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The influence of tillage and chemical plant protection on weed infestation of winter spelt wheat cultivars (*Triticum aestivum* ssp. *spelta*) growing in continuous crop

Wpływ uprawy roli i chemicznej ochrony roślin na zachwaszczenie łanu ozimych odmian pszenicy orkiszowej (*Triticum aestivum* ssp. *spelta* L.) uprawianych w monokulturze

Summary. The aim of the studies carried out over the period 2009–2011 on mixed medium heavy rendzina was to evaluate the weed infestation of winter cultivars of spelt wheat ('Ceralio', 'Ostro', 'Schwabenkorn' and 'Spelt I.N.Z.') depending on the tillage system (conventional and reduced) and chemical plant protection (Mustang 306 SE, Attribut 70 WG, Alert 375 SC, Stabilan 750 SL). Over a three-year study period, the highest dry weight of weeds was found in the crop of cv. 'Spelt I.N.Z.', whereas the level of weed infestation for the other cultivars was similar. Replacing ploughing with cultivating resulted in an increase in the numbers of *Apera spica-venti, Echinochloa crus-galli, Matricaria maritima* and *Papaver rhoeas*. As a result, the total number of weeds increased by 50.1% compared to conventional tillage, while their dry weight by 17.4% after the use of cultivator instead the plough. The dry weight of weeds decreased nearly 5 times under the applied crop protection treatments, but the species composition of weed communities did not change significantly compared to the control treatment without chemical protection.

Key words: spelt wheat, continuous crop, reduced tillage, herbicides, species composition of weeds, dry weight of weeds

INTRODUCTION

Conventional tillage, which involves the use of the plough, is one of the most energy-consuming and hence costly constituents of plant production [Kordas 2009]. Due to the changing economic and production conditions in Poland over recent years and the

need to reduce the labor intensity of tillage operations, it is more and more frequently observed a trend towards leaving conventional tillage in favor of various types of tillage simplifications [Sekutowski and Domaradzki 2009, Małecka *et al.* 2012]. Most often, such simplifications consist in eliminating the plough and replacing it with some other implements that allow the topsoil to be loosened up without turning it over [Jaskulski and Jaskulska 2016]. The goal of modern farming systems is not only to optimize soil productivity, but also to make efforts to preserve the environmental qualities of agricultural landscape, taking into account the need to reduce costs [Małecka *et al.* 2012, Jaskulski *et al.* 2012]. No-tillage may contribute to reduce soil erosion and CO_2 emissions as well as to improve soil fertility and water retention [Holland 2004, Berner *et al.* 2008].

Studies of many authors show that reduced tillage has an adverse effect on yields [Berner *et al.* 2008, Biskupski *et al.* 2009, Orzech *et al.* 2011]. What is more, shallower ploughing or replacing ploughing with disking or no-tillage cause the increase in weed infestation and changes in weed species composition [Sans *et al.* 2011, Woźniak and Soroka 2014]. Perennial and monocotyledonous weeds become particularly troublesome and therefore the use of reduced tillage entail the need to intensify weed control measures [Tuesca *et al.* 2001].

The evaluation of weed infestation of various spelt wheat cultivars under no-till is a new and very topical issue. In the world literature, there is almost no information on that subject [Sans *et al.* 2011]. It confirms the need to conduct research in this area. In Poland spelt wheat enjoys ever greater popularity and hence it is justified to seek cultivars that exhibit high competitiveness against weeds.

The aim of the present studies was to evaluate the effect of no-tillage and chemical plant protection on the dry weight of weeds in crops of winter spelt wheat cultivars. Moreover, the species composition and number of weeds in spelt wheat were determined depending on experimental factors.

MATERIAL AND METHODS

The studies was carried out over the period 2009–2011 at the Bezek Experimental Farm located near the city of Chełm (51°19'N, 23°25'E), on mixed medium heavy rendzina soil derived from Cretaceous rock and with the particle-size distribution of loam (soil class IIIb, defective wheat soil complex). The effect of tillage systems and chemical plant protection on weed infestation of a spelt wheat crop were evaluated. A field experiment was set up as a split-plot design in three replicates, and the area of a single plot was 8 m^2. The studies material consisted of the following four spelt cultivars: 'Ceralio', 'Ostro', 'Schwabenkorn', and 'Spelt I.N.Z.', which were grown in monoculture. Two tillage systems were used: conventional and reduced tillage. In the conventional tillage treatments, skimming and harrowing were done after harvest of the previous crop. Presowing ploughing with harrowing was carried out about 3 weeks before sowing of spelt wheat. The field was also harrowed immediately before spelt wheat sowing. In the no-tillage treatment, cultivating and harrowing were carried out after harvest of the previous crop and subsequently these operations were repeated before sowing. In the crop stands of the evaluated spelt cultivars, the following herbicides were applied at tillering stage

(BBCH 24-29): Mustang 306 SE (6.25 g·l^{-1} florasulam, 300 g·l^{-1} 2,4-D EHE) at a rate of 0.4 l·ha^{-1} and Attribut 70 WG (70% propoxycarbazone, methyl ester of 2-benzoic acid sodium salt) at a rate of 60 g·ha^{-1}. Moreover, the fungicide Alert 375 SC (125 g·l^{-1} flusilazole, 250 g·l^{-1} carbendazim) at a rate of 1 l·ha^{-1} and the growth regulator Stabilan 750 SL (750 g·l^{-1} chlormequat chloride) at a rate of 2 l·ha^{-1} were applied at stem elongation stage (BBCH 32–34). The effect of these crop protection treatments was compared with the control treatment where no plant protection chemicals were used. Spelt wheat was sown in mid-October at a rate of 350 kg spiklets per hectare. The following mineral fertilization was applied (in kg of nutrient per hectare): N 60 (20 + 40); P 26; K 83.

The analysis of in-crop weed infestation was made using the dry-weight-rank method at the dough stage of spelt wheat (85–87 BBCH). This analysis involved the determination of the species composition and number of weeds found in the spelt crop as well as of their above-ground dry weight. The evaluation was made on sampling areas delineated by a 1 m × 0.25 m frame in four randomly selected places in each plot. The results were statistically analyzed by analysis of variance, while the significance of differences was tested by Tukey's confidence half-intervals with an error rate of 5%. ARStat software developed by the Computing Centre of the University of Life Sciences in Lublin was used for the calculations.

RESULTS AND DISCUSSION

On average over the three-year study period, the weed community in the crops of the winter spelt cultivars comprised from 16 to 19 dicotyledonous weed species and from 4 to 5 monocotyledonous taxa (tab. 1). Regardless of the tillage system and chemical protection, they accounted respectively for 58–70% and 31–42% of the overall weed community. As regards the floristic composition of weed communities found in the crops of the individual spelt cultivars, a similar species composition was observed. Small differences were noticed in the number of species. The weed community in the cv. 'Ostro' crop stand proved to be the most numerous (24 species), whereas the lowest number of species (21) accompanied the cultivar 'Spelt I.N.Z.'. In terms of weed abundance, the dominant species were *Galium aparine* and *Apera spica-venti*. Depending on the spelt cultivar, their percentage contribution to the total weed infestation was 29–39% and 20–24%, respectively (Fig. 1). Moreover, *Setaria pumila, Papaver rhoeas* and *Stellaria media* occurred in quite large density in the spelt crop stands, whereas in the canopies of cvs. 'Schwabenkorn' and 'Spelt I.N.Z.' also *Echinochloa crus-galli.* Apart from the above-mentioned species, the following weed species, among others, occurred with different intensity or as single individuals: *Viola arvensis, Matricaria maritima, Fallopia convolvulus, Consolida regalis, Myosotis arvensis, Veronica arvensis, Chenopodium album, Anagallis arvensis, Convolvulus arvensis,* and *Cirsium arvense*. When analyzing the species composition of weeds found in the spelt crop, it can be concluded that it is typical for the cereal studied and this type of soil [Pałys and Kuraszkiewicz 2003, Andruszczak *et al.* 2012].

Table 1. Species composition and number of weeds (plant·m^{-2}) in the canopy of winter spelt wheat depending on cultivar (mean for fears 2009–2011)
Tabela 1. Skład gatunkowy i liczba chwastów (szt.·m^{-2}) w łanie ozimej pszenicy orkiszowej w zależności od odmiany (średnio w latach 2009–2011)

Weed species Gatunek chwastu	Cultivar/ Odmiana			
	Ceralio	Ostro	Schwabenkorn	Spelt I.N.Z.
Dicotyledonous/ Dwuliścienne				
Galium aparine L.	21.3	15.7	18.0	16.3
Stellaria media (L.) Vill.	3.5	1.7	1.8	2.4
Papaver rhoeas L.	3.4	4.0	2.4	4.5
Viola arvensis Murray	3.2	2.6	0.4	0.8
Fallopia convolvulus (L.) Á. Löwe	1.8	2.5	0.8	0.8
Matricaria maritima L. subsp. *inodora (L.) Dostál*	2.2	0.8	1.6	4.3
Others/ Pozostałe	4.4	4.6	1.7	3.6
Total/ Razem	39.8	31.9	26.7	32.7
Number of species/ Liczba gatunków	19	19	17	16
Monocotyledonous/ Jednoliścienne				
Apera spica-venti (L.) P. Beauv.	11.5	10.7	10.8	11.7
Setaria pumila (Poir.) Roem. & Schult.	5.0	2.7	3.4	5.0
Echinochloa crus-galli (L.) P.Beauv.	1.6	0.5	4.0	5.5
Others/ Pozostałe	0.3	0.1	0.7	1.8
Total/ Razem	18.4	14.0	18.9	24.0
Number of species/ Liczba gatunków	4	5	5	5
Total number of weeds Ogólna liczba chwastów	58.2	45.9	45.6	56.7
Total number of species Ogólna liczba gatunków	23	24	22	21

Irrespectively of the spelt cultivar and chemical plant protection, the number of dicotyledonous and monocotyledonous weeds in no-tillage treatments was higher than under conventional tillage by 6.1 weeds·m^{-2} (20.5%) and 14.6 weeds·m^{-2} (125.9%) respectively (tab. 2). Under reduced tillage, Sans *et al.* [2011] found a threefold increase in the number of monocotyledonous weeds in a spelt crop stand compared to conventional tillage. Armengot *et al.* [2014], in turn, did not reveal significant differences in weed infestation of spelt wheat depending on the tillage system. In the present studies, the effect of reduced tillage was manifested in a more than 2.5-fold increase in the numbers of *Apera spica-venti*. Furthermore, the density of *Echinochloa crus-galli, Matricaria maritima, Papaver rhoeas* and *Galium aparine*, among others, was found to increase in the plots where cultivating was used instead of ploughing. At the same time, there was a slight decline in the numbers of *S. pumila, V. arvensis, F. convolvulus* and *S. media*. The differences in weed infestation of the crops as affected by simplifications in tillage which were found in the present experiment are confirmed by the studies of many authors who inform about the increase in the number of weeds as a result of reduced tillage operations [Frant and Bujak 2006, Gawęda 2007, Orzech *et al.* 2011].

Table. 2. Species composition and number of weeds (plant·m^{-2}) in the canopy of winter spelt wheat depending on soil tillage system and chemical protection (mean for fears 2009–2011)
Tabela 2. Skład gatunkowy i liczba chwastów (szt.·m^{-2}) w łanie ozimej pszenicy orkiszowej w zależności od systemu uprawy roli i ochrony chemicznej (średnio w latach 2009–2011)

Weed species Gatunek chwastu	Soil tillage system System uprawy roli		Chemical protection Ochrona chemiczna	
	conventional tradycyjny	reduced uproszczony	control treatment obiekt kontrolny	with chemical protection z ochroną chemiczną
Dicotyledonous/ Dwuliścienne				
Galium aparine L.	17.2	18.5	23.7	12.0
Stellaria media (L.) Vill.	2.5	2.2	2.3	2.5
Papaver rhoeas L.	2.4	4.5	5.7	1.5
Fallopia convolvulus (L.) Á. Löwe	2.2	0.8	1.6	1.5
Viola arvensis Murray	2.0	1.5	1.3	2.2
Matricaria maritima L. subsp. *inodora (L.) Dostál*	0.6	3.9	2.8	1.6
Others/ Pozostałe	2.8	4.4	3.2	3.6
Total/ Razem	29.7	35.8	40.6	24.9
Number of species/ Liczba gatunków	15	14	14	15
Monocotyledonous/ Jednoliścienne				
Apera spica-venti (L.) P. Beauv.	6.3	16.1	10.9	11.5
Setaria pumila (Poir.) Roem. & Schult.	4.3	3.8	2.9	5.1
Echinochloa crus-galli (L.) P. Beauv.	1.0	4.8	3.6	2.2
Others/ Pozostałe	0.0	1.5	0.4	1.2
Total/ Razem	11.6	26.2	17.8	20.0
Number of species/ Liczba gatunków	3	5	3	5
Total number of weeds/ Ogólna liczba chwastów	41.3	62.0	58.4	44.9
Total number of species Ogólna liczba gatunków	18	19	17	20

Opposite results are presented by Małecka *et al.* [2006] who demonstrated that the elimination of ploughing caused a 46% reduction in the number of weeds in a winter wheat crop compared to conventional tillage. In the opinion of Sekutowski and Domaradzki [2009], long-term use of no-till in winter wheat coupled with monoculture cropping lead to the development of simplified weed communities consisting of only several dominant species. According to Stupnicka-Rodzynkiewicz *et al.* [2004], large share of one or several weed species could be the evidence of the greater harmfulness of such weed infestation than in the case where a weed community comprises a large number of weed species represented by few individuals.

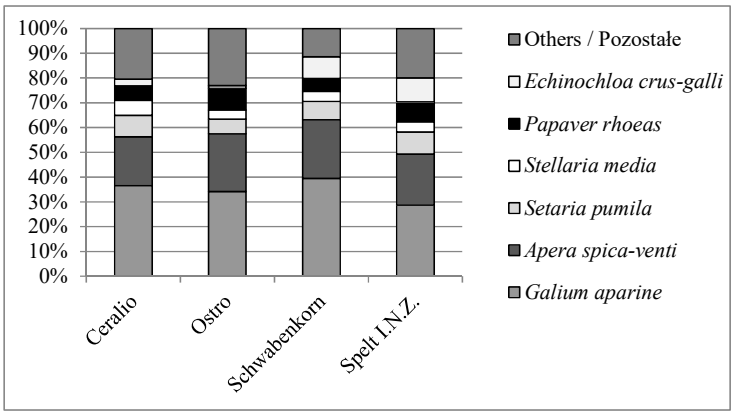
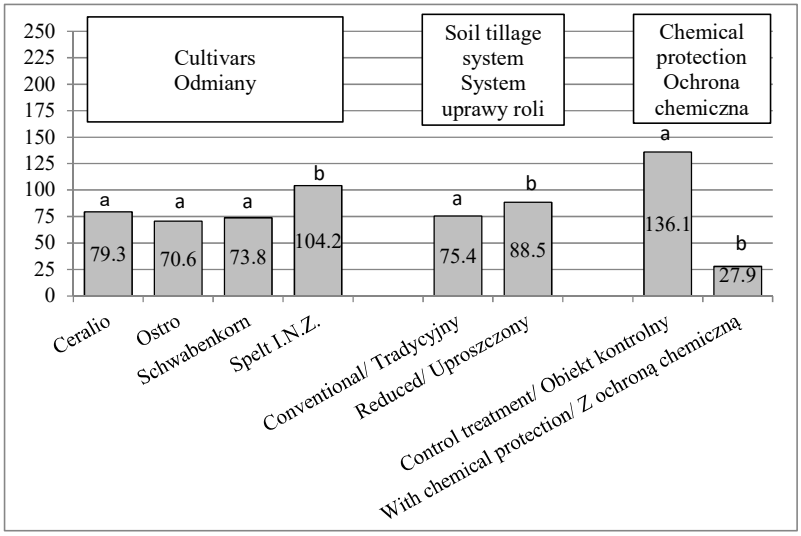


Fig. 1. Percentage share of dominant weed species in the total number of weeds in the canopy of spelt cultivars (mean for years 2009–2011)
Rys. 1. Procentowy udział najliczniej występujących gatunków chwastów w ogólnej liczbie chwastów w łanie odmian pszenicy orkiszowej (średnio w latach 2009–2011)

In evaluating the effect of chemical crop protection on weed species composition, it should be stated that this factor affected the species biodiversity of the tested community to a small extent (tab. 2). However, it should be indicated that the weed community in the chemically protected plots was slightly more numerous in species (on average 20 species relative to 17 in the control treatment). Thus, the relationship reported by some authors that herbicides cause reduced biodiversity of agrophytocoenoses [Adamiak and Adamiak 2004, Piekarczyk 2010] was not confirmed. Regardless of the spelt cultivar and tillage system, the number of dicotyledonous weeds under chemical plant protection decreased on average by 15.7 weeds per 1 m^2 (38.7%) compared to the control treatment. This was primarily attributable to the reduction in the numbers of species such as *G. aparine, P. rhoeas* and *M. maritima.* Relative to the control treatment, their density per 1 m^2 decreased by 11.7 weeds (49.4%), 4.2 weeds (73.7%) and 1.2 weeds (42.9%), respectively. Species such as *S. media* and *V. arvensis* proved to be quite resistant to herbicides, which was probably associated with the high competitive ability of these taxa in crops [Wilson and Wright 1990, Karim 2002]. The response of monocotyledonous to pesticides was varied. After application of chemical agents, the numbers of *E. crus-galli* decreased (by 1.4 weeds·m^{-2}), but an increasing occurrence of *A. spica-venti* and *S. pumila* (by 0.6 and 2.2 weeds·m^{-2}) was noticed. Due to this, the number of monocotyledonous weeds was higher than in the control treatment by 2.2 weeds·m^{-2} on average. Even though the application of pesticides did not reduce the number of monocotyledonous weeds, they were distinctly smaller and hence not dangerous to spelt wheat.

An important weed infestation indicator is the dry matter produced by weeds. In the present studies, the value of this trait was significantly dependent on the spelt cultivar. Regardless of the tillage system and pesticides applied, cv. 'Spelt I.N.Z.' was the most weedy, which could be evidence of its lower weed competitive ability compared to the other cultivars (Fig. 2). At the same time, no significant differences in weed dry weight were shown between the cultivars 'Ceralio', 'Ostro' and 'Schwabenkorn'. In the opinion

of Feledyn-Szewczyk [2012], cereal cultivars differ in their weed competitiveness. It is predominantly determined by the morphological and physiological characteristics of these cultivars, such as plant height, growth rate, tillering, leaf area index, and nutrient utilization. Furthermore, as reported by Bertholdsson [2005] as well as Worthington and Reberg-Horton [2013], the competitive ability of cultivars may be affected by their different allelopathic properties.



Different letters indicate significant differences/ Różne litery oznaczają istotne różnice

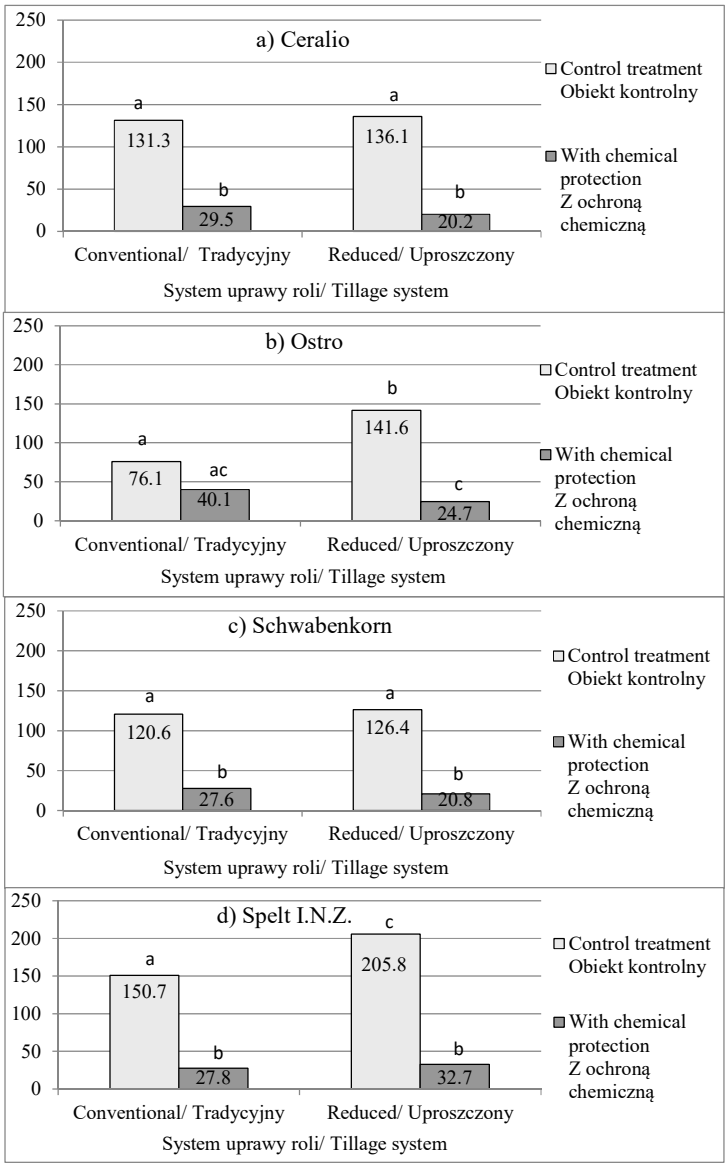
Fig. 2. Air dry weight (g·m^{-2}) of weeds in the canopy of winter spelt wheat depending on cultivars, soil tillage system and chemical protection (mean for years 2009–2011)
Rys. 2. Powietrznie sucha masa (g·m^{-2}) chwastów w łanie ozimej pszenicy orkiszowej w zależności od odmiany, systemu uprawy roli i ochrony chemicznej (średnio w latach 2009–2011)

Reduced tillage promoted increasing weed infestation of spelt wheat. Replacing ploughing with cultivating significantly increased the average weed dry weight by 17.4%. A markedly higher increase in weed infestation as affected by no-tillage was found by Gawęda [2007] in a studies on winter wheat (67%) as well as by Frant and Bujak [2006] in their experiment on spring wheat (83%).

The abandonment of chemical plant protection resulted in a nearly fivefold increase in weed dry weight compared to the treatment where pesticides were applied. Other authors [Brzozowska and Brzozowski 2008, Piekarczyk 2010, Buczek *et al.* 2012] have demonstrated similar relationships in various cereal species.

The confirmed interaction between the experimental factors showed that the response of the spelt cultivars to the tillage system varied (Fig. 3). For cultivars 'Ostro' and 'Spelt I.N.Z.', the elimination of plough with no chemical plant protection significantly increased the weed dry weight by 86.1% and 36.6%, respectively, compared to conventional tillage. However, this relationship was not found on plots with chemical plant protection. Under herbicide application, the weight of weeds colonizing the crops of cvs. 'Ostro'

and 'Spelt I.N.Z.' did not differ significantly between both tillage systems. Tillage system was not proven to have a significant effect on the biomass produced by weeds infesting crop stands of 'Ceralio' and 'Schwabenkorn' cultivars. The value of this trait was at a similar level in both the conventional tillage and no-tillage treatments.



Different letters indicate significant differences/ Różne litery oznaczają istotne różnice

Fig. 3. Air-dry weight of weeds ($g \cdot m^{-2}$) in the canopy of four spelt cultivars depending on soil tillage system and chemical protection

Rys. 3. Powietrznie sucha masa chwastów ($g \cdot m^{-2}$) w łanie czterech odmian orkiszu w zależności od system uprawy roli i ochrony chemicznej

The results of the studies confirm the fact of significant increase in weed infestation of spelt wheat devoid of protection against weeds [Andruszczak *et al.* 2012]. On plots with conventional tillage, only cv. 'Ostro' did not respond with a significant decrease in weed weight as influenced by pesticide application. In the crop stands of cvs. 'Ceralio', 'Schwabenkorn' and 'Spelt I.N.Z.', in turn, the significant reduction in weed infestation was 77.5%, 77.1% and 81.6%, respectively, relative to the control treatment. Under no-tillage, even higher weed control efficacy of tested herbicides was achieved. In the crop stands of all the evaluated spelt cultivars, the weed dry weight decreased significantly relative to the control, from 82.6% (cv. 'Ostro') to 85.2% (cv. 'Ceralio').

CONCLUSIONS

1. Over the three-year study period, the highest weed dry weight was found in the spelt wheat crop stand of cv. 'Spelt I.N.Z.' grown in continuous crop, which could be the evidence of its lower weed competitive ability compared to the cultivars 'Ceralio', 'Ostro' and 'Schwabenkorn'.

2. Under no-tillage system the increase of *Apera spica-venti, Echinochloa crus-galli, Matricaria maritima* and *Papaver rhoeas* was noted. As a result, the total number of weeds under reduced tillage increased by 50.1% compared to the conventional tillage system, while their air-dry weight by 17.4%.

3. Applied plant protection treatments differed the population size of individual weed species, but they did not significantly affect the species composition of weed communities. At the same time, a nearly fivefold decrease in weed dry weight was found compared to the control treatment without chemical protection.

4. The evaluated spelt cultivars responded differently to the tillage system. The implementation of reduced tillage for cultivars 'Ostro' and 'Spelt I.N.Z.', resulted in a significant increase in the dry weight of weeds in crop stands, but only under no chemical plant protection. However, cvs. 'Ceralio' and 'Schwabenkorn' did not show significant changes in weed infestation as affected by no-tillage.

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Streszczenie. Celem badań prowadzonych w latach 2009–2011 na średnio ciężkiej rędzinie mieszanej była ocena zachwaszczenia ozimych odmian pszenicy orkiszowej (‘Ceralio’, ‘Ostro’, ‘Schwabenkorn’ i ‘Spelt I.N.Z.’) w zależności od systemu uprawy roli (konwencjonalny i uproszczony) i chemicznej ochrony roślin (Mustang 306 SE, Attribut 70 WG, Alert 375 SC, Stabilan 750 SL). W trzyletnim okresie badań największą powietrznie suchą masę chwastów stwierdzono w łanie odmiany ‘Spelt I.N.Z.’, natomiast poziom zachwaszczenia pozostałych odmian był zbliżony. Zastąpienie orki kultywatorowaniem spowodowało wzrost liczebności *Apera spica-venti, Echinochloa crus-galli, Matricaria maritima* i *Papaver rhoeas*. W rezultacie ogólna liczba chwastów po zastąpieniu pługa kultywatorem wzrosła o 50,1%, a ich powietrznie sucha masa o 17,4%. Pod wpływem zastosowanych zabiegów ochronnych stwierdzono niemal pięciokrotne zmniejszenie powietrznie suchej masy chwastów, jednak skład gatunkowy zbiorowisk chwastów nie uległ znaczącej modyfikacji.

Słowa kluczowe: orkisz, monokultura, uproszczona uprawa roli, herbicydy, skład gatunkowy chwastów, sucha masa chwastów

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