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FORECROP VALUE OF BLUE AND YELLOW LUPINE FOR WINTER WHEAT

Summary

Besides a very good protein fodder legumes can also leave a good stand for the forecrop. In effect of legumes symbiosis with bacteria they are able to fixed N_2. Thanks to that their cultivation does not require high doses of nitrogen fertilizers, and fixed nitrogen is also available in the soil for the successive crop. The aim of researches was to recognize the impact of blue and yellow lupine forecrops on yielding of winter wheat and compare these effects with the impact of spring barley. The studies were led at Agricultural Experimental Station in Grabów which belongs to the Institute of Soil Science and Plant Cultivation – State Research Institute in Puławy. Winter wheat var. Arkadia was sown after blue lupine var. Zeus, yellow lupine var. Dukat and after spring barley var. Johan. Winter wheat density amounted to 5 m plants per ha, and area of plots to harvest – 24 m^2. During the flowering of wheat following measurements were performed: plant height, leaf area (AM 300; ADC BioScientific Ltd. UK) and SPAD values (SPAD -502; Minolta Japan), whereas before the harvest, at full maturity were determined: number of shoots, number of ears and grains in the ear, the mass of straw, ears and grain, as well as weight of 1000 grains. These measurements were performed on the 10 plants randomly selected from each plots. After the harvest there were determined the grain yield and its moisture as well as nitrogen content in the grain (Kjeldahl method). It was found beneficial effect of a forecrop on wheat yielding and its elements structure (i.e. number of ears, number of grains per plant and weight of 1000 grains). The influence of a forecrop on yielding level of winter wheat was in the great degree dependent on course of weather condition in the years of research and the lupine species. In the unfavorable years to wheat cultivation the difference between yields of winter wheat cultivated after good and weak forecrop was greater than in years with favorable weather course.
Key words: *winter wheat, blue lupine, yellow lupine, barley, residual effect, yielding, yield structure, content and yield of protein*

WARTOŚĆ PRZEDPLONOWA ŁUBINU WĄSKOLISTNEGO I ŻÓŁTEGO DLA PSZENICY OZIMEJ

Streszczenie

Oprócz bardzo dobrej paszy białkowej rośliny strączkowe mogą pozostawiać także dobre stanowisko dla rośliny następczej. Jest to efektem współżycia roślin strączkowych z bakteriami symbiotycznymi (N_2) dzięki czemu w ich uprawie stosuje się mniejsze dawki nawozów azotowych, a związany azot jest dostępny w glebie także dla roślin następczych. Celem badań było rozpoznanie wpływu następczego przedplonów łubinu wąskolistnego i żółtego na plonowanie pszenicy ozimej i porównaniu tego efektu do działania jęczmienia jarego. Badania prowadzono w Rolniczym Zakładzie Doświadczalnym w Grabowie należącym do IUNG-PIB w Puławach. Pszenicę ozimą odmiany Arkadia wysiewano po łubinie wąskolistnym odmiany Zeus, łubinie żółtym odmiany Dukat i jęczmieniu odm. Johan. Obsada pszenicy ozimej wynosiła 5 mln roślin/ha, a powierzchnia poletek do zbioru – 24 m^2. W okresie kwitnienia pszenicy wykonano pomiary wysokości roślin, powierzchni liści (AM-300; ADC BioScientific Ltd., UK) oraz wartość wskaźnika SPAD (SPAD-502; Minolta Co., Ltd Japan), natomiast przed zbiorem w fazie dojrzałości pełnej na 10 roślinach losowo wybranych z każdego poletka określono liczbę pędów, liczbę kłosów i ziaren w kłosie, masę słomy, kłosów i ziarna, a także masę 1000 ziaren. Po zbiorze określono plon ziarna i jego wilgotność oraz zawartość azotu w ziarnie (metodą Kjeldahla). Stwierdzono korzystny wpływ przedplonu na plonowanie i elementy struktury plonu pszenicy ozimej (tj. liczbę kłosów, liczbę ziaren z rośliny i masę 1000 ziaren). Oddziaływanie przedplonu na poziom plonowania pszenicy ozimej było w dużym stopniu zależne od przebiegu warunków pogodowych w latach badań oraz gatunku łubinu. W latach niesprzyjających uprawie pszenicy różnica między plonami pszenicy ozimej uprawianej po dobrych i słabych przedplonach była większa niż w latach z korzystnym przebiegiem pogody.
Słowa kluczowe*: pszenica ozima, łubin wąskolistny, łubin żółty, wpływ następczy, plonowanie, struktura plonu, zawartość i plon białka*

1. Introduction

At present lupines cover the greatest area of cultivation among all species of legumes cultivated in our country [15]. These species are cultivated mainly for seeds which are an important plant raw material to production of high protein fodder [9, 14]. Thanks to symbiosis with bacteria lupines fix great amount of nitrogen [7], therefore nitrogen fertilization is not used at their cultivation [11, 12, 13]. Legumes use only part of fixed nitrogen for their needs and after their cultivation 40-90 kg N/ha remain in the soil, as it results from research of Szukała [18]. Besides, the crop residues left in the soil enrich it by humus, phosphorus and potassium [5]. Additionally thanks to deep root system legumes restrict the soil degradation by drainage and structure-action. Therefore besides very valuable protein fodder lupines remain also very good stand for a successive crop. This issue fits very well for the rules of ecological agriculture, in which the use of mineral nitrogen is forbidden, so nitrogen fixed symbiotically is of particular importance [6]. A great progress made in the breeding of blue and yellow lupine concerns among others obtaining of the new varie-

ties with increased resistance of pods to cracking and greater yielding possibilities [16]. The new lupine species have changed the morphological structure, plants are considerably lower, produce lower vegetative mass if compared to cultivated, older ones. These differences concern also separate species and even varieties of lupines. It can be then supposed that the stand after varieties of blue and yellow lupine cultivated at present could have different forecrop value for successive plants than older varieties and cereal plant.

The aim of studies was to recognize successive impact of blue and yellow lupine on winter wheat yielding in comparison to the effect of spring barley as a forecrop.

2. Material and Methods

The field studies were conducted in the years 2009-2011 at Agricultural Experimental Station in Grabów, which belongs to the IUNG-PIB in Puławy. The experiment was established on very good rye complex (class IIIa), by the method of equivalent blocks (split-plot-split–block), in the 4 replications. Content of nutrients in the soil amounted (mg/kg of soil): M_{min} – 0,24; P – 41,4; K – 36,2; Mg – 1,61 and the pH – 6,5. The following fertilization was applied in the experiment: before sowing – 15 kg N/ha, 50 kg P_2O_5 and 75 kg K_2O in the form of Polifoska 6, whereas in the early spring before starting of vegetation – 25,6 kg N/ha and in the shooting phase – 14,4 kg N/ha in the form of ammonium nitrate. Crop residues were plowed in autumn after the harvest of a forecrop.

An experimental factor included a field for wheat cultivation after: blue lupine var. Zeus, yellow lupine var. Dukat and spring barley var. Johan. Winter wheat var. Bomberka, in the density 500 plants/m^2 was cultivated as a successive crop. Seeds of wheat were sown by drill - Amazone D8, every year in the end of September or in the beginning of October, on the depth 2-3 cm and with the 12 cm row spacing. Certified seed lot which was characterized by 99% purity of seeds and 94% germinating capacity was used in the experiment. As a herbicide was used Komplet 560 SC in the dose of 0,5 l/ha.

During the wheat flowering measurements of plant height, leaves area and the value of SPAD indicator (SPAD-502 were performed (Minolta Co., Ltd. Japan), which shows the chlorophyll content in the leaves, whereas before the harvest (in the full maturity phase) on 10 plants randomly selected from each plot were determined: the number of shoots, number of ears and grains in the ear, mass of all wheat organs, as well as weight of 1000 grains. After the harvest were determined: the grain yield and its moisture as well as nitrogen content in the grain (Kjeldahl method). Protein content in the wheat grain was counted from the formula Z_b=Nx5,7; where Z_b means protein concentration, N- nitrogen concentration according to the Kjeldahl method and 5,7 – coefficient for protein accounting in the cereal grain. Plots area to the harvest amounted to 24 m^2. Grain harvest was performed with the Seedmaster harvester in the end of July or in the beginning of August. Obtained results, as a means from 4 replications, were elaborated with the analysis of variance method, with use of half-interval at the significant level α=0,05.

The course of weather conditions in the years of research was presented on the Fig. 1. The amount of precipitation in the particular years in the period of April – August was similar, but their distribution was not uniform. The greatest precipitation deficit occurred in April and May 2009, and the greatest amount was noted in June and July 2009, May 2010 and July 2011.

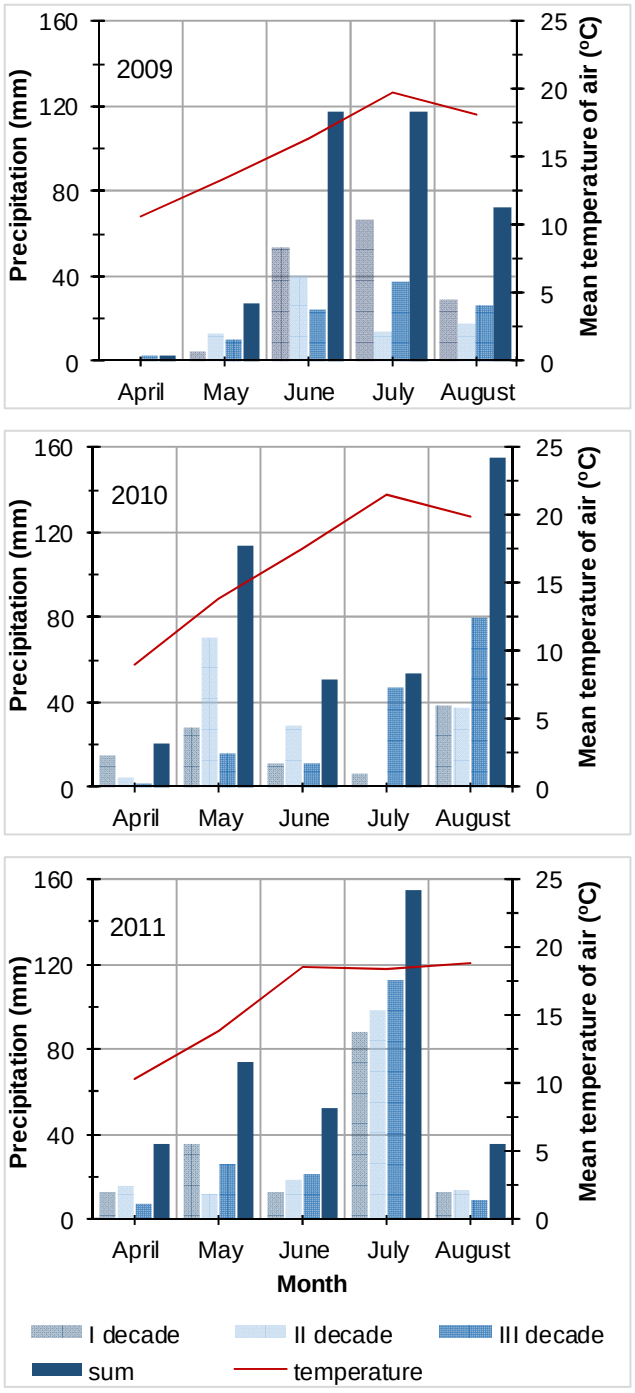

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Fig. 1. Weather conditions in the vegetation period
Rys. 1. Warunki pogodowe w okresie wegetacji

In 2009 summary amount of precipitation during the wheat vegetation amounted to 338 mm and was considerably lower than in 2010 when it was 394 mm, and a slightly lower than in 2011 – 353 mm. It can be considered that difference in amount of precipitation did not occur between the research years, whereas their uniformity was strong differentiated in the period of winter wheat vegetation. Thermal conditions in analyzed years were also very similar. Only the slightly greater differences concerning the values of mean daily temperatures were noted in April 2009 and in July and August 2010.

3. Results and Discussion

In spite of similar amount of precipitation and approximate values of daily mean temperatures in the particular research years, the short term and intensive weather phenomenons occurred that caused the great changes in the plant vegetation course and significantly affected the size of grain yield. Drought was weather factor which has a negative effect on plants vegetation in 2009, especially when occurred in April and May and caused wheat plants inhibition. Moreover, strong winds occurred in the second part of April what increased soil drying, and also considerably restricted the efficiency of soil herbicides action. Abundant rainfall, small amount of sunny days and substantial cooling in June also affected unfavorably growth and development of plants. Then, at the beginning of July abundant rainfall occurred connected to hail what, in a consequence, caused the plant logging. The course of weather conditions in the years 2010 and 2011 was more favorable for winter wheat cultivation than in 2009. However, no occurring unfavorable weather features were noted. Although in July 2010 the amount of precipitation was lower than in the both remaining research years, and in August a slightly higher than the average of daily mean temperatures, weather conditions in these years were more favorable to wheat cultivation.

Plant emergence occurred after 16-19 days from sowing. Wheat seeds were characterized by high germination capacity therefore a great uniformity and dynamics of plant germination was found . Moreover, obtained plant density after the emergence was very close to that presumed in theory.

The forecrop has differentiated the mass of vegetative and generative wheat organs (Fig. 2). The highest yield of these organs of dry matter was produced by wheat plants cultivated after yellow lupine, considerably lower after blue lupine, and the lowest - cultivated after barley. However, significance of differences between yield of lupines and barley was proved statistically as regards all analyzed plant organs. While, in the case of yellow and blue lupine the significance of difference concerned only yield of straw. It means that a forecrop had greater effect on mass of vegetative than generative organs of the successive plant.

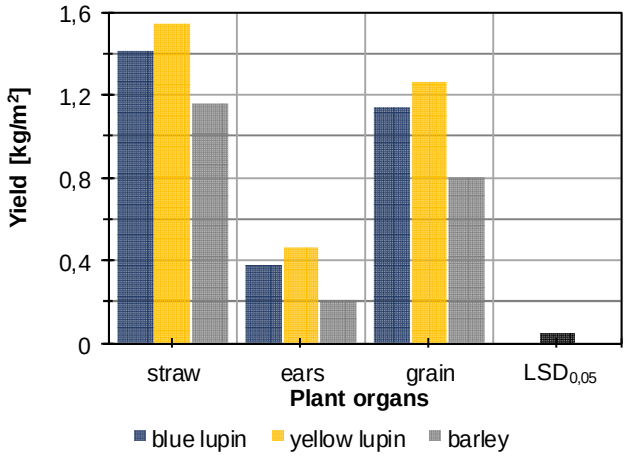

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Fig. 2. Dry matter yield of winter wheat cultivated after various forecrops (2009-2011)
Rys. 2. Plon suchej masy pszenicy ozimej uprawianej po różnych przedplonach (2009-2011)

The course of weather conditions in the research years had the significant effect on wheat grain yield. The greatest grain yield of wheat was obtained in 2010, and the least – in 2009 (Fig. 3). It is worth noting that at the less favorable weather conditions the differences between wheat yield obtained after good forecrop (lupine) and weak (barley) was greater than in the case of wheat cultivation in the more favorable weather conditions. In 2009 which was considered as the unfavorable for wheat cultivation the yield increase caused by good forecrop amounted to 24,8%, and in 2010, in which weather conditions were the best for the wheat cultivation the yield increased only by 6,2%. It must be recognized that obtained yield increase of wheat cultivated after lupine in the pure sowing was not too great. From the Piekarczyk [10] studies results that winter wheat cultivated after the blue lupine can yielding even about 50% better than after the barley. The increase in cereal yield cultivated after the legumes is the most frequently a consequence of nitrogen excess left in the post-harvest residues [19], restriction of diseases development [17], weed infestation of stand [2] and the improving of soil structure [1].

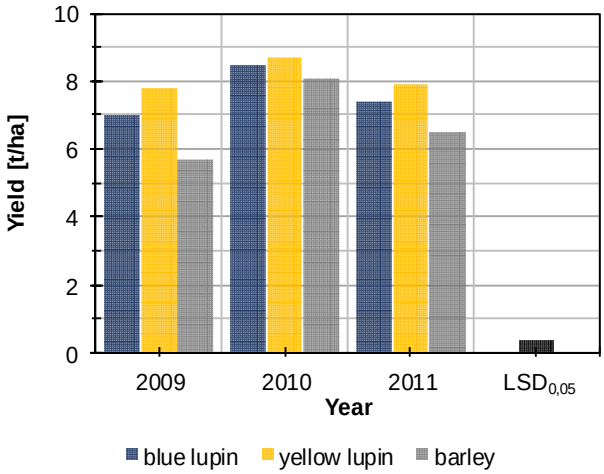

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Fig. 3. Grain yield of winter wheat cultivated after various forecrops
Rys. 3. Plon ziarna pszenicy ozimej uprawianej po różnych przedplonach

It should be also underlined that the stand after the both species of lupine was much better than after the cultivation of barley, while after the yellow lupine considerably better than after the blue lupine. It was found especially in 2009, when weather conditions did not favor the wheat cultivation. It can be supposed that better stand to wheat cultivation after yellow than blue lupine results from the fact that yellow lupine leaves greater amount of after-harvest residues [4] and fixes greater amount of nitrogen than the blue lupine [7]. The confirmation of this supposition can be found in the studies conducted by Kozak and Kotecki [8], in which it was shown that winter wheat yielded the best when most after-harvest residues were in the soil and the greater density of legume -pea was applied in the cultivation.

For all research years the average yield increase of wheat cultivated after blue and yellow lupine in relation to barley as a forecrop amounted: to 10,8 and 16,1%.

The attention should be paid to considerable differentiation of wheat yielding in the research years. The indicator

of wheat yielding stability in the years reached mean for all forecrops and amounted to 87,4%, while for cultivation after blue lupine, yellow lupine and barley, respectively: 88,2; 91,3 and 78,4%. It means that after the good forecrops winter wheat yielding is more stable and less sensitive to unfavorable weather conditions than after weak forecrops i.e. after cereals.

A forecrop modified also some features of wheat yield structure (Table 1). Wheat cultivated after the good forecrops produced more ears per plant and grains per plant compared to cultivation after the weak forecrop which was barley while the number of grains per ear and weight of 1000 grains did not change significantly. However, it results from the researches of another authors that this structure elements can be also modified in dependence on a forecrop [1, 3, 10].

Table 1. Elements of wheat yield structure depending on a forecrop
Tab. 1. Elementy struktury plonu pszenicy w zależności od przedplonu

Yield structure elements	Forecrop			LSD (0.05)
	blue lupin	yellow lupin	barley	
Number of shoots with ear per plant	1.77	1.84	1.58	0.16
Number of grain per plant	64.6	67.1	59.2	4.16
Number of grain per ear	41.7	43.0	38.8	1.94
Weight of 1000 grain (g)	44.9	44.1	45.6	n.s.*

* n.s. – not significant

Source: own study / Źródło: opracowanie własne

A forecrop affected only value of some morphological features of wheat (Table 2). It concerned especially the number of shoots per plant, because the plant height and leaves area did not change significantly.

Table 2. Morphological features of wheat plants
Tab. 2. Cechy morfologiczne roślin pszenicy

Features of plants	Forecrop			LSD (0.05)
	blue lupin	yellow lupin	barley	
Plant height (cm)	84.1	82.4	80.6	n.s.*
Number of culms per plant	1.84	1.88	1.64	1.16
Leaves area (cm^2)	77.6	75.8	76.7	n.s.*

* n.s. – not significant

Source: own study / Źródło: opracowanie własne

SPAD value and protein content in the grain of winter wheat cultivated after the lupines was not changing significantly in dependence on a forecrop (Table 3). The observed increasing tendency in relation to these both factors but these differences have not been proven statistically. SPAD and protein content Admittedly, there was observed an increasing trend in the protein amount in the grain of wheat cultivated after lupines, but these differences were not confirmed statistically. In literature can be found an information that cereals cultivated after the legumes can contain in grain more protein, what is explained by their better supply with nitrogen [2].

Table 3. Wartość SPAD i zawartość białka w ziarnie pszenicy ozimej w zależności od przedplonu
Tab. 3. Value of SPAD and protein content in the grain of winter wheat in dependence on a forecrop

Description	Forecrop			LSD (0.05)
	blue lupin	yellow lupin	barley	
SPAD	564	578	552	n.s.
Protein content in the grain of winter wheat (%)	13,7	13,7	12,9	n.s.

*n.s. – not significant

Source: own study / Źródło: opracowanie własne

Protein yield, as a product of grain yield and protein content, was determined mainly by the size of grain yield. Therefore the highest yield of protein was obtained from the wheat cultivation after the good forecrops, i.e. after lupines, and the weakest after the spring barley (Fig. 4).

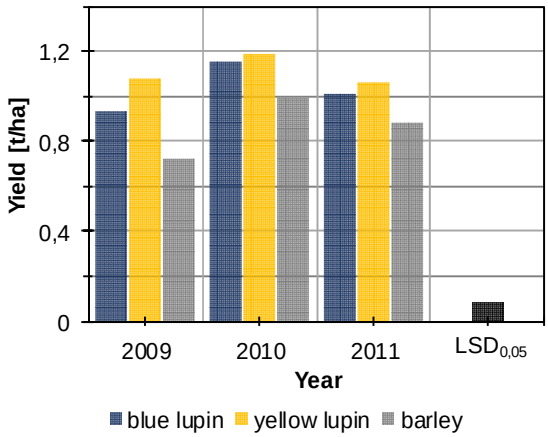

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Fig. 4. Protein yield of winter wheat cultivated after different forecrops
Rys. 4. Plon białka pszenicy ozimej uprawianej po różnych przedplonach

4. Summary

1. It was found the favorable effect of blue and yellow lupine as a forecrop on yielding and features of winter wheat yielding structure i.e. number of shoots, number of ears and grains per plant as well as number of grain per ear.
2. The impact of a forecrop on a level of winter wheat yielding to a great extent depended on course of weather condition during the research years. In the years unfavorable to cultivation (small amount of precipitation or not uniform distribution during the research years) the difference between the yield of wheat cultivated after the good forecrops in comparison to weaker forecrops was greater than in the years with the favorable weather course. Moreover, a good forecrop contributed to decrease the differentiation of wheat yielding which was caused by various weather conditions in the research years.
3. Winter wheat yielded slightly better when was cultivated after the yellow lupine than after the blue lupine, but the significance of differences were proved only for years with unfavorable weather course.

4. Content of protein in the grain of winter wheat did not change in dependence on a forecrop. There was observed an increasing trend in the protein amount in the grain of wheat cultivated after lupine, but these differences were not confirmed statistically.

5. References

[1] Blecharczyk A., Śpitalniak J., Małecka I.: Wpływ doboru przedplonów oraz systemów uprawy roli i nawożenia azotem na plonowanie pszenicy ozimej. Fragm. Agron., 2006, 2(90): 273-286.

[2] Buczek J. , Bobrecka-Jamro D.: Wpływ przedplonu i nawożenia azotowego na plonowanie i cechy jakościowe pszenicy ozimej. Zesz. Probl. Post. Nauk Rol., 2010, 556: 57-64.

[3] Buraczyńska D., Ceglarek F.: Plonowanie pszenicy ozimej uprawianej po różnych przedplonach. Acta Sci. Pol., 2008, Agricultura 7(1): 27-37.

[4] Harasimowicz-Hermann G.: Wpływ architektury łanu na masę resztek roślinnych łubinu żółtego i wąskolistnego odmian samokończących w porównaniu z odmianami tradycyjnymi. W: Łubin-Białko-Ekologia, Instytut Chemii Bioorganicznej Poznań, 1994: 364-369.

[5] Jasińska Z., Kotecki A.: Rośliny strączkowe, PWN Warszawa, 1993.

[6] Jończyk K., Stalenga J.: Możliwości rozwoju gospodarstw o różnych kierunkach produkcji rolniczej w Polsce. Studia i Raporty IUNG-PIB, 2010, 22: 87-100.

[7] Kalembasa S. , Wysokiński A. , Kalembasa D.: Quantitative assessment of the process of biological nitrogen reduction by yellow lupine (*Lupinus luteus* L.),. Acta Sci. Pol., Agricultura, 2014, 13(1): 5-20.

[8] Kozak M., Kotecki A.: Wpływ następczy odmian grochu siewnego na rozwój i plonowanie pszenicy ozimej. Cz. III. Rozwój i plonowanie pszenicy ozimej. Zeszyty Naukowe Uniwersytetu Przyrodniczego we Wrocławiu, Rolnictwo, LXXXIX, 2006, 546: 160-175.

[9] Pastuszewska B.: Wartość pokarmowa roślin strączkowych w żywieniu zwierząt. Zesz. Probl. Post. Nauk Rol., 1997, 446: 83-94.

[10] Piekarczyk M.: Wartość przedplonowa łubinu wąskolistnego i jęczmienia jarego dla pszenicy ozimej w zależności od sposobu odchwaszczania łanu. Acta Sci. Pol., Agricultura, 2007, 6(3): 59-67.

[11] Podleśny J., Brzóska F.: Uprawa łubinu wąskolistnego i wykorzystanie nasion w żywieniu zwierząt. Instrukcja Upowszechnieniowa 172, 2010: 1-34.

[12] Podleśny J., Brzóska F.: Uprawa łubinu żółtego i wykorzystanie nasion w żywieniu zwierząt. Instrukcja Upowszechnieniowa 173, 2010: 1-34.

[13] Podleśny J., Brzóska F.: Uprawa łubinu białego i wykorzystanie nasion w żywieniu zwierząt. Instrukcja Upowszechnieniowa 174, 2010: 1-32.

[14] Podleśny J., Księżak J., Brzóska F., Hanczakowska E., Hołubowicz-Kliza G., Szczurek W.: Groch siewny w uprawie i żywieniu zwierząt. Instrukcja Upowszechnieniowa, 2016, 212: 1-64.

[15] Produkcja upraw rolnych i ogrodniczych w 2017 roku. GUS Warszawa, 2018: 60-61.

[16] Prusiński J.: Ilościowy i jakościowy potencjalny postęp biologiczny w łubinie (*Lupinus* sp.) – rys historyczny i stan aktualny. Zesz. Probl. Post. Nauk Rol., 2007, 522: 23-37.

[17] Sułek A., Podolska G., Jaśkiewicz B.: Plonowanie i zdrowotność dwóch podgatunków pszenicy w zależności od udziału zbóż w strukturze zasiewów w warunkach integrowanej produkcji. Polish Journal of Agronomy, 2016, 27: 118-125.

[18] Szukała J.: Nowe trendy w agrotechnice roślin strączkowych i sposoby zwiększania opłacalności uprawy. Mat. Komisji Rolnictwa i Rozwoju Wsi. Warszawa, 2012, 45: 8-10.

[19] Wysokiński A., Faligowska A., Kalembasa D.: Ilość azotu biologicznie zredukowanego przez łubin żółty (*Lupinus luteus* L.) – wyniki wstępne. Fragm. Agron., 2012, 31(1): 121-128.

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