BIODIVERSITY OF WEED COMMUNITIES IN ORGANIC AND CONVENTIONAL ORCHARDS

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ABSTRACT

The aim of the study was to analyze the occurrence of segetal and ruderal weeds in young apple and cherry organic orchards, where weeds under tree canopies were controlled mechanically with a rototiller, and in conventional orchards, where post-emergence herbicides were used. The research material consisted of phytosociological relevés recorded according to the Braun-Blanquet method, in three organic and three conventional orchards, situated near Skierniewice (central Poland), in 2010-2013. On the basis of the collected source material, species composition for the synanthropic flora, as well as phytosociological stability, the cover factor, and weed infestation rate for the analysed species were determined. The total number of the recorded weeds and the average number of weed species in a single relevé were for each of the three organic orchards greater than for the conventional orchards. The organic orchard situated in the same location as the conventional orchard was characterized by a greater biodiversity of flora. Systematic shallow cultivation of the soil, without herbicide treatments, resulted in the proliferation of perennial weeds.

Key words: synanthropic flora, farming systems, apple and sour cherry trees, weed species

INTRODUCTION

The factors that modify the biodiversity of synanthropic flora in agricultural and horticultural crops are the environmental conditions and soil maintenance method. Research conducted in cereals and vegetables plots has shown that the number of weeds and their relative proportions vary depending on the forecrop, the species being cultivated, crop rotation, the time and number of cultivation treatments, and the type of tools, herbicides and mulches used (Derksen et al. 1993; Błażewicz-Woźniak 2004; Anyszka & Kohut 2011). In winter wheat, the cause of a reduction in biodiversity is systematic, simplified cultivation of the soil (Sekutowski & Domaradzki 2009) as well as monoculture and the use of herbicides (Jędruszczak & Antoszek 2004). Papers dealing with the differences in weed biodiversity between organic and conventional crops concern, for the majority of arable fields, mostly cereals

and root crops (Moreby et al. 1994; Albrecht & Mattheis 1998; Hald 1999; Elsen 2000; Rydberg & Milberg 2000; Hyvönen et al. 2003; Hole et al. 2005). The authors of most of them state that weed communities in organic crops are floristically more varied than those in conventional crops. No significant differences have been found in the total number of weed species between organic and conventional cultivation of root crops (Kuźniewski & Jezierska-Domaradzka 2007) and beans (Dobrzański & Pałczyński 2007). The main method of maintaining the soil under the crowns of trees in commercial orchards is still the use of herbicides, which determine the specific species composition of weed infestation (Wróbel 1999; Lipecki 2004; Lisek 2012), often of a cosmopolitan character (Mashaly & Awad 2003; Ustuner & Ustuner 2011). The literature on the species composition of weeds in organic orchards is scarce. According to Tasseva (2005) the diversity of weeds in organic orchards is greater than in conven-

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tional orchards and the species composition of their agrophytocoenoses can be different (Mika 2004). The authors of papers on the maintenance of soil in organic orchards focus primarily on the growth and yielding of trees, fruit quality, and the physicochemical properties of the soil, remarking only difficulties in controlling certain weed species, for example, *Agropyron repens* (Stefanelli et al. 2009; Rabcewicz & Białkowski 2011; Granatstein et al. 2014). Rabcewicz & Białkowski (2011), while assessing the effectiveness of controlling orchard weeds with a rototiller, reported that annual weeds were controlled more effectively than the perennial ones, but did not provide species composition of the infestation. The diversity of weeds affects the biodiversity of microorganisms, invertebrates, and birds (Marshall et al. 2003).

The aim of the study was to evaluate and compare the communities of weeds in organic and conventional apple and sour cherry orchards, and to identify weed species that can be a problem in the increasing number of new organic orchards.

MATERIALS AND METHODS

Orchards and environmental conditions

Phytosociological studies were conducted in three organic orchards in the localities of Dąbrowice, Mokra Lewa, and Maków, and in three conventional orchards in Dąbrowice, Julków and Ostrowiec, situated within a 20 km radius from Skierniewice (central Poland) and established in 2008. In the experimental orchard in Dąbrowice, owned by the Research Institute of Horticulture, the organic and conventional orchards were adjacent to each other. The organic orchards were comprised of apple trees ('Topaz'/M 26, 'Ariwa'/M 26) and sour cherry trees ('Sabina' and 'Debreceni Botermo', both on *Prunus mahaleb* seedlings), growing at a spacing of 4×2.5 m. The conventional orchards were comprised of apple trees ('Jonagold'/M26) and sour cherry trees ('Schattenmorelle' on *Prunus mahaleb* seedlings), planted at the same or similar (4×2 m) spacing. The orchards were situated on flatland (only the organic orchards in Mokra Lewa and Maków were situated on a slight slope, with a 1-2% gradient), on a pseudopodsolic soil of quality class IV or V, slightly acidic (pH 5.2-6.9). The soil

had the following mechanical composition – sand: 63-84%; silt: 12-35%; clay: 1-8%, and the organic matter content was 1.1-1.9%. The orchards in Dąbrowice, Julków and Ostrowiec were established on a land occupied by intensive fruit crops cultivated for at least 30 years, with a 2-3 year break for forecrops (cereals, mustard). The organic orchards in Mokra Lewa and Maków were established after short-lived crops (cereals, mustard, fruit nurseries in rotation).

Weed management

From the time of establishing the organic orchards, the soil under tree canopies, in 1.5 m wide strips, had been cultivated using an automatic retracting tree rotary weeder, 3-4 treatments per year, the first one in the second half of May, and the last one in August/September. The soil was tilled to a depth of 5-8 cm. In the conventional orchards, during the growing season, 3-4 treatments were performed with foliar herbicides: at least 2 treatments with glyphosate, one treatment with 2-methyl-4-chlorophenoxyacetic acid (MCPA), and one treatment with glufosinate-ammonium in some orchards and seasons. The inter-rows of the conventional orchards and the organic orchard in Dąbrowice were grassed over, whereas in the organic orchards in Mokra Lewa and Maków were cultivated with a rototiller.

Phytosociological relevés

In 2010-2013, 240 phytosociological relevés (60 per year) were recorded from a surface area of 0.8 ha in each of the orchards (0.4 ha apple and 0.4 ha sour cherry trees), prior to weed control treatments, according to the Braun-Blanquet method (1964). Half of the relevés, recorded in the second half of May, documented primary weed infestation. The other half of the relevés were recorded in the second half of August and documented secondary weed infestation. The relevés covered an area of 30 m² (20×1.5 m) of the soil under the tree crowns. Phytosociological stability and the cover factor were calculated for each weed species, and on the basis of these data weed infestation rate was determined.

Phytosociological stability (S) was expressed on a 5-point scale with an additional subclass. The stability classes according to the percentage of relevés in which a given species was found were as

follows: 5 – 81-100%, 4 – 61-80%, 3 – 41-60%, 2 – 21-40%, 1 – 2-20%, $\pm <1\%$ for all the relevés.

The cover factor (CF) represents the sum of the average percentages of soil coverage by a given species in all the relevés in which that species occurs/the total number of relevés $\times 100$. By adding the cover factors for the various short-lived species and the perennials, the percentage share of these two groups in covering the soil with weeds was determined.

Weed infestation rates were as follow:

I – very high: $S = 5$ or 4 , $CF > 1000$;

II – high: $S = 5$ or 4 , $CF = 501-1000$ or $S = 3$, $CF > 750$;

III – moderate: $S = 5$ or 4 , $CF = 251-500$ or $S = 3$, $CF = 501-750$;

IV – low: $S = 5$ or 4 , $CF = 51-250$ or $S = 3$, $CF = 251-500$;

V – sporadic: other lower stability classes and cover factors.

The data obtained from the relevés were analysed separately for each of the orchards under assessment.

Biodiversity of weed communities was compared for the organic orchard and the conventional orchard with apple trees in Dąbrowice with the following indices:

Shannon-Wiener's biodiversity index – H' (Shannon 1948)

$$H' = - \sum_{i=1}^S p_i \ln p_i$$

Simpson's dominance index – D (Simpson 1949)

$$D = \sum_{i=1}^S p_i^2$$

where:

$p_i = n_i/N$, n_i – number of individuals of the i -th species, N – total number of individuals; S – number of species.

The Shannon-Wiener biodiversity index (H') increases with the number of weed species in the community and the degree of equalization in their numbers. The Simpson dominance index (D) takes on values in the range from 0 to 1, and when the value reaches 1, it means there is no diversity (a single-species community). The bigger value of Simpson dominance index (D) means the lower biodiversity. The data on the number of each species, necessary for the calculation of the indices, were collected in mid-May, in randomly selected but evenly distributed

locations in the apple orchard, from 12 squares with an area of 0.25 m^2 ($0.5 \times 0.5 \text{ m}$) each, and converted to a surface area of 1 m^2 . The indices are presented as an average for four years.

RESULTS

The species composition of weed infestation in apple and sour cherry orchards did not differ, therefore data are presented together. The most important short-lived weed species occurring at rate I or II in all three organic orchards were *Echinochloa crus-galli* and *Chenopodium album* (Tables 1, 2, 3). Other annual species occurred at a very high or high rate in one of the organic orchards – *Amaranthus retroflexus*, *Stellaria media*, *Geranium pusillum* in Dąbrowice, and *Polygonum persicaria* and *Setaria pumila* in Mokra Lewa. Among the perennial weeds, *Agropyron repens* occurred at rate I or II in two organic orchards (Mokra Lewa and Maków), and *Equisetum arvense* in one of the orchards (Mokra Lewa).

The short-lived species: *Stellaria media*, *Poa annua* and *Capsella bursa-pastoris* occurred at rate I or II in three conventional orchards, *Chenopodium album* and *Echinochloa crus-galli* in two (Ostrowiec and Julków), and *Geranium pusillum* in one (Julków) (Tables 4, 5, 6). The perennial species *Equisetum arvense* and *Taraxacum officinale* (Ostrowiec), and *Epilobium adenocaulon* (Julków) heavily infested two conventional orchards.

The total number of the recorded weeds and the average number of weed species in a single relevé were for each of the three organic orchards greater than for the conventional orchards (Table 7). The share of short-lived weeds in covering the soil was much higher than the share of perennial weeds in the three conventional orchards and in one organic orchard – in Dąbrowice.

The value of the Shannon-Wiener index was higher, and the value of the Simpson index was lower for the organic orchard compared with the conventional orchard, which means that the weed community in the organically grown part of the orchard in Dąbrowice was characterized by a greater species diversity (biodiversity) than in the conventionally grown part of that orchard (Table 7).

Table 1. Biodiversity of weed communities in the organic orchard Dąbrowice, as an average for four years (2010-2013)

Species	Phytosociological stability (S)	Cover factor (CF)	Weed infestation rate
Short-lived			
<i>Echinochloa crus-galli</i> (L.) P. Beauv.	5	1582	I
<i>Chenopodium album</i> L.	5	1509	I
<i>Amaranthus retroflexus</i> L.	4	511	II
<i>Stellaria media</i> (L.) Vill.	4	505	II
<i>Geranium pusillum</i> Burm. F. ex L.	4	503	II
<i>Capsella bursa-pastoris</i> (L.) Med.	4	392	III
<i>Bromus hordeaceus</i> L.	4	386	III
<i>Bromus tectorum</i> L.	4	295	III
<i>Erodium cicutarium</i> (L.) L'Hér.	3	256	IV
<i>Vicia villosa</i> Roth.	2	165	V
<i>Setaria viridis</i> (L.) P. Beauv.	3	132	V
<i>Digitaria sanguinalis</i> (L.) Scop.	2	119	V
<i>Poa annua</i> L.	3	105	V
<i>Conyza canadensis</i> (L.) Cronq.	3	104	V
<i>Galinsoga parviflora</i> Cav.	3	98	V
<i>Polygonum aviculare</i> L.	4	95	V
<i>Atriplex patulum</i> L.	2	89	V
<i>Polygonum persicaria</i> L.	2	82	V
<i>Senecio vulgaris</i> L.	3	76	V
<i>Viola arvensis</i> Murr.	3	72	V
<i>Arenaria serpyllifolia</i> L.	2	58	V
<i>Crepis capillaris</i> (L.) Wallr.	1	56	V
<i>Crepis biennis</i> L.	1	52	V
<i>Hypochoeris glabra</i> L.	1	48	V
<i>Veronica arvensis</i> L.	2	42	V
<i>Matricaria maritima</i> L. ssp. <i>inodora</i>	2	39	V
<i>Chamomilla suaveolens</i> (Pursh) Rydb.	1	36	V
<i>Myosotis stricta</i> Lk.	1	26	V
<i>Spergularia rubra</i> (L.) Presl.	1	24	V
<i>Cerastium holosteoides</i> Fr. em. Hyl.	1	19	V
Perennial			
<i>Convolvulus arvensis</i> L.	3	459	IV
<i>Agropyron repens</i> L.	3	346	IV
<i>Taraxacum officinale</i> F.H. Wigg.	4	329	III
<i>Equisetum arvense</i> L.	2	298	IV
<i>Rumex crispus</i> L.	2	118	V
<i>Epilobium adenocaulon</i> Hausskn.	2	108	V
<i>Rorippa sylvestris</i> (L.) Besser	2	106	V
<i>Cirsium arvense</i> (L.) Scop.	1	38	V

Table 2. Biodiversity of weed communities in organic orchard Maków, as an average for four years (2010-2013)

Species	Phytoso- cological stability (S)	Cover factor (CF)	Weed infesta- tion rate
Short-lived			
<i>Chenopodium album</i> L.	5	1068	I
<i>Echinochloa crus-galli</i> (L.) P. Beauv.	4	793	II
<i>Raphanus raphanistrum</i> L.	3	620	III
<i>Matricaria maritima</i> L. ssp. <i>inodora</i> (L.)	3	367	IV
<i>Polygonum lapathifolium</i> L.	3	261	IV
<i>Polygonum persicaria</i> L.	3	254	IV
<i>Amaranthus retroflexus</i> L.	2	126	V
<i>Poa annua</i> L.	2	115	V
<i>Fallopia convolvulus</i> (L.) Á. Löve	2	111	V
<i>Digitaria sanguinalis</i> (L.) Scop.	2	106	V
<i>Conyza canadensis</i> (L.) Cronq.	2	106	V
<i>Erodium cicutarium</i> (L.) L'Hér.	2	97	V
<i>Spergula arvensis</i> L.	2	93	V
<i>Stellaria media</i> (L.) Vill.	2	91	V
<i>Scleranthus annuus</i> L.	1	88	V
<i>Capsella bursa-pastoris</i> (L.) Med.	2	63	V
<i>Vicia villosa</i> Roth.	2	58	V
<i>Euphorbia helioscopia</i> L.	2	51	V
<i>Galinsoga parviflora</i> Cav.	2	48	V
<i>Senecio vulgaris</i> L.	3	45	V
<i>Sonchus asper</i> (L.) Hill	3	32	V
<i>Centaurea cyanus</i> L.	2	31	V
<i>Geranium pusillum</i> Burm. F. ex L.	1	26	V
<i>Papaver rhoeas</i> L.	1	22	V
<i>Bromus hordeaceus</i> L.	2	19	V
<i>Thlaspi arvense</i> L.	1	16	V
<i>Spergularia rubra</i> (L.) Presl.	1	14	V
<i>Lactuca serriola</i> L.	+	8	V
<i>Gypsophila muralis</i> L.	+	6	V
<i>Consolida regalis</i> S.F. Gray	+	5	V
Perennial			
<i>Agropyron repens</i> L.	5	1984	I
<i>Cirsium arvense</i> (L.) Scop.	3	673	III
<i>Rumex acetosella</i> L.	3	529	III
<i>Equisetum arvense</i> L.	3	358	IV
<i>Artemisia vulgaris</i> L.	3	314	IV
<i>Sonchus arvensis</i> L.	2	306	V
<i>Rumex crispus</i> L.	1	86	V
<i>Trifolium repens</i> L.	2	82	V
<i>Tussilago farfara</i> L.	1	78	V
<i>Trifolium arvense</i> L.	1	76	V
<i>Taraxacum officinale</i> F. H. Wigg.	2	69	V
<i>Convolvulus arvensis</i> L.	1	63	V
<i>Hypochoeris radicata</i> L.	1	51	V
<i>Centaurea jacea</i> L.	+	9	V

Table 3. Biodiversity of weed communities in organic orchard Mokra Lewa, as an average for four years (2010-2013)

Species	Phytoso- cological stability (S)	Cover factor (CF)	Weed infesta- tion rate
Short-lived			
<i>Echinochloa crus-galli</i> (L.) P. Beauv.	5	1006	I
<i>Polygonum persicaria</i> L.	3	756	II
<i>Chenopodium album</i> L.	5	702	II
<i>Setaria pumila</i> (Poir.) Roem. et Schult.	4	559	II
<i>Matricaria maritima</i> L. ssp. <i>inodora</i> (L.)	3	187	V
<i>Viola arvensis</i> Murr.	2	101	V
<i>Raphanus raphanistrum</i> L.	2	99	V
<i>Conyza canadensis</i> (L.) Cronq.	2	97	V
<i>Polygonum aviculare</i> L.	2	96	V
<i>Fallopia convolvulus</i> (L.) A. Löve	2	72	V
<i>Sinapis arvensis</i> L.	2	68	V
<i>Anthemis arvensis</i> L.	2	66	V
<i>Spergula arvensis</i> L.	2	58	V
<i>Senecio vulgaris</i> L.	2	56	V
<i>Capsella bursa-pastoris</i> (L.) Med.	2	52	V
<i>Poa annua</i> L.	2	48	V
<i>Polygonum lapathifolium</i> L.	2	46	V
<i>Vicia villosa</i> Roth.	2	45	V
<i>Gnaphalium uliginosum</i> L.	1	42	V
<i>Stellaria media</i> (L.) Vill.	2	41	V
<i>Vicia hirsuta</i> (L.) S.F. Gray	1	39	V
<i>Lamium amplexicaule</i> L.	1	38	V
<i>Geranium pusillum</i> Burm. F. ex L.	1	37	V
<i>Galinsoga parviflora</i> Cav.	2	32	V
<i>Galeopsis tetrahit</i> L.	1	31	V
<i>Myosotis stricta</i> Lk.	2	30	V
<i>Spergularia rubra</i> (L.) Presl.	2	29	V
<i>Erigeron acer</i> L.	1	28	V
<i>Erigeron ramosus</i> (Walt.) B.S.P.	1	22	V
<i>Erigeron annuus</i> (L.) Pers.	1	21	V
<i>Senecio jacobaea</i> L.	1	19	V
<i>Polygonum hydropiper</i> L.	1	17	V
<i>Lactuca serriola</i> L.	1	14	V
<i>Anagallis arvensis</i> L.	+	8	V
Perennial			
<i>Equisetum arvense</i> L.	5	1368	I
<i>Agropyron repens</i> L.	4	897	II
<i>Rumex acetosella</i> L.	3	680	III
<i>Artemisia vulgaris</i> L.	3	510	III
<i>Cirsium arvense</i> (L.) Scop.	3	426	IV
<i>Convolvulus arvensis</i> L.	2	394	V
<i>Rorippa sylvestris</i> (L.) Besser	2	282	V
<i>Rumex crispus</i> L.	2	156	V
<i>Stachys palustris</i> L.	1	59	V
<i>Potentilla anserina</i> L.	1	52	V
<i>Potentilla reptans</i> L.	1	49	V
<i>Epilobium adenocaulon</i> Hausskn.	2	48	V
<i>Hieracium pilosella</i> L.	1	45	V
<i>Plantago major</i> L.	2	41	V
<i>Ranunculus repens</i> L.	1	39	V
<i>Tanacetum vulgare</i> L.	1	31	V
<i>Mentha arvensis</i> L.	1	30	V
<i>Heracleum sphondylium</i> L.	1	28	V
<i>Tussilago farfara</i> L.	1	27	V
<i>Taraxacum officinale</i> F.H. Wigg.	1	22	V
<i>Solidago gigantea</i> Aiton	1	19	V
<i>Anthoxanthum odoratum</i> L.	1	18	V
<i>Carex hirta</i> L.	1	16	V
<i>Hypochoeris radicata</i> L.	1	14	V
<i>Leontodon hispidus</i> L.	1	13	V
<i>Holcus mollis</i> L.	1	12	V
<i>Dactylis glomerata</i> L.	1	11	V
<i>Alopecurus pratensis</i> L.	1	10	V
<i>Knautia arvensis</i> (L.) Coult.	+	8	V

Table 4. Biodiversity of weed communities in conventional orchard Dąbrowice, as an average for four years (2010-2013)

Species	Phytosociological stability (S)	Cover factor (CF)	Weed infestation rate
Short-lived			
<i>Stellaria media</i> (L.) Vill.	5	2250	I
<i>Capsella bursa-pastoris</i> (L.) Med.	5	1016	I
<i>Poa annua</i> L.	5	768	II
<i>Chenopodium album</i> L.	4	701	III
<i>Echinochloa crus-galli</i> (L.) P. Beauv.	4	699	III
<i>Geranium pusillum</i> Burm. F. ex L.	4	642	III
<i>Polygonum aviculare</i> L.	4	423	III
<i>Amaranthus retroflexus</i> L.	3	262	IV
<i>Lamium purpureum</i> L.	4	245	IV
<i>Polygonum persicaria</i> L.	2	167	V
<i>Bromus hordeaceus</i> L.	2	153	V
<i>Fallopia convolvulus</i> (L.) A. Löve	2	148	V
<i>Matricaria maritima</i> L. ssp. <i>inodora</i>	2	121	V
<i>Conyza canadensis</i> (L.) Cronq.	2	119	V
<i>Viola arvensis</i> Murr.	2	105	V
<i>Senecio vulgaris</i> L.	2	95	V
<i>Urtica urens</i> L.	1	83	V
<i>Lamium roseum</i> L.	3	59	V
<i>Myosurus minimus</i> L.	1	45	V
Perennial			
<i>Equisetum arvense</i> L.	5	272	III
<i>Taraxacum officinale</i> F. H. Wigg.	5	263	III
<i>Epilobium adenocaulon</i> Hausskn.	5	231	IV
<i>Convolvulus arvensis</i> L.	2	148	V
<i>Cirsium arvense</i> (L.) Scop.	1	79	V

Table 5. Biodiversity of weed communities in conventional orchard Julków, as an average for four years (2010-2013)

Species	Phytosociological stability (S)	Cover factor (CF)	Weed infestation rate
Short-lived			
<i>Geranium pusillum</i> Burm. F. ex L.	5	1120	I
<i>Chenopodium album</i> L.	4	1026	I
<i>Echinochloa crus-galli</i> (L.) P. Beauv.	4	1003	I
<i>Stellaria media</i> (L.) Vill.	5	891	II
<i>Poa annua</i> L.	5	754	II
<i>Capsella bursa-pastoris</i> (L.) Med.	5	692	II
<i>Arabidopsis thaliana</i> (L.) Heynh.	3	495	IV
<i>Lamium purpureum</i> L.	5	198	IV
<i>Galinsoga parviflora</i> Cav.	3	252	IV
<i>Bromus hordeaceus</i> L.	4	147	IV
<i>Senecio vulgaris</i> L.	3	123	V
<i>Polygonum aviculare</i> L.	2	121	V
<i>Myosurus minimus</i> L.	2	119	V
<i>Erophila verna</i> (L.) Chevall.	2	108	V
<i>Fallopia convolvulus</i> (L.) A. Löve	2	105	V
Perennial			
<i>Epilobium adenocaulon</i> Hausskn.	5	596	II
<i>Taraxacum officinale</i> F. H. Wigg.	5	398	III
<i>Trifolium repens</i> L.	2	114	V

Table 6. Biodiversity of weed communities in conventional orchard, Ostrowiec, as an average for four years (2010-2013)

Species	Phytosociological stability (S)	Cover factor (CF)	Weed infestation rate
Short-lived			
<i>Echinochloa crus-galli</i> (L.) P. Beauv.	5	1484	I
<i>Stellaria media</i> (L.) Vill.	5	1256	I
<i>Capsella bursa-pastoris</i> (L.) Med.	5	1126	I
<i>Chenopodium album</i> L.	5	782	II
<i>Poa annua</i> L.	5	541	II
<i>Geranium pusillum</i> Burm. F. ex L.	5	476	III
<i>Amaranthus retroflexus</i> L.	3	166	V
<i>Lamium purpureum</i> L.	4	160	IV
<i>Galinsoga parviflora</i> Cav.	3	154	V
<i>Urtica urens</i> L.	3	152	V
<i>Bromus hordeaceus</i> L.	3	147	V
<i>Conyza canadensis</i> (L.) Cronq.	4	142	V
<i>Viola arvensis</i> Murr.	4	131	V
<i>Polygonum aviculare</i> L.	4	128	V
<i>Lamium roseum</i> L.	3	124	V
<i>Senecio vulgaris</i> L.	4	115	V
<i>Fallopia convolvulus</i> (L.) A. Löve	3	106	V
<i>Polygonum persicaria</i> L.	3	97	V
<i>Veronica persica</i> Poir.	3	92	V
<i>Matricaria maritima</i> L. ssp. <i>inodora</i>	2	81	V
<i>Sinapis arvensis</i> L.	2	78	V
Perennial			
<i>Equisetum arvense</i> L.	5	580	II
<i>Taraxacum officinale</i> F. H. Wigg.	5	532	II
<i>Epilobium adenocaulon</i> Hausskn.	5	302	III
<i>Cirsium arvense</i> (L.) Scop.	3	146	V
<i>Convolvulus arvensis</i> L.	3	139	V
<i>Trifolium repens</i> L.	2	98	V
<i>Rorippa sylvestris</i> (L.) Besser	2	96	V

Table 7. Biodiversity of weed communities in organic and conventional orchards as an average for four years (2010-2013)

Feature	Organic orchards – locality			Conventional orchards – locality		
	Dąbrowice	Maków	Mokra Lewa	Dąbrowice	Julków	Ostrowiec
Total number of weed species	38	44	63	24	18	28
Number of short-lived species	30	30	34	19	15	21
Number of perennial species	8	14	29	5	3	7
Number of broad-leaved species	30	38	53	20	15	24
Number of grassy species (including sedges)	7	5	9	3	3	3
Mean number of species in phytosociological relevé	19	21	24	11	12	16
Mean total cover factor	9278	9418	9867	9094	8262	9431
Total cover factor of short-lived weeds	7476	4740	4562	8101	7154	7538
Total cover factor of perennial weeds	1802	4678	5305	993	1108	1893
Contribution of short-lived species in weed covering (%)	80.6	50.3	46.2	89.1	86.6	79.9
Contribution of perennial species in weed covering (%)	19.4	49.7	53.8	10.9	13.4	20.1

Table 8. Biodiversity of weed communities in organic and conventional apple orchards Dąbrowice, as an average for four years (2010-2013)

Feature	Organic orchard	Conventional orchard
Mean number of weed species in spring relevé	21	13
Mean total number of weeds (plants·m ⁻²)	187.5	199.3
Shannon-Wiener's biodiversity index – H'	2.343	1.686
Simpson's dominance index – D	0.141	0.259

DISCUSSION

The synanthropic flora of orchards is formed under the conditions of a specific monoculture, which is characterized by long-term use, lack of tillage and crop rotation, frequent establishment of one orchard after another on specialized farms, and in the case of conventional orchards – regular use of herbicides as the only method of controlling weed infestation under tree crowns. For these reasons, the results of studies on orchards are difficult to compare with the results obtained for organic and conventional short-lived crops, for example, cereals and vegetables. Comparison of the species composition of the organic and conventional orchards has shown that weed species, such as *Echinochloa crus-galli* and *Chenopodium album* heavily infested both the organic orchards (all 3) and the conventional ones (2 of 3). Other short-lived species: *Stellaria media*, *Poa annua* and *Capsella bursa-pastoris* dominated in all the conventional orchards, which means that the use of postemergence herbicides contributes to their development at the expense of other species. Only one of these species, *Stellaria media*, played an important role in the organic orchard (Dąbrowice), which is undoubtedly connected with the succession of weed infestation. Indeed, the organic orchard in Dąbrowice was established in an area of long-term cultivation of fruit crops that had been treated with herbicides, and is an example of the conversion of conventional farming into organic crop growing. The role of herbicides in the compensation of weed infestation and 'promotion' of some species is proven by the fact that among the 25 weed species occurring in

a young organic orchard in Skierniewice, with soil cultivation and mulching, there was no presence of *Stellaria media*, *Capsella bursa-pastoris* or *Geranimum pusillum*, species typical for conventional orchards in the region, which were probably not competitive with vigorously growing weeds such as *Polygonum hydropiper*, *Amaranthus retroflexus*, and *Setaria pumila* (Mika 2004). An important role in determining the species composition of weed communities is played by the time of tillage. Mechanical weeding of root crops during the weed-growing period reduces the occurrence of overwintering annual weeds and stimulates the growth of summer annual weeds (Elsen 2000). This relationship explains the presence in the assessed organic orchards of large numbers of species such as *Echinochloa crus-galli*, *Chenopodium album*, *Amaranthus retroflexus*, and *Setaria pumila*. Glyphosate – the basic herbicide used in conventional orchards was equally effective in reducing the number of broad-leaved weed species and grassy species (including sedges). This is not consistent with the results of assessments of the flora in arable fields, on the basis of which it was found that grasses are more resistant to the intensive methods of weed control than broad-leaved weeds (Moreby et al. 1994; Hald 1999; Rydberg & Milberg 2000; Hyvönen et al. 2003).

In the organic orchards in Maków and Mokra Lewa, the proportion of short-lived and perennial weeds was similar, with *Agropyron repens* being an important species in both orchards. In all the conventional orchards and in the organic orchard in Dąbrowice, the soil was covered predominantly by short-lived weeds. The small share of *Agropyron repens* and other perennial weeds in the infestation of the organic orchard in Dąbrowice should be attributed to the succession of infestation and effective reduction in perennial weeds by repeated herbicide treatments in the past. The dominance of annual weeds in Dąbrowice confirms the thesis that the conversion of conventional farming into organic crop growing, after many years of herbicide use or frequent soil tillage, increases, to a limited extent, the biodiversity of weeds (Albrecht & Mattheis 1998). The share of *Agropyron repens* in the infestation of the organic orchards increased with each passing year. The total absence of *Agropyron repens*

in the conventional orchards confirms the thesis that the use of herbicides can completely eliminate some species from agrophytocoenoses (Rola & Rola 2001). The proliferation of couch grass in the assessed organic orchards should be attributed to low effectiveness of eradication by a shallow-working tiller or other tools (Rabcewicz & Białkowski 2011; Granatstein et al. 2014). Similar problems with the proliferation of *Agropyron repens* in organic orchards occur following the use of other ineffective methods of controlling it, such as organic (natural) herbicides/flaming, mulching, or mulching/flaming (Stefanelli et al. 2009; Granatstein et al. 2014).

The total number of weed species in each of the three organic orchards was higher than in the conventional orchards, which was likely a result of the way as the soil was maintained, more diverse environmental conditions, the surroundings of the orchard and succession. The assessed conventional orchards and the organic orchard in Dąbrowice were formerly a part of large complexes of orchards, whereas the orchards in Maków and Mokra Lewa were adjacent to field crops. The diversity of weeds in the organic orchards in Maków and Mokra Lewa may have been stimulated by crop rotation, which had been regularly conducted before the orchard was established (Derksen et al. 1993). One has to agree with the view that biodiversity is determined by a number of factors, not only the weed control method, environmental conditions, or crop rotation, but also the size and shape of the field, the type of neighboring crops and weed infestation in them, as well as the proximity of trees and natural habitats, which are, in their own way, random factors (Elsen 2000; Hole et al. 2005). Conclusive data on the effect of soil maintenance method on the diversity of weeds was provided by the comparison of the organic and conventional orchards in Dąbrowice. Biodiversity of weeds expressed by the number of species, Shannon-Wiener's biodiversity index (H') and Simpson's dominance index (D) was higher for the organic orchards than the conventional one. This confirms the results obtained in Bulgaria, where the number of weed species occurring in an organic orchard (16) was twice that found in a conventional orchard (8) (Tasseva 2005).

CONCLUSIONS

1. The biodiversity of weeds in the organic orchard was greater than in the conventional orchard.
2. Repeated shallow cultivation of the soil, without herbicide treatments, resulted in the proliferation of perennial weeds.
3. Species composition of weed infestation was modified by the method of soil cultivation, environmental conditions, and the succession of agrophytocoenoses.

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