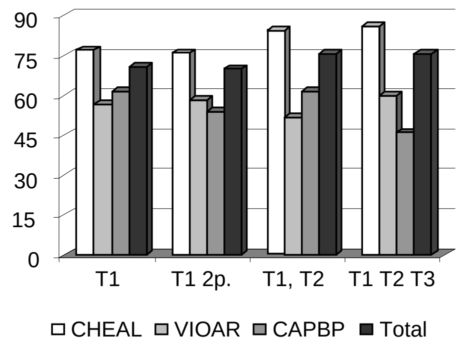


Fig. 7. Weed number reduction % in winter wheat in year 2006.

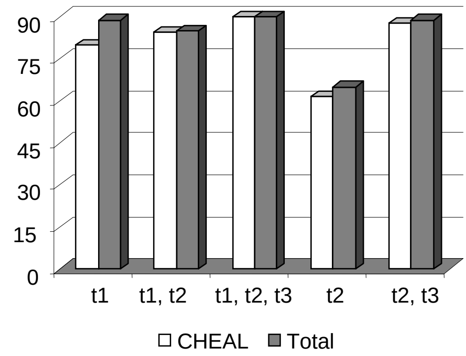


Fig. 8. Weed number reduction % in spring barley in year 2006.

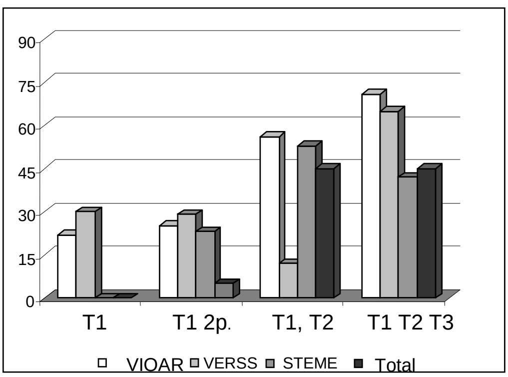


Fig. 9. Weed mass reduction % in winter wheat in year 2007.

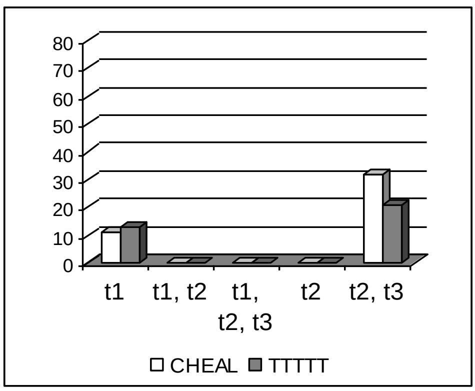


Fig. 10. Weed mass reduction % in spring barley in year 2007.

In the third year of investigation the weed biomass reduction in winter wheat depended on how many times the crop was harrowed. The least effective harrowing on weed biomass at BBCH 65 growth stage of winter wheat was when it was done early in spring. In the moist growing season weed mass was higher than in untreated plots after harrowing (Fig. 9). For spring barley, harrowing timing and frequency had no influence on weed biomass (Fig. 10). Total weed number at the stage of flowering of the spring barley was lower by 12 to 61 percent compare to the unharrowed plots, but there was no effect on the mass of the weeds (Fig. 12). The same tendency was found in winter wheat; if the growing season was moist the weeds left after harrowing grew larger and there was no effect of harrowing visible 5–8 weeks after the last harrowing.

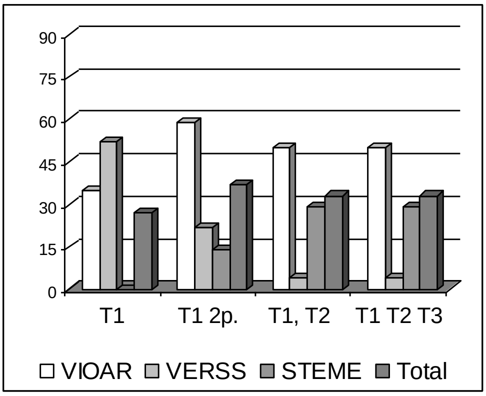


Fig. 11. Weed number reduction % in winter wheat in year 2007.

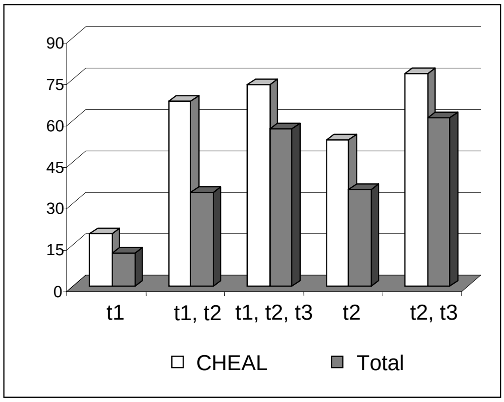
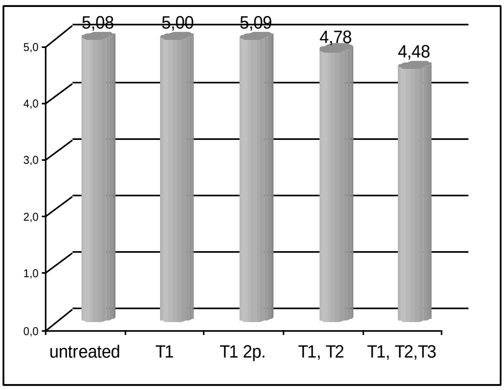
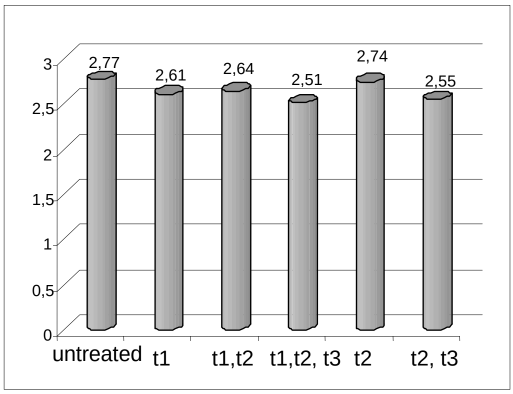


Fig. 12. Weed number reduction % in spring barley in year 2007.



LSD_{05} 0.804 t

Fig. 13. Winter wheat grain yield T ha^{-1} in year 2005–2007.



LSD_{05}-0.446 t

Fig. 14. Spring barley grain yield T ha^{-1} in year 2005–2007.

Harrowing in winter wheat three times had the tendency to decrease grain yield. Harrowing early in spring, when vegetation of the crop had started, had a positive effect on grain yield (Fig. 13). In earlier experiments timing in spring was also important; harrowing at stage 22 resulted in crop yield gains whereas harrowing at growth stage 23 resulted in crop yield losses (Rasmussen & Nørremark, 2006).

We did not find significant differences in spring barley grain yield in all treatments over the three years (Fig.14). This indicated that spring barley crop damage through harrowing was not significant.

No statistical difference of spring barley grain yield was determined between the treatments.

CONCLUSIONS

Experimental results indicate that the efficacy of harrowing on weed biomass and number in winter wheat depended on timing, frequency, the stage of the crop and weed species. In spring barley, in two of the three years the most effective was harrowing two times, early harrowing pre-emergence of crop repeated 7–10 days later.

Harrowing winter wheat three times was most effective in controlling weed mass and number, but had a tendency to decrease grain yield, Contrarily, early harrowing, when vegetation of the winter wheat in spring had started, had the tendency to increase grain yield.

REFERENCES

Auškalnienė, O. & Lukošiūnas, K. 2003. Impact of harrowing on weeds quantity and yield of spring barley. *Agricultural engineering* **35**(2),15–26 (in Lithuanian, English abstr.).

Auškalnis, A. & Auškalnienė, O. 2006. Frequency of harrowing for mechanical weed control in spring barley. *Vagos* **71**(24), 13–17 (in Lithuanian, English abstr.).

Auškalnis, A., Kryževičienė, A. & Auškalnienė, O. 2007. Weed occurence and control in energetic plants in Lithuania. *Progress in plant protection* **47**(4), 313–320 (in Polish, English abstr.).

Bond, W. & Grundy, A.C 2001. Non-chemical weed management in organic farming systems. *Weed research* **41**(5), 383–405.

Cirujeda, A., Melander, B., Rasmussen, K. & Rasmussen, I.A. 2003. Relationship between speed, soil movement into the cereal row and intra-row weed control efficacy by weed harrowing. *Weed research* **43**, 285–296.

Heard, J. 1993. Mechanical weed control in cereals. *Agri-food Research in Ontario,*Ontario, Canada, December, pp. 2–7.

Kurstjens, D. A. G., Perdock, U.D. & Goense, D**.** 2000. Selective uprooting by weed harrowing on sandy soils. *Weed Research* **40,** 431–447.

Rasmussen, J. & Ascard, J. 1995. Weed control in organic farming systems. *Ecology and Integrated Farming Systems,* pp. 49–67.

Rassmussen, J, Bibby, B.M. & Schou, A.P. 2008. Investigating the selectivity of weed harrowing with new methods. *Weed Research* **48**, 523–532.

Rasmussen, I. A. 2004. The effect of sowing date, stale seedbed row width and mechanical weed control on weeds and yields of organic winter wheat. *Weed Research* **44**, 12–20.

Rasmussen, J., Kurtzmann, J. I. & Jensen, A. 2004. Tolerance of competitive spring barley cultivars to weed harrowing. *Weed Research* **44**, 446–452.

Rasmussen, J. & Nørremark, M. 2006. Digital image analysis offers new possibilities in weed harrowing research. *Žemdirbystė–Agriculture* **93**(4), 155–165.

Tarakanovas, P. & Raudonius, S. 2003. The computer system for processing and evaluation of agronomic research data. Akademija, 57 p. (in Lithuanian).

Welsh, J.P., Bulson, H.A.J., Stopes, C.E. Froud-Williams, R.J. & Murdoch, A.J. 1997. Mechanical weed control in organic winter wheat. *Aspects of Applied Biology* **50**, 375–384.