Weed control by two layer ploughing and post-emergence crop tillage in spring wheat and buckwheat

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Abstract. Experiments were carried out at the Kazliškiai organic farm of the Lithuanian University of Agriculture in the period of 2002–2003. The aim of the work was to investigate elements of non-chemical weed control methods as main soil tillage, pre-sowing and post-sowing tillage. According to theoretical preconditions and data of the experiment, it is proved that total turnover of the layer in organic agriculture is a very important means of weed control decreasing weediness of the crop and increasing harvest. Two types of plough in combination with different pre-sowing and post-sowing soil tillage implements and technologies in crops of spring wheat and buckwheat were investigated. Spring wheat crops were grown comprising two varieties differing in plant height for additional investigations of their crop smothering power for weeds. It was proven that, for weed control, two-layer ploughing technology was favourable to conventional ‘cultural’ ploughing technology and that taller varieties had greater smothering power for weeds than shorter ones.

Keywords: non-chemical weed control, two-layer ploughing, post-emergence crop tillage, weediness, spring wheat, buckwheat, organic agriculture

INTRODUCTION

Non-chemical weed control must eliminate the generative and vegetative parts of weeds from the soil and protect the soil from new weeds. Growing together with crop plants, weeds have adapted to their growth and biological cycle of development (Pilipavičius, 2000, 2006). Qualitative and purposive soil tillage is central to weed control because herbicides are not used in organic agriculture. It is necessary to use specialized equipment for soil tillage and weed control. However, the same traditional soil tillage machines are used in the farms of organic agriculture as in conventional ones (Lazauskas & Pilipavičius, 2004).

In Lithuania, spring wheat covered 7.5% and buckwheat 2% of cereal crop structure in 2007 (Lithuanian agriculture review, 2008). However, buckwheat especially has high importance because of extra nutrition value (Nedzinskiene and Baksiene, 2008). Pre-emergence harrowing, or harrowing at the early 1-leaf stage reduced in general the weed number and biomass compared to untreated control. The mean weed reduction over locations and years was about 40%, but this reduction was not always significantly different to control plots. In general, harrowing pre-emergence or at the early 1-leaf stage increased the yield compared to untreated, but harrowing at that stage has also under certain circumstances given small yield reductions as well. The combination of pre-emergence harrowing and harrowing at 3–4 leaf stage gave a significant reduction in weed number and biomass compared to untreated control. In general, harrowing twice gave increased cereal yield, but the differences were only significant at one of the locations. The potential benefit of a second harrowing at the 3-4 leaf stage depends on the weed situation, number and biomass, as well as the compatibility of the cereal (Mangerud et al., 2007).

The most important technological problem of spring wheat and buckwheat growing in organic agriculture is weed control in the crop. It is established that every gram of air-dry weed biomass grown in the crop, decreases spring wheat grain yield by half gram in the same area (Lazauskas, 1990). Crop weediness in the fields of our organic farmers is much higher than a few grams per square metre because of insufficient quality work of our agricultural machinery and so yield losses are also consequently greater.

The hypothesis of the experiment for creating growing technologies for spring wheat and buckwheat focused on bringing together agro-technical means acceptable to organic agriculture. The aim of technologies was to decrease crop weediness and to obtain the highest yield increase.

MATERIALS AND METHODS

The continuous field trial was carried out at the Kazliškiai organic farm of the Lithuanian University of Agriculture in the period of 2002–2003. The spring wheat (2002) was sown after the not particularly suitable preceding crop of spring barley (2001), because there it was not possible to choose another field plant as the fore-crop. The buckwheat (2003) fore-crop was spring wheat (2002) as it was grown in the same field. There were four replications in trial fields. Brutto experimental plot size was 48 m^2 (3 x 16 m) and netto – 36 m^2 (2.4 x 15 m).

The field experiments were carried out on soil: PLb-g4 *Eutric Planosol Endohypogleyi PLe-gln-w*. The agrochemical characteristic of the arable soil was determined at the Research Station of the Lithuanian University of Agriculture using a computer system PSCCO/ISI IBM-PC 4250. Soil samples for agrochemical analyses were taken from 0-25 cm soil layer in the spring of 2002. The characteristic of arable soil is shown in the Table 1.

Table 1. Agrochemical indication of arable soil (0–25 cm layer).

Indices			
P_2O_5, mg kg^{-1}	K_2O, mg kg^{-1}	Humus, %	pH
177	116	3.34	6.8

In the field experiment, two types of plough were compared, a conventional PLN-3-35 plough without skim-jointers and a two-layer plough PJa-3-35. Ploughing depth for both types of plough was 20 cm. In addition, three pre-sowing and post-sowing soil tillage systems were investigated: harrowing and rolling in different combinations with different varieties (spring wheat: short stem *Picolo* and high stem *Torka*) and sowing distance between rows was 15 cm and 45 cm (buckwheat). Seed rate for spring wheat was 212 kg ha^{-1}. Buckwheat was sown with 15 cm and 45 cm inter-row distance with a seed rate in both cases of 50 kg ha^{-1}.

Weed samples for crop weediness establishment were taken from each plot of the trial in 10 places using a 50 x 50 cm frame (the area was 2500 cm^2) and were air-dried.

The trials data were evaluated using analysis of variance by 'Selekcija' (Tarakanovas, 1999) and correlation and regression analysis by 'SigmaPlot 8.0' (SPSS Science, 2000).

RESULTS AND DISCUSSION

Spring wheat grows slowly after emergence and weakly smothers weeds. In organic agriculture, it is suggested that taller cereal varieties are chosen as they have a greater ability to smother weeds than short stem varieties. In our experiment, two spring wheat varieties with different stem heights were compared: the short stem variety *Picolo* with a stem height of 55.8 cm, and the taller variety *Torka* with stem height of 72.5 cm (Table 2). There was not a great difference in plant height, just 16.7 cm, however, two weeks after harrowing in the crop of the tallest variety *Torka* there was an estimated decrease in weediness by 46–51 weed plants per square metre compared with the crop with the shorter variety *Picolo* (Table 2).

Table 2. Smothering power of spring wheat depending on type of variety

Treatment	Plant height, cm	Weed density, weeds m^{-2}	
		Plough type used	
		'Cultural' cylindrical	Two-layer
Picolo (short stem)	55.8	392	297
Torka (tall stem)	72.5	341	251
LSD_{05}	4.7	229	

Evaluating the influence of ploughing on the spring wheat and buckwheat crop weediness and yield, it was confirmed that ploughing with a two-layer plough decreases crop weediness. Weed number decreased by 22–17% and air-dry biomass by 33–36% respectively, in spring wheat and buckwheat compared with fields ploughed with the 'cultural' cylindrical plough.

Most importantly, the decrease of spring wheat and buckwheat crop weediness after ploughing with a two-layer plough consistently increased crop grain yield (Table 3).

Table 3. Effectiveness of ploughing with conventional 'cultural' cylindrical and two-layer ploughs in crops of spring wheat and buckwheat

Type of plough	Spring wheat			Buckwheat		
	Weed density weeds m^{-2}	Weed air-dry mass g m^{-2}	Yield t ha^{-1}	Weed density weeds m^{-2}	Weed air-dry mass g m^{-2}	Yield t ha^{-1}
'Cultural' cylindrical	71.5	83.2	0.81	129	322.2	1.42
Two-layer	55.8	55.7	1.61	107	205.9	1.79
LSD_{05}	22.5	33.6	0.28	71.1	161.3	0.66

In the spring wheat, the number of weeds that emerged were similar in the no-tillage after sowing plots (control I), as in the plots harrowed after sowing but was significantly greater in plots that were harrowed and rolled after sowing.

Table 4. Influence of harrowing and rolling to weediness and yield of spring wheat crop

Treatment	Crop of spring wheat			
	Weed density weeds m^{-2}		Weed air-dry biomass $g\ m^{-2}$	Yield $t\ ha^{-1}$
	after crop emergence	in milk maturity		
Ploughed with 'cultural' cylindrical plough				
Control I, before sowing twice cultivated and harrowed, after sowing no tillage	351	66.7	97.1	0,94
Before sowing twice cultivated and harrowed, after sowing harrowed in stage of 2-3 leafs	341	78.8	75.2	0,68
Before sowing twice cultivated and harrowed, after sowing rolled and harrowed in stage of 2-3 leafs	517	76.6	66.5	1.04
Ploughed with two-layer plough				
Control II, before sowing twice cultivated and harrowed, after sowing no tillage	252	59.4	49.8	1,65
Before sowing twice cultivated and harrowed, after sowing harrowed in stage of 2-3 leafs	251	57.0	78.8	1,84
Before sowing twice cultivated and harrowed, after sowing rolled and harrowed in stage of 2-3 leafs	281	50.9	32.1	1,79*
LSD_{05}	85.9	26.9	53.8	0.28

The yield of spring wheat in plots with 'cultural' ploughing was greater because of rolling and harrowing as harrowing alone was not effective; by contrast, in plots with two-layer ploughing a yield increase was obtained after either harrowing only or rolling and harrowing (Table 4). However, the main reason for the decrease in crop weediness was the two-layer ploughing technology (Table 3).

In the buckwheat, as in the spring wheat (Table 4), weed densities after sowing were similar in the no-tillage plots and plots rolled before and after sowing and harrowed after sowing (Table 5). Yield of buckwheat increased in plots with wider inter-row distance (45 cm). With additional cultivation of inter-rows, crop weediness was consistently lower and there was a tendency for yield increase. In plots ploughed with the two-layer plough the positive influence of wider inter-row distance in decreasing crop weediness and increasing crop yield were not observed. However, significant yield increases were obtained just from ploughing with the two-layer plough. Consequently, main reason for a decrease in buckwheat crop weediness and an increase in yield was not pre-sowing or post-sowing soil tillage, but again the ploughing quality of the two-layer plough (Table 5).

The main factor of crop weediness is weed biomass in the crop and its combination with harvest of crop plants. Calculating the correlation-regression dependence of spring wheat crop yield on weed biomass, it was established that harvest of cultural plants was inversely proportional to weed biomass. Spring wheat harvest dependence on crop weed biomass was on average strong and reliable. When crop weed biomass decreased by 1 g m^{-2} spring wheat harvest increased by 10 kg ha^{-1} (Fig. 1.).

Table 5. Influence of rolling and harrowing to weediness and yield of buckwheat crop

Treatment	Crop of buckwheat		
	Weed density weeds m^{-2}	Weed air-dry biomass g m^{-2}	Yield t ha^{-1}
Ploughed by 'cultural' cylindrical plough			
Control I, before sowing twice cultivated and harrowed, after sowing no tillage, sowing inter-row distance 15 cm	77.8	208.6	1.51
Before sowing cultivated and rolled, after one week harrowed and rolled, sowing inter-row distance 15 cm, harrowed when buckwheat emerged	78.4	223.9	1.32
Before sowing cultivated, after one week harrowed and rolled, sowing inter-row distance 45 cm, after sowing rolled, harrowed when buckwheat emerged, after one week were loosened inter-row spaces	46.4	117.2	1.58
Ploughed by two-layer plough			
Control II, before sowing two times cultivated and harrowed, after sowing no tillage, sowing inter-row distance 15 cm	77.4	178.7	1.96
Before sowing cultivated and rolled, after one week harrowed and rolled, sowing inter-row distance 15 cm, harrowed when buckwheat emerged	57.2	89.1	1.91
Before sowing cultivated, after one week harrowed and rolled, sowing inter-row distance 45 cm, after sowing rolled, harrowed when buckwheat emerged, after one week were loosened inter-row spaces	116.2	156.1	1.59
LSD_{05}	201.9	487.7	0.29

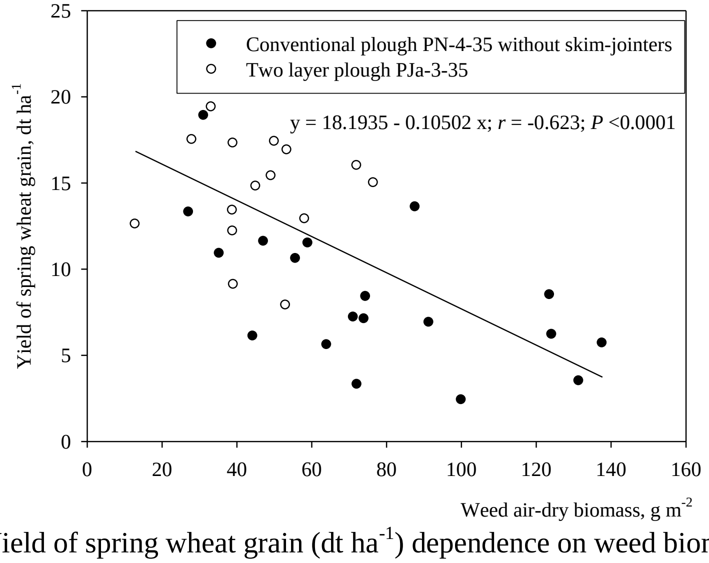

Fig. 1. Yield of spring wheat grain (dt ha^{-1}) dependence on weed biomass (g m^{-2}).

From this aspect, the two-layer plough was also superior in crops of spring barley y = 22.29 - 0.024 x, r = -0.46, P = 0.044, flax y = 26.58 -0.109 x, r = -0.82, P < 0.0001 and cabbage y = 609 -0.29 x, r = -0.98, P = 0.004. Weed biomass was smaller using the two-layer plough in these crops and their harvested yields larger and inversely proportional to weed biomass (Lazauskas & Pilipavicius, 2004). The more that weed propagation rudiments are decreased in the top soil layer, the less is the weediness of the crop – the number and the mass of weeds (Pilipavicius, 2007). So, evaluating technology of two layer ploughing and its effectiveness indicates a clear advantage of this way of ploughing over other known technologies and types of plough. Two-layer ploughing is a potential means to decrease crop weediness in alternative – organic agriculture.

CONCLUSIONS

Ploughing soil with a two-layer plough decreased spring wheat and buckwheat crop weed density by 22–17% and weed air-dry biomass by 33–36%, respectively, compared with plots ploughed with a 'cultural' cylindrical plough without skim-jointers. As a consequence, grain yield of spring wheat was increased by 49% and that of buckwheat by 20%.

The spring wheat variety *Torka* with taller stems suppressed weeds in the crop more than the shorter stem variety *Picolo*. Because of the greater weed smothering power of the taller variety, weed density in the taller crop (variety *Torka*) decreased by 13–15% relative to the crop with the shorter stem (variety *Picolo*).

Soil rolling improved conditions for weed germination. In the spring wheat crop there was established a higher weed density by 32–34% in plots ploughed with 'cultural' cylindrical plough and by 10% in plots ploughed with two-layer plough. However, in spring wheat crop combining rolling with harrowing weed air-dry biomass decreased by 11–31% and 35–59%, respectively.

Soil rolling in the buckwheat crop as well as additional cultivation of inter-rows of wide inter-row (45 cm) sowing plots has not given a clear answer concerning the effectiveness of weed control in the crop by rolling and harrowing. Hence, aspects of pre-sowing and post-sowing soil tillage need further investigation before formatting buckwheat growing technology in the system of organic agriculture. In particular harrowing of spring barley at stage of 2–3 leafs and of buckwheat at emergence has not shown a significant decrease of weediness compared to crops not harrowed.

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