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Weed species diversity and community composition in conventional and organic farming: a five-year experiment

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Abstract

The aim of this investigation was to study the influence of organic (ORGFYM – organic with green and cattle manure, ORGGRM – organic with green manure) and conventional (CONFYM – with green manure, cattle manure, mineral fertilizers and pesticides) treatments on weed species diversity, their abundance and biomass.

A total of 44 weed species/taxa were encountered during the study covering a period of 2007–2011. In the ORGGRM, the number of weed species was 39 (24 annuals and 15 perennials), in the ORGFYM – 36 (21 annuals, 1 biennial and 14 perennials) and in the CONFYM treatment – 30 (19 annuals, 1 biennial and 10 perennials). *Centaurea cyanus*, *Cerastium arvense*, *Geranium pratense*, *Myosurus minimus*, *Polygonum laphatifolia*, *Plantago lanceolata* and *Plantago major* were found only in ORGGRM treatment. The average number of species per 0.25 m^2 was 9.2 and 9.3 in the organic treatments and 4.9 in the conventional treatment. The average values of Shannon diversity index were statistically higher in the organic (ORGGRM – 1.70, ORGFYM – 1.65) than in the CONFYM (1.06; $p < 0.05$) treatments. *Chenopodium album* was the most common annual species in all treatments. We found that herbicide application in the CONFYM treatment decreased the density of the most sensitive species (e.g., *C. album*, *Polygonum convolvulus*, *Mentha arvensis*, *Polygonum persicaria*, *Elytrigia repens*) but had a minor or no effect on the proportion of herbicide-tolerant species (especially *Viola arvensis*, *Veronica* spp., *Myosotis arvensis*). Among the perennials *E. repens* was the most common species in all treatments. The highest number of these plants occurred in the ORGGRM treatment.

We found that the species pool was larger and the average number of species higher in the organic than in the conventional treatment. No significant difference was identified between the organic treatments. Our results suggest that weed species diversity could be promoted by using organic cropping practices.

Key words: weed species diversity, number of weed shoots, weed biomass, Shannon index, solid cattle manure, herbicides.

Introduction

Arable weeds are primary producers and are of central importance to the food web of an arable system. Weeds serve as immediate food sources for herbivores and support prey species for higher trophic levels. Weeds can also alter habitats and microclimatic conditions, and provide shelter and suitable reproduction sites for arthropods. The seeds and vegetative organs of arable weeds represent a pivotal food source for granivorous farmland birds (Potts, 1970; Wilson et al., 1999), and flowering plants support communities of wild pollinators (Bäckman, Tiainen, 2002). In general, species richness and composition of arable weeds are related to local abiotic conditions like soil properties (Dale et al., 1992) and farming practices differing in herbicide use, mechanical weed control, tillage systems, and nitrogen fertilizer input (Py ek, Lep , 1991; McCloskey et al., 1996; Andersson, Milberg, 1998; Hyvönen, Salonen, 2002). Fields are sprayed with herbicides, insecticides and fungicides to avoid the damage to crops caused by pests, weeds and pathogens. Pesticides do not affect only the undesirable pests but also their natural enemies and important pollinators (Marshall et al., 2003).

In the past decades organic farming has rapidly increased in Europe. Therefore, it is also hoped that the biodiversity will be preserved and enhanced. The cropping practices of organic farming differ from those of conventional farming in the non-use of herbicides and mineral fertilizers, the lower rates of nitrogen fertilization and the greater diversity of crop rotation. Such cropping measures have been found beneficial for the species diversity of weed communities, the number of weed species being higher in organically than in conventionally cultivated fields (Moreby et al., 1994; Hald, 1999; Menalled et al., 2001; Hyvönen et al., 2003; Bengtsson et al., 2005; Hole et al., 2005). Organic cropping has also been found to support populations of endangered weed species (Rydberg, Milberg, 2000). Lower nitrogen rates that are used in organic cropping create favourable conditions for non-nitrophilous species (Rydberg, Milberg, 2000) and for legumes (Van Elsen, 2000). On the other hand, it has been found that the composted manure used in organic farming has favourable effects on nitrophilous species, e.g., species of the goosefoot family (*Chenopodiaceae*) (Van Elsen, 2000).

The aim of our investigation was to study the influence of organic (with and without manure) and conventional farming on weed species diversity. In a five-year field experiment we studied the weed species diversity their abundance and biomass in three different treatments. Our hypothesis was that organic treatments support a higher number of weed species than conventional treatment – especially organic treatment without manure application.

Materials and methods

Experimental site. The field trial was performed in Central-Estonia at Olustvere (58º33′ N, 25º34′ E) during 2007–2010. The soil type was *Podzoluvisol* (*PD*) according to FAO (1998). The agrochemical properties of the humus horizon at the beginning of trials were as follows: pH_{KCl} – 5.8–6.3, P – 194–230 mg kg^{-1} (A-L method), K – 136–183 mg kg^{-1} (A-L method), C_{org} – 1.3–1.6% (NIRS method). In the trial area, the field crops have been cultivated according to the principles of organic farming since 2002.

Experimental set up. Since 2007, a five-year crop rotation was conducted at two levels of intensity (conventional and organic with and without manure). The crop rotation was as follows: potato (*Solanum tuberosum* L.), oats (*Avena sativa* L.), barley (*Hordeum vulgare* L.) with undersown red clover (*Trifolium pratense* L.), red clover and winter rye (S*ecale cereale* L.). Each year all five crops were represented in the field trial.

The field trial area was 6 ha and the size of each field in the crop rotation was 1.2 ha, which was divided into three equal parts (4000 m^2) between the treatments. Since 2007 the following treatments were carried out: organic with green manure (ORGGRM); organic with solid cattle manure and green manure (ORGFYM); and conventional – green manure, cattle manure, mineral fertilizers and pesticides (CONFYM) were used.

The tillage method in all treatments was mouldboard ploughing to a depth of 20 cm. In oats and barley fields weeds were controlled after sowing and in rye field at the end of April by spring-tine harrowing. In potato field inter-rows were cultivated three times. In the CONFYM and ORGFYM treatments, manure at the rate of 60 t ha^{-1} was applied in September, after the rye harvesting prior to autumn ploughing. In all three treatments the clover was cut and ploughed into the soil in the beginning of July. The total input of plant nutrients is shown in Table 1.

Table 1. Input of plant nutrients (with solid cattle manure and mineral fertilizers; the input of plant nutrients is the average of 2007–2011)

Treatment	Manure kg ha^{-1} $year^{-1}$							Mineral fertlizers kg ha^{-1} $year^{-1}$		
	N	P	K	Mg	Cu	Mn	B	N	P	K
ORGGRM	–	–	–	–	–	–	–	–	–	–
ORGFYM	69.6	14.4	33.0	12.1	0.04	0.2	0.04	–	–	–
CONFYM	69.6	14.4	33.0	12.1	0.04	0.2	0.04	50.2	14.9	47.7

ORGGRM – organic with green manure; ORGFYM – organic with green and cattle manure; CONFYM – conventional with green and cattle manure, mineral fertilizers and pesticides

The use of pesticides is shown in Table 2.

Table 2. Pesticide use in conventional (CONFYM) treatment

Commercial name	Active ingredient	Dose	Category	Crop
Sencor	metribuzin (700 g kg^{-1})	300 g ha^{-1}	herbicide	potato
Fastac	alpha-cypermethrin (50 g l^{-1})	0.3 l ha^{-1}	insecticide	potato
Ridomil Gold MZ 68 WG	metalaxyl (40 g kg^{-1}), mancoceb (640 g kg^{-1})	2.5 kg ha^{-1}	fungicide	potato
Shirlan	fluazinam (500 g l^{-1})	0.3 l ha^{-1}	fungicide	potato
Shirlan	fluazinam (500 g l^{-1})	0.3 l ha^{-1}	fungicide	potato
Shirlan	fluazinam (500 g l^{-1}),	0.3 l ha^{-1}	fungicide	potato
Sekator 375 OD	amidosulfuron (100 g l^{-1}), iodosulfuron-methyl-sodium (25 g l^{-1})	0.15 l ha^{-1}	herbicide	oats
Roundup Gold	glyphosate (450 g l^{-1})	3 l ha^{-1}	herbicide	oats
MCPA	MCPA (750 g l^{-1})	0.9 kg ha^{-1}	herbicide	barley with undersown red clover
Agil	propaquizafop (100 g l^{-1}),	1 l ha^{-1}	herbicide	red clover
Sekator 375 OD	amidosulfuron (100 g l^{-1}), iodosulfuron-mehtyl-sodium (25 g l^{-1})	0.15 l ha^{-1}	herbicide	winter rye

Weed samples. In the end of June – beginning of July samples from five crops in four replications were taken from a plot of 0.25 m^2 in order to determine the species, abundance and dry mass of weeds in three treatments (20 samples from each treatment, in total 60 samples per year). The growth stage of barley and oats at the time of sampling were 32–36 and rye 52–54 according to BBCH scale (Meier, 2001). Weeds were cut at the soil surface and their biomass was weighed by species after the samples had been dried.

Genera/taxa, e.g., *Galeopsis* spp. (incl. *G. bifida*, *G. tetrahit*) and *Veronica* spp. (*V. arvensis*, *V. sperpyllifolia*, *V. verna*) that could not be identified at species level were considered as a single species in the analysis. The nomenclature of plant species follows that of Kask et al. (1975).

Weather conditions. A weather station situated in Viljandi (10 km from the study area) recorded data on air temperature and precipitation (Table 3).

Table 3. Monthly total precipitation and average temperatures during the 2007–2011 period

Year	Temperature °C					Precipitation mm				
	April	May	June	July	Average	April	May	June	July	Total
2007	6.4	18.8	15.3	16.0	14.1	23.8	54.4	61.8	97.8	237.8
2008	10.1	12.3	14.0	17.5	13.5	46.6	23.4	119.8	47.0	236.8
2009	11.0	14.0	17.7	17.7	15.1	2.2	11.8	85.3	125.2	224.5
2010	6.6	11.8	16.9	22.9	14.6	12.0	52.8	48.0	42.8	155.6
2011	6.7	11.2	18.6	20.3	14.2	10.6	55.6	20.0	64.2	150.4

Data analyses. All results were based on four replicates (in total 100 samples from each treatment). The Shannon diversity index value (H') was calculated for each sample quadrate as follows: $H' = -\Sigma_i\, pi \ln(pi)$, where *pi* is the proportion of total individuals in the *i*th species in the sample quadrate. The Tukey-Kramer honestly significant difference (HSD) test was used, effect of treatment, year and their interaction on weed species diversity, Shannon index, abundance and biomass were tested using the software *JMP 5.0.1.2* (JMP, 2002).

Results and discussion

During the study period 2007–2011, a total of 44 weed species/taxa were encountered, of which 25 were annuals, 1 biennial and 18 perennials (Table 4). In the ORGGRM, the number of weed species was 39 (24 annuals and 15 perennials), in the ORGFYM – 36 (21 annuals, 1 biennial and 14 perennials) and in the CONFYM treatment – 30 (19 annuals, 1 biennial and 10 perennials). In long-term experiments, the use of herbicides has not always been noted to eliminate species from the species pool (Chancellor, 1979; Mahn, Helmecke, 1979; Hume, 1984). This is because almost all weed species have a seed bank that buffers the deleterious effects of herbicides.

Three annual (*Centaurea cyanus*, *Myosurus minimus*, *Polygonum laphatifolia*) and four perennial (*Cerastium arvense*, *Geranium pratense*, *Plantago lanceolata*, *P. major*) species were found only in the ORGGRM treatment (Table 4). *C. cyanus* is susceptible to herbicide treatments and suffers from high rates of nitrogen fertilization (Svensson, Wigren, 1986; Wilson, 1991). In the ORGFYM treatment these species did not occur at all. We assumed that the soil nutrient content in the ORGGRM treatment was lower than in the other treatments because the growth of crops was weaker there, which provided better conditions for the growth of light-demanding weeds. In the ORGGRM, the total abundance of *Matricaria matricarioides* (132 shoots m^{-2}) was 3 to 33-fold, *Gnaphalium uliginosum* (92 shoots m^{-2}) was 6-fold (in ORGFYM treatment it did not occur at all) and *Lapsana communis* (100 shoots m^{-2}) 2 to 6-fold higher than in other treatments (Table 4). Also Schippers and Joenje (2002) have shown that even very slight changes in nutrients, especially nitrogen amount may cause notable changes in species richness and composition.

The highest total number of shoots per m^2 (17824 m^{-2}) occurred in the ORGFYM treatment (Table 4). The total number of shoots per m^2 in the ORGGRM was 10% (16052 m^{-2}) and in the CONFYM 60% (7284 m^{-2}) lower than in the ORGFYM treatment. *Chenopodium album* was the most common annual species in all treatments. The total number of *C. album* shoots in all observations per m^2 was 2.6-fold higher (2424 m^{-2}) in the ORGFYM as in the CONFYM treatment (928 m^{-2}). We found that herbicide application in the CONFYM treatment decreased the density of the most sensitive species (e.g., *C. album*, *Polygonum convolvulus*, *Mentha arvensis*, *P. persicaria*, *Elytrigia repens*) and had a minor or no effect on the proportion of herbicide-tolerant species (especially *Viola arvensis*, *Veronica* spp., *Myosotis arvensis*). In both organic treatments, the total number of *P. convolvulus* shoots m^{-2} was 3.5 to 4-fold (ORGGRM – 1248 and ORGFYM – 1424 m^{-2}) (Table 4), *Elytrigia repens* 1.8 to 2.6 (ORGGRM – 2164 and ORGFYM – 1480 m^{-2}) higher than in the CONFYM treatment (352 and 820 shoots m^{-2}). In organic, with solid cattle manure (ORGFYM) treatment the total number of *P. persicaria* shoots m^{-2} was about 31-fold (ORGFYM – 860, CONFYM – 28 m^{-2}) and *M. arvensis* 8-fold (ORGFYM – 704, CONFYM – 88 m^{-2}) higher than in the CONFYM treatment. For *Thlaspi arvense* (ORGFYM – 1668, CONFYM – 584 shoots m^{-2}), *V. arvensis* (ORGFYM – 864, CONFYM – 480 shoots m^{-2}) and *Galeopsis* spp. (ORGFYM – 952, CONFYM – 308 shoots m^{-2}) was only 1.8 to 3-fold higher than in the CONFYM treatment. Although *Galeopsis* spp. abundance due to the use of herbicides did not decrease, its biomass decreased considerably and ranged from 6.9 to 8.9-fold lower (28.8 g m^{-2}) than in the organic treatments (ORGFYM – 198.8 and ORGGRM – 255.8 g m^{-2}). *V. arvensis* biomass in CONFYM treatment was as much as 33% (31.6 g m^{-2}) higher than in the ORGGRM treatment (21.2 g m^{-2}). The abundance of *Veronica* spp. shoots m^{-2} in the CONFYM treatment was about 8% higher than in the ORGFYM treatment (CONFYM – 216, ORGFYM – 200 m^{-2}). Also, in the CONFYM treatment the number of *Lamium purpureum*, *Sonchus arvensis*, *Spergula arvensis*, *Capsella bursa-pastoris*, *Fumaria officinalis* shoots per m^2, compared to organic treatments decreased by as little as 1.4 to 2.1-fold. It can mean that the weeds are herbicide-resistant.

Arenari serpyllifolia, *Equisetum fluviatile*, *Tussilago farfara* and *Vicia hirsuta* occurred only in organic treatments (Table 4). This might have resulted from the fact that these species were sensitive to herbicides, or their presence may have been rare, because their overall abundance throughout the test cycle was very small.

Table 4. The total number of shoots m^{-2} and their biomass (g m^{-2}) in 2007–2011 (n = 100)

Species/Taxon	Life cycle[1]	ORGGRM		ORGFYM		CONFYM	
		shoots m^{-2}	biomass g m^{-2}	shoots m^{-2}	biomass g m^{-2}	shoots m^{-2}	biomass g m^{-2}
Arenaria serpyllifolia L.	A	4	2.0	12	1.9	–	–
Artemisia vulgaris L.	P	24	108.4	28	58.0	8	0.0
Barbarea vulgaris R. Br.	B	–	–	4	1.3	12	27.8
Capsella bursa-pastoris (L.) Medik.	A	908	161.7	848	176.7	504	126.3
Centaurea cyanus L.	A	16	17.2	–	–	–	–
Cerastium arvense L.	P	16	3.7	–	–	–	–
Chenopodium album L.	A	2216	488.0	2424	543.1	928	120.7
Cirsium arvense (L.) Scop.	P	292	512.8	172	341.6	40	115.1
Convolvulus arvensis L.	P	–	–	4	16.2	–	–
Equisetum arvense L.	P	32	15.6	16	2.2	20	6.5
Equisetum fluviatile L.	P	–	–	12	0.6	–	–
Elytrigia repens (L.) Nevski	P	2164	1526.6	1480	1687.2	820	685.0
Erodium cicutarium (L.) L'Hér.	A	–	–	8	0.0	8	0.4
Erysimum cheiranthoides L.	A	12	1.6	12	1.7	–	–
Festuca arundinacea Schreb.	P	–	–	4	4.0	–	–
Fumaria officinalis L.	A	492	37.1	528	93.1	252	12.6
Galeopsis spp.	A	584	255.8	952	198.2	308	28.8
Galium aparine L.	A	96	15.8	112	13.2	24	10.8
Geranium pratense L.	P	4	0.0	–	–	–	–
Gnaphalium uliginosum L.	A	92	4.9	–	–	16	0.8
Lamium purpureum L.	A	1320	148.8	1628	248.9	760	123.1
Lapsana communis L.	P	100	36.2	48	23.2	16	20.7
Lycopsis arvensis L.	A	276	275.6	200	67.1	120	48.8
Matricaria matricarioides (Less.) Port.	P	132	16.2	4	0.4	44	13.7
Mentha arvensis L.	P	220	29.4	704	255.7	88	10.4
Myosotis arvensis (L.) Hill	A	404	47.3	304	61.0	204	23.8
Myosurus minimus L.	A	4	0.0	–	–	–	–
Plantago lanceolata L.	P	4	0.1	–	–	–	–
Plantago major L.	P	4	0.0	–	–	–	–
Polygonum arenastrum Boreau	A	232	22.5	132	27.7	48	7.4
Polygonum convolvulus L.	A	1248	159.6	1424	211.8	352	40.2
Polygonum lapathifolia L.	A	12	0.3	–	–	–	–
Polygonum persicaria L.	A	68	12.5	860	46.8	28	2.5
Sonchus arvensis L.	P	924	433.7	988	608.6	472	145.3
Spergula arvensis L.	A	888	140.9	880	132.2	644	108.5
Stellaria media (L.) Vill.	A	748	193.0	952	111.0	228	24.7
Taraxacum officinale Weber ex Wigg.	P	16	1.0	8	1.3	4	2.3
Thlaspi arvense L.	A	1252	127.0	1668	139.3	584	53.6
Tripleurospermum inodorum (L.) Sch. Bip.	A	344	373.4	204	67.0	36	4.0
Tussilago farfara L.	P	32	12.4	24	39.1	–	–
Veronica spp.	A	240	16.6	200	19.0	216	18.4
Vicia cracca L.	P	68	11.0	104	27.0	20	4.0
Vicia hirsuta (L.) Gray	A	16	0.9	12	0.5	–	–
Viola arvensis Murray	A	548	21.1	864	46.6	480	31.6
Total		16052	5230.49	17824	5273.03	7284	1817.76

Note. [1] – species were classified as annuals (A), biennials (B) or perennials (P) according to their life cycle.

It is known that animal manure may contain numerous viable weed seeds. In this study, the abundance of weed seeds in manure was not investigated. Weed seeds enter livestock systems from forages, grain, and other feed products. The biggest contribution of weed seed can come from contaminated hay and grain, however. A number of studies have measured the viability of weed seeds following animal digestion (Harmon, Keim, 1934; Blackshaw, Rode, 1991). They found that nearly 25% of the seeds fed to cattle recovered in the manure. Our study showed that the *P. persicaria* abundance in the ORGFYM treatment, was about 31-fold higher (860 shoots m^{-2}) than in the CONFYM treatment (28 shoots m^{-2}) and 12.6-fold higher than in the ORGGRM treatment (68 shoots m^{-2}) (Table 4). Its smaller abundance in the CONFYM treatment, can be explained by the fact that *P. persicaria* was sensitive to herbicides. A similar distribution can be expected in the case of *M. arvensis*. The *Barbarea vulgaris* and *Erodium cicutarium* were found in the treatments where solid cattle manure had been applied (ORGFYM, CONFYM).

Equisetum fluviatile and *Convolvulus arvensis* were the only species that occurred in the ORGFYM treatment, but not in the ORGGRM and CONFYM (Table 4). Furthermore, besides *Chenopodium album* (2424 shoots m^{-2}), *Lamium purpureum* (1682 shoots m^{-2}), and *Thlaspi arvense* (1668 shoots m^{-2}), the *P. convolvulus* (1428 shoots m^{-2}) was one of the most abundant species in the ORGFYM treatment. It is thought that because of its climbing growth form this species is favoured by nitrogen fertilization (Haas, Streibig, 1982).

Among the perennials, *Elytrigia repens* was the most common species in all treatments, but it was the most abundant in the ORGGRM treatment (2164 shoots m^{-2}) (Table 4). The growth and development of *E. repens* are strongly favoured by large amounts of available nitrogen (Wedin, Tilman, 1996; Hansson, Fogelfors, 1998). Since nitrogen is usually deficient in organic cropping systems (Eltun et al., 2002; Kirchmann et al., 2007), normally, *E. repens* does not cause any major problems. Although the *E. repens* is a nitrophilous species, its greater abundance in the ORGGRM treatment might have resulted from its higher light requirements and high soil fertility of the study area. The same conclusion can be made for *Cirsum arvense*, because it was also most numerously represented in the ORGGRM treatment (292 m^{-2}). *C. arvense* is relatively demanding for light and also favoured by high soil fertility (Ellenberg, 1974; Holm et al., 1977). Based on experimental results we can conclude that *E. repens* and *C. arvense* can cause problems in organic farming, especially in fertile soils.

As we expected, organic cropping treatments produced a higher mean species number of weed communities than conventional treatment. Similar results were also found in previous studies (Moreby et al., 1994; Hald, 1999; Menalled et al., 2001; Hyvönen et al., 2003; Bengtsson et al., 2005; Hole et al., 2005).

In general, the number of weed species as well as the total number of shoots and their biomass were higher in the organic treatments than in the conventional treatment ($p < 0.05$; Table 5).

The average number of species per 0.25 m^2 was 9.2 and 9.3 in the organic treatments and 4.9 in the conventional treatment. The average values of Shannon diversity index were statistically higher in the organic (ORGGRM – 1.70, ORGFYM – 1.65) than in the CONFYM (1.06; $p < 0.05$) treatment. No significant difference was identified between the organic treatments.

In addition to the treatment, the sampling year had a significant influence on weed species diversity, their abundance and biomass, especially in the organic treatments ($p < 0.05$) (Table 5). While the weather conditions (Table 3) in different years were quite similar, except for 2008 and 2009. In April 2008 and 2009, the average daily temperature was a little warmer than in other years. In April 2008, the amount of precipitation was 44.6 mm but in 2009 only 2.2 mm.

We assume that the reason for the increase in weed abundance in 2009 and 2011 may be linked with the field usage before our study. Since 2002, the field crops in the trial area have been cultivated according to the principles of organic farming, which could remarkably increase the soil weed seedbank. In 2007, when we started our study, soil seedbank in both organic treatments could be increased further because in the potato field mechanical weed control was delayed. The mechanical weed control, carried out later, did not provide the expected results. In addition to the delayed weed control in the end of July, in the organic treatments potato leaves were almost destroyed due to the late-blight disease. This also gave better light conditions for weed development. In this year, the *C. album*, *L. purpureum*, *T. arvense* and *C. bursa-pastoris* dominated in organic treatments. Although in 2007, the abundance of weeds in the organic treatments was not higher than in other years, the weed biomass was greater than in 2008 and 2010. In the autumn of 2007, the weed seeds that had fallen onto the soil surface were ploughed into the deeper soil layers. With the ploughing in the autumn of 2008, the weed seeds were brought back to the surface and increased weediness in 2009. In the autumn of 2009, again the weed seeds were ploughed into the deeper soil layer, which again were brought back to the surface with ploughing in the autumn of 2010 and increased weediness in 2011.

In Table 5, it is well shown that in 2009 the weed abundance in the ORGGRM (361 m^{-2}) and ORGFYM (473.5 m^{-2}) treatments was significantly higher than in other years. The same tendency was observed in 2011 (ORGGRM – 264.0 m^{-2}, ORGFYM – 208.5 m^{-2}). In 2009, the number of species per 0.25 m^2 (ORGGRM – 12.1, ORGFYM – 12.6) as well as Shannon index (ORGGRM – 2.05, ORGFYM – 2.10) were higher in the organic treatments, which was probably caused by the cultivation, that brought the weed seeds from deeper soil layer to the soil surface. In 2011, the number of species per 0.25 m^2 and Shannon indexes were slightly higher in the organic treatments; however, the differences were not statistically significant.

In conventional treatment, due to the use of herbicides the number of species, Shannon indexes per 0.25 m^2 and total number of weed shoots and their biomass per m^2 showed a decreasing tendency (Table 5).

To sum up, species diversity was higher in the organic than in the conventional cropping. The herbicide application was regarded as the most important factor affecting the number of weed species. Although, significant difference between organic treatments was not identified, the abundance of weeds and their biomass tended to be slightly higher in the organic treatment fertilized with solid cattle manure. However, average Shannon index was slightly higher in the ORGGRM treatment; the difference was not statistically significant.

Table 5. Mean values of treatments, year and their interaction

	Number of species 0.25 m^2	Shannon index 0.25 m^2	Total number of shoots m^{-2}	Biomass g m^{-2}
		Treatment		
CONFYM	4.9 b	1.06 b	94.1 b	23.8 b
ORGGRM	9.3 a	1.70 a	200.7 a	64.3 a
ORGFYM	9.2 a	1.65 a	228.9 a	70.4 a
		Year		
2007	6.2 b	1.38 b	91.2 b	74.2 a
2008	7.4 b	1.38 b	180.8 b	29.8 b
2009	10.3 a	1.80 a	321.8 a	77.5 a
2010	7.1 b	1.49 ab	104.6 b	28.5 b
2011	7.4 b	1.28 ab	171.8 b	56.2 a
		Treatment × year		
CONFYM, 2007	3.7 de	0.92 cd	60.3 ef	21.4 d
CONFYM,2008	6.6 bcde	1.23 bcd	165.3 cdef	20.4 d
CONFYM, 2009	6.1 cde	1.25 bcd	130.8 cdef	40.9 bcd
CONFYM, 2010	5.4 cde	1.28 bcd	71.0 ef	19.7 d
CONFYM, 2011	2.7 e	0.60 d	43.0 f	16.75 d
ORGGRM, 2007	6.8 bcde	1.41 abc	94.3 def	104.5 a
ORGGRM, 2008	7.4 bcde	1.49 abc	145.8 cdef	39.3 cd
ORGGRM, 2009	12.1 a	2.05 a	361.0 ab	77.2 ab
ORGGRM, 2010	8.4 abcd	1.83 ab	138.3 cdef	29.2 cd
ORGGRM, 2011	8.8 abc	1.62 abc	264.0 bc	77.7 ab
ORGFYM, 2007	8.3 abcd	1.79 ab	127.0 cdef	90.5 a
ORGFYM, 2008	8.1 abcd	1.43 abc	231.3 bcd	29.8 cd
ORGFYM, 2009	12.6 a	2.10 a	473.5 a	114.4 a
ORGFYM, 2010	7.5 bcd	1.37 bc	104.5 def	39.8 bcd
ORGFYM, 2011	10.6 ab	1.61 abc	208.5 cde	71.1 abc
		Test effect		
Treatment	<0.0001	<0.0001	<0.0001	<0.0001
Year	<0.0001	0.0001	<0.0001	<0.0001
Treatment × year	0.0062	0.0055	<0.0001	<0.0001

Notes. Different letters behind the mean values indicate significant differences ($p < 0.05$) in a category. Significances of model effects ($p >$ F) are indicated. For significant model effects a post hoc Tukey HSD test was performed to compare mean values.

Conclusions

1. The results of this study showed that land use intensity influenced weed species diversity. The number of weed species in the whole species pool was higher in the organic (ORGFYM and ORGGRM) treatments than in the conventional (CONFYM) treatment. The number of weed species in the ORGGRM was 39, in the ORGFYM – 36 and in the CONFYM – 30.

2. The average number of species per 0.25 m^2 was higher in the organic (ORGGRM – 9.3, ORGFYM – 9.2) than in the CONFYM (4.9) treatment.

3. The average values of Shannon diversity index were statistically higher in the organic (ORGGRM – 1.70, ORGFYM – 1.65) than in the CONFYM (1.06; $p < 0.05$) treatment.

4. *Arenari serpyllifolia*, *Equisetum fluviatile*, *Tussilago farfara* and *Vicia hirsuta* occurred only in the organic treatments, but not in the CONFYM treatment.

5. Herbicide application in the CONFYM treatment decreased the density of the most sensitive species (e.g., *Chenopodium album*, *Polygonum convolvulus*, *Mentha arvensis*, *Polygonum persicaria*, *Elytrigia repens*) but had a minor or no effect on the proportion of herbicide-tolerant species (especially *Viola arvensis*, *Veronica* spp., *Myosotis arvensis*).

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Piktžolių rūšių įvairovė ir bendrijų sudėtis tradicinio bei ekologinio ūkininkavimo sąlygomis: penkerių metų tyrimas

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Santrauka

Tyrimų tikslas – ištirti ekologinių (su mėšlu – ekologinė su kietu galvijų mėšlu ir žaliąja trąša (ORGFYM) bei be mėšlo – ekologinė su žaliąja trąša (ORGGRM)) ir tradicinės (žalioji trąša, galvijų mėšlas, mineralinės trąšos ir pesticidai (CONFYM)) auginimo sistemų įtaką piktžolių rūšių įvairovei, jų gausai ir biomasei.
Per tyrimų laikotarpį 2007–2011 m. iš viso nustatytos 44 piktžolių rūšys/taksonai. ORGGRM variante buvo 39 rūšių piktžolės (24 vienametės ir 15 daugiamečių), ORGFYM variante – 36 (21 vienametė, 1 dvimetė ir 14 daugiamečių) ir CONFYM variante – 30 (19 vienamečių, 1 dvimetė ir 10 daugiamečių). *Centaurea cyanus*, *Cerastium arvense*, *Geranium pratense*, *Myosurus minimus*, *Polygonum laphatifolia*, *Plantago lanceolata* ir *Plantago major* buvo tik ORGGRM variante. Piktžolių rūšių vidutinis skaičius 0,25 m^2 plote buvo 9,2 ir 9,3 taikant ekologinę auginimo sistemą ir 4,9 – tradicinę. Vidutinės įvairovės Shannon indekso vertės buvo statistiškai didesnės taikant ekologines sistemas (ORGGRM – 1,70, ORGFYM – 1,65), palyginus su tradicine CONFYM (1,6, $p < 0{,}05$). *Chenopodium album* buvo pati dažniausia vienametė piktžolių rūšis visuose variantuose. Nustatyta, kad herbicidų taikymas CONFYM variante sumažino pačių jautriausių piktžolių rūšių (pvz., *Chenopodium album*, *Polygonum convolvulus*, *Mentha arvensis*, *Polygonum persicaria*, *Elytrigia repens*) tankumą, bet turėjo nedidelį arba jokio poveikio herbicidams atsparioms piktžolėms (ypač *Viola arvensis*, *Veronica* spp. ir *Myosotis arvensis*). Tarp daugiamečių piktžolių visuose variantuose labiausiai paplitusi rūšis buvo *Elytrigia repens*. Didžiausias šių piktžolių skaičius nustatytas ORGGRM variante.
Nustatyta, kad bendras ir vidutinis piktžolių rūšių skaičius buvo didesnis taikant ekologinę auginimo sistemą, palyginus su tradicine. Esminių skirtumų tarp atskirų ekologinės sistemos variantų nebuvo nustatyta. Tyrimų rezultatai parodė, kad ekologinės auginimo sistemos skatina piktžolių rūšių įvairovę.

Reikšminiai žodžiai: piktžolių rūšių įvairovė, piktžolių daigų skaičius, piktžolių biomasė, Shannon indeksas, kietas galvijų mėšlas, herbicidai.