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THE INFLUENCE OF STRIP CROPPING AND WEED CONTROL METHODS ON WEED DIVERSITY IN DENT MAIZE (*Zea mays* L.), NARROW-LEAFED LUPIN (*Lupinus angustifolius* L.) AND OATS (*Avena sativa* L.)

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Abstract

The experiment was conducted in 2008–2010 at the Experimental Station of the Faculty of Agricultural Sciences in Zamość, University of Life Sciences in Lublin. The research design included two factors: I. Method of cultivation – sole cropping and strip cropping (the cultivation of three plants: maize, narrow-leafed lupin and oats, in neighboring strips); II. Weed control method – mechanical and chemical. The subject of this study was weed infestation in maize, narrow-leafed lupin and oats.

The greatest diversity of weeds was found in the narrow-leafed lupine crop, while the lowest diversity in maize. The dominant weed species in maize, lupine and oats were *Echinochloa crus-galli*, *Chenopodium album* and *Galinsoga parviflora* which ranged from 34% to 99% of the total number of weeds. Strip cropping clearly reduced the number of weeds per unit area in the narrow-leafed lupin and oat crops as well as the aboveground dry weight of weeds in all plant species. Chemical weed control significantly decreased both the number and weight of weeds in comparison with the mechanical method.

Key words: strip cropping, weed infestation, *Avena sativa* L., *Lupinus angustifolius* L., *Zea mays* L.

INTRODUCTION

Biodiversity in agrosystems plays an important role in providing ecological functions such as nutrient cycling, pest control or microclimate regulation [1]. Intensification of agriculture causes genetic uniformity of crops as well as reduced spatial and temporal variation of land use and simplifies the structure of the landscape [2]. Therefore, the idea of sustainable management is promoted, taking into account the high level of production and reducing the negative impact on the environment. It is recommended to use proper crop rotation and intercropping to increase species diversity in fields. Strip cropping is a form of intercropping. It involves growing two or more species of plants in strips wide enough to allow independent mechanical cultivation, yet narrow enough for the interaction of plants in adjacent strips. Placing the plants in separate strips causes the competition between them to be minimized and yield increases especially in the edge rows of a strip [3]. Less competition from pests and diseases gives the possibility to reduce pesticide use [4]. Strip cropping can affect weed infestation in plants. The studies conducted in Poland found that this system had an effect on reducing the density and biomass of weeds in a bean crop, while in maize only the number of weeds was reduced. Both in the bean and maize crops, the beneficial effect of strip cropping was particularly significant under mechanical weed control [5,6]. The effectiveness of strip cropping was dependent of crop species, the width of the strips and the weather conditions during the growing season [7,8]. The aim of this study was to evaluate the impact of cropping method (sole cropping and strip cropping) in combination with various methods of weed control (mechanical and chemical) on the state and degree of weed infestation in dent maize, narrow-leafed lupin and oats.

MATERIALS AND METHODS

The field experiment was carried out in 2008–2010 at the Experimental Station of the Faculty of Agricultural Sciences in Zamość, University of Life

Sciences in Lublin (50º 42'N, 23º 16'E), on brown soil, slightly acidic (pH_{KCl} – 6.0), with medium humus content (18 g × kg^{-1}), high abundance of available phosphorus and potassium (175 mg × P kg^{-1} and 206 mg K × kg^{-1}) and a medium level of available magnesium (57 mg Mg × kg^{-1}). The experiment was set up as a split-plot design, with four replications. The subject of the research was weed infestation of the 'Celio' variety of dent maize, the 'Sonet' variety of narrow--leafed lupin, and the 'Kasztan' variety of oats. The following factors were examined in the experiment: I. Cropping method (CM): 1. Sole cropping, in which the size of one plot of each crop plant was 26.4 m^2; 2. Strip cropping, in which three crops – dent maize (*Zea mays* L.), narrow-leafed lupin (*Lupinus angustifolius* L.) and oats (*Avena sativa* L.) – were grown side by side, each in a separate 3.3 m wide strip. The size of the plots was 13.2 m^2 each. II. Method of weed control: A – Mechanical: maize – weeding of interrows twice (first at the 5–6 leaf stage – BBCH 15–16 – and again two weeks later); narrow-leafed lupin – harrowing twice (first after sowing, pre-emergence – BBCH 00–01, then after emergence, before the plant reached a height of 5 cm – BBCH 13–15); oats – harrowing twice (first at the 1-leaf stage (BBCH 10), then at the 5-leaf stage (BBCH 15); B – chemical herbicides: maize – a.i. bromoxynil + terbuthylazine at 144 g × ha^{-1} + 400 g × ha^{-1} at the 4–6 leaf stage (BBCH 14/16); narrow-leafed lupin – a.i. linuron directly after sowing at 675 g × ha^{-1} + a.i. metamitron at 2,800 g × ha^{-1} after emergence, at the 2–3 leaf stage (BBCH 12/13); spring oats – a.i. 4-chloro-2-methylphenoxyacetic acid at 550 g × ha^{-1} at the full tillering stage (BBCH 22/23).

Agricultural procedures

Maize was grown on a site where the previous crop had been oats. Mineral fertilization was applied uniformly at rates of N 140, P 35, and K 100 kg × ha^{-1}. Phosphorus and potassium fertilizers were applied once before pre-sowing treatments, and nitrogen was applied in split applications (half before sowing, and the remainder at the stage 14/15 BBCH). In the successive years, maize was sown on 28 April as well as on 2 and 5 May. The sowing rate was 110,000 seeds per hectare, and the spacing between rows was 65 cm. In sole cropping, 10 rows of maize were planted in the plot, while in strip cropping 5 rows were planted. The maize was harvested at the milk-dough stage – BBCH 79/83.

Narrow-leafed lupin was grown on a site were the previous crop had been maize. Mineral fertilizers were applied uniformly at rates of N 20, P 26, and K 99 kg × ha^{-1}. All fertilizers were applied once before sowing. Seeding rate was 180 kg × ha^{-1}. The seeds were treated with Vitavax 200 FS (a.i. carboxin 200 g × dm^{-3} + thiram 200 g × dm^{-3}) before sowing. Lupin was grown for seeds and harvested at BBCH 89 in the second or third 10-day period of August.

Oats were grown on a site were the previous crop had been narrow-leafed lupin. Mineral fertilizers were applied uniformly at rates of N 60, P 22, and K 110 kg × ha^{-1}. All nutrients were applied once before sowing. In successive years of the study, oats were sown at the same time as narrow-leafed lupin at a rate of 180 kg × ha^{-1}. Before sowing, the seeds were mixed with the Zaprawa Nasienna T 75 DS/WS seed dressing (a.i. thiram 75%). Oats were harvested in the first or second 10-day period of August (BBCH 89).

In each of the crops grown in the experiment, the herbicides were applied with a Pilmet Sano 2 P-030 backpack sprayer. Mineral fertilizers were applied in following forms: N – ammonium nitrate, P – triple superphosphate, K – potassium salt.

Weather conditions varied over the study period. Rainfall was lowest in 2009 and it was lower than the long-term average. Moreover, rainfall was unevenly distributed over the years. A severe shortage of precipitation occurred in April and July, while heavy rainfall was recorded in May and June. In the years 2008 and 2010, rainfall was much higher and exceeded the long-term average by 56.4–61.8 mm. The average monthly temperatures for each year were higher than the long-term average.

Weed infestation of the crops was assessed two weeks before harvesting by determining the species composition, number and dry weight of weeds. In each plot, two random sample areas were marked off with a 1 m × 0.5 m frame. Within each frame, individual weed plants were counted and the floristic composition was determined. When the weeds had been extracted and their roots cut off, the plants were dried and weighed to determine the air-dry weight of individual species and the total weight of weeds. Species nomenclature followed Mirek et al. [9]. The results were analysed statistically using variance analysis. The differences between means were evaluated with Tukey's test. The results were tested at a probability of 95%.

RESULTS

***Zea mays* L.**

Twenty species were recorded in the maize crop. Of the five monocot taxa, *Echinochloa crus-galli* occurred frequently, while *Setaria pumila, Setaria viridis, Avena fatua* and *Elymus repens* sporadically. Despite the small number of species, monocots accounted for 24.5% to 45.3% of the total number of weeds (Table 1). Neither cropping systems nor weed control methods significantly affected weed species diversity in the maize crop. Irrespective of the experimental factors, *Galinsoga parviflora, Echinochloa crus-galli* and *Chenopodium album* were the dominant species, accounting for 99.0% and 70.8% of the total number of weeds in sole cropping, and for 82% and 47.6% in strip cropping, for mechanical and chemical weed control, respectively. *Polygonum lapathifolium*, *Galinsoga ciliata*, *Veronica arvensis* and *Polygonum convolvulus* were frequent, as well. *Galinsoga parviflora*, *Echinochloa crus-galli* and *Chenopodium album* were dominant due to their high biomass, especially where mechanical weed control was used (Fig. 1). There were no significant differences in the number of weeds per unit area of maize between strip cropping and sole cropping (Table 2). Aboveground biomass of weeds was significantly lower in strip cropping, by an average of 16%. The weed control methods significantly affected weed density in maize. On average in the experiment, the number of weeds in the plots with herbicides was 2.5 times lower than in the mechanically weeded plots. In maize, chemical weed control reduced the occurrence of *Galinsoga parviflora* by 85%, *Echinochloa crus-galli* by 56.6% and *Chenopodium album* by 75.4%. The effect of weed control method on reducing the dry weight of weeds was significant in each year of the study. On average for the study, the dry weight of weeds in the mechanically weeded plots was 3 times greater than in the treatment where herbicides were used. There was no significant interaction between cropping system and weed control method in determining changes in weed infestation indicators in maize.

Lupinus angustifolius L.

Irrespective of the experimental factors, the most frequently occurring species in the narrow-leafed lupin crop were *Chenopodium album*, *Echinochloa crus-galli* and *Galinsoga parviflora* (Table 3), accounting for 74.9% and 47.8% of the total number of weeds in sole cropping as well as for 65.4% and 34.1% in strip cropping, for the mechanical and chemical weed control methods, respectively. The next most frequent taxa were *Galium aparine*, *Polygonum lapathifolium*, Setaria pumila, and *Melandrium album*. Other species were rare or sporadic. Overall, 26 weed species were recorded in the lupin crop – 4 perennials and 22 ephemerals. Only 5 of the 26 taxa were monocots, but their share in the total number of weeds was relatively large – 21.5–34.8%. The cropping systems did not affect weed species diversity in lupin. Chemical weed control increased the number of species in the lupine crop (Table 3). The herbicides significantly reduced the number of *Chenopodium album* and *Galinsoga parviflora*. Strip cropping reduced the number of weeds per unit area, by 6% on average. The impact of the cropping system on weed biomass was much stronger. Strip cropping reduced the aboveground dry weight of weeds by 28.8% on average in relation to sole cropping. The study also confirmed a significant interaction between cropping systems and weed control methods. In the mechanically weeded plots, strip cropping reduced the number of weeds by 14% and their aboveground weight by 37.6%. Where chemical weed control was used, the differences between both the number and biomass of weeds were not significant. The weed control methods significantly affected the weed infestation indicators in lupin. On average for the experiment, chemical weed control reduced the number of weeds by 37.2% and their biomass by 52.7% compared to the mechanical treatment (Table 4). The use of herbicides strongly reduced both the frequency and biomass of *Chenopodium album* and *Galinsoga parviflora* (Table 3, Fig. 2).

Avena sativa L.

In the oat crop, 25 weed species occurred – 21 ephemerals and 4 perennials (Table 5). The most frequent species was *Chenopodium album*. Its percentage in the total number of weeds was 38.3% and 19.3% in sole cropping as well as 40.2% and 22.7% in strip cropping, for mechanical and chemical weed control, respectively. *Chenopodium album* also produced a large amount of dry matter, especially in the mechanically weeded plots (Fig. 3). *Galinsoga parviflora* and *Echinochloa crus-galli* were also common. The next most frequent species were *Melandrium album*, *Setaria pumila*, and *Lapsana communis*. The cropping system did not affect weed species diversity in oats. The weed control methods influenced the number of species in the oats crop. The effect of strip cropping on the number of weeds varied in different years of the study. However, on average for the experiment, strip cropping significantly decreased weed density. Strip cropping significantly reduced the dry weight of weeds in the oat crop, by 23.8% on average. Herbicide use significantly decreased the total number of weeds, by 53.2% on average, while weed biomass by 68.3%, compared to mechanical weed control. The herbicides strongly reduced both the number and biomass of *Chenopodium album* (Table 5, Fig. 3). There was no significant interaction between cropping systems and weed control methods (Table 6).

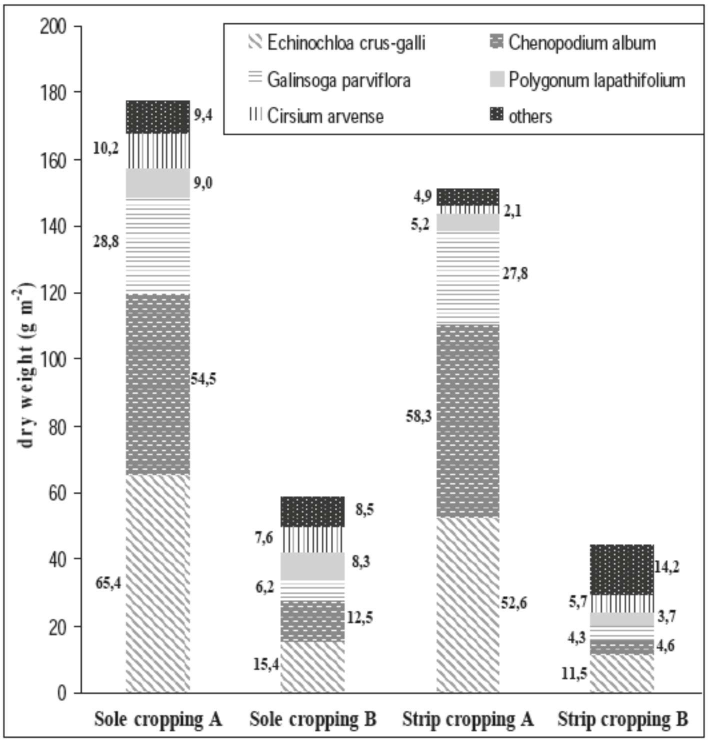

Fig. 1. Air-dry weight of aboveground parts of weeds species in maize canopy (mean for 2008-2010).

Table 1
Species composition and number of weeds per 1 m^2 of maize crop before harvest, depending on the cropping system (mean for 2008–2010 years)

Species composition	Sole cropping			Strip cropping		
	A	B	mean	A	B	mean
Short lived						
Echinochloa crus-galli (L) P. Beauv	13.8	5.5	9.7	7.4	3.7	5.9
Chenopodium album L	5.8	1.3	3.6	7.1	1.8	4.5
Galinsoga parviflora Cav.	18.1	2.9	10.5	12.0	1.5	6.8
Capsella bursa-pastoris (L.) Medik.	0.2	-	0.1	0.5	-	0.3
Galium aparine L.	-	0.3	0.2	0.2	0.5	0.4
Avena fatua L.	-	-	-	0.2	-	0.1
Polygonum lapathifolium L. *subsp. lapathifolium.*	1.0	0.8	0.9	0.3	0.4	0.3
Setaria pumila (Poir) Roem. & Schult	0.5	0.2	0.4	0.3	1.4	0.8
Melandrium album (Mill.) Gracke	0.2	-	0.1	-	-	-
Vicia hirsuta L.	-	0.4	0.2	-	0.3	0.2
Polygonum convolvulus L.	0.2	0.4	0.3	0.3	0.6	0.5
Veronica arvensis L.	0.6	0.9	0.8	0.3	0.9	0.6
Lapsana communis L.	-	0.2	0.1	-	-	-
Setaria viridis (L.) P. Bauer.	-	0.3	0.1	-	0.3	0.1
Galinsoga ciliata L.	1.3	0.2	0.8	0.4	1.4	0.9
Sonchus oleraceus L.	-	0.3	0.2	-	-	-
Geranium pusillum L.	-	0.2		0.1	0.1	0.1
Total of short-lived species	10	14	15	12	12	14
Perennial						
Equisetum arvense L.	-	-	-	-	0.7	0.4
Cirsium arvense (L.) Scop.	1.3	1.9	1.6	1.2	1.1	1.1
Elymus repens (L.) Gould	-	0.2	0.1	-	0.2	0.1
Number of perennial species	1	2	2	1	3	3

Weed control: A – mechanical, B – chemical

Table 2
Weed density and air-dry weight of weeds in the maize crop

I. Method of cultivation	II. Weed control	Weed density (per 1 m^2)				Air-dry weight (g × m^{-2})			
		Years			Average	Years			Average
		2008	2009	2010		2008	2009	2010	
SOLE CROPPING	A*	16.4	44.0	53.1	37.8	177.1	135.7	207.2	177.3
	B	11.2	11.5	18.5	13.7	62.6	53.7	59.1	58.5
Strip cropping	A	17.6	43.5	35.8	32.3	145.0	139.9	187.5	150.9
	B	11.7	13.5	19.0	14.7	55.5	28.0	53.8	44.0
LSD (a = 0.05) for I x II		*n.s*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*
Average for factors									
SOLE CROPPING	-	13.8	27.8	35.8	25.8	119.9	94.7	133.1	115.9
Strip cropping	-	14.7	28.5	27.4	23.5	100.2	83.9	108.1	97.4
LSD (a = 0.05) for I		*n.s*	*n.s.*	*7.42*	*n.s.*	*19.57*	*n.s.*	*25.02*	*14.05*
-	A	17.0	43.7	44.4	35.0	\`61.1	137.8	187.5	162.1
-	B	11.5	12.5	18.7	14.2	59.1	40.8	53.8	51.2
LSD (a = 0.05) for II		*2.15*	*10.41*	*5.70*	*4.90*	*n.s.*	*19.10*	*19.20*	*10.8*

Weed control: A – mechanical, B – chemical

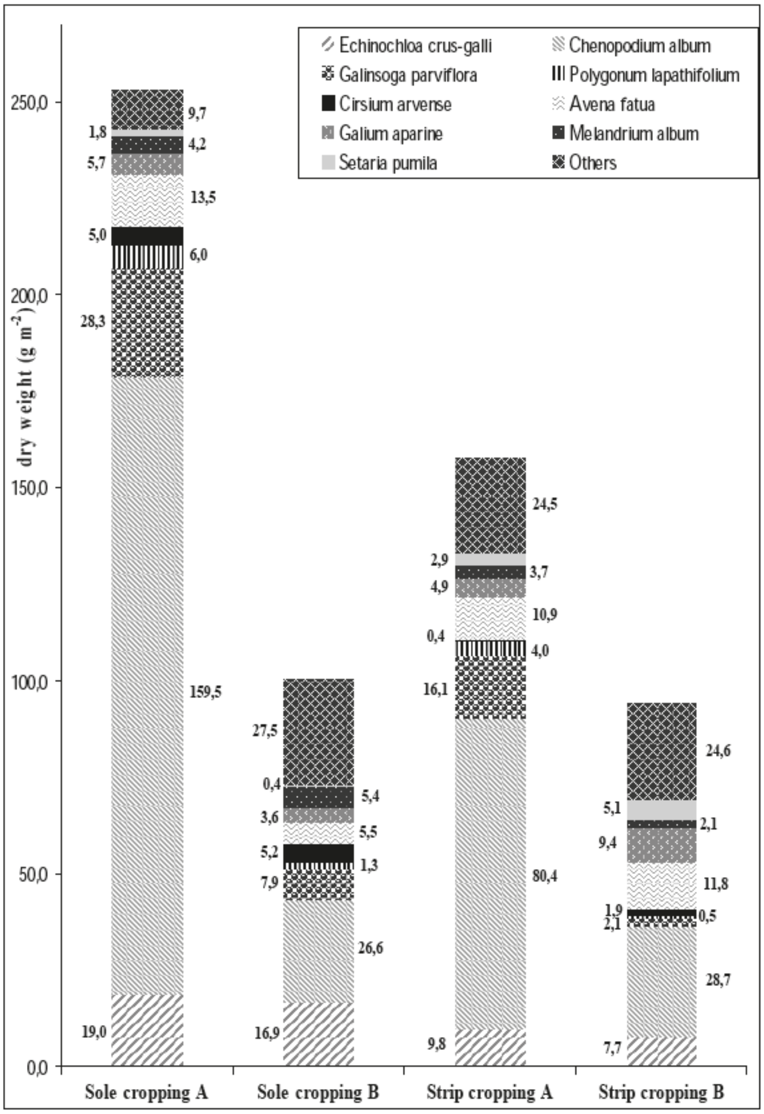

Fig. 2. Air-dry weight of aboveground parts of weeds species in narrow-leafed lupin canopy (mean for 2008–2010).

Table 3
Species composition and number of weeds per 1 m^2 of narrow-leafed lupin crop before harvest, depending on the cropping system (mean for 2008–2010 years)

Species composition	Sole cropping			Strip cropping		
	A*	B	Mean	A	B	Mean
Short lived						
Echinochloa crus-galli (L) P. Beauv	14.3	9.5	11.9	10.2	6.6	8.4
Chenopodium album L.	37.8	10.5	24.2	31.7	9.5	20.6
Galinsoga parviflora Cav.	12.4	3.4	7.9	6.5	2.0	4.3
Capsella bursa-pastoris (L.) Medik.	2.0	-	1.0	1.6	1.3	1,5
Galium aparine L.	2.4	2.7	2.6	2.7	3.1	2.9
Stellaria media (L.) Vill.	0.7	1.0	0.8	1.2	1.0	1.1
Polygonum lapathifolium L. *subsp. lapathifolium*	1.8	0.6	1.2	1.0	0.3	0.7
Setaria pumila (Poir) Roem. & Schult	1.3	5.9	3.6	3.0	0.7	0.5
Melandrium album (Mill.) Gracke	1.7	2.3	2.0	2.4	1.0	1.7
Thlaspi arvense L	0.6	0.3	0.5	0.7	1.3	1.0
Lapsana communis L.	1.0	0.4	0.7	2.3	0.3	1.3
Polygonum convolvulus L.	1.7	2.0	1.9	2.1	1.4	1.7
Vicia tetrasperma L.	1.3	1.0	1.1	1.0	1.4	1.2
Vicia hirsuta (L.) Gray.,	0.6	-	0.3	0.3	1.4	0.9
Matricaria maritima subsp. inodora (L.) Dostal	1.1	2.6	1.9	1.0	-	0.5
Veronica arvensis L.	2.0	0.3	1.1	2.0	-	1.0
Avena fatua L.	4.5	1.6	3.1	2.7	6.7	4.7
Galinsoga ciliata L.	0.7	0.3	0.5	0.8	0.2	1.4
Viola arvensis Murray	-	3.7	1.9	4.2	5.6	4.9
Galeopsis tetrahit L.	-	-	-	-	1.0	0.5
Apera spica venti L.	0.4	-	0.2	-	-	-
Papaver rhoeas L.	-	0.3	0.2	-	-	-
Polygonum persicaria L.	-	0.4	0.2	-	-	-
Total of short-lived species	19	19	22	19	18	20
Perennial						
Equisetum arvense L.	-	-	-	-	5.0	2.5
Cirsium arvense L.	1.3	1.0	1.2	0.3	1.1	0.7
Elymus repens (L.) Gould	-	-	-	-	1.0	0.5
Total of perennial species	1	1	1	1	3	3

*Weed control: A – mechanical, B – chemical

Table 4
Weed density and air-dry weight of weeds in the narrow-leafed lupine

I. Method of cultivation	II. Weed control	Weed density (per 1 m^2)				Air-dry weight (g × m^{-2})			
		Years			Average	Years			Average
		2008	2009	2010		2008	2009	2010	
SOLE CROPPING	A*	70.1	108.1	80.1	86.1	230.5	284.3	243.3	252.7
	B	35.9	68.0	42.8	48.9	96.0	97.9	107.1	100.3
Strip cropping	A	58.4	91.2	66.4	74.0	134.4	196.0	142.4	157.6
	B	38.8	64.5	43.9	48.1	85.8	100.2	95.7	93.9
LSD (a = 0.05) for I x II		*1.86*	*n.s.*	*4.38*	*2.17*	*9.78*	*27.40*	*11.67*	*6.50*
Average for factors									
SOLE CROPPING	-	53.0	88.1	61.5	67.5	163.3	191.1	175.2	176.5
Strip cropping	-	47.7	77.8	53.2	63.6	110.1	148.1	119.0	125.7
LSD (a = 0.05) for I		*3.72*	*8.98*	*2.71*	*1.99*	*9.00*	*19.40*	*7.70*	*5.10*
-	A	63.3	99.6	74.3	78.8	182.5	240.1	192.9	205.2
-	B	37.4	66.3	44.9	49.5	90.9	99.1	101.4	97.1
LSD (a = 0.05) for II		*1.32*	*6.90*	*3.10*	*1.53*	*6.92*	*25.20*	*5.90*	*3.90*

Table 5
Species composition and number of weeds per 1 m^2 of oat crop before harvest, depending on the cropping system (mean for 2008-2010 years)

Species composition	Sole cropping			Strip cropping		
	A	B	mean	A	B	mean
Short lived						
Echinochloa crus-galli (L) P. Beauv	6.8	5.2	6.0	5.9	3.5	4.7
Chenopodium album L.	26.2	6.2	16.2	25.7	6.8	16.3
Galinsoga parviflora Cav.	16.3	8.8	12.6	12.9	5.4	9.2
Capsella bursa-pastoris (L.) Medik.	0.7	1.3	1.0	-	0.2	0.1
Galium aparine L.	2.6	-	1.3	1.1	1.3	1.2
Stellaria media (L.) Vill	0.5	0.2	0.3	0.7	-	0.4
Polygonum lapathifolium L. *subsp. lapathifolium*	1.0	0.4	0.7	0.1	1.0	0.6
Setaria pumila (Poir) Roem. & Schult	1.5	2.1	1.8	2.9	1.8	2.4
Melandrium album (Mill.) Gracke	3.0	2.6	2.8	1.6	4.6	3.1
Thlaspi arvense L	0.8	-	0.4	0.6	-	0.3
Lapsana communis L.	1.9	0.5	0.7	2.6	0.8	1.7
Polygonum convolvulus L.	0.4	0.4	0.4	0.9	-	0.5
Avena fatua L.	0.5	0.7	0.6	-	-	-
Vicia hirsuta L.	0.6	-	0.3	0.5	-	0.3
Myosotis arvensis L.	-	-	-	0.9	-	0.5
Geranium pusillum L.	0.2	-	0.1	-	-	-
Veronica arvensis L.	0.1	0.3	0.2	-	0.4	0.2
Galeopsis tetrahit L.	-	-	-	0.8	-	0.1
Galinsoga ciliata L.	0.3	-	0.2	-	0.8	0.4
Viola arvensis Murray	-	0.7	0.4	0.9	0.7	0.8
Setaria viridis (L.) P. Bauer.	0.2	-	0.1	-	-	-
Anthemis arvensis L.	-	-	-	0.4	-	0.2
Total of short-lived species	17	13	19	16	12	18
Perennial						
Equisetum arvense L.	0.2	-	0.1	0.4	-	0.2
Cirsium arvense (L.) Scop.	1.0	0.4	0.7	0.6	0.4	0.5
Tussilago farfara L.	0.2	-	0.1	-	-	-
Elymus repens (L.) Gould	0.3	0.2	0.3	1.6	0.5	1.1
Total of perennial species	4	2	4	3	2	3

Table 6
Weed density and air-dry weight of weeds in the oat crop

I. Method of cultivation	II. Weed control	Weed density (per 1 m^2)				Air-dry weight (g × m^{-2})			
		Years			Average	Years			Average
		2008	2009	2010		2008	2009	2010	
SOLE CROPPING	A*	61.1	62.8	81.4	68.5	16.0	40.4	52.1	68.5
	B	10.5	49.4	36.4	32.1	5.4	24.8	9.9	32.1
Strip cropping	A	53.7	75.0	62.9	63.9	14.6	49.3	26.5	63.9
	B	11.9	35.8	42.0	29.9	1.9	8.6	12.6	29.9
LSD (a = 0.05) for I x II		*n.s.*	*5.97*	*2.35*	*n.s.*	*n.s.*	*1.48*	*2.58*	*n.s.*
Average for factors									
SOLE CROPPING	-	35.8	56.1	58.9	50.3	10.7	32.6	31.0	50.3
Strip cropping	-	32.8	55.4	52.5	46.9	8.2	29.0	19.5	46.9
LSD (a = 0.05) for I		*n.s.*	*n.s.*	*2.16*	*3.06*	*1.74*	*1.36*	*n.s.*	*3.06*
-	A	57.4	68.9	72.2	66.2	15.3	44.9	39.3	66.2
-	B	11.2	42.6	39.2	31.0	3.6	16.7	11.2	31.0
LSD (a = 0.05) for II		*4.81*	*4.22*	*1.66*	*2.36*	*1.34*	*1.05*	*8.89*	*2.36*

Weed control: A – mechanical, B – chemical

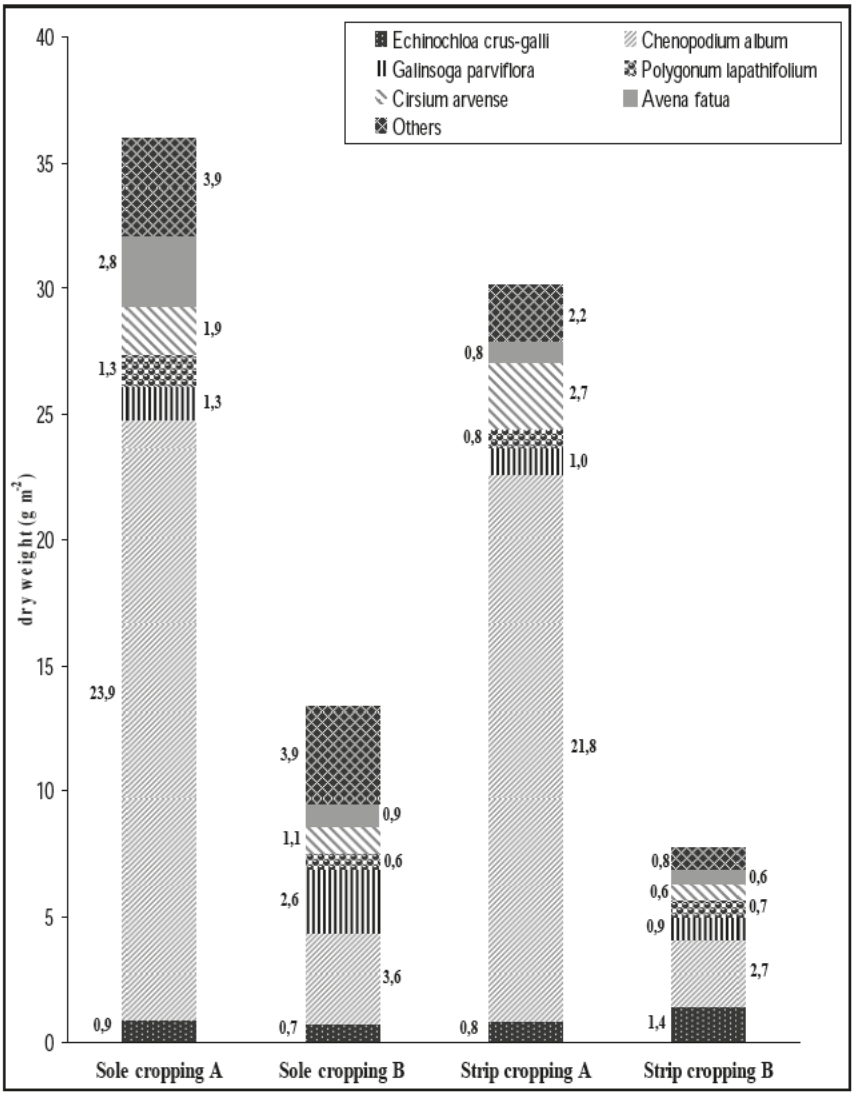

Fig. 3. Air-dry weight of aboveground parts of weeds species in oats canopy (mean for 2008–2010).

DISCUSSION

Weed infestation in the maize, narrow-leafed lupin and oats crops, expressed as the number and dry weight of weeds, varied significantly in different years of the study. This was probably due to weather conditions, especially the amount and distribution of precipitation. Studies confirm the effect of temperature and the amount and distribution of precipitation on both weed density and species diversity [10].

Sekutowski and Rola [11] report that *Echinochloa crus-galli* and *Chenopodium album* are dangerous taxa in maize, as they occur frequently and are potentially harmful. *Chenopodium album*, *Echinochloa crus-galli*, *Amaranthus spp*, *Cirsium arvense* and *Convolvulus arvensis* also occur commonly and present a risk for maize in other parts of the world [12]. In the present study, *Chenopodium album*, *Echinochloa crus-galli* and *Galinsoga parviflora* were the most common taxa. These species can be considered to be dominant, as they accounted for 47.6% to 99% of the total number of weeds. Their share in the total weed biomass was also very large, from 82% to 99% in maize weeded mechanically and 38% to 58% in the treatment where herbicides were used. Among the dominant weeds in maize, *Echinochloa crus-galli* had the largest proportion, especially in terms of biomass. *Chenopodium album*, *Echinochloa crus-galli* and *Galinsoga parviflora* were also the most frequent species in lupin and oats. These species are often found in various cereal crops [13,14]. *Capsella bursa-pastoris*, *Galium aparine*, *Avena fatua* and *Polygonum convolvulus*, taxa observed in lupin and other legumes, were also frequent in the lupin crop [6,15].

Growing maize in wide interrows favours the use of mechanical weed control, but it is not always completely effective [16]. This is confirmed by the present study. In all years of the research, the number of weeds in the mechanically weeded plots was 2.5 times higher than in the treatment where herbicides were used. Even greater differences were found with respect to weed biomass. As in a study by Głowacka [17], highly competitive species, including the uptake of macro- and micronutrients, had a large share of the total weight of weeds in maize: *Echinochloa* crus-*galli* (21.4–37.0%), *Chenopodium* album (8.6–36.7%), and *Galinsoga parviflora* (8.0–18.4%).

Oats are more competitive with weeds than other crops and, according to some authors, do not need chemical weeding [18]. Where weed infestation is severe, however, herbicide use is recommended. In a study by Andruszczak et al. [19], the use of herbicides reduced the number of dicotyledonous weeds by 56.3–70.2% and their biomass by 18.1–24.1% compared to double harrowing, but it increased the number of monocot weeds by 61.8–133.8%. In our study, chemical weed control significantly decreased weed density in oats, by 53.2%, while reducing their weight by as much as 68.3%. However, weed control methods did not affect the frequency of monocot species such as *Echinochloa crus-galli*.

Strip cropping reduces threats from pests, diseases and weeds [7,20]. A study on the effects of strip cropping on weeds in maize, spring wheat and common bean found a decrease in both the number and dry weight of weeds in the bean and wheat crops compared to sole cropping [6]. In maize, however, strip cropping reduced only weed density [5]. The beneficial effects of strip cropping on the weed infestation indicators were particularly significant under mechanical weed control. Strip cropping was also found to affect the weed infestation indicators in the present study, with the nature of the changes depending on the plant species and weed control method. In recent years, much attention has been given to ecosystem biodiversity, and this applies to weeds infesting crops as well. The most commonly used measure is species diversity, expressed as the number of weed species in a community. In this study, the cropping systems did not significantly influence the number of weed species in the crops, but strip cropping decreased the share of the three dominant species – *Echinochloa crus-galli*, *Chenopodium album* and *Galinsoga parviflora* – in maize, oats and lupin.

CONCLUSIONS

The highest weed diversity was observed in narrow-leafed lupin, (26 taxa), while the lowest diversity in the maize crop.

The most common species in the maize, lupin and oat crops were *Echinochloa crus-galli*, *Chenopodium album* and *Galinsoga parviflora*. These taxa also produced the most dry matter.

Strip cropping had no effect on weed species diversity, but decreased the share of the dominant species – *Echinochloa crus-galli*, *Chenopodium album* and *Galinsoga parviflora* – in the total number of weeds.

Chemical weed control reduced both the number and dry weight of weeds in all crops grown in the experiment. The use of herbicides did not affect the number of species inhabiting the maize crop, but increased weed diversity in lupin and decreased it in oats.

Strip cropping significantly reduced both the number and dry weight of weeds in lupin and oats compared to sole cropping. In maize, the reducing effect of strip cropping was significant only in relation to the aboveground dry weight of weeds.

The changes observed in the number and weight of weeds show that strip cropping can affect weed infestation of crop plants. The direction and degree of change depend on the plant species, weed control method, and weather conditions during the growing season.

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Wpływ uprawy pasowej i metod regulacji zachwaszczenia na różnorodność chwastów w kukurydzy pastewnej (*Zea mays* L.), owsie siewnym (*Avena sativa* L.) i łubinie wąskolistnym (*Lupinus angustifolius* L.)

Streszczenie

Doświadczenie przeprowadzono w latach 2008–2010 w Stacji Doświadczalnej Wydziału Nauk Rolniczych, Uniwersytetu Przyrodniczego w Lublinie. Schemat badań obejmował dwa czynniki: I. Metoda uprawy – siew czysty i uprawa pasowa, polegająca na uprawie w sąsiadujących ze sobą pasach o szerokości 3,3 m trzech roślin: kukurydzy pastewnej, łubinu wąskolistnego i owsa siewnego; II. Metoda regulacji zachwaszczenia – mechaniczna i chemiczna Przedmiotem badań było zachwaszczenie kukurydzy pastewnej odmiany 'Celio', łubinu wąskolistnego odmiany „Sonet" i owsa siewnego odmiany 'Kasztan'. Zachwaszczenie roślin określano dwa tygodnie przed zbiorem, metodą botaniczno-wagową, określając skład florystyczny i liczebność poszczególnych gatunków chwastów oraz ich powietrznie suchą masę.

Największą różnorodność chwastów stwierdzono z zasiewach łubinu wąskolistnego, najmniejszą zaś w kukurydzy pastewnej. Gatunkami dominującymi w zachwaszczeniu kukurydzy, łubinu wąskolistnego i owsa siewnego były *Echinochloa crus-galli*, *Chenopodium album* oraz *Galinsoga parviflora* stanowiące od 34,1% do 99% ogólnej liczby chwastów. Uprawa pasowa wyraźnie zmniejszała liczbę chwastów na jednostce powierzchni w zasiewach łubinu wąskolistnego i owsa siewnego oraz wytworzoną przez nie sucha masę części nadziemnych we wszystkich uprawianych gatunkach. Chemiczna metoda regulacji zachwaszczenia zmniejszała istotnie zarówno liczbę jak i masę chwastów w porównaniu z metodą mechaniczną.

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