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WEED INFESTATION OF SPRING BARLEY IN CROP ROTATIONS WITH ITS DIFFERENT SHARE

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K e y w o r d s: spring barley, crop rotation, previous crops, weed infestation, biological indicators.

A b s t r a c t

The paper presents the results of a 3-year-long (2008–2010) study on the dynamics of weed infestation of spring barley sown after different previous crops (potato, spring wheat and spring barley, in 1- and 2-year sequences of the same crop) in four-field crop rotation systems with 25, 50 and 75% shares of spring barley. Weed infestation was evaluated at the barley tillering stage and before harvesting, with a focus on the number and species composition of weeds, as well as weed dry matter during harvest. The results were used for the calculation of the Shannon-Wiener diversity index and evenness index, Simpson's dominance index and Sørensen similarity index. Previous crops and share of spring barley in crop rotation significantly differentiated the infestation of spring barley with weeds at the tillering stage. The lowest weed infestation was found on the site of spring barley grown after potato in crop rotations with a 25 and 50% share of spring barley. Growing spring barley after spring wheat and in monoculture, and a 75% share of spring barley in crop rotation promoted the emergence of weeds. At the end of vegetation the number of annual and biennial weeds decreased by 45.3–79%, and the number of perennial weeds increased almost 3-fold with respect to their numbers in spring. The highest weed infestation was found in a four-field crop rotation with a 25% share of barley and on fields where spring barley was sown without an intercrop, and after spring wheat in crop rotations with a 75% share of spring barley. The highest biomass of weeds was produced in four-field with a 50% share of barley, where barley was grown after itself. Crop rotation had no effect on the species richness of weed communities. Lower diversity and evenness, and higher dominance of weed populations were found in communities on fields where barley followed potato in crop rotation with a 25% share of barley, and where barley was grown for two seasons without an intercrop in a crop rotation with a 75% share of barley.

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ZACHWASZCZENIE JĘCZMIENIA JAREGO W PŁODOZMIANACH Z RÓŻNYM JEGO UDZIAŁEM

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S ł o w a k l u c z o w e: jęczmień jary, płodozmian, przedplony, zachwaszczenie, wskaźniki biologiczne.

A b s t r a k t

W pracy przedstawiono 3-letnie (2008–2010) wyniki badań nad dynamiką zachwaszczenia jęczmienia jarego wysiewanego po różnych przedplonach (ziemniaku, pszenicy jarej oraz jęczmieniu jarym, w 1 i 2-krotnym następstwie po sobie) w czteropolowych płodozmianach z 25, 50 i 75% jego udziałem. Ocenę zachwaszczenia przeprowadzono w fazie krzewienia jęczmienia i przed jego zbiorem. Uwzględniała ona liczebność i skład gatunkowy chwastów, a podczas zbioru również ich suchą masę. Wyniki te posłużyły do obliczeń wskaźników różnorodności i równomierności gatunkowej Shannona-Wienera, dominacji Simpsona i współczynnika podobieństwa Sørensena. Przedplony i udział jęczmienia jarego w płodozmianie istotnie różnicowały jego zachwaszczenie w fazie krzewienia. Najmniejsze zachwaszczenie stwierdzono w stanowisku jęczmienia jarego po ziemniaku w płodozmianach z 25 i 50% jego udziałem. Uprawa po pszenicy jarej i po sobie oraz 75% udział jęczmienia w płodozmianie sprzyjały wschodom chwastów. Pod koniec wegetacji, w stosunku do stanu wiosennego, liczebność chwastów krótkotrwałych zmniejszyła się o 45,3–79%, a wieloletnich prawie 3- krotnie wzrosła. Najwięcej chwastów stwierdzono w czteropolówce z 25% udziałem jęczmienia oraz na polach po jęczmieniu jarym i pszenicy jarej w płodozmianach z 75% jego udziałem. Najobfitszą biomasę chwasty wykształciły w czteropolówce z 50% udziałem jęczmienia, w stanowisku jęczmienia po sobie. Nie stwierdzono wpływu płodozmianów na bogactwo gatunkowe zbiorowisk chwastów. Mniejszą różnorodność i wyrównanie, a zarazem większą dominację populacji odnotowano w zbiorowiskach pola po ziemniaku w płodozmianie z 25% udziałem jęczmienia oraz po jęczmieniu uprawianym dwa razy po sobie w płodozmianie z 75% jego udziałem.

Introduction

Specialised plant production increasingly frequently leads to simplification in crop rotation systems. This is reflected, for example, in a reduced number of grown plants and shorter intervals between the return of the same crop on the field. In most farms production methods are driven by economic factors. Farmers deliberately limit or even eliminate labour-intensive crops, and replace them with cereals, which are popular mainly because of economic reasons and usability. By exceeding a 70% share of cereals in the crop structure farmers switch from natural, correct crop rotation to its simplified forms, or even monoculture. This approach leads to increased abundance and biomass of weeds, with the simultaneous compensation of selected species (CAVERS and BENOIT 1989, STEVENSON et al. 1997, THOMPSON 1992). This results in lower yields of individual crops and whole cropping systems (MARSHAL et al. 2003, OERKE et al. 1994).

Many studies have demonstrated a significant role of the proper choice and sequence of plants in crop rotation in limiting weed infestation in cereals (SEIBUTIS and FEIZA 2008). The scale of weed pressure depends on the species and cultivar of cereals, but also on their natural competitiveness with segetal flora. Spring barley has a low tolerance to sowing without an intercrop (JOHNSTON 1997, ROUS 1992, STRNAD 1993), and its incorrect position in crop rotation creates favourable conditions for increased weed infestation of its canopy (JASTRZĘBSKA et al. 2012). ZAWIŚLAK and SADOWSKI (1992) concluded that only natural, correct crop rotation with a suitable interval between growing spring barley after itself helps to maintain weed density at the level not decreasing barley yield, while KOSTRZEWSKA and WANIC (2005) indicated that it also promotes the preservation of biodiversity in agrophytocenoses.

Considering the above, a research hypothesis was proposed that weed infestation of spring barley depends on its position in crop rotation. To verify the hypothesis a field experiment was established in order to evaluate the effect of position in crop rotations with 25, 50 and 75% shares of spring barley on the number and biomass of weeds and diversity of their communities.

Materials and Methods

The analysed data were obtained from 3-year-long (2008–2010) studies carried out in a strict static field experiment established in 2005 at the Production and Experimental Station in Bałcyny, near Ostróda (53°36’ N, 19°51’ E), an experimental centre of the University of Warmia and Mazury in Olsztyn. The experiment was carried out using the random block method in 4 replicates, on typical lessive (Systematyka gleb Polski 2011), Haplic Luvisol (Loamic) (IUSS 2015) soil formed from sandy clay loam. The topsoil (0–20 cm) contained 8.9 to 10.4 $g \cdot kg^{-1}$ C_{org}, was acidic (pH_{KCl} 5.5–5.7), and contained from high to very high levels of phosphorus and potassium (80 to 99 $mg \cdot 100\ g^{-1}$P of soil and 182 to 233 $mg \cdot 100g^{-1}$ K) and low levels of magnesium (36 to 47 $mg \cdot 100\ g^{-1}$). The studied crop was spring barley, Rastik cultivar, grown after different previous crops in the following crop rotations:

A (25% of barley – control site): potato – spring barley$^{(2)}$ – peas – spring wheat

B (50% of barley): potato – spring barley$^{(2)}$ – spring wheat – spring barley$^{(4)}$

C (50% of barley): potato – spring wheat – spring barley$^{(3)}$ – spring barley$^{(4)}$

D (75% of barley): potato – spring barley$^{(2)}$ – spring barley$^{(3)}$ – spring barley$^{(4)}$.

Soil for the experiment was prepared using a traditional tillage. In spring the soil was cultivated, treated with mineral fertilizers and harrowed. The barley seeding rate was 500 germinating kernels per m^2. The field was harrowed after sowing. Mineral fertilization did not differ depending on previous crops, and was adjusted to the content of nutrients in the soil. The dose of pure NPK component was 161 $kg \cdot ha^{-1}$ (N – 60; P- 35 and K – 66). Manure at a dose of 30 t ha^{-1} was applied once in autumn before planting potatoes in a four-year rotation. Barley was protected against mono- and dicotyledonous weeds from the tillering stage (BBCH 23–29) to the shooting stage (BBCH 30–32). Monocotyledonous weeds were controlled with a herbicide containing fenoxaprop-P-ethyl (Puma Universal 069 EW at a dose of 1.0 $l \cdot ha^{-1}$), and dicotyledonous with Mustang 306 SE (florasulam + 2,4D EHE) at a dose of 0.5 $l \cdot ha^{-1}$. Current weed infestation was assessed annually before the application of herbicides at the initial stage of barley tillering (BBCH 21–22) and before the barley harvest (BBCH 89–92). The assessment was focused on the number and species composition of weeds per m^2, as well as weed dry matter during the barley harvest. Measurements were taken using the frame technique in two replicates on each plot. The results were used for the calculation of Simpson's dominance index (1949) and the Shannon-Wiener diversity index and evenness index (1948). Weed communities were compared using the Srrensen similarity index (1948). Data on the number and biomass of weeds were processed statistically by using the analysis of variance and Duncan's test at a significance level of $p = 0.05$. Nomenclature of weed species was adopted after MIREK et al. (1995).

Results

Previous crops and the share of spring barley in crop rotation significantly differentiated barley weed infestation at the tillering stage (Table 1). Significantly lower weed density was found on the field after potato in four-field rotation A (control site) and the same sequence in crop rotation B with a 50% share of barley. Growing spring barley in crop rotations with a 50% of its share on the fields after spring wheat (B and C) and without an intercrop (C), as well as in rotation with a 75% share of the spring barley after potato and without an intercrop (D) significantly increased weed infestation. The number of taxa in the analysed plots in relation to the control crop rotation (A) was on average 27.2% higher, with the greatest difference (36.5%) in crop rotation B, with a 50% share of barley on the site after spring wheat. Weed communities were formed by 15–20 species. The highest weed richness was found in four-field crop rotation B, where barley was grown without an intercrop, and the lowest

Table 1

Weed infestation of spring barley at the tillering stage, plants · m^{-2}

Weed species	Crop rotation/field								Mean
	A/2	B/2	B/4	C/3	C/4	D/2	D/3	D/4	
Annuals and biennials									
Thlaspi arvense L.	29.7	10.0	54.7	28.0	41.0	36.9	26.2	24.2	31.34
Chenopodium album L.	43.9	23.0	33.4	36.3	32.2	25.8	31.3	17.3	30.40
Fallopia convolvulus (L.) A. Love	17.7	22.8	19.7	19.3	16.0	26.7	24.9	34.8	22.74
Veronica arvensis L.	4.4	18.3	11.4	21.6	22.0	22.5	25.0	15.3	17.56
Stellaria media (L.) Vill.	7.9	5.7	8.7	7.4	6.7	13.1	4.7	5.2	7.43
Galium aparine L.	0.9	1.3	1.7	7.3	4.0	7.3	5.4	5.8	4.21
Viola arvensis Murray	4.4	6.3	5.0	6.8	–	4.8	3.3	3.0	4.20
Spergula arvensis L.	–	6.1	3.7	6.0	8.7	–	3.8	3.7	4.00
Polygonum aviculare L.	3.2	4.7	5.5	3.4	7.0	1.4	–	2.7	3.49
Capsella bursa-pastoris (L.) Medicus	2.5	5.3	5.5	1.4	6.0	3.3	–	2.8	3.35
Polygonum lapathifolium L.	1.3	0.7	4.0	3.8	–	2.1	4.0	10.8	3.34
Galinsoga parviflora Cav.	3.3	–	2.2	0.7	–	4.7	7.7	3.0	2.70
Fumaria officinalis L.	2.0	0.4	4.7	–	–	5.8	3.3	1.8	2.25
Raphanus raphanistrum L.	2.0	2.7	–	4.3	1.1	–	3.3	1.8	1.90
Mentha arvensis L.	–	–	–	2.7	5.3	–	3.3	3.3	1.83
Vicia hirsuta (L.) S.F. Gray	–	5.0	0.7	2.0	1.8	–	–	–	1.19
Lamium amplexicaule L.	–	2.5	–	–	1.7	2.7	0.7	–	0.95
Lycopsis arvensis L.	–	2.9	2.2	–	–	–	1.2	1.2	0.94
Echinochloa crus-galli (L.) P.B.	1.8	–	–	–	3.7	1.3	–	–	0.85
Myosotis arvensis (L.) Hill	–	–	3.8	–	–	–	–	–	0.48
Veronica persica Poir.	–	–	–	–	–	3.2	–	–	0.40
Matricaria maritima (L.)	–	–	–	2.2	–	–	–	–	0.28
Erodium cicutarium (L.) L'Hérit.	–	–	–	–	–	–	–	1.6	0.20
Galeopsis tetrahit L.	–	–	1.0	–	–	–	–	–	0.13
Total annuals and biennials	125.0	117.7	167.9	153.2	157.2	161.6	148.1	138.3	146.1
Perennials									
Equisetum arvense L.	1.0	1.8	0.9	5.3	–	1.0	2.0	2.8	1.85
Sonchus arvensis L.	–	1.4	2.2	–	–	–	–	3.8	0.93
Cirsium arvense (L.) Scop	0.7	–	2.0	–	–	2.9	–	–	0.70
Agropyron repens (L.) Beauv.	–	–	–	–	1.4	–	–	–	0.18
Total perennials	1.7	3.2	5.1	5.3	1.4	3.9	2.0	6.6	3.65
Total per m^2	126.7^{c*}	120.9^{c}	173.0^{a}	158.5^{ab}	158.6^{ab}	165.5^{ab}	150.1^{b}	144.9^{bc}	149.78
Number of species	16	18	20	17	15	17	16	19	17

**a, b, c* – values marked with the same letter do not differ significantly at $p = 0.05$

on field C, with the same cropping sequence. The analysed phytocoenoses were formed mainly by annual and biennial weeds, typical spring and wintering species (more than 90% of all weeds). Of these, 4 species were dominant: *Thlaspi arvense, Chenopodium album, Fallopia convolvulus* and *Veronica arvensis*. Their share in weed communities ranged from 63.2% (crop rotation D on a field where barley was grown without an intercrop) to 75.5% (control four-field crop rotation). The higher weed infestation of barley grown after spring wheat in crop rotation B was mainly attributed to the greater abundance of *Thlaspi arvense* (density greater by 84.2% than in the control four-field crop rotation), the presence of *Myosotis arvensis* (not recorded on other sites) and the presence of *Sonchus arvensis* and *Agropyron repens*, while on site C – to *Veronica arvensis, Galium aparine, Viola arvensis* and *Matricaria maritima* (the latter taxon was not found on other fields). The higher weed infestation of barley grown after itself in crop rotation C was caused by the more abundant presence of *Thlaspi arvense, Spergula arvensis, Polygonum aviculare, Capsella bursa-pastoris* and *Mentha arvensis*, and on field D after potato because of *Thlaspi arvense, Fallopia convolvulus, Veronica arvensis, Stellaria media, Galinsoga parviflora* and *Fumaria officinalis*.

The number of weeds at the end of vegetation was 45.3–79% lower than in spring (Table 2). However, the decrease concerned annuals and biennials, while an almost 3-fold increase was found for perennial weeds. The highest weed density was found on the field where barley was grown after potato in the control crop rotation, and after spring wheat and without an intercrop in the four-field crop rotations B and C. On these fields the number of weeds was significantly greater (almost 2-fold) than on the other low-diversified sites. The analysed communities were formed by annual and biennial taxa, i.e. typical spring weeds and wintering weeds (69.3 to 86.8% of the total number of weeds) and perennials. *Galissoga parviflora, Chenopodium album, Fallopia convolvulus, Equisetum arvense, Veronica arvensis*, *Agropyron repens* and *Thlaspi arvense* were the dominant species. Perennial weeds not encountered in spring were also found, i.e. *Taraxacum officinale, Plantago lanceolata* and *Plantago major*. The highest species richness was found in four-field crop rotation B, on the site where barley was grown after wheat, and the lowest in the control crop rotation. Higher weed infestation resulted from the more abundant presence of *Galinsoga parviflora, Chenopodium album, Thlaspi arvense* and *Cirsium arvense* in the control crop rotation, *Galinsoga parviflora, Fallopia convolvulus, Polygonum aviculare* and *Equisetum arvense* in barley grown after wheat on site B, and *Galinsoga parviflora, Chenopodium album*, *Polygonum aviculare* and *Agropyron repens* on site C, where barley was grown without an intercrop.

The largest biomass of weeds was produced in four-field crop rotation C, on the site where barley was grown after itself (Table 3), and it was significantly greater than on other fields of the analysed cropping systems (almost 3-fold greater than in the control site). Weed biomass was also significantly greater in the field in crop rotation B, where barley was grown after wheat, than on the sites with potato as an intercrop in crop rotation C and both fields of crop rotation D. Differences between weed infestation on other fields were not

Table 2

Weed infestation of spring barley before harvest, plants · m^{-2}

Weed species	Crop rotation/field								Mean
	A/2	B/2	B/4	C/3	C/4	D/2	D/3	D/4	
Annuals and biennials									
Galinsoga parviflora Cav.	18.7	8.2	15.8	8.7	16.7	5.4	21.1	12.5	13.39
Chenopodium album L.	22.0	1.8	5.0	0.9	8.3	3.3	1.8	2.4	5.69
Fallopia convolvulus (L.) A.Love	1.0	5.8	10.3	6.1	6.0	4.6	3.3	7.2	5.54
Veronica arvensis L.	4.7	4.3	5.7	4.9	3.3	3.4	2.0	2.0	3.79
Thlaspi arvense L.	10.6	–	2.9	–	11.7	–	–	–	3.15
Echinochloa crus–galli (L.) P.B.	3.1	5.3	2.5	0.4	4.0	3.3	3.3	–	2.74
Polygonum aviculare L.	–	1.3	6.0	4.8	5.8	1.2	–	1.5	2.58
Veronica persica Poir.	–	2.7	3.3	1.7	2.3	1.4	4.7	2.0	2.26
Polygonum lapathifolium L.	–	0.7	0.8	2.4	–	–	0.7	0.8	0.68
Spergula arvensis L.	–	–	–	1.8	1.0	0.3	–	–	0.39
Mentha arvensis L.	–	–	1.0	1.2	–	–	–	–	0.28
Galium aparine L.	–	–	–	–	–	0.4	0.8	0.5	0.21
Capsella bursa-pastoris (L.) Medicus	–	–	–	–	–	0.8	–	0.9	0.21
Lamium amplexicaule L.	–	–	0.7	0.8	–	–	–	–	0.19
Galeopsis tetrahit L.	–	–	1.3	–	–	–	–	–	0.16
Viola arvensis Murray	–	0.7	–	–	–	–	–	0.5	0.15
Stellaria media (L.) Vill	–	–	1.4	–	0.8	–	–	–	0.28
Total annuals and biennials	60.1	30.8	56.7	33.7	59.9	24.1	37.7	30.3	41.69
Perennials									
Equisetum arvense L.	3.3	2.8	8.4	4.3	3.0	8.0	3.2	3.8	4.60
Agropyron repens (L.) Beauv.	1.8	1.3	5.0	2.5	11.2	2.7	0.7	1.5	3.34
Cirsium arvense (L.) Scop.	2.6	1.3	1.2	0.5	1.5	–	2.0	–	1.14
Sonchus arvensis L.	0.6	2.5	1.8	1.9	–	–	0.4	1.8	1.13
Taraxacum officinale F.H. Wigg.	–	1.0	–	–	–	–	1.0	–	0.25
Plantago major L.	–	–	–	–	0.7	–	–	–	0.10
Plantago lanceolata L.	0.8	–	–	–	–	–	–	–	0.09
Total perennials	9.1	8.9	16.4	9.2	16.4	10.7	7.3	7.1	10.65
Total per m^2	69.2^{a*}	39.7^{b}	73.1^{a}	42.9^{b}	76.3^{a}	34.8^{b}	45.0^{b}	37.4^{b}	52.34
Number of species	11	14	17	15	14	12	13	13	14

**a, b* – values marked with the same letter do not differ significantly at $p = 0.05$

significant. The dominant species in dry weed matter were *Chenopodium album, Thlaspi arvense, Galinsoga parviflora, Equisetum arvense* and *Agropyron repens*. The greater mass of dry weeds from the field of barley grown after itself in four-field rotation C was associated with the large biomass of *Chenopodium album*, *Thlaspi arvense* and *Equisetum arvense*. These weeds together formed 70% of the total biomass of the weed community. Growing barley after wheat in four-field crop rotation B promoted the development of *Agropyron repens;* the mass of this weed was almost 15-fold greater than in the control crop rotation, where barley was grown after potato. *Agropyron repens* was also abundant on the field where barley was grown after itself (site C).

Table 3

Weed infestation of spring barley before harvest, $g \cdot m^{-2}$

Weed species	Crop rotation/field								Mean
	A/2	B/2	B/4	C/3	C/4	D/2	D/3	D/4	
Annuals and biennials									
Chenopodium album L.	8.0	3.6	3.7	1.4	20.5	3.1	1.2	4.4	5.74
Thlaspi arvense L.	4.3	-	3.1	-	21.5	-	-	-	3.61
Galinsoga parviflora Cav.	3.0	2.7	2.7	1.3	6.0	3.7	5.9	1.9	3.40
Fallopia convolvulus (L.) A.Love	1.5	1.1	3.4	1.9	2.1	2.1	1.0	1.6	1.84
Veronica arvensis L.	0.2	1.2	2.8	2.6	0.8	1.7	0.4	0.9	1.33
Echinochloa crus-galli (L.) P.B.	2.8	2.5	0.6	0.5	0.8	1.0	1.5	-	1.18
Veronica persica Poir.	–	1.0	1.6	0.5	1.6	0.2	2.2	0.7	0.98
Polygonum aviculare L.	–	0.2	2.3	1.5	2.5	1.0	–	0.1	0.95
Polygonum lapathifolium L.	–	0.2	0.2	0.9	–	–	0.1	0.3	0.21
Galium aparine L.	–	–	–	–	–	0.2	0.6	0.2	0.12
Spergula arvensis	–	–	–	0.4	0.2	0.1	–	–	0.09
Mentha arvensis L.	–	–	0.1	0.4	–	0.1	–	–	0.06
Viola arvensis Murray	–	–	–	–	–	–	–	0.2	0.03
Galeopsis tetrahit L.	–	–	0.4	–	–	–	–	–	0.05
Avena fatua L.	–	–	0.3	–	–	–	–	–	0.04
Stellaria media (L.) Vill	–	–	0.1	–	0.1	–	–	–	0.03
Lamium amplexicaule L.	–	–	–	0.4	–	–	–	–	0.05
Capsella bursa-pastoris (L.) Medicus	–	–	–	–	0.01	–	–	0.3	0.05
Viola arvensis L.	–	0.1	–	–	–	–	–	–	–
Total annuals and biennials	19.8	12.6	21.4	11.8	56.1	13.0	12.9	10.6	19.76
Perennials									
Equisetum arvense L.	3.8	2.9	6.4	4.2	12.0	10.7	4.2	4.8	6.13
Agropyron repens (L.) Beauv.	0.7	5.0	10.7	0.5	6.7	1.5	0.2	0.6	3.24
Cirsium arvense (L.) Scop.	2.8	2.6	0.7	0.3	2.3	–	5.9	–	1.83
Taraxacum officinale F.H. Wigg.	–	0.9	–	–	–	–	0.2	–	0.14
Sonchus arvensis L.	0.1	4.0	–	0.1	–	–	0.1	1.8	0.90
Plantago major L.	–	–	0.7	–	–	–	–	–	0.09
Plantago lanceolata L.	0.4	–	–	–	–	–	–	–	0.05
Total perennials	7.8	15.4	18.5	5.1	21.0	12.2	10.6	7.2	12.38
Total per m^2	27.6^{bc*}	27.9^{bc}	39.9^{b}	17.5^{c}	77.1^{a}	25.2^{bc}	23.5^{c}	17.8^{c}	32.06

**a, b, c* – values marked with the same letter do not differ significantly at $p = 0.05$

Biological indicators reflecting the diversity of weed communities calculated based on their abundance demonstrated that both in spring and at the end of vegetation the barley canopy in the control crop rotation (grown after potato) was characterised by a greater dominance of weeds and a lower diversity and evenness of their individual populations (Table 4). Before harvest, populations less diversified in terms of their size were also recorded on the field cultivated in crop rotation D, where barley was grown after itself. There were no significant differences between other sites in terms of diversity. However, the values of indicators calculated based on weed biomass were different. The highest species dominance and the lowest diversity and even-

Table 4

Biological indicators for weed communities

Index	Crop rotation/field							
	A/2	B/2	B/4	C/3	C/4	D/2	D/3	D/4
Barley tillering – based on the number of weeds								
Dominance (λ)	0.21	0.12	0.16	0.13	0.15	0.13	0.14	0.12
Diversity (H')	1.99	2.43	2.27	2.35	2.20	2.31	2.25	2.43
Evenness (J')	0.72	0.84	0.76	0.83	0.81	0.81	0.81	0.83
Before barley harvest – based on the number of weeds								
Dominance (λ)	0.21	0.11	0.11	0.11	0.12	0.13	0.26	0.18
Diversity (H')	1.83	2.37	2.34	2.43	2.29	2.19	1.89	2.10
Evenness (J')	0.76	0.90	0.81	0.88	0.87	0.88	0.74	0.82
Before barley harvest – based on the air-dry matter of weeds								
Dominance (λ)	0.17	0.11	0.14	0.12	0.19	0.24	0.18	0.17
Diversity (H')	1.98	2.32	2.30	2.40	1.93	1.80	1.96	2.38
Evenness (J')	0.83	0.88	0.80	0.87	0.73	0.73	0.77	0.80

ness of weed populations were found for the field in crop rotation D, where barley was grown after potato. A lower evenness in comparison to other sites was also found for barley grown after itself in four-field crop rotation C.

The assessment of similarity for the analysed phytocenoses demonstrated significant differences between weed communities in barley grown after various previous crops (Table 5). At the tillering stage the greatest similarity was found for both fields of crop rotation: C – barley after wheat and after itself, C – barley after wheat and D – barley after barley, D – barley after potato and barley and D – after barley grown without an intercrop for one or two seasons. At the end of vegetation the greatest similarity in the population size and biomass was found for communities on the field in crop rotation B after potato and D – barley grown without an intercrop for two seasons, and C – after spring wheat and D – after barley. High levels of similarity in terms of population size were also found for the following pairs: B – after potato and D – after barley grown twice after itself, B – after wheat and C – after barley grown twice after itself and B – after wheat and C – after wheat, and in terms of biomass for D – after potato and D – after barley grown twice after itself.

Discussion

The effects of previous crops and share of spring barley in crop rotation on weed infestation of barley has been investigated by many authors (GAWĘDA at al. 2014, LÈGÈRE et al. 2005, LIEBMAN and STAVER 2001, O'DONOVAN et al. 2007). In our study the position and share of barley in crop rotation significant-

Table 5

Similarity index for weed communities, %

Compared weed communities in barley after different previous crops	Similarity based on		
	number	number	biomass
	at the barley tillering stage	before barley harvest	
A2/B2	61.3	43.4	59.1
A2/B4	74.3	54.3	50.7
A2/C3	76.2	39.5	42.7
A2/C4	69.1	67.8	47.2
A2/D2	71.4	39.4	50.5
A2/D3	70.9	56.4	55.5
A2/D4	64.0	44.1	55.7
B2/B4	65.5	60.9	58.5
B2/C3	73.0	70.6	46.6
B2/C4	68.0	55.3	38.6
B2/D2	66.5	67.8	51.8
B2/D3	69.9	66.7	53.8
B2/D4	68.9	73.2	61.1
B4/C3	73.0	66.4	54.4
B4/C4	75.1	70.6	52.2
B4/D2	74.3	60.2	59.0
B4/D3	70.4	59.1	40.2
B4/D4	65.6	64.2	52.8
C3/C4	78.8	55.1	27.7
C3/D2	74.6	63.0	59.7
C3/D3	83.1	51.4	47.1
C3/D4	72.4	70.4	64.9
C4/D2	73.5	51.3	46.4
C4/D3	73.3	57.1	34.9
C4/D4	63.1	54.3	31.9
D2/D3	79.0	54.1	49.4
D2/D4	70.7	65.2	61.5
D3/D4	78.5	65.9	47.1

ly determined its infestation with weeds. At the tillering stage (before treatments with herbicides) barley grown on the field after potato in four-field crop rotations A and B was infested by a significantly lower number of weeds than in other positions. However, in crop rotations with a 50 and 75% share of barley, growing barley without an intercrop (crop rotations C and D), after spring wheat (four-field crop rotation B), and after potato (system D) resulted in increased weed infestation. The lower weed infestation of barley grown after potato was associated with the use of well-decomposed manure in autumn and intensive soil management on that site (harrowing, cultivating, earthing), which destroyed the emerging weeds, thus reducing the size of the soil seed bank. The positive role of potato in reducing weed infestation of following crops was also emphasized by JASTRZĘBSKA et al. (2012) and of other root crops by MAJCHRZAK and PIECHOTA (2013).

Growing spring barley after itself and after spring wheat significantly increased weed infestation. Such a crop sequence promotes the emergence of weeds that have a developmental cycle similar to spring cereals (ZAWIŚLAK and SADOWSKI 1992). Moreover, it causes negative changes in the soil system that weaken the growth of the crop. This is reflected in a thinner canopy, and shorter plants with weaker foliage, which creates favourable conditions for the development of weeds producing greater numbers of seeds enlarging their soil bank (CAVERAS and BENOIT 1989, RIEMENS at al. 2007, ROBERTS 1981). In crop rotation D, higher weed infestation of barley grown after potato indicates that despite the positive effect of potato in other cropping systems reducing the infestation of barley with weeds, the one-year break after three seasons of growing barley on the same field was insufficient. Different findings were made by KOSTRZEWSKA and WANIC (2005), who reported no effect of growing barley without an intercrop in crop rotations systems with a 75% share of cereals on the number of weeds in the barley canopy during spring.

The use of herbicides, combined with the competitive effect of barley clearly reduced the number of weeds at the end of the growing season, eliminating the differences resulting from the crop position in the rotation system in most sites. DERKSEN et al. (1995) concluded that the use of herbicides has a stronger effect than the share of species in crop rotation. WOŹNIAK (2004) also found that weeding methods can significantly affect the density and biomass of weeds. In the analysed experiment higher weed infestation was only found for barley grown after spring wheat (four-field crop rotation B) and after barley following wheat (C). Greater weed biomass was also noted on site C. Importantly, growing barley after itself and a 75% share of barley in crop rotation was not associated with a significant increase in weed biomass, which was comparable to that in the control crop rotation, where barley followed potato. JASTRZĘBSKA et al. (2012) reported that the weed biomass was lower in barley grown after potato, and was higher in crop rotation with a 75% share of barley grown continuously on the same site for 3 seasons. Similar findings on the role of potato as a previous crops in limiting weed biomass were reported by KOSTRZEWSKA et al. (2011) and ORZECH and WANIC (2014).

In our experiment the position of barley in crop rotation did not significantly differentiate the species richness of weed communities. A slightly greater number of taxa was recorded only in crop rotation B, where barley was grown after spring wheat. MAJCHRZAK and PIECHOTA (2013) also concluded that the position in crop rotation has no significant effect on the number of weed species. The minor effect of crop rotation on the number of weed species in the barley canopy was also reported by LÈGÈRE et al. (2005). According to ZAWIŚLAK and SADOWSKI (1992), the sequence of cereals (including spring barley) has a stronger differentiating effect on the dominance of weeds than their species richness.

In the analysed communities the dominant species were typical spring annual and biennial weeds characteristic for spring cereals: *Thlaspi arvense*, *Chenopodium album*, *Fallopia convolvulus* and *Veronica arvensis,* and also *Galinsoga parviflora* at the end of vegetation. A greater share of perennial weeds (particularly *Equisetum arvense* and *Agropyron repens*) was also noted at the end of vegetation. Generally, the presented results are consistent with those reported by other authors. JASTRZĘBSKA et al. (2012) and KOSTRZEWSKA et al. (2011) indicated *Chenopodium album* as the dominant weed in the barley canopy. Similar conclusions were reached by ORZECH and WANIC (2014).

In our study the diversity index (H') was similar in spring and at the end of vegetation, regardless of the herbicide treatments. However, LÈGÈRE et al. (2005) demonstrated reduced values of this index when intensive agronomic methods were used. Contrasting findings were made by WILSON et al. (2003), who stated that data on the significant effects of herbicides on the diversity of weed communities are either limited or lacking, as demonstrated in our study.

In the presented study the values of the evenness index were moderate (0.72–0.90), suggesting a slight dominance of species in weed communities (LÈGERÈ et al. 2005).

Potato as a previous crops in crop rotation with a 25% share of barley caused a slight increase in the dominance and a decrease in the diversity and evenness of species in weed populations (calculated based on the population size). Before harvest the highest diversity in the population size was found in the crop rotation with a 75% share of barley grown without an intercrop. KOSTRZEWSKA and WANIC (2005) also found greater dominance and lower evenness of distribution for individual weed species in a crop rotation with a 50% share of barley on the site after potato. Moreover, KOSTRZEWSKA et al. (2011) documented minor differences in the diversity of weed species in spring barley as the effect of previous crops, while MAJCHRZAK and PIECHOTA (2013) demonstrated that a previous crops has no significant effect on the values of diversity and dominance indices. LÈGERÈ et al. (2005) found no significant effects of crop rotation on species diversity, but reported a clear trend towards reduced diversity in a monoculture and increased diversity in a crop rotation system, which was also proven by STEVENSON et al. (1997).

Conclusions

1. At the tillering stage (before herbicide treatment) the lowest weed infestation was found on fields where spring barley was grown after potato in crop rotations with 25 and 50% shares of barley. Growing barley after spring wheat and without an intercrop, and a 75% share of barley in crop rotation promoted the emergence of weeds.

2. At the end of vegetation the number of weeds was 45–79% lower than in spring. The highest weed infestation was found in a four-field crop rotation with a 25% share of barley, and on fields after spring barley and spring wheat in crop rotations with a 75% share of barley.

3. Crop rotation had no effect on the species richness of weed communities. Lower species diversity and evenness and higher species dominance were found in weed communities on fields where barley was grown after potato in crop rotation with a 25% share of barley and after barley grown twice after itself in a crop rotation with a 75% share of barley.

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