

DOI: 10.5586/aa.1674

Publication history

Received: 2016-01-24 Accepted: 2016-05-27 Published: 2016-09-23

Handling editor

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Authors' contributions

EW: idea of the study, writing the manuscript, AK: carrying out the research; GN: performed computations

Funding

Research was supported by the Polish Ministry of Science and Higher Education as part of the statutory activities of the Department of Agronomy of the West Pomeranian University of Technology in Szczecin.

Competing interests

No competing interests have been declared.

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Citation

Wrzesińska E, Komorowska A, Nurkiewicz G. The impact of stubble crop on spring barley weed infestation. Acta Agrobot. 2016;69(3):1674. http://dx.doi. org/10.5586/aa.1674

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ORIGINAL RESEARCH PAPER

The impact of stubble crop on spring barley weed infestation

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Abstract

The condition and degree of weed infestation were determined in a spring barely crop grown in a short-term monoculture after mulching the soil with plants grown as a stubble crop (the control treatment without cover crop – lacy phacelia, white mustard, sunflower). The field experiment was carried out in 2010–2013 on good rye soil complex using a split-block design in four replications. The obtained results (the mean from all years of the experiment) showed that the stubble crop, especially sunflower, reduced the diversity of weed species without causing at the same time changes in weed species dominance. In all the control treatments of the experiment, *Chenopodium album* and *Fallopia convolvulus* were the dominant species. The degree of spring barley weed infestation depended on the species grown in the cover crop. White mustard and lacy phacelia slightly increased the number of weeds but their fresh matter significantly increased. However, the sunflower cover crop significantly increased the number of weeds without any substantial differentiation of their fresh mass.

Keywords

crop weed infestation; spring barley; monoculture; stubble crop; mulch

Introduction

Due to the prevailing share of cereals in the crop structure (75%) that has been maintained in Poland for many years, cereals are sown after previous grain crops or in a monoculture. Wheat and barley belong to the type of plants that are particularly sensitive to crop sequencing, even in the short term. The effect of monoculture is a decrease in yield mainly due to the severity of infection caused by diseases and pests [1,2], the accumulation of toxins due to the decay of crop residue [3,4] as well as increased weed infestation [5–8].

One of the methods of reducing the negative effects of cereals sown after each other is the cultivation of phytosanitary plants such as stubble crops [9-11]. Among plants grown as stubble crops, the most useful ones prove to be short vegetation species that sprout and grow quickly, shadow the soil well and provide lots of organic matter which easily undergoes the decay process. The effect of intercrop plants on weed infestation of cereals is not explicit, although more studies indicate a reduction in weed infestation, especially if plants from the Brassicaceae family possessing allelopathic features were grown as a stubble crop [12-15].

The aim of the study was to determine the influence of three plant species (lacy phacelia, white mustard, and sunflower) grown as a stubble crop on weed infestation of a spring barley crop cultivated in a short-term (3 years) monoculture.

Material and methods

The field experiment was carried out in 2010–2013 in RSD Lipnik near Stargard Szczeciński, W Poland on light soil classified as good rye soil complex in a field after winter wheat. The experiment was set up as a split-block design in four replications in plots with an area of 25 m². The experimental factor was the plant species grown as a stubble crop: the control treatment (without cover crops), lacy phacelia (*Phacelia tanacetifolia* Benth.), white mustard (*Sinapis alba* L.), and sunflower (*Helianthus annuus* L.).

Immediately after the harvest, for the catch crop skimming with harrowing was conducted. Next, mineral fertilizers were applied (N – 52 kg ha⁻¹, P – 40 kg ha⁻¹, K – 60 kg ha⁻¹). Seeds (lacy phacelia – 15 kg ha⁻¹, white mustard – 20 kg ha⁻¹, sunflower – 30 kg ha⁻¹) were sown using a seed cultivator. In the control treatment without catch crop, the herbicide Roundup Energy 450 SL (3 dm³ ha⁻¹) was sprayed to destroy weeds. Crop yield was determined in autumn before ground frost by collecting whole plants from two points of the 25-m² area. Fresh and air-dry weight yield was determined. The crushed plants were left in the field until spring as a mulch. The highest mean air-dry weight yield was obtained from white mustard – 2.09 t ha⁻¹, while the yield of lacy phacelia and sunflower was lower by about 10% (1.90 t ha⁻¹) and 21% (1.65 t ha⁻¹), respectively.

Spring barley 'Azit' was sown during the best agronomic season (the first 10-day period of April) using a seed drill. The amount of seeds sown, fertilization, and tillage operations were according to the agronomic requirements of the particular species.

Weed infestation in the spring barley crop was determined in fixed areas of 1 $\rm m^2$ (protected with plastic foil against the herbicides applied) by the dry-weight-rank method which was applied twice during plant growth: at the heading stage (BBCH 55) the composition of weed species and their number were determined, whereas at the fully ripe stage (BBCH 92) the composition of weed species as well as their number and fresh weight were determined.

The statistical analysis of the number of weeds and their fresh weight was carried out using FR-ANALWAR calculation package (by Franciszek Rudnicki, University of Life Science and Technology in Bydgoszcz, Poland), while the significance of the differences was estimated by means of Tukey's test (at a significance level of $\alpha = 0.05$).

Results

During the 3-year study period, in both seasons in which weed infestation was estimated, 23 annual weed species and one perennial species (Cirsium arvense; Tab. 1, Tab. 2), were found in the spring barley crop. The highest diversity of species was observed in the control treatment and in both seasons of weed infestation estimation it was at the same level of 15 species. In the control treatment, after the stubble crops it was slightly lower in the first period of the research (BBCH 55); from 14 species after the lacy phacelia catch crop, 13 species after white mustard, and 12 species after sunflower (Tab. 1, Tab. 2). In the second period of the research (BBCH 92), the stubble crops visibly reduced the weed species diversity: lacy phacelia - 5 species (Tab. 2). In all the control treatments, the dominant species, characteristic for their significant share in the overall weed infestation of the crop, were Chenopodium album and Fallopia convolvulus (Tab. 1, Tab. 2). The percentage share of these species was very high, ranging from 89.4% to 98.2% of the total number of weeds. At the heading stage, the smallest number of dominant species was determined in the control treatment (89.4% of the total number of weeds), whereas after lacy phacelia, white mustard and sunflower it was 94.9%, 93.6%, and 94.4%, respectively. At the fully ripe stage, their share in overall weed infestation of the barley crop increased; in the control it reached 91.4%, after the sunflower catch crop it reached 95.5%, after white mustard it was 97.2%, and after lacy phacelia it was as much as 98.2%. The other weed species found in the spring barley crop occurred scarcely. Apart from that, a small number of common taxa were found which occurred in each of the control treatments. In

Tab. 1 The share of weed species in spring barley weed infestation (BBCH 55; means from 2011–2013).

	Plant species grown as a stubble crop (%)				
Weed species	control	lacy phacelia	white mustard	sunflower	
Chenopodium album L.	46.1	34.7	38.1	30.3	
Fallopia convolvulus L. Á. Löve	43.3	60.2	55.5	64.1	
Viola arvensis Murray	4.7	1.1	1.6	1.3	
Thlaspi arvense L.	0.7	0.3	2.5	0.9	
Lamium purpureum L.	1.6	0.7	0.8	0.9	
Stellaria media (L.) Vill.	1.0	0.0	0.3	0.7	
Polgonum aviculare L.	0.9	0.4	0.4	0.8	
Geranium pusillum Burm. f. ex L.	0.3	0.0	0.3	0.4	
Capsella bursa-pastoris (L.) Medik.	0.5	0.3	0.0	0.1	
Lycopsis arvensis L.	0.2	1.4	0.0	0.2	
Cirsium arvense (L.) Scop.	0.2	0.0	0.0	0.0	
Fumaria officinalis L.	0.2	0.1	0.1	0.0	
Centaurea cyanus L.	0.1	0.0	0.1	0.0	
Erodium cicutarium (L.) L' Hér.	0.1	0.0	0.0	0.0	
Phacelia tanacetifolia Benth.	0.1	0.3	0.0	0.0	
Matricaria maritima subsp. inodora L. Dostál	0.0	0.2	0.1	0.1	
Sisymbrium officinale (L.) Scop.	0.0	0.1	0.0	0.2	
Spergula arvensis L.	0.0	0.1	0.1	0.0	
Sinapis alba L.	0.0	0.0	0.1	0.0	
Veronica arvensis L.	0.0	0.1	0.0	0.0	
Number of species	15.0	14.0	13.0	12.0	

both seasons of the experiment, apart from the dominant species *Viola arvensis* and *Polygonum aviculare* were observed, whereas at the heading stage *Thlaspi arvense* and *Lamium purpureum* occurred.

The statistical analysis of the number of weeds and their fresh weight showed a significant dependence of the obtained values on the year of the study. In all years of the study period, the number of weeds determined at the time of heading was smaller than after the stubble crop (Tab. 3).

When compared to the number of weeds determined in the control treatment, the catch crop with lacy phacelia and white mustard considerably increased the number of weeds (from 18% to 34%). After the sunflower catch crop, a significantly higher number of weeds than in the control (by 20%) was found only in the last year of the experiment – 2013. The statistical analysis of the mean number of weeds in the spring barley crop over the whole period showed that, compared to the number determined in the control treatment, after each stubble crop their number was significantly higher (after sunflower by about 13%, while after lacy phacelia and white mustard by about 25%). Before the harvest of the crop, at the fully ripe stage the effect of stubble crop on the degree of crop weed infestation during the particular years of the experiment was not explicit. In the first year of the research (2011), the highest number of weeds was recorded after the catch crop with lacy phacelia and this number was considerably lower (by 14%) only in the control after white mustard. During the rest of the

Tab. 2 The share of weed species in spring barley weed infestation (BBCH 92; means for 2011–2013).

	Plant species grown as a stubble crop (%)				
Weed species	control	lacy phacelia	white mustard	sunflower	
Chenopodium album L.	47.8	52.9	51.1	49.9	
Fallopia convolvulus (L.) Á. Löve	43.6	45.3	46.1	45.9	
Lamium ampexicaule L.	2.3	0.0	0.0	0.0	
Viola arvensis Murray	2.7	0.5	1.1	2.1	
Lamium purpureum L.	0.5	0.0	0.1	0.3	
Vicia hirsuta (L.) S. F. Gray	0.4	0.0	0.0	0.0	
Apera spica-venti (L.) P. Beauv.	0.4	0.0	0.0	0.0	
Polgonum aviculare L.	0.8	1.2	0.9	1.0	
Echinochloa crus-galli (L.) P. Beauv.	0.4	0.0	0.0	0.0	
Cirsium arvense (L.) Scop.	0.4	0.0	0.0	0.0	
Capsella bursa-pastoris (L.) Medik.	0.3	0.0	0.0	0.1	
Geranium pusillum Burm. f. ex L.	0.1	0.0	0.0	0.1	
Vicia tetrasperma (L.) Schreb.	0.1	0.0	0.1	0.0	
Lycopsis arvensis L.	0.1	0.0	0.1	0.2	
Veronica arvensis L.	0.1	0.0	0.0	0.1	
Thlaspi arvense L.	0.0	0.1	0.0	0.3	
Centaurea cyanus L.	0.0	0.0	0.1	0.0	
Spergula arvensis L.	0.0	0.0	0.4	0.0	
Number of species	15.0	5.0	9.0	10.0	

 $\textbf{Tab. 3} \quad \text{The number of weeds in the spring barley crop (pcs } m^{-2}\textbf{)}.$

	Time of experimental measurements							
	BBCH 55			BBCH 92				
Stubble crop	2011	2012	2013	mean	2011	2012	2013	mean
Control	85.00	88.00	82.00	85.00	78.00	77.70	66.40	74.00
P. tanacetifolia	102.00	116.40	100.80	106.40	82.00	84.70	64.40	77.00
S. alba	106.00	103.50	110.00	106.50	71.00	89.80	60.50	73.70
H. annuus	93.00	95.70	98.50	95.80	81.00	99.60	83.10	87.90
LSD _{0.05}	7.13	9.54	6.92	6.12	10.99	8.52	6.51	7.08

1ab. 4 Fiesh weight of weeds (g iii ; bbCn 9	Tab. 4	weight of weeds (g m ⁻² ; BBCH 92).
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	Year					
Stubble crop	2011	2012	2013	mean		
Control	432.00	381.00	400.50	404.50		
P. tanacetifolia	676.00	534.30	643.60	617.90		
S. alba	708.00	519.60	644.00	623.80		
H. annuus	465.00	492.40	464.50	473.90		
LSD _{0.05}	29.13	38.98	92.78	94.92		

study period (2012 and 2013), most weeds were recorded after the sunflower catch crop, significantly more than in all other control treatments. This relationship was confirmed by the statistical analysis of the mean results over the study period. In comparison to the number of weeds determined in the control, approximately the same number was recorded after the white mustard catch crop, slightly higher (by 4%) after lacy phacelia, and significantly larger (by 19%) after sunflower.

In each year of the study, the fresh weight of weeds (as determined before the harvest) after the lacy phacelia and white mustard cover crops proved to be significantly higher (from

40% to 64%) than the one in the control treatment (Tab. 4). However, after the sunflower cover crop a significantly higher fresh weight of weeds was recorded in the first 2 years of the experiment; in 2013 it was not much different from the one recorded in the control. The means from the whole study period showed that, when compared to the fresh weight determined in the control treatment, a similar number (the difference was not proven statistically) was determined after the sunflower cover crop, but it was significantly higher (by about 54%) after the lacy phacelia and white mustard cover crops.

Discussion

In sustainable agriculture, weeds are considered both as competitors of the cultivated plants and as an element enhancing the species diversity in an agrocenosis [16,17]. The harmfulness of weeds depends not only on their species number, but also on their overall number and weight. The results of the 3-year research showed that all the plants grown as a stubble crop reduced the species diversity of weeds. A reduced number of species was found mainly at the end of the spring barley-growing season after the sunflower stubble crop. Before the harvest of the crop at the fully ripe stage, the effect of stubble crop on the degree of weed infestation during the particular years of the experiment was not explicit. In the first year of the study (2011), the highest number of weeds was recorded after the catch crop with lacy phacelia and this number was considerably lower (by 14%) only in the control after white mustard. During the rest of the study period (2012 and 2013), most weeds were recorded after the sunflower catch crop, significantly more than in all other control treatments. This relationship was confirmed by the statistical analysis of the mean results over the study period. In comparison to the number of weeds determined in the control, approximately the same number was recorded after the white mustard catch crop, slightly higher (by 4%) after lacy phacelia, and significantly larger (by 19%) after sunflower.

As regards weed infestation of spring barley, in comparison to the control without cover crop, after the application of black mustard and oily radish mulch Duer [18] found a decrease in the percentage of *Chenopodium album*, but Małecka et al. [19] observed an increase in the number of weed species after white mustard mulch. Gawęda [20–22] found, with respect to weed infestation of spring barley as well as spring wheat and oats, that *Chenopodium album* was the dominant weed species in the barley crop, irrespective of the stubble crop used. In spring barley, the number of its representatives was most reduced by the winter rape cover crop, whereas in case of spring wheat it was due to the mixture of legumes and lacy phacelia. In the oat crop, the largest number of *Chenopodium album* representatives was found after white mustard, whereas the smallest number was observed in the plots without cover crop. Gawęda et al. [23] found that in the spring barley crop sown after the stubble crop the most numerous species was *Veronica persica*, whereas in the control treatment it was *Avena fatua*; however, all the plants grown as a stubble crop reduced its share in overall weed infestation of the crop.

The study results showed that the effect of stubble crop on the degree of spring barley weed infestation depended on the mulch species. In comparison to the control treatment, the white mustard and lacy phacelia cover crops slightly increased the number of weeds, but significantly increased their fresh weight. The effect of the sunflower cover crop was different - it significantly increased the number of weeds but there was no difference in their fresh weight. It might have been caused by the allelopathic potential of sunflower, which reduces the growth and development of crops [24]. As far as the effect of brassicas on the number and weight of weeds is concerned, a similar relationship was observed by Duer [18]. When the mulch was left over the winter for the spring barley crop, she noted a decrease in the number of weeds and at the same time an increase in their dry weight. The results of the research by Gaweda [20] showed no impact of the winter rape cover crop on the number of weeds in the spring barley crop but with a very significant (by 43%) reduction of their weight, with the highest weight observed after the lacy phacelia cover crop, which was much higher than in the other control treatments. In another experiment conducted by Gaweda et al. [23], on the other hand, ploughed under white mustard reduced (by 49.5%) the dry weight of weeds in the spring barley crop. The research conducted by Małecka et al. [19] shows that mulch plants reduced the number of weeds by 20–25% without modifying their fresh weight; however, the results obtained by Kwiatkowski [15] showed that the white mustard cover crop significantly reduced the number of weeds (over threefold) and their dry weight (almost fourfold) in the spring barley crop. No impact of field pea cover crop on spring barley weed infestation was observed in the results obtained by Wilczewski [25].

Conclusions

The use of a stubble crop as a mulch, mainly sunflower in a short-term monoculture of spring barley, reduced the species diversity of weeds. The tested stubble crops did not cause changes in the dominance of weed species. In all control treatments, the dominant species were *Chenopodium album* and *Fallopia convolvulus*. The degree of weed infestation in spring barley depended on the plant species grown as a cover crop. The white mustard and lacy phacelia cover crops slightly increased the number of weeds but their fresh weight was significantly higher than that determined in the control treatment. The sunflower cover crop significantly increased the number of weeds, but their fresh weight did not differ much from that obtained in the control treatment.

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Wpływ międzyplonu ścierniskowego na zachwaszczenie łanu jęczmienia jarego

Streszczenie

W łanie jęczmienia jarego 'Azit' uprawianego w krótkotrwałej monokulturze po mulczowaniu gleby roślinami uprawianymi w międzyplonie ścierniskowym (kontrola – bez międzyplonu,

facelia błękitna, gorczyca biała, słonecznik zwyczajny) określano stan i stopień zachwaszczenia. Doświadczenie polowe przeprowadzono w latach 2010–2013 na glebie kompleksu żytniego dobrego w czterech powtórzeniach metodą bloków losowych. Wykazano, że międzyplon ścierniskowy, zwłaszcza ze słonecznika zwyczajnego, ograniczał różnorodność gatunkową chwastów nie powodując jednocześnie zmian dominacji gatunkowej. Na wszystkich obiektach doświadczenia gatunkami dominującymi były *Chenopodium album* i *Fallopia convolvulus*. Stopień zachwaszczenia jęczmienia jarego zależał od gatunku rośliny uprawianej w międzyplonie. Międzyplony z gorczycy białej i facelii błękitnej nieznacznie zwiększyły liczbę gatunków występujących chwastów, ale ich świeża masa była istotnie wyższa. Natomiast międzyplon ze słonecznika zwyczajnego istotnie zwiększył liczbę chwastów nie różnicując istotnie ich świeżej masy.