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WEED SPECIES DIVERSITY IN ORGANIC AND INTEGRATED FARMING SYSTEMS

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Abstract

Phytosociological data were collected in 1994–1996 in plots (relevés) at the Research Station for Organic Farming and Conservation Breeding of the Polish Academy of Sciences in Popielno included in a large-area experiment conducted according to the concept and method proposed by Prof. S. Nawrocki. In a four-field crop rotation (root crops – spring barley undersown with red clover and grasses – red clover/grass mixture – winter triticale), each field was divided into two management units, organic and integrated. Data were collected in relevés by the Braun-Blanquet method, each year at the peak of the growing season. Weed abundance (% cover) in cultivated fields and the number of weed species (species richness) in crops were determined, which provided a basis for calculating the Shannon-Wiener indices of species diversity and evenness, and the Rényi profiles. The qualitative (species) and quantitative structure of weed communities was compared using the Sřrensen index.

A total of 115 weed taxa (species, subspecies and varieties) were identified in the examined agro-phytocenoses. *Echinochloa crus-galli*, *Chenopodium album*, *Matricaria maritima* subsp. *inodora*, *Capsella bursa-pastoris*, *Thlaspi arvense* and *Stellaria media* were the most abundant. Weed infestation was slightly higher in the organic farming system than in the integrated system. Organic farming contributed to higher weed species diversity in root crops, red clover/grass mixtures and winter triticale. Weed species richness was reduced in red clover/grass stands, while root crops and – to a lesser degree – spring barley undersown with red clover and grasses decreased weed species diversity. The species composition and in particular the quantitative structure of weeds were affected by crop species and cultivation regime rather than by the farming system. Weed communities of crops grown under organic and integrated farming systems were more similar with regard to species composition than the quantitative structure.

Key words: weeds, species richness**,** Shannon–Wiener index, Rényi profiles, Sørensen index, organic farming, integrated farming, crop rotation,

INTRODUCTION

The role of weeds in agricultural ecosystems has been the subject of an ongoing debate in recent years. On the one hand, weeds are pests harmful to crop plants [1], but on the other hand they may contribute to preserving biodiversity [2]. Weeds of arable land are a component of biological diversity in agricultural ecosystems, and they play a vital role in supporting diversity within crop fields. Many trophic and paratrophic relationships rely on arable weeds as primary producers [3].

Intensive farming focused on maximizing production efficiency has been a major cause of weed biodiversity decline, adverse changes in the species composition of weed communities, and ecological disturbances in agricultural ecosystems [4]. Increased awareness regarding the high environmental costs of agricultural intensification has prompted a search for solutions that promote the preservation and restoration of natural resources [5, 6, 7]. In view of human population growth, reconciling food security and biodiversity conservation is a grand challenge for agriculture [7, 8]. Organic farming contributes to the preservation and enhancement of biodiversity [9, 10], but it is not able to ensure sufficiently high production levels [11]. Integrated farming seems to bring harmony between agricultural production and the environment [12, 13]. As regards weed management, an ideal solution would combine eliminating aggressive species from croplands with maintaining ecologically “desirable” species [4].

Species richness (the number of species in a community) is a common measure of weed biodiversity, but relative abundance indices are also used to assess

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diversity [14]. The Shannon-Wiener index is one of the most popular and the most reliable diversity indices [15]. A relatively new approach to diversity assessment in segetal communities relies on biodiversity profiles [16].

Due to an increasing interest in weed biodiversity and new methodological trends in biodiversity studies, we analyzed data collected during an earlier experiment to compare weed species diversity in organic and integrated farming systems. The objective of this study was to compare the species diversity of weed communities in a four-field crop rotation under organic and integrated farming systems, using different measures of biodiversity.

MATERIALS AND METHODS

Phytosociological data were collected in 1994–1996 in plots (relevés) at the Research Station for Organic Farming and Conservation Breeding of the Polish Academy of Sciences in Popielno (Fig. 1), included in a large-area experiment conducted according to the concept and method proposed by Prof. S. Nawrocki. The following four-field crop rotation was applied over an area of 8 ha:

1. root crops (potatoes or fodder beets)
2. spring barley undersown with red clover and grasses
3. red clover/grass mixture
4. winter triticale.

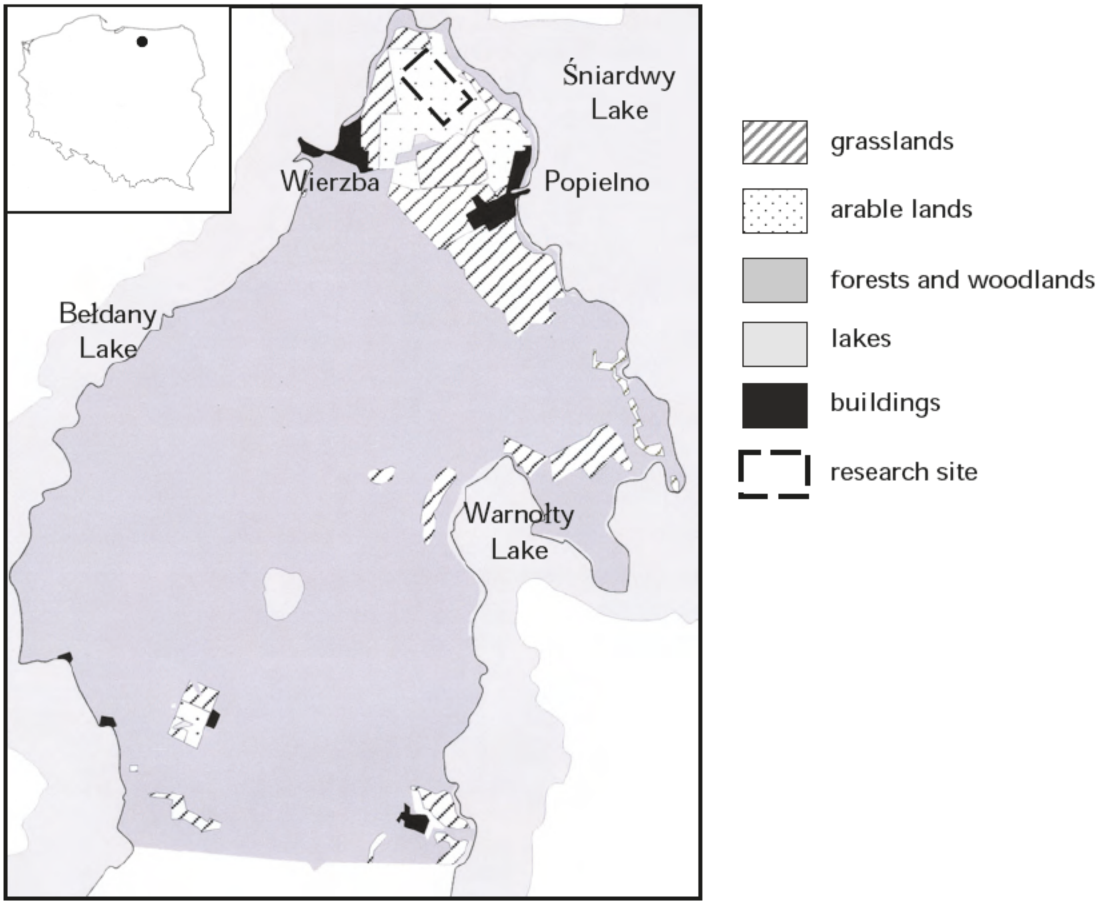

Fig. 1. Location of the research site on the Popielno Peninsula and land use structure.

Each of the four fields was divided into two management units, organic (O) and integrated (I) – both terms were defined by Prof. Nawrocki. In the organic cropping system, fertilization was limited to the application of composted manure to root crops, chemical plant protection products were not used, and weeds were controlled mechanically and manually (cereals – harrowing, root crops – mechanical and manual weed control). In the integrated cropping system, in addition to manure application and mechanical weed control (as in organic farming), mineral fertilizers and pesticides were applied at optimum rates so as to meet the economic criteria and nutrient requirements of plants, with strict observance of environmental regulations.

Proper brown soils developed from light loam, with the addition of heavy loamy sand and medium-heavy loam, are the predominant soil type on the Popielno Peninsula. Local climate conditions are influenced by Atlantic climate and continental climate [17, 18], with a moderating effect of water masses (in particular Lake Śniardwy) surrounding the Peninsula.

Data were collected in relevés each year at the peak of the growing season (five sets per plot, 120 in total). Cover-abundance values were listed for each species by the Braun-Blanquet method. The datasets were used to determine weed species composition and weed abundance (% cover) in cultivated fields. The grades of the quantitative Braun-Blanquet scale were converted as follows: r – weed species cover 0.5%, + – 2.5%, 1 – 7.5%, 2 – 17.5%, 3 – 37.5%, 4 – 62.5%, 5 – weed species cover 87.5%. The abundance of an individual weed species within the community was measured as the average area covered by this species. The abundance of the entire community was measured as the total area covered by all species. Datasets from each field were synthesized to form eight artificial communities (referred to as communities). The data grouped in this way were further processed.

Weed biodiversity within communities was estimated and compared based on:

- species richness (S) – number of species in the community;
- Shannon-Wiener diversity index (H'):
  $H' = -\Sigma (p_i \times \ln p_i)$,
- Shannon-Wiener evenness index (J'):
  $J' = H' \times (\ln S)^{-1}$,

where:

p_i – relative abundance of the *i*-th species in the community.

The effects of management system and crop species on the abundance and biodiversity of weed communities, measured by species richness and the Shannon-Wiener indices of species diversity and evenness, were determined by one-way ANOVA. The levels of the "farming system" factor were used as replications of the "crop species" factor, and vice versa. The homogeneity of variance within groups was determined by Cochran's C, Hartley's and Barlett's tests. Differences between treatments were estimated by Duncan's test at p=0.05. All calculations were performed using the STATISTICA 7 software package.

The Rényi profiles (H_α) were also generated to compare the effects of two cropping systems on weed biodiversity, using the below formula:

$$H_\alpha = (\ln \Sigma p_i^\alpha)(1-\alpha)^{-1},$$

where:

p_i – as in the Shannon-Wiener index;

α – diversity levels assuming that $\alpha \geq 0, \alpha \neq 1$; for α = 1, H' values were substituted into the formula.

The qualitative (species) and quantitative structure of weed communities was compared using the Sřrensen similarity index (SSI):

$$SSI = 2c \times 100 \times (a + b)^{-1},$$

where:

c – total number of species shared by the two communities or total abundance of species shared by the two communities

a – number of species or total abundance of species in the first community

b – number of species or total abundance of species in the second community

The scientific (Latin) names of weed species follow M i r e k et al. [19].

RESULTS

In a four-field crop rotation, weed infestation was slightly higher in the organic cropping system than in the integrated system, which was particularly noticeable in root crops and spring barley undersown with red clover and grasses (Table 1). However, the observed differences were statistically non-significant. Regardless of the farming system, the lowest weed abundance was observed in dense stands of red clover and grasses. Weed infestation was higher in grain crops than in red clover/grass mixtures, but a significant difference was only noted with respect to spring barley undersown with red clover and grasses. Weed infestation levels were highest in root crops.

Table 1
Weed abundance expressed as average cover (%) of all species (means for three years)

Crop species	Farming systems		
	O	I	mean
Root crops	110.7	81.1	95.9 a*
Spring barley undersown with red clover and grasses	66.2	45.2	55.7 b
Red clover/grass mixture	17.3	13.5	15.4 c
Winter triticale	45.6	37.9	41.8 bc
Mean	59.9 a*	44.4 a	

O – organic, I – integrated
* – values followed by the same letters within columns and rows are not significantly different at p=0.05

A total of 115 weed taxa (species, subspecies and varieties, including self-sown crop plants; Tab. 2) were identified in the examined agro-phytocenoses. The following weed taxa were most abundant in root crops: *Echinochloa crus-galli* (average cover of 42.5% and 33.5% in organic and integrated farming systems, respectively), *Chenopodium album* (17.5% and 10.8%, respectively), *Thlaspi arvense* (2.5% and 6.2%), *Sonchus arvensis* (5.8% and 0.5%), *Matricaria maritima* subsp. *inodora* (2.5% and 4.2%), *Agropyron repens* (3.5% and 1.2%), *Sonchus asper* (3.5% and 1.2%), *Sinapis arvensis* (3.3% and 0.8%). The majority of weed taxa identified in root crops did not reach 1% cover (79.8% of species in the organic system and 77.4% of species in the integrated system). In the phytocenosis of spring barley undersown with red clover and grasses, apart from the predominant species *Echinochloa crus-galli* (average cover of 21.2% in the organic system and 12.5% in the integrated system) and *Chenopodium album* (7.5% and 6.8%, respectively), the following taxa were characterized by relatively high abundance: *Agropyron repens* (2.8% and 3.5%), *Matricaria maritima* subsp. *inodora* (2.5% and 3.5%), *Stellaria media* (2.7% and 1.0%), *Veronica arvensis* (2.8% and 0.5%); the majority of taxa (77.4% in the organic system and 88.0% in the integrated system) were accessory and did not reach 1% cover. In dense stands of red clover and grasses, the following taxa reached 1.5% cover: *Stellaria media* (in both cropping systems), *Cirsium arvense* (in the organic system) and *Artemisia vulgaris* (in the integrated system), while the other taxa did not exceed the 0.5% threshold. In winter triticale fields, the highest abundance levels were reported for *Matricaria maritima* subsp. *inodora* (average cover of 3.5% and 7.5%, respectively) and *Vicia villosa* (6.0% and 2.8%, respectively), followed by *Capsella bursa-pastoris* (2.8% in both systems), *Stellaria media* (1.2% and 3.3%, respectively), *Agropyron repens* (3.5% and 0.5%), *Galeopsis tetrahit* (2.8% and 0.5%), and self-sown *Secale cereale* (2.7% and 2.5%). The average cover of the remaining species (80.2% in the organic system and 86.4% in the integrated system) did not exceed 1%.

Table 2

Species composition (total for three years) and average abundance of weeds (means for three years)

Weed species	Crop species							
	root crops		spring barley undersown with red clover and grasses		red clover/ grass mixture		winter triticale	
	Farming systems							
	O	I	O	I	O	I	O	I
Achillea millefolium	+	+	–	–	+	+	+	–
Agropyron repens	++	++	++	++	+	+	++	+
Alopecurus pratensis	–	–	–	–	–	–	+	+
Amaranthus retroflexus	+	–	–	–	–	–	–	–
Anagallis arvensis	+	+	–	–	–	–	+	–
Anchusa arvensis	++	++	+	+	–	–	+	+
Apera spica-venti	–	–	+	+	–	–	+	+
Aphanes arvensis	+	–	–	–	–	–	+	–
Arctium tomentosum	+	+	+	–	–	–	+	–
Arrhenatherum elatius	–	–	–	–	+	+	–	–
Artemisia vulgaris	+	+	+	+	+	++	+	+
Anthemis arvensis	–	+	–	–	–	–	–	+
Atriplex patula	+	+	+	+	–	–	–	–
Avena fatua var. glabrata	–	–	+	+	–	–	–	–
Avena fatua var. intermedia	+	+	++	+	–	–	–	–
Avena fatua var. vilis	–	–	–	+	–	–	–	–
Avena sativa	–	–	+	+	–	–	+	+
Brassica napus var. napus	+	+	–	–	–	–	–	–
Bromus hordeaceus	–	–	–	–	+	–	–	–
Capsella bursa-pastoris	++	++	++	++	+	+	++	++

Cardaminopsis arenosa	+	–	–	–	–	–	+	–
Centaurea cyanus	+	+	+	+	–	–	+	+
Cerastium arvense	–	–	–	–	+	–	+	+
Chamomilla suaveolens	+	–	+	+	+	+	–	–
Chenopodium album	+++	+++	++	++	+	+	++	++
Chenopodium rubrum	+	–	–	–	–	–	–	–
Cichorium intybus	+	–	+	+	–	–	–	–
Cirsium arvense	++	++	++	+	++	+	++	+
Consolida regalis	+	+	–	–	–	–	+	–
Convolvulus arvensis	+	–	–	–	–	–	+	–
Conyza canadensis	+	+	+	+	+	–	+	–
Cuscuta trifolii	–	–	–	–	+	–	–	–
Dactylis glomerata	–	–	+	+	–	+	–	–
Echinochloa crus-galli	++++	++++	+++	+++	–	–	+	+
Equisetum arvense	++	+	++	+	+	–	++	+
Erodium cicutarium	+	+	+	+	+	–	+	+
Euphorbia helioscopia	+	+	+	+	–	–	+	+
Euphorbia peplus	+	+	–	–	–	–	–	+
Fallopia convolvulus	+	+	+	+	–	–	+	+
Festuca pratensis	–	–	+	+	–	–	–	–
Fumaria officinalis	+	++	+	+	+	+	+	+
Galeopsis bifida	+	+	+	+	–	–	+	–
Galeopsis tetrahit	++	+	+	+	–	–	++	+
Galinsoga parviflora	+	+	+	+	–	–	+	+
Galium aparine	+	–	+	+	+	+	+	+
Galium spurium	+	–	+	+	+	+	+	+
Geranium pusillum	+	+	–	–	–	–	+	–
Glechoma hederacea	+	–	–	–	–	–	–	–
Gnaphalium uliginosum	+	+	–	–	–	–	+	+
Hypericum perforatum	+	–	–	–	–	–	+	+
Juncus bufonius	–	+	–	–	–	–	+	+
Lamium amplexicaule	+	+	–	+	–	–	+	+
Lamium purpureum	+	+	–	+	–	–	–	+
Lapsana communis	+	+	+	+	+	–	+	+
Lathyrus pratensis	–	–	–	–	–	–	+	–
Matricaria maritima subsp. *inodora*	++	++	++	++	+	+	++	++
Medicago lupulina	++	++	+	+	+	+	+	+
Melandrium album	–	–	+	+	+	+	+	–
Myosotis arvensis	+	+	+	+	–	–	+	+
Myosurus minimus	–	–	–	–	–	–	+	+
Papaver rhoeas	+	–	–	–	–	–	+	+
Pisum arvense	–	–	+	–	–	–	+	+
Plantago intermedia	+	–	+	+	+	–	+	+
Plantago lanceolata	+	+	+	+	–	–	–	+
Plantago major	+	–	–	–	+	–	+	+
Plantago media	+	+	+	+	+	+	+	+
Poa annua	+	+	+	+	+	+	+	+
Poa pratensis	–	–	–	–	+	+	–	–

Polygonum amphibium	–	–	+	–	–	–	–	–
Polygonum aviculare	++	+	++	+	+	+	+	+
Polygonum lapathifolium subsp. *lapathifolium*	++	+	++	+	+	+	+	+
Polygonum lapathifolium subsp. *pallidum*	+	–	–	+	–	–	+	–
Polygonum persicaria	+	+	–	–	–	–	+	–
Ranunculus arvensis	–	–	–	–	–	–	+	–
Raphanus raphanistrum	+	–	–	–	–	–	–	–
Rumex acetosa	–	–	+	+	–	–	–	+
Rumex acetosella	–	–	+	+	–	–	–	–
Rumex crispus	–	–	+	+	–	–	–	–
Rumex obtusifolius	–	–	+	+	–	+	–	–
Scleranthus annuus	+	+	+	–	–	–	–	–
Secale cereale	+	+	+	+	–	–	++	++
Senecio vulgaris	+	–	–	–	–	–	–	–
Setaria pumila	+	+	–	–	–	–	–	–
Setaria viridis	+	+	+	+	–	–	+	–
Sinapis arvensis	+	++	++	+	+	+	+	+
Solanum nigrum	++	++	–	–	–	–	+	–
Solanum tuberosum	+	–	–	–	–	–	–	–
Sonchus arvensis	++	+	++	+	+	+	++	+
Sonchus asper	++	++	+	++	+	–	+	+
Sonchus oleraceus	+	+	+	–	+	–	+	+
Spergula arvensis	+	+	+	+	+	–	+	+
Stellaria graminea	–	–	–	+	–	–	–	–
Stellaria media	+	++	++	++	++	++	++	++
Taraxacum officinale	+	–	+	+	+	+	++	+
Thlaspi arvense	++	++	++	+	+	+	++	++
Trifolium pratense	+	–	–	–	–	–	–	–
Trifolium repens	+	+	+	+	+	+	+	+
Triticale	+	+	–	–	–	–	–	–
Triticum aestivum	–	–	–	+	–	–	–	+
Tussilago farfara	–	–	–	–	+	–	–	+
Urtica dioica	+	–	–	–	–	–	–	–
Urtica urens	–	–	–	–	+	–	–	–
Veronica agrestis	+	+	+	+	+	+	+	+
Veronica arvensis	+	+	++	+	–	+	+	+
Veronica chamaedrys	–	–	–	–	+	–	+	–
Veronica hederifolia	+	+	+	+	+	+	–	+
Veronica persica	++	+	++	++	+	+	++	++
Veronica polita	+	+	–	–	–	–	–	–
Vicia cracca	+	–	+	+	–	–	+	+
Vicia hirsuta	+	–	++	+	–	–	+	+
Vicia sativa	–	–	+	–	–	–	+	+
Vicia tetrasperma	+	–	–	+	–	–	+	+
Vicia villosa	+	+	–	–	–	–	++	++
Viola arvensis	+	+	+	+	+	–	++	++
Viola tricolor	–	–	–	–	–	–	+	+

cover range: + – 0-0.99%, ++ – 1-9.99%, +++ – 10-24.99%, ++++ – 25-50%
O – organic, I – integrated

In general, more weed species were identified in the organic farming system (except in spring barley fields with undersown red clover and grasses; Tab. 3), but a statistical analysis did not confirm differences in weed species richness between the studied management systems. The phytocenosis of red clover and grasses was characterized by a significantly lower number of weed species than the other communities which formed a homogeneous group.

Table 4 data show that the species composition and in particular the quantitative structure of weeds were affected by crop species and cultivation regime rather than by the management system. Weed communities of crops grown under organic and integrated farming systems were more similar with regard to species composition (similarity coefficient of 74.7–90.2%) than abundance (66.9–72.9%). A comparison of pairs of crop plant communities in each system revealed substantially higher similarity with respect to floristic composition (47.3–75.2%) than quantitative structure (17.8–62.6%); in most cases, the communities in fields under organic farming were more similar than the corresponding pairs in the integrated system.

Table 3
Species richness (S) of weed communities (total for three years)

Crop species	Farming systems		
	O	I	mean
Root crops	84.0	62.0	73.0 a*
Spring barley undersown with red clover and grasses	66.0	67.0	66.5 a
Red clover/grass mixture	44.0	31.0	37.5 b
Winter triticale	76.0	66.0	71.0 a
Mean	67.5 a*	56.5 a	

O – organic, I – integrated
* – values followed by the same letters within columns and rows are not significantly different at p=0.05

Table 4
Similarity (SSI) of weed communities (total for three years)

Compared communities	Similarity based on	
	presence / absence of species	species abundance
O – I		
Root crops	80.8	72.9
Spring barley undersown with red clover and grasses	90.2	72.8
Red clover/grass mixture	74.7	71.5
Winter triticale	81.7	66.9
O		
Root crops – spring barley undersown with red clover and grasses	70.7	62,6
Root crops – red clover/grass mixture	54.7	18.0
Root crops – winter triticale	78.8	35.5
Spring barley undersown with red clover and grasses – red clover/grass mixture	61.8	29.0
Spring barley undersown with red clover and grasses – winter triticale	71.8	43.9
Red clover/grass mixture – winter triticale	60.0	37.0
I		
Root crops – spring barley undersown with red clover and grasses	68.2	56,3
Root crops – red clover/grass mixture	47.3	17.8
Root crops – winter triticale	70.3	32.3
Spring barley undersown with red clover and grasses – red clover/grass mixture	57.1	28.2
Spring barley undersown with red clover and grasses – winter triticale	75.2	43.5
Red clover/grass mixture – winter triticale	49.5	31.2

O – organic farming system, I – integrated farming system

In comparison with the integrated cropping system, organic farming contributed to higher weed species diversity (H' index) in root crops, red clover/grass mixtures and triticale (a statistical tendency, Table 5). The above data correspond to those based on species richness. A different trend was noted in weed species diversity in crop plant communities. Root crop fields, where the number of weed species was highest, were characterized by the lowest index of species diversity. Weed species diversity was higher in stands of spring barley undersown with red clover and grasses, and the highest in stands of red clover and grasses (where species richness was lowest) and winter triticale.

The Rényi profiles show that weed communities of root crops, red clover and grasses, and winter triticale grown under the organic farming system were characterized by higher biodiversity at all alpha (α) values than the corresponding communities in the integrated system (the respective curves do not intersect at any point; Fig. 2). An opposite, yet equally clear trend was observed for weed biodiversity in stands of spring barley with undersown red clover and grasses: the integrated system supported higher weed biodiversity at values of the parameter α ranging from zero to infinity.

The indices of weed species evenness (J') in the analyzed communities were high – they exceeded 0.5 and in some cases approached the maximum value (Table 6). The compared management systems had no significant effect on species evenness (to the advantage of the organic system). Each of the crop plant species formed a separate homogeneous group. The highest, almost maximum, species evenness was noted in the weed community in stands of red clover with grasses, followed by winter triticale, spring barley with undersown red clover and grasses, and root crops (relatively lowest evenness).

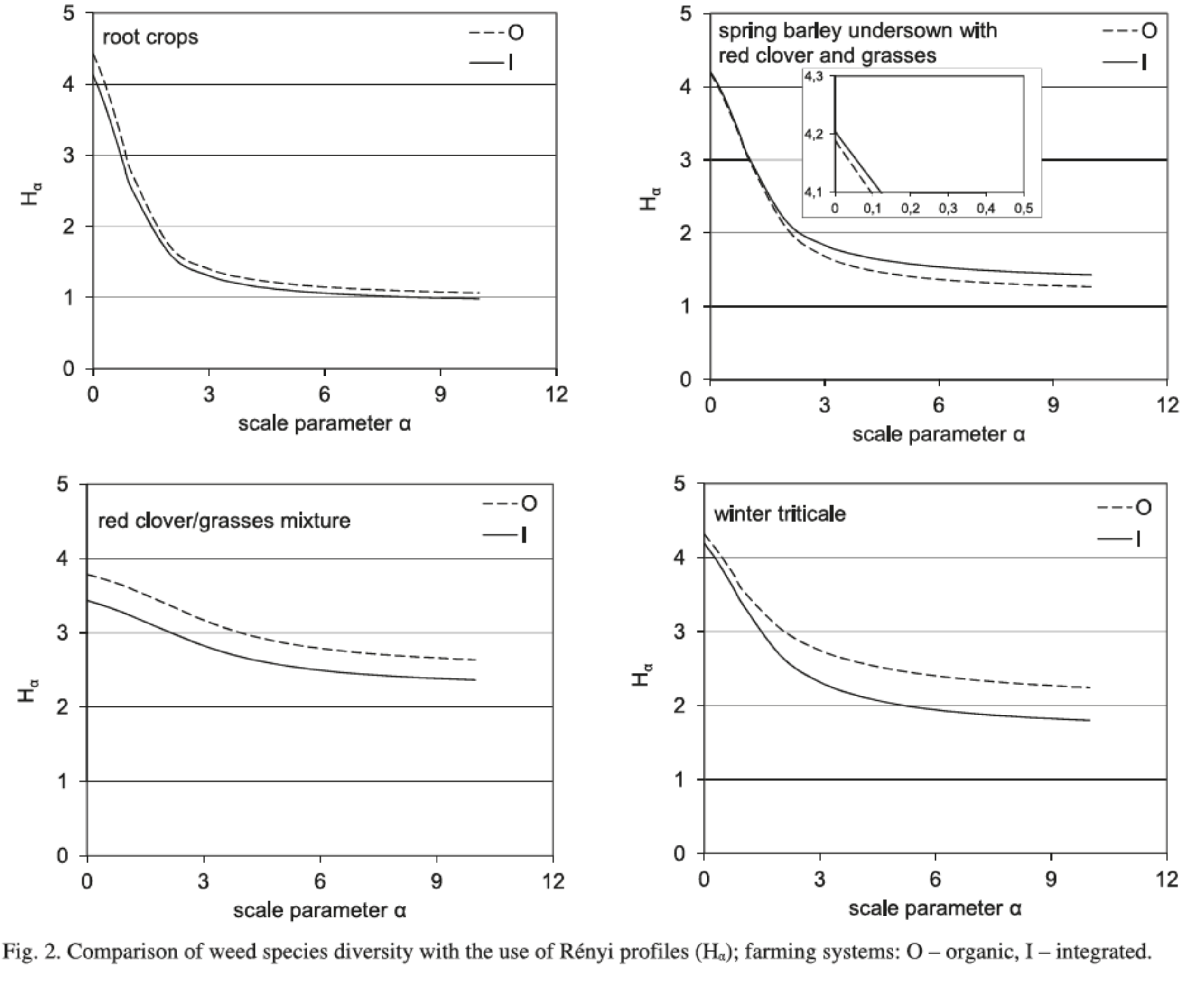

Fig. 2. Comparison of weed species diversity with the use of Rényi profiles (H_α); farming systems: O – organic, I – integrated.

Table 5
Species diversity (H') of weed communities (total for three years)

Crop species	Farming systems		
	O	I	mean
Root crops	2.75	2.53	2.64 b*
Spring barley undersown with red clover and grasses	3.02	3.04	3.03 ab
Red clover/grass mixture	3.62	3.26	3.44 a
Winter triticale	3.56	3,37	3.47 a
Mean	3.25 a*	3.05 a	

O – organic, I – integrated
* – values followed by the same letters within columns and rows are not significantly different at p=0.05

Table 6
Species evenness (J') of weed communities (total for three years)

Crop species	Farming systems		
	O	I	mean
Root crops	0.621	0.613	0.617 d*
Spring barley undersown with red clover and grasses	0.721	0.723	0.722 c
Red clover/grass mixture	0.957	0.949	0.953 a
Winter triticale	0.822	0.804	0.813 b
Mean	0.780 a*	0.772 a	

O – organic, I – integrated
* – values followed by the same letters within columns and rows are not significantly different at p=0.05

DISCUSSION

According to numerous authors [20–27], organic farming promotes weed biodiversity. Both weed abundance and the number of weed species are higher in the organic system than in the conventional system [20, 22, 24]. The above is associated with the absence of herbicides and earlier application of fertilizers, which leads to lower stand density thus creating niches for weed growth [28]. Less attention has been paid to comparing organic farming with integrated farming or integrated and conventional farming [22, 28–30], most probably due to differences in the definitions and classifications of agricultural management systems [31]. In some approaches, integrated farming is considered as part of the conventional system [32]. Due to differences in classification as well as in the scale and protocol of experiments, weed species diversity in fields under the integrated cropping system cannot be unambiguously placed in between the biodiversity values determined in conventional and organic systems [33, 34]. According to some authors [30], weed species diversity in integrated and conventional systems can be considered comparable, while other studies [35] point to higher similarity between integrated and organic systems in this respect. In a study by Feledyn-Szewczyk et al. [29], the Shannon-Wiener (H') diversity index calculated for segetal flora was higher in the integrated system than in the organic system, whereas a reverse trend was noted in species richness. Our findings suggest that organic farming had a protective effect on weed diversity, as compared with integrated farming. However, a different response of weed communities of spring barley with undersown red clover and grasses was noted: weeds in fields under the integrated system were characterized by higher biodiversity, as most clearly shown by the Rényi profiles. Feledyn-Szewczyk et al. [29] also reported higher weed diversity (determined using the Shannon-Wiener index) in spring wheat grown under the integrated system, as compared with the organic system; an opposite trend was observed in potato and winter wheat fields, which is consistent with our findings.

According to popular belief, more diverse weed communities are less harmful to crops and easier to control [36, 37]. In the exact sense, species diversity is defined as a combination of the number of species and their relative abundance [38]. Popular diversity indices, such as the Simpson index and the Shannon-Wiener index, are measures of diversity defined above, as opposed to species richness that refers to the number of species in a community, with each species given the same rank. High species richness is expected to be positively correlated with high diversity and low dominance. However, a comparison of the number of species and species diversity in weed communities does not always give consistent results [37] and this was also found in our study. Diversity profiles (Rényi entropy) quantify diversity as a multidimensional concept with the use of the parameter α [39]. A group of indices for measuring species diversity at different levels of α forms a "family", where α = 0 represents the number of species, α = 1 represents the Shannon-Wiener index (H'), α = 2 represents the Simpson index (C), and infinity represents the Berger-Parker index [16, 40]. The indices may be presented graphically by plotting a curve (a diversity profile). Assemblages can be ordered with respect to biodiversity if their profiles do not intersect. One assemblage is more diverse than another if its diversity has been confirmed at all levels of α If their profiles intersect, assemblages are incomparable and cannot be ordered with respect to biodiversity, because one of them is more diverse due to the presence of rare species (characterized by low abundance) than the other, and vice versa with regard to dominant species [41]. The Rényi profiles have been successfully used to assess the biodiversity of plant communities, while only a few authors have applied this method to compare weed communities [14, 37, 41] in different farming systems [42]. In a study conducted in Hungary, Zalai [42] used the Rényi diversity profiles to compare weed flora of organic and conventional maize and wheat fields. An assessment carried out by the cited author in May revealed higher weed species diversity in organic fields.

The hypothesis proposed in our study that the qualitative and quantitative structure of weed communities is affected by crop species and cultivation regime rather than by the management system corroborates the findings of Hyvönen and Salonen [43]. The cited authors compared low-input and conventional systems, but their general conclusions are identical to ours.

CONCLUSIONS

1. Weed infestation was slightly higher in the organic cropping system than in the integrated system.
2. Organic farming contributed to higher weed species diversity in root crops, red clover/grass mixtures and winter triticale.
3. Weed species richness was reduced in red clover/grass stands, while root crops and – to a lesser degree – spring barley undersown with red clover and grasses decreased weed species diversity.
4. The species composition and in particular the quantitative structure of weeds were affected by crop species and cultivation regime rather than by the farming system.
5. Weed communities of crops grown under organic and integrated farming systems were more similar with regard to species composition than quantitative structure.

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Authors' contributions

The following declarations about authors' contributions to the research have been made: designing the experiments: WPJ, CH; field research: WPJ; data analyses: MJ, WPJ, MKK; comments on the manuscript: CH, MKK; writing the manuscript: MJ, WPJ.

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Różnorodność gatunkowa chwastów na polach prowadzonych według zasad ekologicznego i integrowanego systemu gospodarowania

Streszczenie

Podstawą pracy są zdjęcia fitosocjologiczne wykonane w latach 1994–1996 na polach Stacji Badawczej Rolnictwa Ekologicznego i Hodowli Zachowawczej PAN w Popielnie, objętych doświadczeniem łanowym wg koncepcji i metodyki Prof. S. Nawrockiego. Każde z czterech pól realizowanego płodozmianu (okopowe – jęczmień jary z wsiewką koniczyny czerwonej z trawami – koniczyna czerwona z trawami – pszenżyto ozime) zostało podzielone na dwie części, na których rośliny uprawiano według zasad rolnictwa ekologicznego i integrowanego. Zdjęcia wykonywano corocznie w pełni wegetacji, metodą Braun-Blanqueta. Materiał wyjściowy poddano dalszemu opracowaniu pod kątem ustalenia przeciętnego pokrycia pól przez chwasty i liczby gatunków zachwaszczających rośliny uprawne (bogactwa gatunkowego chwastów). Na tej podstawie obliczono wskaźniki różnorodności i równomierności gatunkowej Shannona-Wienera oraz wyznaczono profile Rényi'ego. Strukturę gatunkową i ilościową zbiorowisk porównano za pomocą współczynników podobieństwa Sřrensena.

W badanych agrofitocenozach zidentyfikowano łącznie 115 taksonów (w randze gatunków, podgatunków lub odmian botanicznych), wśród których największą obfitością wyróżniały się: *Echinochloa crus-galli*, *Chenopodium album*, *Matricaria maritima* subsp. *inodora*, *Capsella bursa-pastoris*, *Thlaspi arvense*, *Stellaria media*. Rośliny uprawiane wg zasad rolnictwa ekologicznego były nieco silniej zachwaszczone niż w uprawie integrowanej. System ekologiczny sprzyjał różnorodności gatunkowej chwastów w uprawie okopowych, koniczyny czerwonej z trawami i pszenżyta. Łan koniczyny czerwonej z trawami ograniczał bogactwo gatunkowe chwastów, a okopowe oraz w mniejszym stopniu jęczmień jary z wsiewką – różnorodność gatunkową chwastów. System gospodarowania mniej różnicował skład gatunkowy chwastów, a zwłaszcza ich strukturę ilościową niż roślina uprawna i związana z nią agrotechnika. Zbiorowiska chwastów formujące się w roślinach uprawianych w systemie ekologicznym i integrowanym były bardziej podobne pod względem składu gatunkowego niż struktury ilościowej.

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