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THREE YEAR ASSESSMENT OF WEED DYNAMICS IN HERBICIDE - FREE BARLEY CULTURE: A FIELD STUDY

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Abstract

Field trials were carried out at the Experimental Station of the Lithuanian University of Agriculture during 1997-1999. Agrophytocenosis of spring barley crop was chosen for research. The aim of the present study was to evaluate weed seed rain and ways to prevent it in a spring barley crop. Preventive weed control mostly depended on its ability to eliminate reproductive organs of weeds and to protect the soil from the newly ripened weed seed and other reproductive plant parts. Weed seed rain in the spring barley crop began at the stem elongation stage and increased until the hard maturity stage. The total amount of weed seed shed ranged from 5.8 % to 22.7 % until spring barley medium milk stage of maturity, from 26.6 % to 41.8% until late milk-early dough stage, from 48.4 % to 90.6 % until dough stage. The seed ripened by weeds was removed from the field together with the mass of spring barley harvested at milk maturity or at the end of milk maturity-beginning of dough maturity. As a result, spring barley harvesting at these stages significantly reduced soil contamination with new weed seed and weed infestation level in the postcrop.

Key words: weed seed, dynamics of weediness, spring barley, organic agriculture.

Introduction

The weeds growing together with cultivated plants adapt to their growth and biological development cycle. The spread of weed seed is also promoted by the contemporary cereal harvesting technology, where even late-maturing weeds had shed seed before harvesting. Herbicides are used to prevent soil contamination with new weed seed. Although herbicides cannot destroy all weeds, they damage them and consequently fewer seeds are ripened. However, weeds ripen seed even in the herbicide-sprayed crops and contaminate the soil, straw and chaff /Čiuberkis, 1995a, 1995b/. In recent years ecological and economic factors have necessitated a reduction in the use of herbicides or even their complete abandonment /Wacker, 1989/. This is possible only using alternative means of weed control. It is noteworthy that reproduction by seed is specific not only to annual but also to perennial weeds /Zwerger, 1996/. The importance of regulating seed set and seed rain is increasingly being realized in the management of highly adapted weeds such as *Raphanus raphanistrum* /Blackshaw et al., 2002; Jones & Medd, 2005/. The quality of weed control in today's agriculture depends on its ability to eliminate weed seed already present in the soil and to prevent the new weed seed from getting into the soil. The aim of the present study was to evaluate weed seed spread and ways to prevent it in the agrophytocenosis of spring barley.

Materials and Methods

Preventive weed control trial in the organic farming system was carried out at the Experimental Station of the Lithuanian University of Agriculture in 1997, 1998 and 1999. The field trial was arranged and carried out according to the design developed on the basis of spring barley maturity stages by Zadoks et al. (1974).

The experimental design. Spring barley was harvested at the following maturity stages:

1. Hard 92*, 91-92, 92
2. Dough 87, 85, 87
3. Late milk-early dough 77-83, 77-83, 77-83
4. Medium milk 75, 73-75, 73
5. Early milk 71-73, 69-71, 69-71
6. Heading 57-59, 55, 57-59
7. Steam elongation 39-41, 37-39, 31

Note. * - Decimal code for the growth stages of cereal in 1997, 1998 and 1999

Preceding crops for spring barley were winter wheat *Triticum aestivum* (1997), spring barley *Hordeum vulgare* (1998) and cultivated amaranth *Amaranthus spp.* (1999). A two-row barley cultivar 'Roland' was grown each experimental year. Herbicides were not used in the field and soil tillage was the same every experimental year. The soil of the experimental site is *Calcari-Epihypogleyic Luvisol (LVg-p-w-cc)*. The agrochemical characteristics in the arable soil under spring barley did not vary considerably. Topsoil characteristics in 1997, 1998 and 1999 were as follows: pH_{KCl} 7.08-7.25, humus 2.22-2.45 %, available P_2O_5 245.0-251.3 mg kg^{-1} and available K_2O 93.6-110.5 mg kg^{-1}.

With reference to the hydrothermal coefficient (HTC) of spring barley growth periods in 1997 and 1998 it was wet (HTC 1.53 and 1.70) and in 1999 it was insufficiently wet (HTC 0.75). In 1997 during spring barley 3-leaf, stem elongation and heading stages the period was wet, during the early milk stage the period was extremely dry, during the milk stage the period was wet, during the late milk-early dough the period was dry, during the dough stage the period was wet and during the hard stage the period was dry. In 1998 during spring barley 3-leaf stage the period was sufficiently wet, during the stem elongation stage the period was dry, during the heading and early milk stage the period was wet, during the milk stage the period was very dry, during the late milk-early dough stage the period was wet, during the early dough stage the period was sufficiently wet and during the hard stage the period was wet. In 1999 during spring barley 3-leaf stage the period was wet, during the stem elongation stage the period was dry, during the heading and early milk stages the period was sufficiently wet, during the late milk-early dough stage the period was dry and during early dough and hard stages the period was very dry.

Weed samples were taken at the early milk stage for the determination of total weed infestation. Ten samples per plot, in total 280 samples were taken using a wire frame of 20x30cm. Air-dried weeds were divided into groups according to species and were counted and weighed. Dynamics of weed seed rain in the spring barley crop was established according to Rabotnov's (1960) methodology taking into account the crop weed seed rain trials of Stancevicius & Girkute (1972), Moss (1983) and Leguizamon & Roberts (1982) and their methodological refinements. Weed seeds that fell on the soil were analysed. Fifty troughs were laid out in each of the four replications, in chess-order, in tens. Weed seed from the troughs was collected every 2-4 days, divided into groups according to species and counted.

The data were analysed by ANOVA. The treatment effects were tested for least significant differences (LSD_{05} and LSD_{01}) using „Selekcija" software /Tarakanovas, 1997, 1999/. Each year the data were analysed separately. Using the statistical method for long-term data evaluation (Gomez & Gomez, 1984), based on the analysis of variance of data, namely Fisher *F*-test, we analysed statistical expedience of the presentation of three years' means of the experimental data. While analysing the year-treatment interaction it was found that derivation and use of mean of multi-year experiment (1997, 1998 and 1999) are statistically unacceptable. As a result, long-term (three years) means of the experimental data are not presented in this paper.

Results and discussions

Over the experimental period of 1997-1999 *Chenopodium album*, *Stellaria media*, *Sonchus asper* prevailed among annual weeds, and *Sonchus arvensis* among perennial weeds in the spring barley crop (Table 1).

In 1997 the trial was arranged in a heavily weed-infested field (Table 1). In 1998 the number of weeds was more than thrice lower and biomass by 2.6 times lower than in 1997 (Table 1). In 1999 the weed number was similar to that in 1998 but their air-dried mass was more than 6 times lower (Table 1). During the weed infestation assessments the weeds were attributed to biological groups (annual or perennial): in 1997 annual weeds made up 98.2 % and perennial weeds 1.8 %; in 1998 84.0 % and 15.6 % and in 1999 89.2 % and 10.8 %, respectively. Comparison of weed mass suggests that the differences between annual and perennial weeds were lower compared with the differences in the number of annual and perennial weeds. The distribution of annual and perennial weeds according to their biomass was as follows: 97.7 % annual and 2.3 % perennial in 1997, 70.2 % annual and 29.8 % perennial in 1998, and 67.6 % annual and 32.4% perennial in 1999, respectively. During the three experimental years annual weeds reproducing from seed predominated (Table 1).

Table 1. The number and air-dry mass of weeds in spring barley
1 lentelė. *Piktžolių skaičius ir orasausė masė vasarinių miežių pasėlyje*

Weeds and weed group *Piktžolės ir piktžolių grupės*	Weed number and air-dry mass *Piktžolių skaičius ir orasausė masė*					
	1997		1998		1999	
	weeds m^{-2} *piktžolės* m^{-2}	g m^{-2}	weeds m^{-2} *piktžolės* m^{-2}	g m^{-2}	weeds m^{-2} *piktžolės* m^{-2}	g m^{-2}
1	2	3	4	5	6	7
Stellaria media (L.) Vill.	37.9	17.1	7.1	3.8	9.2	2.7
Poa annua L.	7.5	0.50	0	0	5.0	0.10
Annual ephemeral *Trumpaamžės pavasarinės*	45.4	17.6	7.1	3.8	14.2	2.8
Chenopodium album L.	29.5	131.2	70.0	54.0	66.2	5.7
Sinapis arvensis L.	147.9	69.2	1.7	1.0	0	0.0
Galeopsis tetrahit L.	0	0.0	1.7	0.3	0	0.0
Spergula arvensis L.	0	0.0	0.4	0.2	0	0.0
Galium aparine L.	2.5	0.3	2.1	1.1	0	0.0
Polygonum aviculare L.	0.4	0.1	0	0.0	0	0.0
Erysimum cheiranthoides L.	62.1	6.4	1.7	0.2	1.2	0.1
Galinsoga parviflora Cav.	0	0.0	0.8	0.2	0	0.0
Raphanus raphanistrum L.	0.4	0.2	0	0.0	0	0.0
Polygonum laphatifolium L.	8.3	0.9	3.8	0.6	0.4	0.01
Fallopia convolvulus (L.) A. Löve	2.1	0.1	5.4	1.4	0	0.0
Euphorbia helioscopia L.	3.8	0.2	0.8	0.2	0.8	0.05
Veronica arvensis L.	2.5	0.1	0	0.0	4.2	0.1
Amaranthus spp. L.	0	0.0	0	0.0	10.8	0.1
Chaenorrhinum minus (L.) Lange	0.4	0.01	1.2	0.04	2.5	1.6
Crepis tectorum L.	3.3	0.9	0	0.0	0	0.0
Sonchus asper (L.) Hill.	16.4	9.0	3.3	5.2	0.9	0.4
Summer annual *Trumpaamžės vasarinės*	279.6	218.6	92.9	64.4	87.1	8.0
Medicago lupulina L.	1.2	0.2	0	0.0	0	0.0
Tripleurospermum inodorum (L.) Sch. Bip.	34.2	10.9	0	0.0	2.9	0.2
Thlaspi arvense L.	4.6	0.5	0	0.0	0.4	0.1
Viola arvensis Murray	3.3	0.2	0.4	0.04	1.7	0.05
Myosotis arvensis (L.) Hill.	1.7	0.1	0	0.0	0	0.0

Table 1 continued
1 lentelės tęsinys

1	2	3	4	5	6	7
Lamium purpureum L.	1.2	0.05	0	0.0	0.8	0.2
Capsella bursa-pastoris (L.) Medik.	17.1	1.4	2.5	0.4	13.3	1.4
Winter annual *Trumpaamžės žieminės ir žiemojančios*	63.3	13.3	2.9	0.5	19.2	1.9
Annual / *Trumpaamžės*	388.3	249.5	102.9	68.7	120.5	12.7
Plantago major L.	2.5	0.1	0.4	0.8	2.9	0.1
Trifolium pratense L.	1.3	0.1	0	0.0	0	0.0
Perennial spreading by seed *Daugiametės plintančios sėkla*	3.8	0.2	0.4	0.8	2.9	0.1
Tussilago farfara L.	0	0.0	1.3	0.1	0	0.0
Elytrigia repens (L.) Nevski	0	0.0	0	0.0	2.5	2.3
Stellaria graminea L.	0	0.0	0	0.0	0.4	0.1
Sonchus arvensis L.	0.3	0.2	15.8	24.8	6.2	3.1
Cirsium arvensis (L.) Scop.	2.9	5.6	2.1	3.4	0.8	0.3
Mentha arvensis L.	0	0.0	0	0.0	1.7	0.3
Perennial spreading by vegetative parts *Daugiametės plintančios vegetatyviai*	3.2	5.8	19.2	28.3	11.6	6.1
Perennial / *Daugiametės*	7.0	6.0	19.6	31.1	14.5	6.2
Total weeds *Iš viso piktžolių*	395.3	255.5	122.5	99.8	135.0	18.9

In the crop of spring barley there were established 34 weed species (Table 1). However, because of spring barley competitive power not all weed species were able to produce seeds in the crop The weed seeds collected during the three experimental years were attributed to 29 weed species of 12 families. In the crop of spring barley at the growth stage of stem elongation weeds of short growing season *Stellaria media*, *Poa annua* and early summer weeds *Chenopodium album* ripened and seed rain began. Winter weeds such as *Capsella bursa-pastoris* ripened and shed seed at spring barley heading stage. When spring barley had reached milk maturity stage *Lamium purpureum*, *Apera spica-venti*, *Atriplex patula*, *Veronica arvensis*, *Sonchus asper* and *Myosotis arvensis* ripened and started shedding seed. At spring barley medium milk stage *Thlaspi arvensis*, *Raphanus raphanistrum*, *Spergula arvensis*, *Galium aparine*, *Fallopia convolvulus* and *Polygonum lapha-tifolium* ripened and began to shed seeds. At spring barley transition from milk to dough stage of maturity, *Sinapis arvensis*, *Sonchus arvensis*, *Erysimum chei-*

ranthoides and *Cirsium arvense* ripened and began to shed seeds. At spring barley dough maturity stage *Avena fatua*, *Crepis tectorum*, *Anthemis arvensis* and *Anthemis tinctoria* ripened and began to shed seeds. At that time all species of weeds, that shed seeds, were ripe except for the year 1998 when *Crepis tectorum* started shedding seed only when spring barley had reached hard maturity stage. But the beginning of ripeness and seed rain of some weed species lasted longer than the spring barley growth stages presented; in 1997 *Chenopodium album* began to shed seed at the stem elongation stage, in 1999 at heading and in 1998 at medium milk stage of spring barley. It depended on climate conditions and crop weediness. In a weedier crop seed shed was more intensive, and it was easier to determine the beginning of weed seed rain. Since early milk stage of barley weed seed rain intensified: in 1997 – 17.4 %, 1998 – 20.0 %, 1999 – 40.0 % and at late milk-early dough stage of spring barley in 1997 – 74 %, in 1998 – 90 % and in 1999 – 80 % of crop stand weed species ripened seed.

When spring barley was ripening, weed seed shed more intensively. During the first ten days from the beginning of stem elongation stage of spring barley weed seed shed 0.2, 0.3 and 7.2 % in 1997, 1998, and 1999, respectively. At the end of spring barley growing season weed seed shed was 27.9, 62.7 and 44.5 % 1997, 1998 and 1999, respectively. Different weed species shed different amount of seed. In 1997 the greatest number of seed was found of *Stellaria media* (1260 seeds m^{-2}), *Sonchus asper* (1173 seeds m^{-2}), *Sinapis arvensis* L. (496 seeds m^{-2}), *Capsella bursa-pastoris* L. (457 seeds m^{-2}) and *Chenopodium album* (289 seeds m^{-2}). They accounted for 81 % of the total weed seed shed in 1997. In 1998 seeds of *Chenopodium album*, *Stellaria media* and *Sonchus arvensis* predominated: 1484, 802 and 133 seeds m^{-2}, respectively and they accounted for 88 % of the total weed shed. In 1999 the greatest number of *Chenopodium album* (519 seeds m^{-2}), *Stellaria media* (157 seeds m^{-2}) and *Capsella bursa-pastoris* (52 seeds m^{-2}) seeds was found; they accounted for 89 % of the total weed seed shed.

In 1997 the total amount of weed seed shed (Table 2) made up only 4.6 % at spring barley transition to milk stage, 16.8 % of seed was shed until medium milk stage of maturity, 28.4 % till late milk-early dough stage and 85.2 % until dough stage. In 1998 the total amount of weed seed shed made up 1.7 %, 5.8 %, 26.6 % and 48.4 % and in 1999 7.3 %, 22.7 %, 41.8 % and 90.6 %, respectively (Table 2).

The data of the field trial proved that weeds ripened regularly. It was established that to 4543 seeds m^{-2} shed until spring barley harvesting (Table 2).

The number of weed seed depended on the crop density, crop cultivation and management practices, weather conditions and soil characteristics /Petraitis et al., 1993/. Moreover, the seeds that got into silage /Grigas & Smulkienė, 1989a; Blackshaw & Rode, 1991/, manure /Sarapatka et al., 1993/, slurry /Grigas & Smulkiene, 1989b/ and compost /Tereshchuk, 1995/, lost their germinating power and did not contaminate the crop Harvest timings included barley harvested 1 week after heading (early), approximately 14 to 16 days later at the soft dough stage (normal), and at maturity (grain) (Harker et al., 2003). In the absence of herbicides, wild oat densities decreased in silage plots harvested 1 week after heading and

Table 2. Weed seed rain in the crop of spring barley
2 lentelė*. Piktžolių sėklų byrėjimas vasarinių miežių pasėlyje*

Growth stage of spring barley *Vasarinių miežių branda*	Weed seed rain m^{-2} *Piktžolių sėklų byrėjimas* m^{-2}		
	1997	1998	1999
Stem elongation *Bamblėjimas*	8**	0**	0**
Heading *Plaukėjimas*	16**	0**	12**
Early milk *Pieninės brandos pradžia*	207**	47**	60**
Medium milk *Pieninė branda*	764**	161**	189**
Late milk-early dough *Pieninės brandos pabaiga-vaškinės brandos pradžia*	1289**	731**	343**
Dough *Vaškinė branda*	3871	1331**	744*
Hard maturity *Kietoji branda*	4543	2753	821
LSD_{05} / R_{05}	707.0	417.7	71.5
LSD_{01} / R_{01}	968.4	572.1	97.9

N o t e . * – significant differences from the control treatment (hard maturity stage) at 95 % probability level; and ** - at 99 % probability level.
*P a s t a b a . * – esminiai skirtumai nuo kontrolinio varianto (kietoji branda) 95 % tikimybės lygiu ir ** - 9 9% tikimybės lygiu.*

increased in grain plots. Half rates of wild oat herbicides did not augment reductions in wild oat densities after early silage harvest, but did improve wild oat management after normal silage harvest, and in grain production. Early silage harvest reduced wild oat densities more than did herbicides in grain production. Early barley silage harvests may be an effective integrated weed management tool for wild oat (Harker et al., 2003). Webster et al. (2003) indicated that seedling recruitment of weed species present was correlated with seed rain. However, seedling recruitment of the dominant annual grasses was related to seedbank populations or a combination of seedbank and seed rain densities. Weed grasses accounted for at least 16 to 77% of the seed rain /Webster et al., 2003/. For instance, strategies involving a selective spray-topping herbicide to control seed rain not only resulted in lower seed banks, but the range in possible values was considerably reduced, implying lower likelihood of a population increase /Jones & Medd, 2005/. Eradication, containment, and revegetation are facilitated if weed seed rain can be stopped /Carrithers et al., 2004/.

Conclusions

1. In 1997 the trial was carried out in a very weed-infested field, there were found 395.3 weeds per square meter that made up 255.4 g. In 1998 the number of weeds increased thrice and the mass decreased by 2.6 times compared with 1997. In 1998 the number of weeds per square meter was 122.5 and their weight was 97.8 g. In 1999 the number of weeds in the trial field reached 135.0 per square meter and it was similar to the number in 1998, though, the mass decreased 6 times and amounted to 18.9 g per square meter. In total 34 weed species were found during the three-year-trial. In 1997 there were found 26 species, in 1998 and 1999 19 and 20 species, respectively.

2. Weed seed rain in the spring barley crop began at the stem elongation stage and gradually increased until hard maturity. From 6 % to 23 % of weed seed shed until spring barley medium milk stage and from 27 % to 42 % till late milk-early dough stage.

3. Weed seeds which were left in the crop were removed from the field together with the biomass of spring barley and therefore did not contaminate the soil: 77 % - 94 % till medium milk stage and 58 % - 73 % - until late milk-early dough stage of maturity of spring barley.

4. For successful weed control, eliminating ripened new weed seeds from the crop, spring barley should be harvested for silage at milk or late milk-early dough stage when unshed weed seeds are removed from the field together with the crop yield.

5. The spring barley management practices discussed here meet the criteria set for organic farms and are promising to be used in organic as well in conventional agriculture.

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VASARINIŲ MIEŽIŲ PASĖLIO PIKTŽOLIŲ KITIMO DINAMIKOS VERTINIMAS BE HERBICIDŲ NAUDOJIMO: TREJŲ METŲ LAUKO TYRIMAS

V. Pilipavičius

Santrauka

Lauko bandymai atlikti Lietuvos žemės ūkio universiteto Bandymų stotyje 1997-1999 m. Tyrimų objektas – vasarinių miežių pasėlio agrofitocenozė. Darbo tikslas – įvertinti piktžolių sėklų plitimą ir prevenciją vasarinių miežių pasėlyje. Prevencinė piktžolių kontrolė daugiausia priklauso nuo sugebėjimo eliminuoti generatyvinius ir vegetatyvinius piktžolių plitimo pradus iš dirvos ir nuo sugebėjimo apsaugoti dirvą nuo naujų patekimo. Piktžolių sėklos pradeda plisti vasarinių miežių bamblėjimo tarpsniu ir intensyvėja iki kietosios brandos. Bendras išbyrėjusių piktžolių sėklų skaičius iki vasarinių miežių pieninės brandos siekia nuo 5,8 % iki 22,7 %, iki pieninės brandos pabaigos-vaškinės brandos pradžios – nuo 26,6 % iki 41,8 %, ir iki vaškinės brandos – nuo 48,4 % iki 90,6 %. Sėklos, esančios ant piktžolių pasėlyje, išvežamos iš lauko kartu su vasarinių miežių mase, nuimant juos pieninės brandos ar pieninės brandos pabaigos-vaškinės brandos pradžios metu. Taigi, nuimant vasarinius miežius šiais brandos tarpsniais, dirvos užteršimas naujomis piktžolių sėklomis ir potencialus posėlio piktžolėtumas sumažinami iš esmės.

Reikšminiai žodžiai: piktžolių sėklos, piktžolių kitimo dinamika, vasariniai miežiai, ekologinė žemdirbystė.