# Mechanical weed control in organically grown spring oat and field pea crops

A. Velykis, S. Maiksteniene, A. Arlauskiene, I. Kristaponyte and A. Satkus

Lithuanian Institute of Agriculture, Joniskelis Research Station,
Joniskelis, LT–39301 Pasvalys District, Lithuania; e–mail: velykisalex@gmail.com

**Abstract.** Experiments to study the effects of weed harrowing in an organic farming system were carried out during 2005–2007 at the Joniskelis Experimental Station of the Lithuanian Institute of Agriculture on a clay loam *Gleyic Cambisol.* Spring oat (*Avena sativa* L.) and field pea (*Pisum sativum* L.) crops were harrowed once and twice with a *Regent* spring-tine harrow at pre-emergence, early post-emergence and late post-emergence stages. This study indicates that at early growth stages of crops the uprooting effect of harrowing could be more important for weed control than at late stages. Early post-emergence harrowing (at 2–3 leaf stage) was the most effective for spring oat. Twice (pre-emergence and early post-emergence) harrowing of oat was not more effective than early post-emergence harrowing once, since early harrowing stimulates new sprouting of weeds. Pea crop damage by harrowing was less when the crop was harrowed at late post-emergence (beginning of stem elongation) stage. No difference of crop yield was determined among the treatments.

**Key words:** clay loam, organic farming, spring oat, field pea, harrowing, weed, crop yield

## INTRODUCTION

In organic farming systems, where the primary focus is safe food and reduction of environmental pollution, efforts are made to achieve the balance between cultivated crops and weeds that would be favourable for the grower. The basis for the control of weed populations in these systems is crop alteration, right choice of suitable plant species and varieties, effective soil tillage and its timely application. Mechanical weed control by harrowing is one of the direct non-chemical weed control methods.

One of the chief purposes of harrowing is to create conditions for cultivated crops that could ensure their dominance over weeds as soon as growth begins. Research conducted in various countries suggests that the efficiency of weed harrowing depends on the type of implement used, timing, frequency and regime. The use of this practice is also influenced by weed morphology. Optimal harrowing time is generally determined by weed growth stage and crop competitive ability (Bond & Grundy, 2001; Hatcher & Melander, 2003; Rasmussen, 2004; Melander et al., 2005; Rasmussen & Norremark, 2006). Harrowing only once is often insufficient to provide a marked reduction in weed incidence. With early harrowing, some weeds may be missed because they are still non-germinated, while with late harrowing weeds are difficult to eradicate because they are firmly established (Hatcher & Melander, 2003; Auskalnis & Auskalniene, 2008). Fine weed seeds emerge only from the 1–2 cm depth and larger ones from the deeper 5–6 cm soil layer (Spokiene & Povilioniene, 2003). As a result, with deeper harrowing, non-emerged weed seeds can be lifted close to the soil surface, which may promote a new flush of weed emergence. It is maintained that the efficiency of harrowing increases when cultivated crops are at more advanced growth stage than weeds, but also is highly dependent on dominant weed species. Shallow-rooted weeds, due to their growth habit, are more efficiently controlled in spring, while those having strong and lengthy roots, in autumn. The harrowing process kills not only weeds uprooted by harrow tines but also a large part of weeds covered by soil (Bond & Grundy, 2001; Rasmussen & Norremark, 2006). However, Hurstjens & Kroff (2001) found that only 47–61% of the uprooted weeds and 1–17 % of non-uprooted covered weeds were killed. Inevitably, cultivated plants are also damaged by harrowing. The scope and character of damage depend on crop species and growth stage, sowing and harrowing depth, harrow type, soil, weather, and other factors. Flexible tines do less damage to plants than solid ones. A spring-tine harrow can be used not only in cereal crops but also in broad-leaved crops, though it can do greater damage to the cultivated plants weakly established in the soil. When harrowing at different growth stages of cultivated crops and weeds it is important that an adequate driving speed is chosen. It was found that increasing harrowing depth slightly increased weed control, while high speed was found to increase weed covering by soil. Soil surface moisture is also an important factor in harrowing efficiency. When the soil surface is dry but not overdry, the efficiency of harrowing increases; when it is wet, fewer weeds are controlled, moreover, new weed seed may start sprouting (Bond & Grundy, 2001; Hurstjens & Kroff, 2001; Rasmussen & Norremark, 2006).

Harrowing not only controls weeds but also improves soil aeration and destroys soil crust, saves moisture, strengthens organic matter mineralization and improves plant nutrition, and destroys disease hotspots. On the other hand, intensive harrowing has some deleterious effects, such as deterioration of soil structure and increased nitrogen leaching (Bond & Grundy, 2001; Steinmann, 2002).

Crop harrowing is most often more efficient on sandy loam or loamy soils than on clayey soils. On clayey soils it is more difficult to choose the moisture range suitable for harrowing, since its efficiency declines markedly when applied on either too wet or too dry soils (Melander et al., 2005). Moreover, on clayey soils harrowing efficiency is reduced by rapid densification after rain, formation of soil crust, large clods remaining after sowing, uneven emergence of crops and weeds and other adverse conditions.

The present study was designed to ascertain the effects of harrowing timing and intensity on weed incidence and yield of organically grown spring cereals and grain legumes on clay loam.

## MATERIALS AND METHODS

*Site and soil description.* This research was conducted at the Lithuanian Institute of Agriculture's Joniskelis Experimental Station situated in the northern part of Central Lithuania's lowland ($56^{o}21'$ N, $24^{o}10'$ E) during the period 2005–2007 on drained clay loam *Endocalcari-Endohypogleyic Cambisol.* Clay particles (<0.002 mm) in $A_a$ horizon (0–25 cm) made up 27.0%, humus content – 4.05%, $P_2O_5$ – 186.1 mg $kg^{-1}$, $K_2O$ – 255.1 mg $kg^{-1}$, pH – 7.2.

*Experimental design and parameters.* Research was conducted in the Research Station's organic crop rotation spread over space and time: 1. cropped fallow; 2. winter wheat (*Triticum aestivum* Host.) with undersown red clover (*Trifolium pratense* L.) for green manure; 3. spring barley (*Hordeum vulgare* L.) with undersown lucerne; 4. sown lucerne (*Medicago sativa* L.) of the 1st year of use; 5. sown lucerne of the 2nd year of use; 6. winter wheat; 7. field pea (*Pisum sativum* L.); 8. spring oat (*Avena sativa* L.). The weed control consisted of harrowing once and twice at pre-emergence, early post-emergence and late post-emergence crop stages. Spring oat cv. 'Migla' was harrowed to the scheme: 1) unharrowed (control); 2) before crop emergence (BBCH 0–3); 3) at crop 2–3 leaf stage (BBCH 12–13); 4) before crop emergence (BBCH 0–3) and at crop 2–3 leaf stage (BBCH 12–13); 5) at crop 2–3 leaf (BBCH 12–13) and at tillering (BBCH 20–29) stages; 6) before crop emergence (BBCH 0–3) and at tillering stage (BBCH 20–29). Field pea cv. 'Eiffel' was harrowed to the scheme: 1) unharrowed (control); 2) before crop emergence (BBCH 0–3); 3) at crop 4–6 leaf stage (BBCH 13–16); 4) at beginning of crop stem elongation (BBCH 19–22); 5) at crop 4–6 leaf stage (BBCH 13–16) and at beginning of stem elongation (BBCH 19–22); 6) before crop emergence (BBCH 0–3) and at beginning of stem elongation (BBCH 19–22). The field experiment was arranged as a randomized single row design in four replicates. Each harrowed sub–plot was 15.4 m long and 4 m wide of which 13 by 2.3 m was harvested.

*General conditions of the experiment.* The harrowing was performed lengthwise, the crop rows using a spring-tine harrow Regent (Austria). Harrowing parameters (depth 2–4 cm, tine attack angle 30–45$^{o}$, driving speed 4–6 km h$^{-1}$) were chosen taking into account the state of soil, weeds and crops. Cereal and legume grain was harvested by a combine harvester 'Sampo-500' and adjusted to 15% moisture. Other crop management practices were performed following the standards set for organic farming.

*Meteorological conditions.* In 2005, April was cold and dry; the weather indicators in May were close to long-term mean, and in the middle of summer drought set in. In 2006, during April – May, and especially in summer the crops were badly short of moisture, the weather was warm. In 2007, the growing season was warm, April was dry, and the middle of summer was wet. The average daily air temperature at pre-emergence, early post-emergence and late post-emergence weed harrowing was respectively: in 2005 – 8.0, 8.0 and 15.8$^{o}$C; in 2006 – 11.9, 14.4 and 13.2$^{o}$C; in 2007 – 2.1, 10.1 and 22.1$^{o}$C.

*Experimental methods.* Weed assessments were made in four sites 0.25 m$^2$ in size. Dynamics of the total number of weeds and weed species was estimated before each harrowing. Efficiency of harrowing and the character of weed damage were determined 1–2 days after harrowing, by counting uprooted and soil-covered weeds. Weed species composition and biomass were assessed for the last time at oat heading stage and for pea, before flowering. The experimental data were processed by the analysis of variance (ANOVA).

## RESULTS AND DISCUSSION

*The effect of harrowing on spring oat crop weed incidence and yield*. Weed incidence in the oat crop was low. At oat heading stage annual dicotyledonous weeds, most frequently *Chenopodium album* L., *Thlaspi arvense* L., *Sinapis arvensis* L., *Viola arvensis* Murray, *Matricaria inodora* L. *Capsella bursa-pastoris* (L.) Med. *Galium aparine* L. dominated in the crop. Having harrowed the oat crop once pre-emergence the weed incidence as well as weed air-dried mass declined inappreciably (Table 1).

**Table 1.** Influence of harrowing on annual weeds in spring oat. Average data of 2005–2007.

| Weed harrowing time and frequency | Weed | | Air-dried mass of weeds | |
|---|---|---|---|---|
| | plants $m^{-2}$ | mortality % | g $m^{-2}$ | reduction % |
| Unharrowed (control) | 38.2 | 0 | 2.32 | 0 |
| Before crop emergence | 31.8 | 16.8 | 1.71 | 26.3 |
| At crop 2–3 leaf stage | 14.7 | 61.5 | 0.69 | 70.3 |
| Before crop emergence and at 2–3 leaf stage | 18.5 | 51.6 | 1.51 | 34.9 |
| At crop 2–3 leaf and at tillering stages | 11.7 | 69.4 | 2.07 | 10.8 |
| Before crop emergence and at tillering stage | 24.0 | 37.2 | 2.21 | 4.7 |
| $LSD_{05}$ | 19.54 | – | 0.813 | – |

Crop harrowing at 2–3 leaf stage resulted in a significant (61.5%) reduction in weed incidence compared with the crop that had not been harrowed. Harrowing twice at the above indicated stages was not more effective than harrowing once at 2–3 leaf stage, since early harrowing promotes emergence of new weeds whose seeds are turned up near the soil surface. Such a mode of weed spread caused by harrowing at the intensive weed emergence period is also indicated in other literature sources (Bond & Grundy, 2001; Auskalnis & Auskalniene, 2008). In addition, weeds that are covered by soil at different growth stages during harrowing continue their vegetation if rain occurs later. Too low air and soil temperature also accounted for insufficient pre-emergence harrowing efficacy for weed seed germination. Effective weed control (69.4%) was provided by twice harrowing at 2–3 leaf and tillering stages. It is noteworthy that in separate years, the efficiency of harrowing performed at different growth stages for reducing weed incidence was inconsistent. In the drier year of 2006, when fewer weeds emerged, harrowing at 2–3 leaf stage controlled 15.4% and at tillering stage 40.0% of weeds, compared with the weed incidence before harrowing.

Research done in Lithuania on a light loam indicated that with two- or three-time harrowing in organically grown spring barley crop it was feasible to reduce weed pressure by 76–82%, compared with the unharrowed crop. Based on these findings, it was recommended to harrow spring barley crops twice – when weeds start emerging and at the beginning of the tillering stage (Auskalnis & Auskalniene, 2008).

The character of weed damage by harrowing was highly dependent on weed development stage as well as on harrowing timing, the weather conditions, and soil state at harrowing (data not shown). When the oat crop was harrowed at 2–3 leaf stage, when the soil was still friable, more weeds were uprooted and covered by soil compared with harrowing at later growth stage. The further fate – survival or mortality of soil-covered weeds was determined by the rainfall. The highest number of uprooted and soil-covered weeds in oat crop was found when harrowing had been performed at 2–3 leaf stage in the spring of 2005. When the oat crop was harrowed at tillering, the number of damaged and killed weeds was much lower compared with harrowing at 2–3 leaf stage. When harrowing was performed at later crop growth stages, the surface of clay loam soil was more densified, and weeds more strongly developed and established in the soil, therefore fewer of them were uprooted and covered by soil. *C. album*, *S. arvensis*, *M. inodora* were the most sensitive to harrowing.

Grain yield data showed that harrowing of the oat crop did not have any tangible effect on the yield (data not shown). When harrowing was performed at a later stage, during a wetter period, tines did more damage to oat seedlings than at an earlier stage.

**Table 2.** Influence of harrowing on annual weeds in field pea. Average data of 2005–2007.

| Weed harrowing time and frequency | Weed | | Air-dried mass of weeds | |
|---|---|---|---|---|
| | plants $m^{-2}$ | mortality % | g $m^{-2}$ | reduction % |
| Unharrowed (control) | 31.7 | 0 | 60.43 | 0 |
| Before crop emergence | 28.7 | 9.5 | 38.70 | 36.0 |
| At crop 4–6 leaf stage | 15.2 | 52.1 | 26.80 | 55.7 |
| At beginning of crop stem elongation | 13.7 | 56.8 | 29.07 | 51.9 |
| At crop 4–6 leaf stage and beginning of stem elongation | 14.9 | 53.0 | 37.53 | 37.9 |
| Before crop emergence and at beginning of stem elongation | 18.7 | 41.0 | 37.90 | 37.3 |
| $LSD_{05}$ | 8.25 | – | 49.89 | – |

**Table 3.** Type of initial weed damage caused by field pea harrowing.

| Harrowing time | Type of weed damage | Weed plants $m^{-2}$ | | |
|---|---|---|---|---|
| | | 2005 | 2006 | 2007 |
| Before field pea emergence | undamaged | 11.5 | 8.0 | 8.5 |
| | uprooted | 6.3 | 5.5 | 6.5 |
| | covered with soil | 9.5 | 3.3 | 3.7 |
| At field pea growth 4-6 leaf stage | undamaged | 8.3 | 5.5 | 4.3 |
| | uprooted | 5.5 | 2.0 | 1.3 |
| | covered with soil | 17.8 | 0.3 | 0.8 |
| At beginning of field pea stem elongation | undamaged | 11.2 | 7.8 | 10.5 |
| | uprooted | 2.7 | 1.0 | 1.7 |
| | covered with soil | 9.0 | 1.8 | 1.7 |

Having harrowed the crop at 2–3 leaf stage, more oat plants were uprooted and covered by soil compared with harrowing at tillering stage.

However, harrowing twice also did not significantly reduce oat grain yield. Many researchers summarize that the crop yield response is the result of positive impact from reduced weed competition and negative impact from crop damage caused by harrowing. (Melander et al., 2005; Rasmussen & Norremark, 2006).

*The effects of harrowing on field pea crop weed incidence and yield.* Harrowing efficiency in pea crop was highly dependent on weed development stage and weather conditions. Annual dicotyledonous weeds dominated in the crop before pea flowering: *C. album, T. arvense, C. bursa-pastoris, S. arvensis*. In separate years, crop harrowing gave very diverse results. In spring 2005, pre-emergence harrowing did not reduce the number of weeds which was determined by recurrent rain. However, in drier years 2006 and 2007, the number of weeds in the harrowed crop significantly declined compared with the unharrowed crop. Post-emergence harrowing at later pea growth stage (stem elongation) additionally decreased weed incidence. In both cases of harrowing twice, nearly the same number of weeds was killed, 52.1 and 56.8%, respectively, compared with the not harrowed crop (Table 2). Pre-emergence harrowing of the pea crop did not give a significant reduction in weed number and dry matter.

By harrowing of pea crop pre-emergence and at 4–6 leaf stage the number of uprooted weeds was higher (excluding 2005) than that of soil-covered ones (Table 3). At later pea growth stage, when plants are more strongly established in the soil, harrowing was more intensive by adjusting tine attack angle and depth, and the number of soil-covered weeds was by 2–3 times higher (excluding 2007) than that of uprooted ones. *C. album* and *S. arvensis* were sensitive to harrowing. According to Kurstjens & Kroff (2001), harrowing on a sandy soil uprooted 48–59% of the weeds, 17–26% of the weeds in young seedling stage and 70% of all uprooted plants were covered by soil.Pea crop harrowing did not have any marked effect on grain yield. Pea crop damage by harrowing was less when the crop was harrowed at the beginning of stem elongation compared with harrowing at earlier growth stages.

## CONCLUSIONS

One time pre-emergence harrowing of spring oat crop exhibited a low efficiency, however, harrowing at 2–3 leaf stage gave a significant reduction in weed incidence compared with the unharrowed crop. Twice harrowing the spring oat crop pre-emergence and at 2–3 leaf stage was not markedly more effective than harrowing once at 2–3 leaf stage, since early harrowing promotes later emergence of weed seeds.

The efficiency of harrowing in field pea crop was highly dependent on weed growth stage and weather conditions. In pea crop, post-emergence harrowing was found to be more efficient, especially at late growth stage (stem elongation) when more intensive harrowing is possible due to stronger establishment of pea plants in the soil.

The character of weed damage resulting from harrowing depended on weed growth stage, harrowing timing, soil state and weather conditions during the process. When harrowing is performed at earlier crop growth stages while the soil is still sufficiently friable and moist, a higher number of weeds is uprooted or covered by soil compared with harrowing at later growth stages. Harrowing of spring oat and field pea crops did not have any significant effect on grain yield.

## REFERENCES

Auskalnis, A. & Auskalniene, O. 2008. Weed control in spring barley by harrowing. *Zemdirbyste / Agriculture* **95**(3), 388–394.

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

Hatcher, P.E. & Melander, B. 2003. Combining physical, cultural and biological methods: prospects for integrated non-chemical weed management strategies. *Weed Research* **43** (5), 303–322.

Kurstjens, D.A. & Kroff, M.J. 2001. The impact of uprooting and soil - covering on the effectiveness of weed harrowing. *Weed Research* **41**(3), 211–228.

Melander, B., Rasmussen I.A. & Barberi, P. 2005. Integrating physical and cultural methods of weed control – examples from European research. *Weed Science* **53**(3), 369–381.

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. & Norremark M. 2006. Digital image analysis offers new possibilities in weed harrowing research. *Zemdirbyste / Agriculture* **93**(4), 155–164.

Spokiene, N. & Povilioniene, E. 2003. *Weed*. Kaunas, – 200 pp. (in Lithuanian)

Steinmann, H.H. 2002. Impact of harrowing on the nitrogen dynamics of plant and soil. *Soil & Tillage Research* **65**(1), 53–59.