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THE AFTER-EFFECT OF BLUE LUPINE MIXTURES WITH BARLEY ON YIELDING OF WINTER WHEAT

Summary

Legume-cereal mixtures cover a considerable cultivated area in Poland what follows mainly from better and more stable yielding of mixed stands than pure ones. Besides a very good protein fodder the legume – cereal mixture can leave also good stand for subsequent plant. It is an effect of symbiosis of legumes with symbiotic bacteria and thanks to that lower doses of nitrogen are used in the mixture stands and fixed nitrogen is also available in the soil to the subsequent plants. This kind of cultivation become a very good part of ecological agriculture rules where due to forbidden nitrogen fertilizers use, this nitrogen fixed symbiotically is of great importance. The aim of studies was to recognize a residual effect of the forecrop which were: pure sowing of lupine, lupine and barley mixture and pure sowing of barley, on yielding of winter wheat. Studies were led at the Agricultural Experimental Station in Grabów, which belongs to the Institute of Soil Science and Plant Cultivation – State Research Institute (IUNG-PIB) in Puławy. Winter wheat var. Arkadia was sown after blue lupine var. Regent which was cultivated in the pure stand and in the mixture with spring barley var. Johan. Wheat plant density amounted to 5,5 mln plants per hectare, and area of plots to harvest – 24 m^2. Before harvest selected biometric measurements of plants were performed and, after the harvest in the full maturity, yield and features of its structure as well as chemical content of winter wheat grain were determined. It was found a favorable effect of forecrop on yielding and features of winter wheat yield structure (e.g. number of ears, number of grain per plant and 1000 grain weight). The influence of forecrop on the level of winter wheat yielding depended to a large extent on weather conditions course in the experimental years and on blue lupine variety as well as composition of lupine – barley mixture. In years unfavorable for winter wheat cultivation the difference between yields of wheat cultivated after good and weak forecrop was greater than in the years with favorable weather course.
***Key words**: winter wheat, mixtures, blue lupine and barley, subsequent effect, yielding, yield components*

WPŁYW NASTĘPCZY MIESZANEK ŁUBINU WĄSKOLISTNEGO Z JĘCZMIENIEM JARYM NA PLONOWANIE PSZENICY OZIMEJ

Streszczenie

Mieszanki strączkowo-zbożowe zajmują znaczną powierzchnię uprawy w Polsce, co wynika w dużej mierze z lepszego i bardziej wiernego plonowania zasiewów mieszanych niż czystych. Oprócz bardzo dobrej paszy białkowej mieszanki strączkowo-zbożowe mogą pozostawiać także dobre stanowisko dla rośliny następczej. Jest to efektem współżycia roślin strączkowych z bakteriami symbiotycznymi (N_2), dzięki czemu stosuje się mniejsze dawki nawozów azotowych w zasiewach mieszanych, a związany azot jest dostępny w glebie także dla roślin następczych. Ten sposób uprawy wpisuje się bardzo dobrze w zasady rolnictwa ekologicznego, w którym ze względu na zakaz stosowania azotu mineralnego, azot związany symbiotycznie ma szczególne bardzo duże znaczenie. Celem badań było rozpoznanie wpływu następczego przedplonów jakim były siew czysty łubinu, mieszanek łubinu z jęczmieniem i jęczmienia w siewie czystym na plonowanie pszenicy ozimej. Badania prowadzono w Rolniczym Zakładzie Doświadczalnym w Grabowie należącym do IUNG-PIB w Puławach. Pszenicę ozimą odmiany Arkadia wysiewano po łubinie wąskolistnym odmiany Regent uprawianym w siewie czystym i w mieszankach z jęczmieniem jarym odmiany Johan. Obsada pszenicy ozimej wynosiła 5,5 mln roślin/ha, a powierzchnia poletek do zbioru – 24 m^2. Przed zbiorem wykonano pomiary biometryczne roślin, a po zbiorze w dojrzałości pełnej określono plon i cechy jego struktury, a także skład chemiczny ziarna pszenicy ozimej. Stwierdzono korzystny wpływ przedplonu na plonowanie i cechy struktury plonu pszenicy ozimej (tj. liczbę kłosów, liczbę ziaren z rośliny i masę 1000 ziaren). Oddziaływanie przedplonu na poziom plonowania pszenicy ozimej w dużym stopniu zależało od przebiegu warunków pogodowych w latach badań oraz odmiany łubinu wąskolistnego i składu mieszanki łubinu z jęczmieniem.. 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, mieszanki, łubin wąskolistny z jęczmieniem, wpływ następczy, plonowanie, struktura plonu*

1. Introduction

One of the methods of legumes yielding stability increase consists in their cultivation in mixture with cereals [16]. In the years with unprofitable weather course low seed yield of legume plant is in a considerable level compensated by grain yield of a cereal plant. Thus species differentiation is followed by compensating growth and development of cultivated species, decrease of diseases and pests infestation, and also control of weeds [4, 7, 10, 14]. Mixtures of spring cereals with legumes play an important role in integrated and ecological system of production [6, 8], where care of soil environment has a special significance. At the beginning in this type of stands there were cultivated pea plants because of easier harvest of this plant prone to logging and better quality of obtained seeds [12, 13]. Another species of legumes, especially blue lupine, were at that time less useful to this kind of stands, among others due to its big prone to pods dehiscence and trouble with matching their rhythm of growth and development of cereal plant. A great progress achieved in the last years in the blue lupine breeding, results in obtaining new varieties, with increased resistance of pods to dehiscence, changed morphological structure and greater yielding possibilities. Thanks to this blue lupine can be used to cultivation in mixture with cereals [15]. Besides very good protein fodder the legume-cereal mixture probably could also leave better stand for successive crop than cereals. Moreover, thanks to symbiosis with rhizobia lupine fixes great amount of nitrogen [5], which is utilized by plants cultivated in the mixture stands [11], and its considerable part stays in the soil for the successive plants. Therefore, for cultivation of legume-cereal mixtures less doses of nitrogen are used than in the pure stands of cereals, what has both ecological and economic importance. This kind of cultivation corresponds well to the ecological agriculture principles, in which symbiotic fixed nitrogen has a special importance in aspect of ban of mineral nitrogen use. The considerable popularity of this kind of stands creates also the requirement of agricultural practice on knowledge concerning the rules of agricultural practices of legume-cereal mixtures and benefits from their cultivation, also in reference to effects measured by the size and quality of successive plant.

The aim of presented studies was to recognize successive impact of a forecrop (as: pure sowing of lupine, mixtures of lupine with barley and pure sowing of barley) on yielding of winter wheat.

2. Material and methods

Studies were conducted in years 2008-2010, in the Agricultural Experimental Station located in Grabów (Mazowieckie province), belonging to Institute of Soil Science and Plant Cultivation – State Research Institute in Puławy. An experiment was established by equivalent sub-blocks method (split-plot-split block), at four replications on very good rye complex soil, class III a. An experimental factor defined a position for winter wheat after: A) lupine in the pure stand (lupine 100% = 100 plants·m^{-2}), B) lupine with barley mixture (lupine 75% = 75 plants·m^{-2} + barley 25% = 75 plants·m^{-2}, C) lupine with barley mixture (lupine 50% = 50 plants·m^{-2} + barley 50% = 150 plants·m^{-2}, D) lupine with barley mixture (lupine 25% = 25 plants·m^{-2} + barley 75% = 225 plants·m^{-2} and E) pure stand of barley (barley 100% = 300 plants·m^{-2}).

Blue lupine var. Regent and barley var. Johan were sown in the experiment. Winter wheat var. Arkadia, in the density 550 plants·m^{-2} was cultivated as a successive crop. Winter wheat was sown by Amazone D8 drill, every year in the end of September or in the beginning of October, on the depth 2-3 cm and with row spacing 12 cm. There was used only qualified seed lot whose purity amounted to 99% and germination capacity- to 94%.

Detailed observations of growth and plant development were performed during the vegetation with noting among others the course of plant developmental phases and occurring pests and diseases. After emergence and before the harvest of plants there was evaluated plants' density by counting them on 1 m^2 area. Before harvest in the full maturity phase (BBCH 99) measurements of plant height were performed and number of shoots, number of ears and grain per ear, weight of shoots, ears and grain as well as 1000 grain weight were evaluated. After the harvest yield of grain and its moisture was evaluated as well as grain chemical composition (content of N, fat, fibber, BAW and ash). Content of protein in the wheat grain was counted according to the formula: $P_{Cont.}$ = N x 5,7. Plots area to harvest amounted to 24 m^2. Grain harvest was performed by plot drill "Seedmaster" (Wintersteiger) in the end of July or in the beginning of August. The results of studies as means from replications were elaborated statistically in program Statistica v. 13.1, by analysis of variance with Tukey's confidence interval, at significance level α = 0,05.

Course of weather conditions in the study years was shown in the table 1. Amount of precipitations in the individual years in period April-August was similar, but their distribution was irregular. The greatest precipitations deficit occurred in the April 2009, and their greatest amount was noted in June and July 2009 as well as in May 2010. Very big amount of precipitations occurred also at III decade of 2010, but it was just after the plant harvest. In 2008 total amount of precipitations in the vegetation period amounted to 350 mm, and was a little lower than in 2009 (360 mm), and a considerably lower than in 2010 (394 mm), but their uniformity was greater than in the other study years. Thermal conditions in the analyzed years were also very similar. Only the slightly greater differences concerning mean values of daily temperature were noted in April 2009 as well as in July and August 2010.

Table 1. Weather conditions in the vegetation period
Tab. 1. Warunki pogodowe w okresie wegetacji

Month	Decade	Precipitations (mm)			Temperature (°C)		
		2008	2009	2010	2008	2009	2010
April	I	10.7	0.0	14.8	7.5	10.2	7.9
	II	57.2	0.0	4.1	8.9	9.6	9.3
	III	3.9	0.6	1.9	10.6	12.3	10.0
		$71.8^{1/}$	0.6	20.8	$9.0^{2/}$	10.7	9.0
May	I	43.4	4.5	28.4	12.0	12.9	13.1
	II	33.4	12.7	70.0	13.6	13.1	13.6
	III	10.8	10.3	15.6	13.8	14.4	14.9
		87.6	57.5	114.0	13.1	13.5	13.9
June	I	0.0	53.4	11.1	18.0	14.6	18.7
	II	19.9	40.4	28.5	18.4	15.4	17.3
	III	21.2	24.1	11.1	18.6	16.3	16.8
		41.1	117.9	50.7	17.6	16.4	17.6
July	I	13.6	66.3	6.4	17.9	19.7	20.0
	II	15.5	14.1	0.0	19.2	20.2	24.4
	III	56.3	37.4	47.0	19.4	19.4	20.2
		85.4	117.8	53.4	18.9	19.7	21.5
August	I	8.4	29.1	38.1	19.7	19.3	21.3
	II	21.8	17.8	37.3	19.0	17.7	21.4
	III	24.3	25.7	79.7	17.1	17.3	20.7
		54.5	74.6	155.1	18.9	18.1	19.9

$^{1/}$ monthly sum of precipitations (mm); $^{2/}$ mean temperature of air (°C)

Source: own work / Źródło: opracowanie własne

3. Results and Discussion

In spite of similar amount of precipitations and close values of mean daily temperatures in the particular study years, occurring of short-lived and intensive weather features which caused the big changes in the course of plant vegetation and considerably affected size of obtained grain yield. In the II half of April 2008 very intensive rainfall occurred contributing to strong soil crusting, and in the beginning of June water shortage in the soil was noted as well as high air temperature, what caused the limitation of growth and development of plants. In 2009 drought was a weather factor which unfavorably affected plant vegetation. It occurred in April and in the beginning of May and caused hinder of wheat growth. Moreover, in the second half of April occurred strong winds which increased drying of soil, what in a consequence, considerably limited also the efficiency of soil herbicides action. Abundant and frequent rainfalls, small amount of sunny days and considerable chilling in the June also had unfavorable effect on growth and development of plants. Then in the beginning of June occurred intensive rainfall connected with hail, what caused plant logging. The course of weather conditions in 2010 was more favorable for winter wheat cultivation than in the both remaining years. Since unfavorable weather features were not noted. Indeed, in June 2010 a lower amount of precipitations than in the both remaining study years was found, and in August slightly higher than average values of daily temperatures, but weather conditions in this year turned out the most favorable for wheat cultivation.

Emergences of wheat plants occurred after 14-16 days from sowing. Wheat seeds were characterized by high germination capacity therefore a great uniformity and dynamics of plant growth was found. Moreover, plant density obtained after emergence was very close to that which was theoretically supposed.

Course of weather conditions had a very big effect on wheat growth and development (Table 2). Lower amount of precipitations in July 2010 resulted in shortening of a vegetation period, whereas their great amount in June and July 2009 caused its considerable elongation.

Table 2. Course of development stages of wheat plants (days)

Tab. 2. Fazy rozwojowe fenologicznych roślin pszenicy (dni)

Developmental phases of wheat	Year of study			
	2008	2009	2010	mean
Sowing – emergency	15	16	14	15
Emergency – tillering	24	26	25	25
Shooting – heading	18	19	17	18
Earing – flowering	8	10	8	9
Flowering – milk maturity	21	24	20	22
Milk maturity – full maturity	38	36	35	36
Lenght of vegetation period	124	131	119	125

Source: own work / Źródło: opracowanie własne

A forecrop differentiated the weight of vegetative and generative organs of wheat. The greatest dry matter yield of these organs produced wheat plants cultivated after lupine in the pure stand and after mixtures of lupine with greater number of barley, and the lowest - after barley in the pure stand. Decrease in lupine share and increase in barley in the forecrop caused decreasing in dry weight of straw, ears and grain of wheat (Table 3), so share of legume plant decided on the forecrop value of lupine mixture with barley. This dependency concerns also another legume-cereal mixtures [3].

The course of weather conditions in the study years had a significant effect on wheat grain yield. The greatest wheat grain yield was obtained in 2010, and the least in 2008 (Fig. 1). It is noteworthy that in the less favorable weather conditions the difference between the wheat yield obtained after good (lupine in the pure stand) and poor forecrop (barley in the pure stand) was greater than in the case of its cultivation in the most favorable weather conditions. In 2008 evaluated as less favorable for winter wheat cultivation the yield increase amounted to 23.1%, and in 2009 the increase in yield amounted only to 6.5%, although weather conditions were the most favorable for wheat cultivation. However, obtained yield increase in wheat cultivated after lupine in the pure stand was not so big because, according to the Piekarczyk [9] studies, winter wheat cultivated after blue lupine can yielding even by about 50% better than after barley. The increase in cereals yield cultivated after legumes is most frequently a consequence of nitrogen which remained in the considerable amounts in the postharvest residues, limitation of diseases development and weed infestation as well as improved soil structure [1].

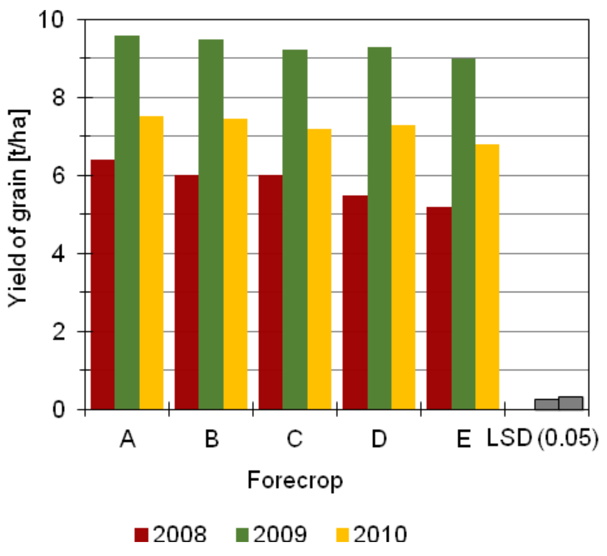
Table 3. Dry matter yield of wheat cultivated after various forecrops (kg·m^{-2})

Tab. 3. Plon suchej masy pszenicy uprawianej po różnych przedplonach (kg·m^{-2})

Plant organ	Forecrop *					LSD (0.05)
	A	B	C	D	E	
Culms + leaves	1.16	1.03	0.98	0.95	0.92	0.24
Ears	0.48	0.44	0.46	0.39	0.34	0.11
Grain	0.94	0.91	0.86	0.83	0.70	0.14
Total yield	2.58	2,38	2,12	2,17	1,96	-

*Forecrop for winter wheat according to the Material and Methods

Source: own work / Źródło: opracowanie własne



Source: own work / Źródło: opracowanie własne

Fig. 1. Grain yield of wheat cultivated after various forecrops

Rys. 1. Plon ziarna pszenicy uprawianej po różnych przedplonach

It should be also underlined that sequence after mixture of lupine with barley was much better than after cultivation of barley in the pure stand. The average increase in wheat yield for all mixtures in comparison with forecrop which was pure sowing of barley amounted to 12.3 and 3.8%, respectively for 2008 and 2009. It was confirmed by Wanic and Nowicki [17] studies, in which was shown favorable effect of mixtures as a forecrop on yielding of cereals. It can be assumed that in the condition of great share of cereals in the cropping area and low share of legumes, cereal-legumes mixtures can be a good crop-rotation element which stopped a frequent sequence of cereals after cereals.

A forecrop modified also some features of wheat yield structure (Table 4). Wheat cultivated after good forecrops produced more ears per plant and grain per plant in comparison to that cultivated after barley as a poor forecrop. The forecrop did not affect significantly number of grain per ear and weight of 1000 grains. While, another authors found that these structure elements could be also modified depending on a forecrop [1, 3, 9].

Table 4. Elements of wheat yield structure depending on a forecrop
Tab. 4. Elementy struktury plonu pszenicy w zależności od przedplonu

Yield structure elements	Forecrop					LSD (0.05)
	A	B	C	D	E	
Number of shoots with ear per plant	1.80	1.60	1.40	1.47	1.20	0.18
Number of grain per plant	68	61	57	59	45	3.64
Number of grain per ear	37.8	38.1	40.7	40.1	37.5	n.s.*
Weight of 1000 grain (g)	36.4	37.4	39.2	38.1	37.6	n.s.

*not significant

Source: own work / Źródło: opracowanie własne

A forecrop influenced only value of some wheat morphological features (Table 5). In particular it concerned the number of shoots per plant, because height of plants and leaves area did not change significantly.

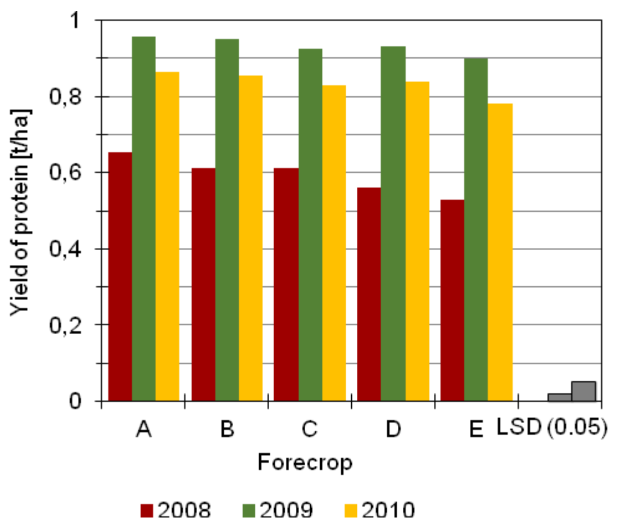
Table 5. Morphological features of wheat plants
Tab. 5. Cechy morfologiczne roślin pszenicy

Features of plants	Forecrop					LSD (0.05)
	A	B	C	D	E	
Plant height (cm)	84.1	82.4	80.6	83.8	81.5	n.s.*
Number of culms per plant	1.7	1.8	1.4	1.5	1.2	0.24
Leaves area (cm^2)	83	88	84	80	80	n.s.

*not significant

Source: own work / Źródło: opracowanie własne

Content of protein in the wheat grain did not change significantly in dependence on the forecrop. Indeed, it was observed a increasing trend in concentration of protein in the wheat grain cultivated in the pure stand and in mixtures with barley, but these differences were not confirmed statistically. From the literature results, that cereals cultivated after legumes can contain more protein in grain as these plants are better supplied with nitrogen [2]. Protein yield which is a product of grain yield and protein concentration, was in our studies determined mainly by size of grain yield. Therefore, the biggest protein yield was obtained from wheat cultivated after the good forecrops – lupine in the pure stands and mixtures of lupine with cereals, and the poorest – after the only spring barley (Fig. 2).



Source: own work / Źródło: opracowanie własne

Fig. 2. Protein yield of wheat cultivated after different forecrops
Rys. 2. Plon białka pszenicy uprawianej po różnych przedplonach

4. Conclusions

1. It was found a favorable effect of forecrop (lupine in the pure stand and mixtures of lupine with barley) on winter wheat yield and its structure features e.g. number of ears and grain per plant as well as weight of 1000 grain.
2. Effect of the forecrop on the level of winter wheat yielding to a great degree depended on the course of weather conditions in the study years. In years unfavorable winter wheat cultivation (small amount or irregularly distributed precipitations in the vegetation) the difference between winter wheat yields cultivated after good (lupine in the pure stand or mixture of lupine with barley) and poorer forecrops (barley in the pure stand) was greater than in the years with favorable course of weather.
3. It should be supposed that in conditions of great water deficit in soil resulted from insufficient or irregular distribution of rainfalls, the signification of crop rotation in the plant cultivation will increase.
4. Protein concentration in the wheat grain did not change significantly depending on a forecrop. It was observed however, growing trend at protein amount in the grain of wheat cultivated after lupine cultivated in the pure stand and in mixtures with barley, but these difference were not confirmed statistically.

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