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EFFECT OF MIXED CULTIVATION OF NAKED BARLEY WITH YELLOW AND BLUE LUPIN ON YIELDING AND SELECTED BIOMETRIC COMPONENT CHARACTERS IN ECOLOGICAL PRODUCTION SYSTEM

Summary

The conducted study aimed at the determination of the optimum share of the blue and yellow lupin in mixtures with the naked barley for the seed yielding on less productive land. An analysis of the component biometric characters and their yielding level constituted the basis for the determination of the optimum mixture for cultivation in specific soil conditions. The study was conducted on dusty soil belonging to the good rye soil complex. The experiment factor included a different share in the mixture (in % of pure sowing of the species) of naked barley (100, 60, 20, 0), yellow lupin (0, 40, 80, 100) and blue (01, 40, 80, 100). On the basis of the obtained results it was determined, that independently of the cultivation method, both yellow and blue lupin did not exhibit diversification in the number of pods per plant, as well as the number and weight of seeds from one plant. However, significant differences were observed for the weight of 1000 seeds. A significantly higher weight of one thousand seeds was exhibited by pure sown blue lupin and in the mixture with 20% share of barley, whereas in the case of yellow lupin only in the mixture with 60% share of barley. The blue lupin yielding was similar in pure sowing, as well as in the mixture with its 80% share. The highest yellow lupin yields were observed for the pure sowing, no statistical differences were observed for yielding of the species in the mixtures. Independently of the component species in the mixtures, higher yielding of barley at its 60% share, comparable to pure sowing was observed, which translated into the highest, total yields obtained from this cultivation variant within each of the used components.
***Key words**: yellow lupin, blue lupin, naked barley, mixed sowing*

WPŁYW UPRAWY MIESZANEJ JĘCZMIENIA NAGOZIARNISTEGO Z ŁUBINEM ŻÓŁTYM I WĄSKOLISTNYM NA PLONOWANIE I WYBRANE CECHY BIOMETRYCZNE KOMPONENTÓW W EKOLOGICZNYM SYSTEMIE PRODUKCJI

Streszczenie

Podjęte badania miały na celu ustalenie optymalnego udziału łubinu wąskolistnego i żółtego w mieszankach z jęczmieniem nagoziarnistym pod względem plonowania nasion w warunkach gleb słabszych. Podstawą do określenia optymalnego składu mieszanki przy uprawie w konkretnych warunkach glebowych, była analiza cech biometrycznych komponentów oraz poziom ich plonowania. Badania przeprowadzono na glebie pyłowej należącej do kompleksu żytniego dobrego. Czynnikiem doświadczenia był różny udział w mieszance (w % siewu czystego gatunków) jęczmienia nagoziarnistego (100, 60, 20, 0) łubinu żółtego (0, 40, 80, 100), oraz łubinu wąskolistnego (0, 40, 80,100). Na podstawie uzyskanych wyników stwierdzono, że niezależnie od sposobu uprawy, zarówno łubin żółty jak i wąskolistny nie wykazywał zróżnicowania pod względem ilości strąków na roślinie, jak też ilości i masy nasion z rośliny. Natomiast istotnie różnice zauważono pod względem masy tysiąca nasion. Istotnie wyższą MTN odznaczał się łubin wąskolistny z uprawy w siewie czystym oraz w mieszance z 20% udziałem jęczmienia, w przypadku łubinu żółtego dotyczy to tylko mieszanki z 60% udziałem jęczmienia. Plonowanie łubinu wąskolistnego było podobne w siewie czystym, jak również w mieszance z jego 80% udziałem. Najwyższe plony łubinu żółtego stwierdzono w siewie czystym, nie obserwowano statystycznych różnic w plonowaniu tego gatunku w mieszankach. Niezależnie od gatunku komponenta w mieszankach, zauważono wyższe i porównywalne do siewu czystego plonowanie jęczmienia przy jego 60% udziale, co przełożyło się na najwyższe, łączne plony uzyskane z takiego wariantu uprawy w obrębie każdego z zastosowanych komponentów.
***Słowa kluczowe**: łubin żółty, łubin wąskolistny, jęczmień nagoziarnisty, siew mieszany*

1. Introduction

Naked barley differs from the husky forms in higher protein content and lower fiber content. It can be used as animal feed as well in the dietary food production [1]. It is widely known that naked varieties have lower yielding levels than husky varieties [2, 3, 4]. Results of study conducted in 2011-2013 by Cierpiał and Wesołowski [5] clearly indicate, that despite the careful agricultural practice, the efficiency and quality of naked barley of the Rastik cultivar in organic cultivation are significantly lower as compared to the conventional method.

Contrary to cereals, legumes enhance physical, chemical and biological properties of soil. The use of cereal and legume mixtures also means an increase of the biodiversity of cultivations, which according to Yachi and Loreau [6] increases ecological stability. This may result in better plant health. The use of mixtures with legumes in cultivations may to a certain extent replace nitrogen fertilization, which is particularly significant for organic farms. Kontturi et al. [7] points out to one further favorable aspect of mixtures, related to the reduction of weed infestation. The author notices, that higher weed infestation occurs in pure sowings of pea than in mixtures of barley and pea, which constitutes

another indication for further introduction of such cultivations in ecological production systems. Furthermore, the risk of unreliable component yielding is decreased in mixtures as compared to independent sowings, which particularly applies to legumes [8, 9]. The interaction mechanisms between the components of the mixtures still constitute a subject of research. It is considered, that the mutual plant interaction applies to both above-ground as well as underground parts, and the greater role is usually attributed to the underground part [10]. Due to the inability to use such means of production as mineral fertilization and pesticides in organic farming, the choice of species and cultivars is of paramount importance. According to Rudnicki [11], yellow and blue lupin constitute valuable components in legume mixtures on average and less productive soils. However, the diverse habitat conditions and interspecific competition in the field cause the results of the cultivations to slightly differ [12, 13, 14]. However, certain tendencies can also be observed, which were searched by the authors for the mixtures of naked barley with two lupin species under the conditions of ecological production system.

The objective of the conducted study was to determine the optimum blue and yellow lupin share in mixtures with naked barley for the seed yielding in the conditions of less productive soils.

It was assumed that the use of yellow lupin as well as blue lupin as components for mixed cultivations with barely on less productive land, according to the share adopted in study, will positively impact on yielding of barley in relation to cultivation in pure sowing.

2. Methodology

The study was conducted in the years 2010-2011 as a field experiment, located in Mydlniki near Krakow (latitude 50°04′N longitude 19°51′E) at the Institute of Machinery Exploitation, Ergonomics and Production Processes of the University of Agriculture in Krakow. The climatic conditions of the area where the study was conducted are characterized by monthly accumulated rainfall and average monthly temperatures in the years 2010-2011, presented in Table 1. The presented data originate from the meteorological station located nearby the study area.

The study material originated from a microfield experiment, established using the random block method on dusty soil belonging to the good rye soil complex. In each year of study, the field in which the experiment was conducted, constituted black fallow. The surface area of a single field was 2 m^2. Every variant appeared in 3 replications. The single fields were separated by tracks of width 1 m. The protective area around the experiment space has the same width. The study included naked barley of the Rastik cultivar, which was used for cultivation in mixtures with yellow lupin of the Mister cultivar and blue lupin of the Sonet cultivar. The assumed plant density in pure sowing was: barley 350 pcs.·m^{-2}, yellow and blue lupin 115 pcs.·m^{-2}. The experiment factor was different share in the mixture (in % of pure sowing of the species) of naked barley (100, 60, 20, 0), yellow lupin (0, 40, 80, 100) and blue lupin (0, 40, 80, 100). The diagram of experiment is presented in Figure 1.

Table 1. Monthly and annual temperatures and accumulated rainfall for the study period and long-term averages
Tab. 1. Średnie temperatury miesięczne i roczne oraz poziom opadów w okresie badań i średnie długoterminowe

Month	1961-99	2010	2011
	Monthly average temperature [°C]		
January	-3,3	-6,3	-0,1
February	-1,6	-2,2	-5,5
March	2,4	3,3	5,8
April	7,9	9	12,3
May	13,1	12,8	15,3
June	16,2	17,5	20,0
July	17,5	20,7	21,0
August	16,9	18,4	19,1
September	13,1	12,3	14,8
October	8,3	8,7	8,5
November	3,2	3,1	4,7
December	-1,0	-2,3	-0,8
Annual mean	*7,7*	*7,9*	*9,6*
	Precipitation [mm]		
January	34	44,2	52
February	32	31,5	27
March	34	31,0	23
April	48	39,9	43
May	83	299,0	23
June	97	135,1	144
July	85	105,2	64
August	87	127,5	55
September	54	112,8	42
October	46	14,0	97
November	45	26,6	24
December	51	43,4	26
Annual sum	*696*	*1010,2*	*620*

A_3	A_1	A_7
A_1	A_2	A_5
A_5	A_7	A_4
A_2	A_5	A_6
A_7	A_3	A_1
A_4	A_6	A_2
A_6	A_4	A_3

Source: own work / Źródło: opracowanie własne

A_1 - barley 100%, A_2 - yellow lupin 100%, A_3 - blue lupin 100%, A_4 - yellow lupin 80%, barley 20%, A_5 - blue lupin 80%, barley 20%, A_6 - yellow lupin 40%, barley 60%, A_7 - blue lupin 40%, barley 60%.

Fig. 1. The diagram of experiment (the order of combinations within blocks in the year 2010)
Rys. 1. Schemat doświadczenia (kolejność kombinacji w obrębie bloków w 2010 r.)

The plants were not treated with any of the fertilizer. In the technological phase of maturity, 20 plants of each lupin species within each combination were collected from each experimental field, and their biometric characters were determined: number of first order branches, number of pods per plant, number of seeds per pod, weight of one thousand seeds (at 15% humidity). Lupin seed and barley grain moisture

was determined following the norm PN-86/A-74011 [15]. Lupin and barley yielding was determined on the basis of seed/grain weight obtained after threshing of plants collected from the area of $1m^2$. The yield size was corrected for the missing plants obtained before the collection for biometric measurements. The results were statistically elaborated using the variance analysis in the Statistica 12 software. Means were compared using the Duncan test with the significance level of $\alpha = 0.05$, separating the homogeneous groups.

3. Study results

When it comes to the temperature both years were similar to each other (Table 1). Differences were observed in the precipitation sum. In the year 2010 was wet May. Lack of rainfall in the same month in the year 2011 was compensated by rainy June. No significant differences were determined in yielding and biometric component characters of analysed species between years.

Slight differences were observed in the reaction of yellow and blue lupin to sowing in mixtures with naked barley. The highest number of first-order branches on the main stem of yellow lupin was observed for the plants originating from pure sowing, as well as from a mixture with 60% share of barley. The least numerous branches of the main stem of the species were observed in the mixture containing 80% of lupin (Table 2). Lower number of main stem branches usually results in lower lupin yielding, due to the decreased number of setting pods [16]. In the presented results, a decrease of lupin yielding was observed for this variant (tab. 3), however, both lower number of pods, as well as seeds and their weight were not statistically confirmed (Table 2). In the case of traditional yellow lupin cultivars, contrary to self-completing cultivars, the poorer branching of the main stem may also have a positive aspect, increasing the uniformity of seed maturation. This issue in conditions of a mixed cultivation is pointed out by [17].

The yellow lupin cultivation method also had an influence on the weight of one thousand seeds. Its highest value characterized the seeds originating from the mixture with their 40% share (Table 2). It was only 4% lower from its maximum value provided by the breeder for this lupin cultivar [18]. Similar reaction of yellow lupin in terms of the weight of one thousand seeds to the cultivation method was recorded during a previous study in similar soil conditions, however, then the character value did not exhibit a statistically important difference as regards the mixture with lower (20%) barley share [19]. The study of Księżak and Staniak [20] on the cultivation of blue lupin with cereals in organic farming indicates a certain, slight variability of morphological characters of legumes sown in mixtures with cereals in subsequent cultivation years.

The present study did not demonstrate an effect of yellow lupin sowing combination on its characters such as the number of pods per plant, number of seeds and seed weight from one plant. Values of these characters in plants originating from cultivation with pure sowing as well as mixed sowing with barley, independently of its share, were similar and did not exhibit a statistically significant variability (Table 2).

The reaction of narrow-leaved lupin to the mixed cultivation with barley pertained to, similarly to the case of yellow lupin, the level of branching of the main stem and the weight of one thousand seeds (Table 3). Plants of the species mixed with barley developed a lower number of the first-order branches, as compared to the pure sowing. Contrary to yellow lupin, the level of the main stem branching of blue lupin in both mixture variants was similar and did not exhibit a statistically significant variability.

Blue lupin in the pure sowing, as well as in the mixture with barley at its 20% share, developed seeds with similar weight of a thousand, and higher as compared to the mixture with 60% barley share. The highest mean weight of one thousand seeds of blue lupin obtained in the study was similar to the highest value of this parameter provided by the breeder of the cultivar, equal to 165 g [18].

Table 2. Mean values of morphometric characters and structural elements of plant yield of the yellow lupin, in cultivation with pure sowing and mixed sowing with barley in the years 2010-2011
Tab. 2. Średnie wartości cech morfometrycznych i elementów struktury plonu roślin łubinu żółtego, przy uprawie w siewie czystym i mieszanym z jęczmieniem w latach 2010-2011

Sowing combination		Number of first-order branches (pcs.)	Number of pods per plant (pcs.)	Number of seeds from one plant (pcs.)	Seed weight from one plant (g)	Weight of 1000 seeds (g)
Barley share (%)	Yellow lupin share (%)					
60	40	3.75 a*	11.85 a	44.52 a	5.83 a	138.89 a
20	80	2.80 b	10.68 a	39.71 a	4.96 a	122.43 b
0	100	3.95 a	11.55 a	41.66 a	5.13 a	121.75 b

*a, b - homogeneous groups according to the Duncan test

Source: own work / Źródło: opracowanie własne

Table 3. Mean values of morphometric characters and structural elements of plant yield of the blue lupin, in cultivation with pure sowing and mixed sowing with barley in the years 2010-2011
Tab. 3. Średnie wartości cech morfometrycznych i elementów struktury plonu roślin łubinu wąskolistnego, przy uprawie w siewie czystym i mieszanym z jęczmieniem w latach 2010-2011

Combination		Number of first-order branches (pcs.)	Number of pods per plant (pcs.)	Number of seeds from one plant (pcs.)	Seed weight from one plant (g)
Barley share (%)	Blue lupin share (%)				
60	40	1.15 b*	7.80 a	24.80 a	4.718 a
20	80	1.10 b	10.75 a	34.75 a	5.839 a
0	100	3.05 a	10.30 a	33.65 a	5.885 a

*a, b - homogeneous groups according to the Duncan test

Source: own work / Źródło: opracowanie własne

In the study of Podleśny and Podleśna [21], conducted in a vegetation chamber, on the effect of drought stress on the yielding of blue lupin, cultivar Sonet in pure sowing and mixed sowing with barley, it was determined, that a higher weight of one thousand seeds is exhibited by this lupin cultivar in the mixture, as compared to the pure sowing. This fact may additionally argue for the use of the cultivar in the mixed sowing. Blue, similarly to yellow lupin, did not exhibit any reaction to the cultivation method in terms of the developed pods, seeds, and the seed weight from single plants (Table 3). Analysis of yellow and blue lupin yield demonstrated variability of its size depending on the used cultivation variant. The highest yellow lupin yield was obtained in the pure sowing. On the other hand, in both variants of mixed cultivation with barley, its yielding was at a similar level (Table 4). The fact of lower yielding of yellow lupin in mixtures with cereals is also corroborated by the study of Rudnicki and Kotwica [22] on the competitive interaction between spring cereals and lupins in mixtures. In the case of blue lupin, the yielding level in the pure sowing and mixed sowing with its 80% was similar, and higher by 44.6% than in the mixture with its 40% share. Therefore the yield values exhibited a similar relationship to the cultivation variant as the above discussed weight of one thousand seeds. This indicates the considerable importance of this element of the total yield structure of blue lupin.

Table 4. Mean values of seed yields of both lupins depending on sowing combination in the years 2010-2011
Tab. 4. Średnie wartości plonu nasion łubinów w zależności od kombinacji wysiewu w latach 2010-2011

Sowing combination		Yellow lupin seed yield ($dt \cdot ha^{-1}$)	Blue lupin seed yield ($dt \cdot ha^{-1}$)
Barley share (%)	Lupin share (%)		
60	40	14,6 b*	5,4 b
20	80	18,4 b	14,5 a
0	100	27,4 a	17,9 a

*a, b - homogeneous groups according to the Duncan test
Source: own work / Źródło: opracowanie własne

Yielding of spring barley in the pure sowing and mixed sowing with yellow and blue lupin is presented in Table 5.

Table 5. Yielding of naked barley of the Rastik cultivar in pure sowing and mixed sowing in individual experiment variants in the years 2010-2011
Tab.5. Plonowanie jęczmienia nagoziarnistego odmiany Rastik w siewie czystym i mieszanym w poszczególnych wariantach doświadczenia w latach 2010-2011

Combination	Barley seed yield ($dt \cdot ha^{-1}$)	Total mean yield of lupin and barley ($dt \cdot ha^{-1}$)
nl80b20	11,9 b*	26,4
yl80b20	18,3 b	36,7
b100%	23,5 a	
nl40b60	24,8 a	30,2
yl40b60	240 a	386

*a, b - homogeneous groups according to the Duncan test
Source: own work / Źródło: opracowanie własne

Similar reaction of naked barley in terms of its yielding to the sowing in mixtures with both lupin species was determined. The assumed research hypothesis has not fully confirm the results. Independently of the component species in the mixtures, higher and stable barley yielding with its 60% share was observed. In this variant, barley yielded at a similar level as in the pure sowing. On the contrary, a decrease of its share to 20% in mixture, resulted in a lower yield, which appears to be logical. The high yielding of barley in the mixtures with its 60% share resulted in the highest total mixture yields (seeds and grain) for each lupin species. The present results corroborate the observations of Kotwica and Rudnicki [13], that in a mixed cultivation of spring cereals with lupin in the good rye soil complex, the total mixture yield depends to a large extent on the cereal component. However, in the discussed study results, higher yields of yellow lupin than of blue lupin were determined, which resulted in slightly higher yields of the analogous mixtures of both lupin species.

4. Conclusions

1. In the ecological production system, the highest yields of yellow lupin were determined from the cultivation with pure sowing. In the mixtures, the yielding level was lower and did not exhibit variability depending on the component share. On the other hand, the blue lupin yield was significantly higher in the pure sowing, as well as in the mixture with its 80% share.
2. Independently of the share in sowings, both yellow lupin, as well as blue lupin did not exhibit variability in terms of the number of pods per plant, as well as the number and weight of seeds per plant. However, differences in terms of the weight of one thousand seeds were observed. A significantly higher weight of one thousand seeds was exhibited by pure sown blue lupins and with its 80% share, whereas in the case of yellow lupin only in the mixture with its 40% share.
3. Independently of the component species in the mixtures, a higher yielding of barley at its 60% share, comparable to pure sowing was observed, which translated into the highest, total yields obtained from this cultivation variant within each of the components.

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