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WEED INFESTATION OF NEW SPRING BREEDING LINES OF SPELT WHEAT DEPENDING ON SOWING RATE AND NITROGEN FERTILIZATION

Sylwia Andruszczak[1]

Department of Agroecology, University of Life Sciences in Lublin, Akademicka 13, 20-950 Lublin

Abstract. The field experiment was carried out in 2012–2014 on medium heavy mixed rendzina soil. The aim of this study was to evaluate species composition, number and air-dry weight of weeds occurring in spring spelt wheat canopy depending on three experimental factors: I. breeding lines of spring spelt wheat (A10 and A12), II. spikelet sowing rate (150, 200 and 250 kg·ha^{-1}), III. nitrogen rate (50 and 80 kg·ha^{-1}). The species that occurred in greatest number was *Avena fatua* and its percentage in the total number of weeds was estimated at 68–72%. Higher competitiveness against weeds showed A10 breeding line, as compared to A12. Nitrogen application at the rate of 80 kg·ha^{-1} only slightly changed weed infestation of spring spelt wheat in relation to 50 kg N·ha^{-1}. Increasing sowing rate from 150 to 200 and 250 kg spikelets per hectare decreased the total number of weeds. However, the reduction of dry weight of weeds as a result of increasing sowing rate was found only under condition of lower nitrogen rate.

Key words: spring spelt wheat, sowing rate, nitrogen fertilization, species composition of weeds

INTRODUCTION

Due to their high competitiveness against crops, weeds are treated as undesired components of an agricultural plant community and for years they have been controlled using mainly herbicides. Currently, being guided by the principles of sustainable agriculture, other options to reduce weed infestation are gaining more and more significance, among which a great role is ascribed to the genetic properties of cultivars or breeding lines [Andrew et al. 2015, Jędruszczak et al. 2004]. Therefore, it seems to be of key importance to seek more weed-competitive genotypes, not only among existing cultivars but also in breeding lines prepared for registration.

In the opinion of Blackshaw [2004] and Stępień [2004], the competitive ability of cereals against weeds can be enhanced by proper mineral fertilization, with special attention being paid to nitrogen as the most yield-increasing element. In integrated crop protection programs, an effective weed management method is to seek appropriate crop density by using an optimum seeding rate [Kolb and Gallandt 2012, Kristensen et al. 2008, Olsen et al. 2006].

It is assumed that under conditions of increased nitrogen fertilization and denser seeding, it is possible to reduce pressure from segetal flora. The aim of this study was to compare the weed competitive ability of two breeding lines of spring spelt wheat under various agronomic conditions which included different amounts of seeded spikelets and different nitrogen rates. This study included evaluation of the species composition of weeds, their numbers and above-ground dry weight.

[1] *Corresponding address* – Adres do korespondencji: sylwia.andruszczak@up.lublin.pl

MATERIAL AND METHODS

The field-study was carried out in 2012–2014 at the Bezek Experimental Farm (51°19′ N, 23°25′ E) owned by the University of Life Sciences in Lublin. The experiment was located on medium heavy mixed rendzina soil formed from chalk rock, with granulometric composition of loam [PTG 2009]. The soil is classified as the IIIb quality class, and defective wheat complex. In the first year of experiment total precipitation from April to August was lower than mean rainfall total from the long-term mean by 68.2 mm. Particularly low rainfall was observed in July. The years 2013 and 2014 were much wetter - the total rainfall in these years was higher than the mean for long-term period by 84.2 and 81.3 mm, respectively. In May in the year 2014, total monthly precipitation visibly exceeded the long-term mean (by 94.2 mm), while in July was lower (by 45.7 mm). In all years of experiment the average air temperature from April to August (except June 2014) was higher than average temperature in the long-term period (Table 1 and 2).

Table 1. Total monthly precipitation (mm) and divergence from the long-term average (mm) (1974–2010) during growing season in the years 2012–2014

Month	2012		2013		2014	
	Precipitation	Divergence from average	Precipitation	Divergence from average	Precipitation	Divergence from average
April	47,3	+9.4	54.8	+16.9	44.0	+6.1
May	42.9	-14.5	113.5	+56.1	151.6	+94.2
June	66.5	-10.4	143.1	+66.2	88.2	+11.3
July	31.0	-50.6	82.0	+0.4	35.9	-45.7
August	67.7	-2.1	14.4	-55.4	85.2	+15.4
Total	255.4	-68.2	407.8	+84.2	404.9	+81.3

Table 2. Mean monthly air temperature (°C) and divergence from the long-term average (°C) (1974–2010) during growing season in the years 2012–2014

Month	2012		2013		2014	
	Air temperature	Divergence from average	Air temperature	Divergence from average	Air temperature	Divergence from average
April	9.3	+1.5	8.1	+0.3	9.3	+1.5
May	15.1	+1.6	15.7	+2.2	13.9	+0.4
June	17.2	+0.9	18.3	+2.0	15.8	-0.5
July	21.5	+3.3	19.2	+1.0	20.8	+2.6
August	19.2	+1.6	19.3	+1.7	18.8	+1.2
Average	16.5	+1.8	16.1	+1.4	15.7	+1.0

The experiment was established as a split-split plot design in three replications, and the area of the plot was 15 m^2. Three experimental factors were considered in the experiment:

• breeding lines of the spring form of spelt wheat (*Triticum aestivum* ssp. *spelta* L.), i.e. A10 and A12 (the spelt breeding lines derive from University of Warmia and Mazury in Olsztyn);

• spikelet sowing rate of spelt wheat (kg of spikelets per 1 ha): 150, 200 and 250;

• nitrogen rate (kg·ha^{-1}): 50 N and 80 N.

The previous crop for spelt wheat was oat. Tillage was done in a typical way of plowing. In the spring, cultivating and harrowing were done. Sowing was carried out in the middle of April. Before spring cultivating, the same mineral fertilization was applied in all experimental treatments. Nitrogenous fertilizers at a rate of 50 kg N·ha^{-1} in the form of ammonium nitrate, phosphorous fertilizers at a rate of 22 kg P·ha^{-1} in the form of granulated triple superphosphate and potassium fertilizers at a rate of 50 kg K·ha^{-1} in the form of 60% potassium salt were sown. Additionally, 30 kg N·ha^{-1} was applied at stem elongation stage in the treatment with the higher nitrogen rate.

Evaluation of weed infestation of the spring spelt canopy was determined with the quantitative-gravimetric method at the dough stage (BBCH 83–85). Analysis consisted in determining the species composition, numbers and air-dry weight of above-ground parts of weeds. The assessment of weed infestation was carried with a frame of dimensions 1 m × 0,5 m in two randomly chosen places on each plot.

Obtained results concerning the number and air-dry weight of weeds were elaborated statistically with the method of variance analysis. The means were compared with the use of the least significant differences based on Tuckey test ($P \leq 0.05$). The calculations were performed using ARStat software developed by the Faculty of Applied Mathematics and Information Technology of the University of Life Sciences in Lublin.

RESULTS AND DISCUSSION

Weed infestation of winter spelt wheat cultivars has been the object of many studies [Andruszczak et al. 2012, 2013, Feledyn-Szewczyk 2009, Krawczyk and Sulewska 2012], but there is a lack of information on segetal flora colonizing spring spelt wheat crops. In the present experiment, the number of weed species both in the canopy of the A10 and A12 breeding line, was similar (16 dicotyledonous and 4 monocotyledonous taxa), though the species composition was slightly diversified (Table 3 and 4). Several taxa (*Portulaca oleracea*, *Lamium amplexicaule*, and *Cirsium arvense*) found in the treatments with the breeding line A10 did not have their representatives in the A12 spelt community. At the same time, in the plots with the breeding line A12 some species occurred (*Melandrium album*, *Veronica arvensis*, and *Artemisia vulgaris*) that were not found in the A10 spelt treatment.

Over a three-year study period, most of the weed species accompanying spelt wheat occurred sporadically and their effect on weed infestation in crops was small. Regardless of the sowing rate and nitrogen rate, *Avena fatua* dominated in the crop communities of the breeding lines A10 and A12, and its percentage in the total number of weeds was estimated at 68 and 72%, respectively (Fig. 1). In the opinion of Dąbkowska and Łabza [2010], *Avena fatua* is now considered to be one of the most dangerous competitors of cereals. The occurrence of this species in Poland has been increasing from the beginning of the 1990's, in particular on rendzina soils where it finds the most favorable conditions. Numerously occurring individuals of *Avena fatua* are harmful not only due to the fact that they compete with the crop plant, but their harmfulness is also associated with their inhibitory effects arising from the allelopathic properties of this species [Majchrzak 2007].

Table 3. Species composition of weeds in the canopy of spelt breeding lines A10 and A12 depending on sowing rate (mean for years 2012–2014) (plants·m^{-2})

Species	A10			A12		
	Sowing rate (kg·ha^{-1})					
	150	200	250	150	200	250
Dicotyledonous						
Amaranthus retroflexus L.	0.3	1.6	1.3	0.9	0.3	1.8
Anchusa arvensis (L.) M. Bieb.	0.1	-	0.1	0.1	-	-
Artemisia vulgaris L.	-	-	-	-	-	0.3
Cirsium arvense L.	-	0.4	0.2	-	-	-
Convolvulus arvensis L.	0.2	1.1	0.4	0.1	0.4	0.1
Euphorbia helioscopia L.	0.1	0.1	0.1	0.7	0.1	0.1
Fallopia convolvulus L.	0.1	-	0.1	-	-	0.1
Galium aparine L.	1.7	5.1	0.9	3.5	4.1	2.7
Lamium amplexicaule L.	0.1	1.3	0.5	-	-	-
Matricaria maritima ssp. *inodora* (L.)	1.4	1.6	0.4	0.7	0.1	0.7
Melandrium album (Mill.) Garcke	-	-	-	0.1	0.5	-
Myosotis arvensis (L.) Hill	0.2	0.2	0.8	0.3	0.2	0.2
Papaver rhoeas L.	2.1	1.8	0.2	0.9	0.4	0.3
Portulaca oleracea L.	0.2	0.3	0.4	-	-	-
Sonchus arvensis L.	0.1	0.6	1.2	-	0.1	-
Stellaria media (L.) Vill.	-	-	0.1	0.1	-	0.1
Veronica arvensis L.	-	-	-	0.1	0.4	0.2
Veronica persica Poir.	0.4	2.7	0.9	0.7	0.3	1.4
Viola arvensis Murray	0.9	2.2	3.0	1.1	2.7	1.1
Monocotyledonous						
Apera spica-venti L.	8.7	6.4	0.9	12.2	3.1	0.9
Avena fatua L.	64.2	36.1	36.2	57.3	39.9	45.6
Echinochloa crus-galli L.	0.1	4.7	0.7	3.1	1.4	2.0
Setaria pumila (Poir.) Roem. & Schult	0.2	3.2	2.9	0.5	1.1	3.1

Table 4. Species composition of weeds in the canopy of spelt breeding lines A10 and A12 depending on nitrogen level (mean for years 2012–2014) (plants·m^{-2})

Species	A10		A12	
	Nitrogen level (kg·ha^{-1})			
	50	80	50	80
Dicotyledonous				
Amaranthus retroflexus L.	1.7	0.4	0.8	1.2
Anchusa arvensis (L.) M. Bieb.	0.1	-	-	0.1
Artemisia vulgaris L.	-	-	-	0.1
Cirsium arvense L.	-	0.4	-	-
Convolvulus arvensis L.	0.6	0.6	-	0.3
Euphorbia helioscopia L.	-	0.1	0.5	0.1
Fallopia convolvulus L.	0.1	-	0.1	-
Galium aparine L.	3.6	1.6	3.6	3.3
Lamium amplexicaule L.	0.6	0.6	-	-
Matricaria maritima ssp. *inodora* (L.)	1.2	1.1	0.5	0.5
Melandrium album (Mill.) Garcke	-	-	-	0.4
Myosotis arvensis (L.) Hill	0.6	0.2	0.2	0.3
Papaver rhoeas L.	1.0	1.7	0.3	0.8
Portulaca oleracea L.	0.4	0.2	-	-
Sonchus arvensis L.	1.2	0.1	-	0.1
Stellaria media (L.) Vill.	-	0.1	0.1	-
Veronica arvensis L.	-	-	0.4	0.1
Veronica persica Poir.	1.3	1.4	1.4	0.2
Viola arvensis Murray	2.0	2.1	2.5	0.8
Monocotyledonous				
Apera spica-venti L.	10.4	0.3	6.8	4.0
Avena fatua L.	44.2	46.9	42.2	53.0
Echinochloa crus-galli L.	2.7	0.9	1.9	2.4
Setaria pumila (Poir.) Roem. & Schult	2.5	1.6	1.6	1.5

The *Avena fatua* number showed great changes depending on the spikelet sowing rate of spelt (Table 3). At a higher sowing rate (200 and 250 kg spikelets per hectare), the numbers of this species in the crop of the breeding line A10 decreased on average by 44% compared to a sowing rate of 150 kg·ha^{-1}, whereas in the A12 spelt treatments by 20–30%. In the case of *Apera spica-venti*, these differences were 26–90% and 75–93%, respectively. However, the reduction in the intensity of the most numerous weeds provided an opportunity for the growth of other species. As a result, in the A10 spelt canopy under conditions of higher sowing rate an increase in the percentage of most dicotyledonous species (among others *Viola arvensis, Veronica persica, Amaranthus retroflexus, Convolvulus arvensis*) as well as *Setaria pumila* and *Echinochloa crus-galli* was recorded. In the A12 spelt canopy, the above described relationship was observed, among others, for *Setaria pumila*.

Intensification of nitrogen fertilization had a small influence on the floristic composition of the crop, but it was shown to have a differential effect on the numbers of some species (Table 4). The higher nitrogen rate promoted the occurrence of *Avena fatua* and *Papaver rhoeas*, among others, but reduced the numbers of *Apera spica-venti*. According to Stępień [2004], the effect of nitrogen on weed infestation in spring wheat is not unambiguous – depending on the fertilization method (organic or conventional), it can reduce or stimulate the occurrence of weeds. In their study concerning the influence of fertilization on the competitive effects of weeds on the crop plant, Blackshaw and Brandt [2008] revealed that increased nitrogen fertilization is not very effective if a weed community comprises mainly nitrophilous species. A study by Rola et al. [2013] shows similar results.

Spelt genotype and nitrogen rate did not affect the number of monocotyledonous weeds, but sowing rate was a factor that differentiated the value of this trait (Table 5). Regardless of the other experimental factors, denser seeding (200 and 250 kg·ha^{-1}), compared to the sowing rate of 150 kg·ha^{-1}, significantly reduced the level of weed infestation in this respect, on average by 35–37%. The significant interaction of the experimental factors indicates that for the breeding

Table 5. Number of monocotyledonous weeds in the canopy of spring spelt wheat depending on experimental factors (mean for years 2012–2014) (plants·m^{-2})

Breeding line	Nitrogen level (kg·ha^{-1})	Sowing rate (kg·ha^{-1})			Mean
		150	200	250	
A10	50	90.1	52.9	36.4	59.8
	80	56.3	47.8	44.9	49.7
	Mean	73.2	50.4	40.7	54.8
A12	50	77.3	38.6	41.8	52.6
	80	68.9	52.4	61.3	60.9
	Mean	73.1	45.5	51.6	56.7
Mean	50	83.7	45.7	39.1	56.2
	80	62.6	50.1	53.1	55.3
	Mean	73.2	47.9	46.1	–
$LSD_{0.05}$	Sowing rate – 12.8; Breeding lines × sowing rate – 22.1; Sowing rate × nitrogen level – 22.1				

line A10, the sowing rate of 250 kg spikelets per hectare was most effective in reducing monocotyledonous weeds, whereas in the case of A12 it was 200 kg·ha^{-1}.

The spelt breeding lines evaluated differed in the number of dicotyledonous weeds (Table 6). The A10 spelt crop showed a significantly higher value of this trait. The significant interaction revealed that the breeding lines responded differently to sowing rate. In the case of A10, the seeding rate of 200 kg spikelets per hectare was least favorable, since it resulted in a significant increase in the number of dicotyledonous weeds relative to the other sowing rates, whereas in the plots with the spelt breeding line A12 the number of dicotyledonous weeds was at a similar level in all treatments. Nitrogen fertilization was a factor that differentiated the value of the trait in question – significantly fewer dicotyledonous weeds were found in the treatment with the higher nitrogen rate.

Table 6. Number of dicotyledonous weeds in the canopy of spring spelt wheat depending on experimental factors (mean for years 2012–2014) (plants·m^{-2})

Breeding line	Nitrogen level (kg·ha^{-1})	Sowing rate (kg·ha^{-1})			Mean
		150	200	250	
A10	50	9.0	19.4	14.8	14.4
	80	6.7	18.6	6.4	10.6
	Mean	7.9	19.0	10.6	12.5
A12	50	4.8	13.0	13.3	10.4
	80	13.8	6.2	4.8	8.3
	Mean	9.3	9.6	9.1	9.3
Mean	50	6.9	16.2	14.1	12.4
	80	10.3	12.4	5.6	9.4
	Mean	8.6	14.3	9.9	–
$LSD_{0.05}$	Breeding lines – 2.9; Sowing rate – 4.3; Nitrogen level – 2.9; Breeding lines × sowing rate – 7.5; Sowing rate × nitrogen level – 7.5				

On average over the three-year study period, a similar total number of weeds was found in the crops of the spelt breeding lines compared, but sowing rate was a factor that significantly modified this trait (Table 7). The use of the higher amounts of seeded spikelets (200 and 250 kg·ha^{-1}) resulted in a decrease in the total number of weeds by respectively 24% and 32% compared to the lowest sowing rate. Buczek et al. [2012] did not show seeding rate to affect the numbers of weeds in a spring wheat crop, whereas in a study by Piekarczyk [2010] the reduction in the number of weeds in winter wheat as influenced by a higher seeding rate was small (15%).

In the present experiment, the higher nitrogen rate reduced the total number of weeds by 6% on average. In the opinion of Duer [1988], the dynamic growth of spring wheat well supplied with nitrogen suppresses the growth of weeds, but the biomass of weeds, not their numbers, is primarily reduced. This is confirmed by a study by Stępień [2004] which demonstrated that nitrogen application at a rate of 60 kg·ha^{-1}, compared to a rate of 90 kg, had practically no effect on weed number, but caused an about 20% reduction in their dry weight.

Table 7. Total number of weeds in the canopy of spring spelt wheat depending on experimental factors (mean for years 2012–2014) (plants·m^{-2})

Breeding line	Nitrogen level (kg·ha^{-1})	Sowing rate (kg·ha^{-1})			Mean
		150	200	250	
A10	50	99.1	72.3	51.2	74.2
	80	63.0	66.4	51.3	60.3
	Mean	81.1	69.4	51.3	67.3
A12	50	82.1	51.6	55.1	63.0
	80	82.7	58.6	66.1	69.2
	Mean	82.4	55.1	60.7	66.0
Mean	50	90.6	61.9	53.2	68.6
	80	72.8	62.5	58.7	64.7
	Mean	81.8	62.2	56.0	–
$LSD_{0.05}$	Sowing rate – 12.7; Breeding lines × sowing rate – 21.8; Sowing rate × nitrogen level – 21.8				

Due to their varying morphological characteristics related to stem length, tillering or leaf surface area, cereal cultivars exhibit different competitive potential against weeds [Andrew et al. 2015, Didon 2002, Feledyn-Szewczyk 2013]. In the present experiment, a significantly lower air-dry weight of weeds was found in the A10 crop, which indicates its better competitive ability against weeds compared to the breeding line A12 (Table 8). In the opinion of Kristensen et al. [2008], denser seeding is an important factor that reduces weed biomass in cereal crops, being

Table 8. Dry weight of weeds in the canopy of spring spelt wheat depending on experimental factors (mean for years 2012–2014) (g·m^{-2})

Breeding line	Nitrogen level (kg·ha^{-1})	Sowing rate (kg·ha^{-1})			Mean
		150	200	250	
A10	50	123	98	95	105
	80	95	82	104	94
	Mean	109	90	100	100
A12	50	156	116	96	123
	80	132	122	133	129
	Mean	144	119	114	126
Mean	50	140	107	96	114
	80	114	102	118	111
	Mean	127	104	107	–
$LSD_{0.05}$	Breeding lines – 16; Sowing rate × nitrogen level – 40				

an alternative method to the chemical and mechanical weed control method. Based on a study conducted on four cultivars of spring common wheat, Weiner et al. [2001] demonstrated that under conditions of severe weed infestation of a crop, an increase in seeding rate from 400 to 600 seeds per 1 m^2 reduced weed biomass by 60%. Buczek et al. [2012] obtained similarly high effectiveness. In the own study, in spite of the earlier described changes in the weed infestation structure, only a small decrease in weed biomass produced, on average 16–18%, was found under the influence of the higher sowing rate (200–250 kg·ha^{-1}) compared to the treatment with 150 kg spikelets per hectare.

The higher sowing rate and increased nitrogen fertilization did not affect the competitiveness of the A10 and A12 spelt against weeds and hence no significant interaction between these factors and breeding lines was proven. However, the interaction between nitrogen rate and sowing rate was revealed. A significant reduction in weed biomass as affected by increasing sowing rate was only found under condition of the lower nitrogen level, but a statistically proven difference (31%) was only recorded after the sowing rate had been increased to 250 kg spikelets per hectare.

Regardless of the agronomic factors, total number of weeds in all years of the study was similar. Interaction between experimental factors indicate that in hot and dry season of 2012 diversification of sowing rate did not affect the weed infestation of spring spelt canopy, while in 2013 and 2014, when the total rainfall exceeded the long-term average, an increase in sowing rate significantly decreased the total number of weeds.

Table 9. Total number of weeds in the canopy of spring spelt wheat depending on years and experimental factors (plants·m^{-2})

Year	Breeding line		Sowing rate (kg·ha^{-1})			Nitrogen level (kg·ha^{-1})		Mean
	A10	A12	150	200	250	50	80	
2012	57.4	76.8	64.3	60.8	76.2	73.1	61.1	67.1
2013	71.5	63.9	101.4	57.1	44.7	58.7	76.8	67.7
2014	72.8	57.4	79.5	68.8	47.0	73.9	56.2	65.1
$LSD_{0.05}$	Year × sowing rate – 29.3							

CONCLUSIONS

1. Over the three-year study period, the crops of the spelt breeding lines were dominated by *Avena fatua*, whose percentage in the overall weed community averaged 68–72%.
2. The spring spelt breeding line A10 can be considered to be more competitive against segetal flora, as evidenced by a significantly lower dry weight of weeds in the crop compared to the breeding line A12.
3. Weed infestation of the spring spelt crop was mostly independent of the level of nitrogen fertilization, though in the treatment with higher rate of 80 kg N·ha^{-1} a lower number of dicotyledonous weeds was noted than in the treatment with lower nitrogen rate (50 kg·ha^{-1}).
4. An increasing of sowing rate from 150 to 200 and 250 kg·ha^{-1}, respectively, resulted in a significant decrease in the number of monocotyledonous weeds and in the total number of

weeds in the crop. At the same time, it was revealed that a higher sowing rate may reduce weed compensation, in particular in relation to *Avena fatua*.

5. The significant reduction of dry weight of weeds as a result of increasing sowing rate was only found in the case of application of 50 kg $N \cdot ha^{-1}$.

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S. Andruszczak

ZACHWASZCZENIE ŁANU NOWYCH RODÓW HODOWLANYCH JAREJ PSZENICY ORKISZ W ZALEŻNOŚCI OD NORMY SIEWU I NAWOŻENIA AZOTEM

Synopsis. Eksperyment polowy przeprowadzono w latach 2012–2014 na średnio ciężkiej rędzinie mieszanej. Celem badań była ocena składu gatunkowego, liczby i powietrznie suchej masy chwastów w łanie jarych form orkiszu w zależności od następujących czynników badawczych: I. rody hodowlane jarej pszenicy orkisz (A10 i A12), II. norma wysiewu kłosków (150, 200 i 250 kg·ha^{-1}), III. dawka azotu (50 i 80 kg·ha^{-1}). Dominującym gatunkiem w łanie orkiszu był *Avena fatua,* którego udział w ogólnym zbiorowisku chwastów oceniono na 68–72%. Bardziej konkurencyjny wobec chwastów okazał się orkisz A10 w porównaniu z rodem A12. Intensyfikacja nawożenia azotem w niewielkim stopniu wpływała na zachwaszczenie orkiszu, natomiast czynnikiem istotnie różnicującym florę segetalną była norma wysiewu. Zwiększenie ilości wysiewu kłosków ze 150 do 200 i 250 kg·ha^{-1} ograniczyło liczbę chwastów w łanie, natomiast istotną redukcję powietrznie suchej masy chwastów pod wpływem zwiększonej normy siewu stwierdzono jedynie w warunkach stosowania niższej dawki azotu.

Słowa kluczowe: orkisz jary, norma siewu, nawożenie azotem, skład gatunkowy chwastów

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