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COMPARISON OF THE PRODUCTIVITY OF CEREALS WITH UNDERSOWN SERRADELLA GROWN FOR GREEN MASS

Summary

The aim of the study was to assess the yielding of four cereal species harvested at milky-dough maturity stage for green mass, cultivated in pure sowing and with undersown serradella in organic farm. Field experiment was carried out in the years 2011-2013, in a split-plot design, in four replications. The experiment included two factors. Four species of cereals, winter cereals: rye, spelt wheat and spring cereals: barley and oats were the first factor. A second factor involved the method of cereal cultivation: pure sowing, or sowing with undersown serradella. The studies showed that yield level of cereals grown with undersown serradella depended on weather conditions, which varied during the experiments. Among the tested species of cereal, the highest grain yields were obtained with oats, grown both with undersown serradella, and in pure stands. The yield of green mass of serradella depended on the species of cereal, which was used as a protective crop. Higher yields of serradella were recorded when it was undersown into spring cereals, compared to its undersowing into winter cereals. It yielded highest when cultivated with barley, slightly lower - with winter rye and the lowest - with oats. Undersowing serradella into barley and winter wheat had a little impact on the contents of total $N_{.,}$ and C_{org} in the soil, compared to pure sowings of cereals, while undersowing it into oats caused a decrease in their amounts.
Key words: *green mass, organic farm, spring cereals, undersown serradella, winter cereals*

PORÓWNANIE PRODUKCYJNOŚCI ZBÓŻ Z WSIEWKĄ SERADELI UPRAWIANYCH NA ZIELONĄ MASĘ

Streszczenie

Celem przeprowadzonych badań była ocena poziomu plonowania czterech gatunków zbóż zbieranych w dojrzałości mleczno-woskowej uprawianych w siewie czystym oraz z wsiewką seradeli w warunkach gospodarowania ekologicznego. Doświadczenie polowe przeprowadzono w latach 2011-2013, w układzie losowanych podbloków (split-plot), w czterech powtórzeniach. W doświadczeniu uwzględniono cztery gatunki zbóż: żyto ozime, pszenica orkisz, jęczmień jary, owies. Drugim czynnikiem był sposób uprawy zbóż: siew czysty lub z wsiewką seradeli. W badaniach wykazano, że poziom plonowania zbóż uprawianych z wsiewką seradeli zależał od przebiegu warunków pogodowych, które były zróżnicowane w czasie prowadzenia doświadczeń. Spośród badanych gatunków zbóż najwyższe plony uzyskano z owsa, uprawianego zarówno z wsiewką seradeli jak w siewie czystym. Plon zielonej masy seradeli uzależniony był od gatunku zboża, jako rośliny ochronnej. Większe plony seradeli zebrano, gdy była wsiewana w zboża jare niż w ozime. Najlepiej plonowała w uprawie z jęczmieniem, nieco mniej z żytem ozimym, zaś najniżej z owsem. Wsiewanie seradeli w jęczmień oraz zboża ozime miało niewielki wpływ na zawartość $N_{całk.}$ i C_{org} w glebie w porównaniu do siewu czystego zbóż, natomiast wsiewanie w owies powodowało zwiększenie ich zawartości.
Slowa kluczowe: *rolnictwo ekologiczne, wsiewka seradeli, zboża jare, zboża ozime, zielona masa*

1. Introduction

Growing serradella brings a lot of advantages, and is of great importance to crop rotation, as it positively affects soil fertility, and its phytosanitary state, as well as constitutes a good pre-crop for other plants, especially for cereals, cultivated on pure soil. Serradella leaves behind nitrogen-rich positions. Fodder obtained from serradella contains a lot of proteins, mineral soils, and vitamins. It can be grown as a main crop, a second crop, as an undersown crop, or as a stubble crop. Cultivating serradella makes it possible to produce animal feed on pure soils [1, 2, 3], significantly limites the results of frequent sowings of cereals one after another [4, 5, 6], and significantly reduces the occurrence of diseases [7]. According to Losakov et al. [8], Andersen et al. [9], Svenson et al. [10] undersown catch crops, including serradella, constitute a source of organic matter, whose impact on certain pests, and soil biological activity differs from the impact of cereals. Cultivating of serradella in pure sowing is not recommended, due to its strong lodging, and problems with the harvest. Good results were obtained when it was sown with protective crops, such as cereals [11]. A proper selection of a protective crop significantly reduces the risk of poor yields of serradella under adverse weather, and habitat conditions [12, 13]. According to many authors, serradella is more frequently undersown into winter rye [14, 15], oats [16], barley [17], and winter triticale [15]. Yet, in the opinion of Witkowicz [18], specific habitat requirements of serradella strongly limit the scope of species which can be used as its protective crop. At present, cultivation of seradella has become popular in organic farms, especially in ones which are located on light soils. Such farms take a large percentage of agricultural lands in Poland [19].

The aim of the study was to assess the yielding of four cereal species harvested on green mass cultivated in pure sowing and with undersown serradella in organic farm.

2. Material and methods

Field experiment was carried out in the years 2011-2013 at Agricultural Advisory Center in Szepietowo (the Podlaskie voivodeship), [52°52′11″N 22°32′27″E] in a split-plot design, in 4 replications. The studies included 4 cereal species, winter: spelt wheat (*Triticum spelta* L.) and rye (*Secale cereale* L.), spring: oat (*Avena sativa* L.) and barley (*Hordeum vulgare* L.), and the method of cereal cultivation: pure sowing, or sowing with undersown serradella (*Ornithopus sativus* L.). The density of cereals amounted to: oats, rye, and spelt wheat - 500 plants·m^{-2}, barley – 300 plants·m^{-2}, and seradella 60 kg·ha^{-1}. The size of a plot at the set-up of the experiment was 30.0 m^2, while at the harvest, it was 27.6 m^2. The experiment was carried out on the soil of good rye complex, class IVb. The sowing of winter cereals was performed in the term between 29 September and 29 October, while spring cereals and serradella between 9 and 26 April, depending on weather conditions. The cereals were harvested at milky-dough stage. Harvesting of spring cereals was performed at the milky-dough stage between 16 and 18 July, while winter cereals - between 28 June and 1 July, and serradella between 23 September and 20 October. Yields of green and dry mass of cereals and yield of green mass of serradella were determined. During the harvest, the percentage of serradella in the yield was determined only for the crops undersown into spring cereals. The cereals height and a number of productive shoots grown as protective crops were determined. In order to remove weeds from the mixtures, double harrowing was performed. In 2012, and 2013 before harvest of cereals, the contents of total N, and C_{org} were determined in the 30 cm layer of soil.

The impact of the tested experimental factors on the observed characteristic were assessed using the analysis of variance, setting Tukey's half-intervals at significance level of α =0,05.

3. Results and discussion

The analysis of the obtained results showed that the yield of cereals, and serradella depended on the course of weather conditions, which varied throughout the time of the experiment (Tab. 1). In 2011, the total amount of precipitation during the vegetation period was significantly higher than the mean from a multi-annual period, which was characterized by heavy rains in July, while in June, there was a deficit of moisture. Unfavorable weather conditions during winter, including low temperatures in December, and lack of snow cover caused freezing of cereal crops (spelt wheat), which resulted in a very low plant density per area unit. Overwintering conditions were unfavorable for the cereals. In 2012, the weather conditions, both in terms of quantity, and distribution of precipitations, as well as air temperature during the growing season, were favorable for the growth, and development of mixed crops. In 2013 there was a big deficit of moisture in July (rainfall accounted for 25% of the norm of the multi-annual period), resulting in a lower yield of serradella.

The levels of cereal yields were significantly influenced by the tested factors (cereal species and cultivation method).

Among the tested cereal species, harvested at milky-dough stage, the highest yields were obtained with oats, grown both with undersown serradella and in pure stands. Barley and rye yielded lower, while spelt wheat - the lowest. Barley, and winter cereal species which were grown in pure stands, yielded lower than oats, by respectively 26, 32 and 38%. Undersown serradella favorably influenced the dry matter yield of both winter and spring cereals, harvested at milky-dough maturity (Tab. 2). Significantly higher yields were recorded in the cultivation of barley with undersown serradella compared to pure stands of cereals, especially in the first two years of the study. The lowest yields of spring and winter cereals, grown both in pure stands and with undersown serradella, were obtained in the third year of the study, which saw the deficiency of moisture in July. The average yield of spring cereals obtained in 2013 was lower by 47% from the average yield obtained in the first year of the study. In the year of limited precipitation, serradella contributed to the increase of cereal yield by no more than 5%. According to Andrzejewska [20], undersown serradella only slightly differentiated the yield of winter rye grown for green mass. In a study conducted by Jasiewicz et al. [21], the yield of cereals depended on the species of undersown legume. In their research, serradella caused a decrease in the yield of triticale, while favorably affected the yield of grain and oat straw.

Table 1. Meteorological conditions in the vegetation periods of cereals
Tab. 1. Warunki meteorologiczne w okresie wegetacji zbóż

Months	Mean monthly air temperature, °C			Many-year average	Sum of monthly precipitation, mm			Many-year average
	2011	2012	2013		2011	2012	2013	
IX	14,5	13,9	13,5	12,0	47,0	23,5	22,0	55,1
X	7,0	6,8	6,7	7,0	10,0	21,8	41,0	48,3
XI	4,3	2,7	4,6	1,8	41,0	12,2	43,0	43,5
XII	–6,6	2,1	-5,3	-2,3	7,0	28,5	24,0	43,7
I	–2,3	–1,8	-5,3	-4,5	28,0	49,7	37,0	29,0
II	–6,4	–7,9	-0,4	-3,8	24,0	22,9	20,0	29,9
III	0,4	3,2	-4,2	1,6	20,0	19,5	18,5	30,0
IV	9,9	8,5	10,8	7,7	36,0	44,6	45,8	39,0
V	13,9	14,1	14,0	13,4	44,0	61,0	82,0	57,0
VI	18,5	15,6	18,4	16,7	91,0	105,5	82,9	71,0
VII	19,0	19,7	19,0	18,3	78,0	101,1	21,0	84,0
VIII	18,2	17,3	15,1	17,3	45,0	67,8	67,6	75,0
Mean	**11,7**	**10,4**	**7,2**		**39,3**	**46,5**	**42,1**	
Sum of precipitation				**12,5**	**471,0**	**558,1**	**504,8**	**356,0**

Source: Bulletin of State Hydrological and Meteorological Service IMGW-PIB
Źródło: Biuletyn Państwowej Służby Hydrologiczno-Meteorologicznej IMGW-PIB

Jaskulski [22] found, that in the year with a small amount of precipitation, serradella receded from the stand of spring barley, which confirmed its high water requirements, and indicated its limited usefulness for growing on the areas with water deficits. Under sufficient amounts of precipitation, this author did not observe a clearly negative impact of serradella and white clover, grown as undersown crops into barley, on the cereals yielding. Maciejewicz-Ryś et al. [23] recorded a positive impact of undersown serradella on the yielding of oat on light soils. On heavy soils, such an effect was not observed. According to Tworkowski and Szczukowski [13], during dry years, in the sowings of oat and serradella, the first one was more competitive to serradella, than in the years with a higher amount of precipitation. It often outgrow and overshadow this species.

Table 2. Dry matter yield (t·ha^{-1})
Tab. 2. Plon suchej masy zbóż (t·ha^{-1})

Object	Year of the study			
	2011	2012	2013	mean
oat	8,42b	8,30d	4,93c	7,22
oat+serradella	7,42a	8,99d	5,04c	7,15
barley	6,72a	5,81a	3,46a	5,33
barley+serradella	9,43c	7,49c	3,61a	6,84
spelt wheat	-	4,98a	4,04b	4,51
spelt wheat+serradella	-	5,35a	4,14b	4,75
rye	-	5,68a	4,09b	4,89
rye+serradella	-	6,42b	4,14b	5,28

Source: own work / Źródło: opracowanie własne

Whereas, according to Andrzejewska [20], undersown crops, despite a slow initial growth rate, can strongly compete against the plants from the main crops and reduce their yields, especially under not very favorable habitat and agri-environmental conditions. According to Sobkowicz and Lejman [24], the impact of undersown crops of cereal yields depended on habitat conditions, which affect the competitiveness between a protective crop and undersown crop.

The level of serradella green mass yields depended on a cereal species which was used as a support crop. Higher yields of serradella were collected when it was undersown into spring cereals, compared to its undersowing into winter cereals (tab. 3). It yielded higher when it was undersown into barley, slightly lower - into winter rye, while the lowest – into oats. A similar impact of a protective crop on the undersown crop was observed also by Ceglarek et al. [25, 26]. Sypniewski and Ignaczak [15] reported a higher level of serradella yielding, when it was undersown into rye, compared to its undersowing into winter triticale. Moreover, according to these authors, the probability of obtaining a commercially important yields of serradella when it is undersown into the above-mentioned cereal species in most regions of Poland amounts to 40-50% and it is higher in the south and south-east parts of Poland.

The highest yields of serradella green mass were obtained in the second year of the studies, which saw the most favorable weather conditions in the growing period. The yields were then higher on average by 88% compared to 2011, and by 349% compared to 2013.

Low yields in 2013 were highly influenced by a late term of sowing, the shortage of rainfall, and high temperatures in July, which resulted in losses of serradella plants, and their weaker development, especially after the harvest of the protective crop. In 2011, a small amount of precipitation during April – May period, strongly decreased the emergence of serradella, caused the losses of plants and strongly limited its growth.

I n the yields of dry mass of cereals with undersown serradella grown for green mass, the percentage of serradella undersown into barley was higher by 11%, compared to its undersowing into oats (Tab. 3).

The studies evaluated more important morphological traits which determine cereal yields (Tab. 4). It was found that the species of winter cereals (especially rye) were, on average, by 46% higher than spring cereals. Undersown serradella had a small impact on the tillering of cereals in the years with favourable weather conditions (2012 and 2013), while in the year when they were less favourable (2011), the number of production shoots in spring cereals decreased.

Table 3. Green matter yield and share of serradella in the yield
Tab. 3. Plon zielonej masy i udział seradeli w plonie

Object	Green matter of serradella (t·ha^{-1})				Share of serradella in the yield (%)			
	2011	2012	2013	mean	2011	2012	2013	mean
oat+serradella	5,00a	9,67b	2,21a	5,63	48,9	38,8	9,0	32,2
barley+serradella	5,67b	10,59c	2,57a	6,28	48,1	45,3	14,3	35,9
spelt wheat+serradella	-	9,26a	2,32a	5,79	-	-	-	-
rye+serradella	-	10,33c	1,92a	6,13	-	-	-	-

Source: own work / Źródło: opracowanie własne

Table 4. Height of cereals and number of production shoots cereals depending on sowing method
Tab. 4. Wysokość zbóż i liczba pędów produkcyjnych zbóż uprawianych jako rośliny ochronne w zależności od sposobu siewu

Object	Height of cereals(cm)				Number of production shoot cereals (units)			
	2011	**2012**	**2013**	**mean**	**2011**	**2012**	**2013**	**mean**
oat	-	-	85	85	2,31	1,68	3,57	2,52
oat+serradella	71	89	73	78	1,64	1,49	3,80	2,31
barley	-	-	67	67	3,02	2,67	3,63	3,11
barley+serradella	86	93	71	83	1,69	2,41	3,80	2,63
spelt wheat	-	123	100	98	-	2,65	2,13	2,00
spelt wheat+serradella	-	126	107	104	-	2,74	2,03	2,03
rye	-	132	122	128	-	2,68	1,90	1,92
rye+serradella	-	135	119	126	-	2,46	1,83	1,82

Source: own work / Źródło: opracowanie własne

Undersowing serradella into barley and winter cereals had only a slight impact on the contents of total N and. C_{org} in soil compared to pure sowings of cereals, while undersowing serradella into oats caused an increase of those component. (Tab. 5). Harasimowicz-Herman [27] recorded a significant increase of nitrogen content in the soil after the harvest of serradella for green mass, compared to those contents before the sowing. In 2013 there was a higher content of $C_{org.}$ compared to 2012, which can indicate that there was an increase in the content of green mass due to undersowing serradella into cereals.

The research of Andrzejewska and Andrzejewski [28] and Krężel et al. [29, 30] on serradella, of Lyngstad i Breland [31] - on white clover and Italian ryegrass and of Thomsen [32] – on perennial ryegrass, showed that growing of these species increased the contents of organic carbon, nitrogen, phosphorus, and potassium in the soil. The studies of Pałys et al. [33] showed that serradella increased the content of total carbon in the soil. The results obtained by these authors also indicated that the content of total carbon was significantly lower under winter triticale compared to its undersowing into spring cereals, whereas its content was significantly lower under winter rye than under oats.

Table 5. Concentration N_{tot} and $C_{org.}$ in soil (before harvest)
Tab. 5. Zawartość $N_{cał.}$ i $C_{org.}$ w glebie (przed zbiorem)

Specification	2012		2013	
	$N_{cał.}$	$C_{org.}$	$N_{cał.}$	$C_{org.}$
oat	0,084	0,73	0,062	0,80
oat+serradella	0,099	0,79	0,068	0,83
barley	0,090	0,80	0,084	0,97
barley+serradella	0,087	0,77	0,080	0,92
spelt wheat	0,077	0,71	0,074	0,86
spelt wheat+serradella	0,075	0,71	0,076	0,91
rye	0,075	0,71	0,078	0,92
rye+serradella	0,076	0,73	0,069	0,85

Source: own work / Źródło: opracowanie własne

4. Conclusions

The highest grain yields were obtained from oats, cultivated as with undersown serradella as in pure stands. Undersown serradella favorably influenced the dry matter yield of both winter and spring cereals, harvested at milky-dough maturity. Significantly higher yields were recorded in the cultivation of barley with undersown serradella compared to pure stands of cereals. However, it did not significantly affect the grain yields of spring cereals.

The yield of green mass of serradella depended on a species of cereal, which was used as a support crop. Higher yields of this species were collected when it was undersown into spring cereals, lower - into winter rye, and the lowest – into oats.

The plants of the species of winter cereals (especially rye) were higher by 46% compared to spring cereals. Growing cereals with undersown serradella had only a slight impact on their tillering in the years with favourable weather conditions. In the years with less favourable weather conditions, undersown serradella significantly reduced a number of productive shoots of spring cereals.

Undersowing serradella into barley and winter cereals had a low impact on the contents of total N. and C_{org} compared to pure stands of cereals, while undersowing it into oats increased these contents.

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