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OAT VS WHITE MUSTARD AS CATCH CROP

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ABSTRACT

Background. The number of species suitable for late summer sowing as catch crops intended for mulching soil is insufficient. It has been hypothetically assumed that oat (*Avena sativa* L.) may be an alternative to white mustard (*Sinapis alba* L.) that is commonly grown for this purpose. The aim of this study was to compare the yield and nitrogen accumulation of oat and white mustard planted as catch crops at different late summer dates, and the effect of mulch from these plants on spring barley (*Hordeum sativum* L.) yield.
Material and methods. In the period from 2011 to 2013, oat and white mustard were sown separately on August 15 and September 1 and 15. No nitrogen fertilization was used for the catch crops. At the end of October, dry matter accumulation and nitrogen accumulation were determined. Photographic documentation of the mulch coverage of the soil was made. Over a 3-year period (2012–2014), spring barley was grown after the oat and mustard mulch. Plant density and grain yield of the barley was determined.
Results. Delaying the sowing date resulted in a decrease in catch crop dry matter accumulation, on average for both species, from 2.36 to 0.61 $Mg \cdot ha^{-1}$, and in nitrogen accumulation from 45.4 to 30.3 $kg \cdot ha^{-1}$. Differences in biomass and nitrogen accumulation, in favor of mustard, were associated with the earliest sowing date only. Oat plants did not lose leaves in winter and thus provided greater soil cover than mustard plants. These species cultivated as a catch crop and used for mulch did not differ in their effect on plant density or spring barley yield.
Conclusion. In crop rotations with a large proportion of cruciferous plants, oat may replace white mustard to capture residual N and to mulch the soil, however its sowing date should not be later than the beginning of September.

Key words: *Avena sativa* (L.), cover crop, mulch, *Sinapis alba* (L.), spring barley

INTRODUCTION

Catch crops, often called cover crops, have been successfully integrated into conservation agriculture systems. They play a substantial role in the reduction of water and wind erosion, help prevent nutrient leaching, enrich soil with organic matter, limit weed infestation, increase diversity of soil microorganisms and enzyme activity (De Baets *et al.*, 2011; Campiglia *et al.*, 2012; Kaspar *et al.*, 2012; Hashemi *et al.*, 2013; Piotrowska-Długosz and Wilczewski, 2014; Wanic *et al.*, 2019). The policy of the European Union, within the framework of programs concerning soil and water protection, is to financially support farmers growing winter or stubble catch crops left during winter on the field in the form of mulch (European Commission, 2019).

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Of the plants useful as catch crops, species from the family Fabaceae are of special value as they leave the soil rich in nitrogen, which has a positive effect on the yield of successive crops (Askegaard and Eriksen, 2007; Skinder *et al.*, 2007; Çarpici, 2017). However, in the northern and central parts of Europe these plants require early sowing, and seed is usually expensive. In Poland, the greatest yields of green forage from Fabaceae crops are obtained with a July sowing, while under current conditions cereal grain is usually harvested at the beginning of August (Skinder *et al.*, 2007). For this reason species from other botanical families are also used for cultivation as catch crops, and most often this is white mustard (*Sinapis alba* L., Brassicacea), less frequently it is oilseed radish (*Raphanus sativus* L. var. *oleiferus*, Brassicaceae) and phacelia (*Phacelia tanacetifolia* Benth., Boraginaceae) (De Baets *et al.*, 2007; Wilczewski, 2011; Brust *et al*., 2014). White mustard and oilseed radish, however, are hosts of dark leaf spot (*Alternaria alternata*, *A. brassicae*, *A. brassicicola*), white mold (*Sclerotinia sclerotiorum*) and noble rot (*Botrytis cinerea*) (Kurowski and Jankowski, 2003), the same pathogens that affect oilseed rape (*Brassica napus* L.) (Jajor and Mrówczyński, 2013). In recent years a considerable increase in the area of oilseed rape production has occurred in Europe (FAO, 2019), and consequently, an increase in infestation with its diseases. Rapeseed yield losses caused by fungal pathogens can be as high as 70–80% (Jajor and Mrówczyński, 2013). In this situation it is justified to look for species that can be grown as catch crops in crop rotations with oilseed rape which could replace white mustard and oilseed radish. An alternative may be oat, which additionally in autumn gives the chance of obtaining fodder of excellent nutritive value (Contreras-Govea and Albrecht, 2006; Coblentz *et al.*, 2011; Andrzejewska *et al.*, 2019; Favre *et al.*, 2019). Moreover, oat is not a host of fungal pathogens attacking wheat (*Triticum aestivum* L.), rye (*Secale cereale* L.), triticale (x *Triticosecale* Wittmack) and barley (Cichy *et al.*, 1994; Lemańczyk and Sadowski, 2002). This is a significant attribute of oat, since in the countries of western and central Europe the percentage of cereals in crop rotation exceeds 70%, and they are often the only species grown as the main crop (FAO, 2019). The results of experiments conducted in the USA show that oat as a catch crop can significantly reduce NO_3 losses to surface water from agricultural drainage systems used for corn and soybean production (Kaspar *et al.*, 2012).

Until now the usefulness of oat for mulching soils intended for typical agricultural crops in Europe has not been studied, although it works well in this role in vegetable crops, including cabbage, pepper, chicory, parsley and snap pea (Grimmer and Masiunas, 2004, Błażewicz-Woźniak, 2005; Jabłońska-Ceglarek *et al.*, 2006; Błażewicz-Woźniak and Konopiński, 2009; Campiglia *et al.*, 2012; Campiglia *et al.*, 2014).

The aim of this study was to compare biomass and nitrogen accumulation by oat and white mustard planted as catch crops with different late summer sowing dates, and the effect of mulch from these crops on spring barley yield.

MATERIAL AND METHODS

The experiment was conducted at Mochełek Research Station, University of Science and Technology in Bydgoszcz, Poland (53°13' N; 17°51' E) over 4 years from 2011 to 2014 (catch crops were grown in 2011–2013 and spring barley in 2012–2014). Soil characteristics in the field were fine sandy loam, mixed mesic, Ustic, Typic Hapludalf (acc. to World Reference Base for Soil Resources), pH in KCl of 5.8, organic matter (Tiurim method) of 2% and high levels of potassium and phosphorus (Egner-Riehm method), and optimum levels of magnesium (Schachtschabel method) based on local recommendations for soil tests.

Experimental factors:

I – sowing date:
- 15 August (+/- 3 days)
- 1 September (+/- 2 days)
- 15 September (+/- 3 days)

II – species:
- oat (cultivar 'Berdysz')
- white mustard (cultivar 'Nakielska').

The experiment was established after barley was harvested at the beginning of August. The sowing rate of oat was 180 $kg \cdot ha^{-1}$, and of mustard was 15 $kg \cdot ha^{-1}$. The area of plots for sowing was 15 m^2, and for harvest 9 m^2. Row spacing was 12 cm, and sowing depth 2–3 cm. In this experiment no fertilization was applied to the catch crops. The experiment was established with eight replications in a split-plot design, of which four were harvested in autumn to determine fresh and dry matter biomass accumulation. Plant harvest was performed with a cutter bar mower. In 2011 and 2012 the plots were harvested on 20 and 23 October, respectively, and in 2013 the harvest was performed on 2 November. The fresh, green plant material from each of the harvested plots was weighed, and then subsamples of 600 g were taken. The plant material was dried at 60°C for determination of dry matter concentration and dry matter accumulation per unit of area. Total nitrogen concentration was calculated using the rapid combustion method with an automatic analyzer (LECO Model FP-528; LECO Corp, St Joseph, Ml). Based on dry matter accumulation and total nitrogen concentration in the biomass, accumulation of nitrogen by the aboveground parts of oat and mustard was calculated.

Four replications of both catch crop treatments were left in the field in order to mulch the soil. Plots with mulch were plowed in spring and spring barley was sown. Barley was sown at a rate of 160 $kg \cdot ha^{-1}$ and mineral fertilizer was applied as follows: 80 $kg \cdot ha^{-1}$ N, 50 $kg \cdot ha^{-1}$ P_2O_5 and 80 $kg \cdot ha^{-1}$ K_2O. After full emergence, plant density per 1 m^2 was counted. Barley was harvested with a plot combine and grain yield was determined.

Statistical analysis

Data were analyzed using SAS Proc Mixed software version 9.4 (SAS Institute, 2009). Sowing date, crop, and sowing date x crop interaction were fixed effects while year, block within year, and sowing date × block within year were random effects. When treatment means were significant, least-squares means separation was conducted using the PDIFF option, with differences declared significant at $P < 0.05$.

RESULTS AND DISCUSSION

Weather conditions

Generally, the weather conditions in August, September and October, the period of catch crop growth, were similar among the years and similar to the long-term normal at the Mochełek Research Station over the 3-year experiment (Table 1). An exception is that September 2013 was markedly cooler than the other 2 years. Three-month total precipitation was slightly below normal in 2011 and above normal in 2012 and 2013.

Table 1. Long-term temperatures and precipitation and monthly mean/sum during cover crops and spring barley growing seasons at the Mochełek Research Station*

Months	Daily mean of air temperature, °C					Total precipitation, mm				
	2011	2012	2013	2014	1949–2012	2011	2012	2013	2014	1949–2012
Catch crop										
August	17.7	17.6	18.1	–	17.5	68	82	57	–	53
September	14.3	13.3	10.7	–	13.2	37	25	64	–	41
October	8.4	7.4	8.2	–	8.1	13	40	19	–	33
Mean/Total	13.5	12.8	12.3	–	12.9	118	147	140	–	127
Spring barley										
April	–	8.4	7.0	9.9	7.4	–	26	14	41	27
May	–	14.5	14.2	13.3	12.8	–	25	92	66	44
June	–	15.2	17.4	16.0	16.3	–	139	49	45	55
July	–	18.8	18.9	21.5	18.1	–	116	79	55	74
Mean/Total	–	14.2	14.4	15.2	13.7	–	306	234	207	200

* prepared by J. Żarski

During the growing season of spring barley, the air temperatures were similar among the years and similar to, or higher than, the long-term normal (Table 1). A particularly high temperature was recorded in July 2014. In 2012, the total precipitation in April – July was more than 100 mm greater than the long-term normal and distribution was not favorable, with this extra rain occurring in June and July. In 2013 and 2014, the total and distribution of rainfall was similar to the long-term normal.

Plant development

At the end of autumn growth, white mustard plants from the earliest sowing were on average 15 cm taller than the oat plants sown at the same time (Table 2). At later sowing dates, mustard plants were only slightly taller than oat. Oat sown on August 15 reached the final shooting stage and mustard the flowering stage. Oat from the second sowing date was in full tillering stage, and the inflorescence shoot had appeared in mustard. Plants from the 15 September sowing date were small, because oat reached only the initial tillering stage and mustard rosettes consisted of 2–8 leaves.

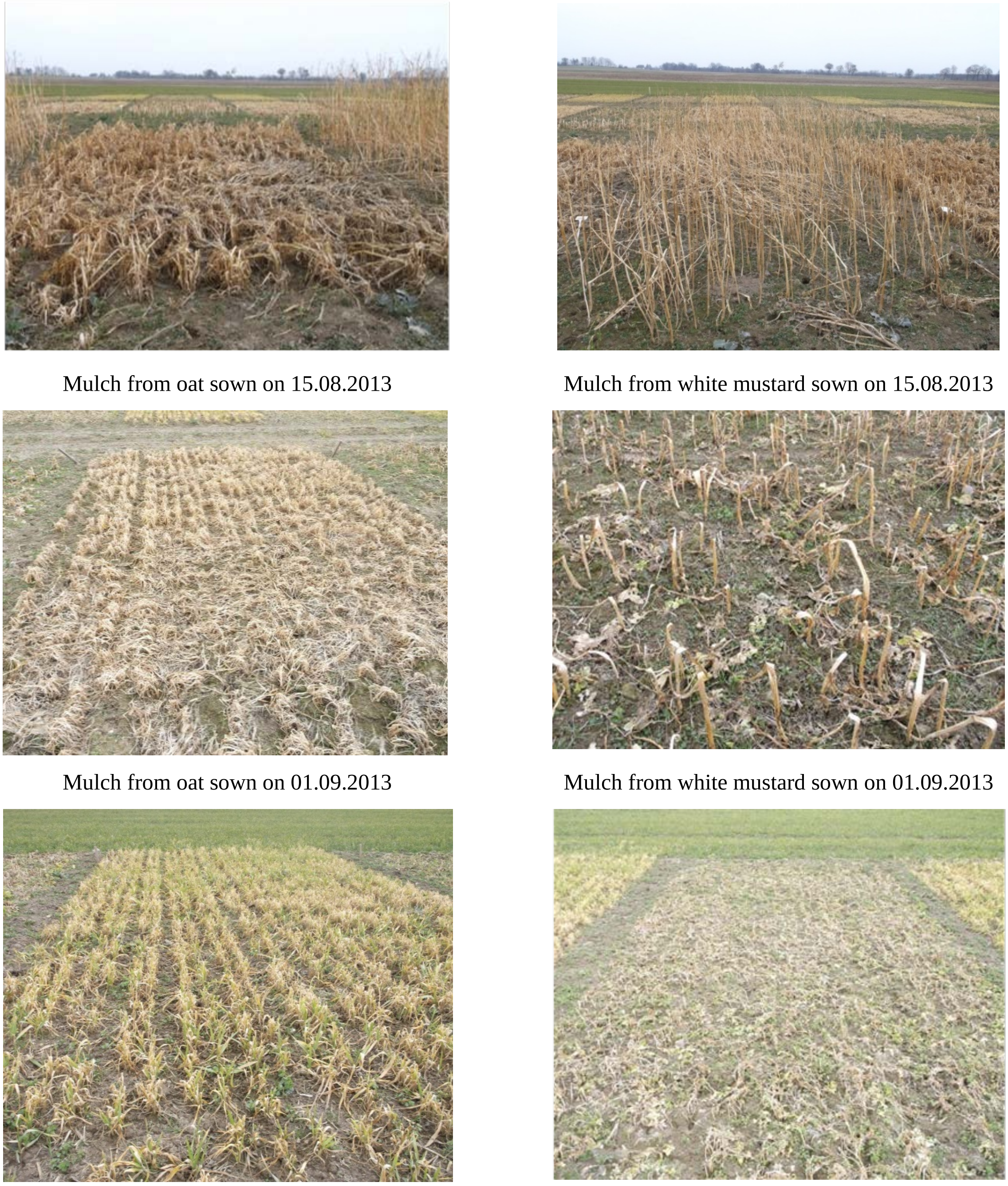
The typical condition of plants at the end of winter is shown in Fig. 1. All the photos were taken on 09/02/2014. Soil cover by oat plant residue was much greater compared to residue left by white mustard, especially the mulch from the first and second sowing dates. Mustard sown at the earlier dates lost leaves, which were blown away from the plots by the wind. Oat leaves, however, remained on the stalks, which significantly improved soil cover. Similar observations in relation to white mustard and oat have been described by Grimmer and Masiunas (2004). According to these authors, the mass of mustard residue left in spring was 38% of the autumn mass, while in the case of oats this was as much as 94%. Therefore, in future studies on the usefulness of various species for soil mulching, it is worth taking into account not only the vegetative mass that they are able to accumulate, but also their morphological structure, e.g. susceptibility of stems to lodging, abundance and type of foliage.

Sowing date of catch crops

Sowing date significantly affected dry matter accumulation, nitrogen concentration in plants, and nitrogen accumulation by the above-ground mass of plants grown as catch crops (Table 3). Greatest dry matter accumulation was associated with the August 15 sowing date. Delaying the sowing date by two weeks resulted in a yield reduction of approximately 55%, and delaying the sowing date by one month resulted in a yield decrease by as much as 75%. The concentration of nitrogen in plants decreased significantly with growth and development of both crops. The total amount of nitrogen accumulated in plants, however, depends mainly on biomass accumulation, and therefore plants sown on August 15 accumulated significantly more nitrogen (45.4 $kg \cdot ha^{-1}$) than plants sown on September 15 (30.3 $kg \cdot ha^{-1}$).

Table 2. Plant height and developmental stages of oat and white mustard after inhibition of growth in late autumn

Sowing date	Oat		White mustard	
	height (cm)	development stage acc. to BBCH	height (cm)	development stage
15 August	30–45	32–38	45–60	flowering
1 September	15–30	26–29	15–35	beginning of stem elongation
15 September	10–15	21–24	10–20	rosette (2–8 leaf)



Mulch from oat sown on 15.08.2013 | Mulch from white mustard sown on 15.08.2013

Mulch from oat sown on 01.09.2013 | Mulch from white mustard sown on 01.09.2013

Mulch from oat sown on 15.09.2013 | Mulch from white mustard sown on 15.09.2013

Fig. 1. Comparison of mulch from oat and white mustard in late winter 2014, after autumn sowing (author of photographs – J. Andrzejewska)

Barley reaction to the sowing date of catch crops was not one-way (Table 3) as it was, for example, in the experiment by Hashemi *et al.* (2013), where corn-silage yield decreased linearly when the planting of catch crops (oat and rye) was delayed from early September to early or mid-October. In our study, greater barley plant density and grain yield were obtained from barley cultivated after catch crops sown on August 15 and September 15 than was the case after catch crops sown on September 1 (Tables 3 and 5), which was the result of lower barley plant density with the intermediate date. Based on the collected results, however, it is difficult to explain the reason for this reduction of barley plant density. Literature data indicate that catch crops can exacerbate moisture deficiencies in the soil, particularly in water-limited environments, and thus affect the emergence of successive crops (Murungu *et al.*, 2011; Nielsen *et al*., 2016). In the current research, the decrease in yield after catch crops sown on September 1 occurred in 2012 and 2013 (data not presented), when spring precipitation was significantly lower than in 2014 (Table 1).

Table 3. Response of catch crop (independent of species) and spring barley as a successive crop, with three late summer sowing dates of catch crop

Studied traits	Date			SE	*P*-value
	15 August	1 September	15 September		
Catch crop DM accumulation, $Mg \cdot ha^{-1}$	2.36 A	1.03 B	0.61 C	0.099	<0.0001
N in catch crop, % DM	1.94 C	3.37 B	5.24 A	0.378	<0.0001
Catch crop N accumulation, $kg \cdot ha^{-1}$	45.4 A	32.8 B	30.3 C	2.253	0.0002
Barley plant density, plants per 1 m^2	275 A	241 B	276 A	13.96	<0.0001
Barley yield, $Mg \cdot ha^{-1}$	4.27 A	3.80 B	4.30 A	0.169	0.007

SE – standard error. Values within a row followed by the same letter are not different at $P < 0.05$

Species of catch crop

Average biomass accumulation from mustard was 0.4 $Mg \cdot ha^{-1}$ greater than from oat (Table 4), although the seeding rate for mustard was less than one-tenth that of oat. Both species contained similar N concentrations in the above ground biomass, but mustard accumulated 10.4 $kg \cdot ha^{-1}$ more N than the oat. There was no differential effect of mustard and oat on spring barley plant density or grain yield. In a study by Askegaard and Eriksen (2007), grain yield of spring barley grown after catch crops of non-legume plants ranged from 1.5 to 2.0 $Mg \cdot ha^{-1}$, the same level as from barley grown without catch crops and without nitrogen fertilization. Usually a strongly differential impact on a successive crop is noted when species from non-legume and legume groups are compared as catch crops (Skinder and Wilczewski, 2004; Askegaard and Eriksen, 2007; Wilczewski, 2011).

Interaction of the sowing date and species

A clear differentiation of dry matter accumulation between species was found with the earliest catch crop sowing date (Table 5). Mustard dry matter accumulation was 0.87 $Mg \cdot ha^{-1}$ greater than oat for plants sown on 15 August. As a consequence, the amount of nitrogen accumulated by mustard was also greater (16.2 $kg \cdot ha^{-1}$) than that accumulated by oat. The amount of nitrogen accumulated in aboveground parts of oat from the sowing on 15 August and 1 September and mustard sown on 1 and 15 September was very similar, ranging from 32.6 to 38.1 $kg \cdot ha^{-1}$. The smallest amount of nitrogen accumulated was by oat sown on 15 September. Hashemi *et al.* (2013) report that depending on the year of cultivation, oat sown between 2 and 30 September accumulated from 7 to 87 $kg \cdot ha^{-1}$ nitrogen.

Table 4. Dry matter accumulation, N concentration and N accumulation by oat and white mustard catch crops, and their effect on spring barley as a successive crop

Studied traits	Catch crop		SE	*P*-value
	oat	white mustard		
Catch crop DM accumulation, $Mg \cdot ha^{-1}$	1.13 B	1.53 A	0.081	0.0009
N in catch crop, % DM	3.50 A	3.53 A	0.360	0.6305
Catch crop N accumulation, $kg \cdot ha^{-1}$	31.0 B	41.4 A	1.839	0.0003
Barley plant density, plants per m^2	262 A	265 A	13.54	0.558
Barley yield, $Mg \cdot ha^{-1}$	4.04 A	4.21 A	0.150	0.0756

SE – standard error. Values within a row followed by the same letter are not different at $P < 0.05$

Table 5. Effect of sowing date and catch crop species interaction on dry matter accumulation, N concentration, and N accumulation by oat and white mustard, and their effect on spring barley as a successive crop

Studied traits	15 August		1 September		15 September		SE	*P* value
	oat	white mustard	oat	white mustard	oat	white mustard		
Catch crop DM accumulation, $Mg \cdot ha^{-1}$	1.92 B	2.79 A	0.99 C	1.06 C	0.48 D	0.74 CD	0.137	0.0159
N in catch crop, % DM	1.95 A	1.92 A	3.48 B	3.27 B	5.17 A	5.30 A	0.383	0.1473
Catch crop N accumulation, $kg \cdot ha^{-1}$	37.3 B	53.5 A	33.0 B	32.6 B	22.6 C	38.1 B	3.19	0.0207
Barley plant density, plants per m^2	270 A	280 A	237 B	245 B	280 A	271 A	14.62	0.2899
Barley yield, $Mg \cdot ha^{-1}$	4.25 AB	4.29 A	3.71 C	3.89 BC	4.14 AB	4.46 A	0.188	0.4954

SE – standard error. Values within a row followed by the same letter are not different at $P < 0.05$

The experiment did not assess the accumulation of underground biomass, but according to research by De Baets *et al.* (2011), with oat above-ground mass accumulation at the level of 1.4 $Mg \cdot ha^{-1}$, the underground biomass was 0.2 $Mg \cdot ha^{-1}$ (15%), and white mustard biomass accumulation was 1.5 and 0.3 $Mg \cdot ha^{-1}$, respectively (20%). Moreover, according to those authors, the root distribution of oat and white mustard, as well as ryegrass and rye, are the most suitable species for controlling concentrated flow erosion.

The aim of this research was to obtain results that can be directly related to actual conditions in practice. Therefore, the methodological assumptions had to be in line with cultivation guidelines for the agricultural region described, and thus the fertilization of barley with mineral nitrogen at a rate of 80 $kg \cdot ha^{-1}$ was used in the experiment. It can be assumed that if nitrogen fertilizer had not been applied to the barley, there would have been greater differences between the effect of white mustard and oat on barley yield because of different amounts of N in the mulch residues. However, the rate of nitrogen release from decaying catch crop plants may not be synchronized with the nutritional needs of the developing successive plant, which has been demonstrated by Cicek *et al.* (2015).

CONCLUSIONS

Oat cultivated as a catch crop accumulated slightly less biomass and nitrogen than white mustard. However, this did not affect the yield of spring barley as a successive crop, and, therefore, oat may be an alternative species to white mustard for use as mulch. An unfavorable feature of oats is its high sowing rate and the associated seed cost. An advantage is the fact that during winter oat plants do not lose their leaves, which, in comparison with mustard, provides greater soil cover. Due to reduced biomass and nitrogen accumulation with later sowing dates, oat used as a catch crop should be sown no later than the beginning of September in Poland.

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OWIES VS GORCZYCA BIAŁA W MIĘDZYPLONIE ŚCIERNISKOWYM

Streszczenie

Liczba gatunków przydatnych do uprawy w międzyplonie z późnoletniego siewu i przeznaczonych do mulczowania gleby jest niewielka. Hipotetycznie założono, że alternatywą dla powszechnie uprawianej na te cele gorczycy białej (*Sinapis alba* L.) może być owies (*Avena sativa* L.). Celem badań było porównanie plonów i akumulacji azotu przez owies i gorczycę białą wysiewane w różnych późnoletnich terminach oraz wpływ mulczu z tych roślin na plonowanie jęczmienia jarego (*Hordeum sativum* L.). W latach 2011–2013 owies i gorczyca biała były wysiewane 15 sierpnia oraz 1 i 15 września. Pod zasiewy międzyplonów nie stosowano nawożenia azotowego. W końcu października oznaczono plony oraz pobranie azotu. Opóźnianie terminu siewu skutkowało spadkiem plonu suchej masy, średnio dla obu gatunków z 2.36 do 0.61 $Mg \cdot ha^{-1}$ oraz pobraniem azotu z 45.4 do 30.3 $kg \cdot ha^{-1}$. Różnice w plonach i pobraniu azotu na korzyść gorczycy stwierdzono tylko w przypadku najwcześniejszego siewu. W latach 2012–2014 po mulczu z owsa i gorczycy uprawiano jęczmień jary. Oznaczono obsadę roślin i plony ziarna. Oba gatunki uprawiane jako międzyplon z przeznaczeniem na mulcz nie miały wpływu na obsadę roślin i plony jęczmienia jarego. W zmianowaniach z dużym udziałem roślin kapustowatych owies może zastępować gorczycę białą, zwłaszcza przy przeznaczeniu do produkcji mulczu. Termin siewu owsa nie powinien być późniejszy niż 1 września.

Słowa kluczowe: *Avena sativa*, międzyplon ścierniskowy, mulcz, *Sinapis alba*, jęczmień jary