Reaction of white lupin (*Lupinus albus* L.) to the initial nitrogen feeding and foliar feeding

Reakcja łubinu białego (*Lupinus albus* L.) na dawkę startową azotu i dokarmianie dolistne

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Abstract

In the years 2009-2011 field experiment was carried out, whose aim was determination of reaction of white lupin cultivar Boros to the initial nitrogen feeding and foliar feeding Basfoliar 6-12-6 (2 x 10 $dm^3 \cdot ha^{-1}$). It was found that the initial nitrogen feeding a significant increase prolonged lodging degree and stage of maturity compared with the control (without fertilization). The initial nitrogen feeding increased significantly number of pods per plant and the weight of one thousand seeds. Applied Basfoliar 6-12-6 did not modified yield components. Yielding of white lupin was variable between studies and averaged 3.95 $Mg \cdot ha^{-1}$. Starting dose of nitrogen significantly increased seed yield to the control of 0.15 $Mg \cdot ha^{-1}$. Applied foliar fertilizer had no effect on the average seed yield, but significantly increased the total protein content in the seeds.

Keywords: foliar feeding, initial nitrogen feeding, total protein, white lupin, yield

Streszczenie

W latach 2009-2011 przeprowadzono ścisłe doświadczenie polowe, którego celem było określenie reakcji łubinu białego odmiany Boros na dawkę startową azotu i dokarmianie dolistne wieloskładnikowym nawozem Basfoliar 6-12-6 (2 x 10 $dm^3 \cdot ha^{-1}$). Stwierdzono, że dawka startowa azotu istotnie podniosła stopień wylegania roślin oraz wydłużyła fazę dojrzewania w odniesieniu do kontroli. Nawożenie startowe azotem istotnie zwiększyło liczbę strąków na pojedynczej roślinie oraz masę tysiąca nasion. Aplikacja Basfoliaru 6-12-6 nie zmodyfikowała elementów struktury plonu. Plonowanie łubinu białego było zmienne w latach badań i wyniosło średnio 3.95 $Mg \cdot ha^{-1}$. Dawka startowa azotu istotnie zwiększyła plon nasion wobec obiektu kontrolnego o 0.15 Mg·ha^{-1}. Zastosowany nawóz dolistny nie miał wpływu na średni plon nasion, zwiększył natomiast istotnie zawartość białka ogólnego w nasionach.

Słowa kluczowe: białko, dawka startowa azotu, dokarmianie dolistne, łubin biały, plon

Streszczenie szczegółowe

Ścisłe doświadczenie polowe z łubinem białym przeprowadzono w latach 2009-2011 w Stacji Doświadczalnej Wydziału Biologiczno – Rolniczego Uniwersytetu Rzeszowskiego w Krasnem (50°03’ N, 22°06’ E) koło Rzeszowa. Eksperyment zrealizowany został wg metody split-plot w czterech powtórzeniach. Badanymi czynnikami były: dawka startowa azotu 30 kg·ha^{-1} (Saletra amonowa 34% N), dokarmianie dolistne (Basfoliar 6-12-6) oraz obiekt kontrolny. Do doświadczeń wybrano samokończącą odmianę Boros. Wysiewu nasion dokonano w następujących terminach: 16.04.2009 r., 13.04.2010 r. i 05.04.2011 r. Norma wysiewu wyniosła 110 szt·m^{-2}. Przedplonem w każdym roku badań była pszenica ozima. Powierzchnia jednego poletka wynosiła 15 m^2 (do zbioru 12 m^2). Na powierzchni 1 m^2 policzono obsadę roślin przed zbiorem. W okresie wegetacji notowano występowanie ważniejszych fazy rozwojowych. Wyleganie oceniono w skali od 1° do 9°.W fazie pełnej dojrzałości nasion, z każdego poletka, pobrano losowo 20 roślin i określono ich elementy struktury plonu: liczbę strąków na roślinie, liczbę nasion w strąku i masę tysiąca nasion (przy 15% wilgotności). Zbiór przeprowadzono w terminie: 20.08.2009 r., 24.08.2010 r. i 19.08.2011 r. Plon nasion przeliczono na powierzchnię 1 ha i sprowadzono do stałej wilgotności 15%. W nasionach oznaczono zawartość azotu ogólnego metodą Kjeldahla i przeliczono na białko ogólne stosując mnożnik 6.25. Okres wegetacji odmiany Boros wyniósł średnio 128 dni. Dawka startowa azotu istotnie zwiększyła stopień wylegania roślin o 1.25° oraz wydłużyła fazę dojrzewania o 4.5 dnia w odniesieniu do obiektu kontrolnego. Liczba strąków na pojedynczej roślinie oraz masa tysiąca nasion były istotnie większe po zastosowaniu dawki startowej azotu. Dokarmianie dolistne Basfoliarem 6-12-6 nie zmodyfikowało elementów struktury plonu. Plon nasion był zmienny w latach badań i wyniósł średnio 3.95 Mg·ha^{-1}. Dawka startowa azotu istotnie zwiększyła plonowanie łubinu. Nawóz dolistny nie miał wpływu na średni plon nasion, zwiększył natomiast istotnie zawartość białka ogólnego w nasionach.

Introduction

White lupin cultivation occupies a small area in Poland, although has the great yield-forming potential. The growing importance of this species is possible by spreading the forms determinate and improve their agricultural technology (Podleśny, 2005; Jarecki and Bobrecka-Jamro, 2012). Lupins (*Lupin albus, Lupin angustifolius, Lupin luteus, Lupin mutabilis*) are cultivated for three main reasons: as a ruminant feed, as a green manure contributing to improved soil structure, and for human nutrition because of their high protein and oil contents (Faluyi et al., 2000; Huyghe, 1997).

Seeds of white lupin have a protein content ranging from 33% to 47%, according to genotype and location (Erbas et al., 2005). White lupin varieties of determinate type, characterized by a shorter vegetation period, earlier and more uniform maturing, and different dynamics of accumulation of assimilates in seed yield in comparison with other traditional varieties (Podleśny, 2005). White lupin seed yield obtained in Poland ranges from 3 to 4 Mg·ha^{-1} (Jarecki and Bobrecka-Jamro, 2012). The fertilization of white lupin with mineral nitrogen and foliar fertilization with macro- and microelements may affect the quantity and quality of yield seeds. It is claim that legumes should be treated only with 20-40 kg·ha^{-1} pre-sowing nitrogen doses to meet the requirements of plants before starting symbiosis (Prusiński, 2005). Foliar feeding is recommended to be used in the beginning of budding stage.

New varieties of white lupin with determinate type have different plant habit, produce lower biomass in the vegetation period and are characterized by other rhythm of growth and development than traditional ones (Podleśny, 2005). The present results of experiments on foliar feeding legumes are not clear and need for further detailed agronomic research in different habitats (Prusiński, 2005).This applies especially new varieties with determinate type. They are characterized by a clear reduction or absence of latter shoots, which reduces shading of plants (Podleśny, 2005).

In the research hypothesis was assumed that the initial nitrogen feeding and foliar feeding with macro- and microelements influence on quantity and quality of the yield as well as the growth and development of plants

Materials and Methods

Field experiments with white lupin were carried out in the years 2009-2011 at the Experimental Station of the Faculty of Biology and Agriculture of the University of Rzeszów in Krasne (50°03' N; 22°06' E) near Rzeszow. The experiment was realized according to the split-plot design in four replications. The studied factors included:

I - the initial nitrogen feeding 30 kg·ha^{-1} (ammonium nitrate 34% N),

II - the foliar feeding (Basfoliar 6-12-6; before flowering - 10 dm^3·ha^{-1} and after flowering - 10 dm^3·ha^{-1})

III - the initial nitrogen feeding 30 kg·ha^{-1} (ammonium nitrate 34% N) +the foliar feeding (Basfoliar 6-12-6; before flowering - 10 dm^3·ha^{-1} and after flowering - 10 dm^3·ha^{-1})

IV - control object (without fertilization).

Boros (determinate form) was used for the experiment. Weather conditions are given according to Weather Reports for Rzeszow from the Institute of Meteorology and Water Management (IMiGW) in Warsaw. In the research years, the rainfall total was unstable (Table 1.). In the period April-August it was: 372.5 mm in 2009, 651.8 mm in 2010 and 450.0 in 2011. Mean temperatures in the same period were less diversified (Table 2.).

The experiment was set up on the soil of good wheat complex, bonitation class IIIa, with pH in the range from 5.10 (2009) to 5.94 (2010). The content of assimilable phosphorus, potassium and microelements was average, however magnesium content was very low. Soil samples were collected to a depth of 20 cm. Soil analysis was carried out at the Regional Chemical-Agricultural Station in Rzeszow, according to the accepted methods. Seed material was dressed with Sarfun T 450 FS and was sown on the following dates: 16 April 2009, 13 April 2010 and 05 April 2011. The amount of sown seeds was 110 seeds·m^{-2}.

Winter wheat was the forecrop of white lupin in every year of research. The area of a plot was 15 m^2 (for harvest 12 m^2). Mineral phosphoricpotassic fertilization (triple superphosphate 46% and potassium salt 60%) was applied under autumn ploughing at the following rates: 35 P kg·ha^{-1}, 100 K kg·ha^{-1}. Directly after sowing lupin, preparation Afalon Dispersive 450 SC was used for weed control at a rate of 1.5 dm^3·ha^{-1}. Pesticides for the control of pests and diseases were not applied. Foliar feeding was used twice. The first dose (10 dm^3·ha^{-1}) was applied before flowering. The second dose after flowering.

Every year, on the area of 1 m^2 plant density of white lupin was calculated before its harvest. In the vegetation period, occurrence of more important development stages of plants was observed, i.e. budding, flowering and maturity. Lodging was evaluated in the scale from 1^o to 9^o. In the stage of full seed maturity, from each plot, 20 plants were collected at random, and their yield components were determined: the number of pods per plant, number of seeds per pod, and weight of one thousand seeds (with 15% moisture).

The harvest was conducted in a single stage on the following dates: 20 August 2009, 24 August 2010 and 19 August 2011. During harvest, from each plot, seed yield was determined calculating it per area of 1 ha, and leading it to a constant moisture of 15%.

In the seeds the total nitrogen content was determined with the use of Kjeldahl method, and it was calculated into total protein with the use of a multiplier 6.25.

Obtained results for the yield, yield structure and protein content were elaborated statistically with the use of analysis of variance. Significance of difference between trait values were tested based on Tukey’s honestly significant difference test, with significance level P=0.05. Statistical program ANALWAR–5FR was used for calculations.

Table 1. Distribution of precipitations (mm) for white lupin vegetation period

Tabela 1. Rozkład opadów atmosferycznych (mm) w okresie wegetacji łubinu białego

Year	Month					Precipitations total
	April	May	June	July	August	
2009	3.7	102.6	146.4	98.0	21.8	372.5
2010	49.9	177.0	126.1	200.2	98.6	651.8
2011	50.0	49.2	88.5	233.7	28.6	450.0
Many years 1986-2008	50.6	80.8	82.0	88.2	68.8	370.4

Table 2. Distribution of mean air temperatures (^{o}C)

Tabela 2. Rozkład średnich temperatur powietrza (^{o}C)

Year	Month					Mean
	April	May	June	July	August	
2009	11.1	13.8	16.6	20.7	19.4	16.3
2010	8.9	14.3	17.9	20.8	19.5	16.3
2011	10.3	13.9	18.1	18.6	19.0	16.0
Many years 1986-2008	8.7	13.9	17.0	19.0	18.2	15.4

Results and discussion

It was found that the initial nitrogen feeding and foliar feeding did not have significant effect on plant density during the growing season. Plant density before harvest was on average 87.25 plants·m^{-2} (Table 3.). Prusiński (2002a) adds that, with morphological diversity of white lupin cultivars, it is important to maintain a suitable plant density. It has a fundamental significance for the yield and cultivation costs.

It was found that a significant increase prolonged lodging the initial nitrogen feeding compared with the control (without fertilization).

Foliar feeding did not modify the discussed features (Table 3.). Podleśny (2005) reported no lodging of white lupine plants which have an effect on the stiffness of the stems and favorable weather conditions in the system during the growing season.

The plants were green longer on a control object compared to the objects fertilized with nitrogen. The dose of nitrogen significantly extended the starting stage of maturation (Table 3.). Vegetation period was on average 127.75 days. Podleśny (2005, 2006) collected white lupin seeds after 115 days in the dry year and after 138 days in the wet year.

Table 3. Plant density, lodging and length of development stages in days since the date of sowing (mean in years)

Tabela 3. Obsada roślin, wyleganie i długość faz rozwojowych w dniach od daty siewu (średnia z lat)

Initial nitrogen feeding	Foliar feeding	Number of plants before harvest, pcs.$\cdot m^{-2}$	Lodging 1-9°	Budding	Flowering	Maturity
Control	Control	86	8.5	52	61	125
	Basfoliar	86	8.5	52	62	126
30 N kg$\cdot ha^{-1}$	Control	88	7.5	54	65	129
	Basfoliar	89	7.0	54	65	131
Mean for factor						
Control		86.0	8.50	52	61.5	125.5
30 N kg$\cdot ha^{-1}$		88.5	7.25	54	65.0	130.0
LSD I $_{0.05}$		ns	0.953	ns	ns	3.694
Control		87.0	8.00	53	63.0	127.0
Basfoliar 6-12-6		87.5	7.75	53	63.5	128.5
LSD II $_{0.05}$		ns	ns	ns	ns	ns
LSD IxII $_{0.05}$		ns	0.359	ns	ns	ns
Mean		87.25	7.88	53	63.25	127.8

ns – non – significant differences

The initial nitrogen feeding increased significantly number of pods per plant and the weight of one thousand seeds as compared to the control (Table 4.). The number of seeds per pod showed no statistically significant differences. The cultivar Boros developed average 4.74 pod per plant and 3.43 seeds per pod. Weight of one thousand seeds was on average 300 g.

Borowska and Prusiński (2005) obtained on average 8.77 pods in cultivar Butan; while Podleśny (2006) 6.9 pods per plant. In experiments on indeterminate white lupin, Prusiński (2005) considered it important to take into account yield components on the main shoot and lateral shoot, as the proportion of pods and seeds from lateral shoots in the total yield of this species is approximately 50%. The situation is different in the varieties of determinate type. Borowska and Prusiński (2005) obtained weight of 1000 seeds in cultivar Butan of 288 g.

Foliar feeding did not modify a number of pods per plant, number of seeds per pod and the weight of one thousand seeds. Borowska and Prusiński (2005) found no significant effect of foliar fertilizer (Ekolist) on the weight of one thousand seeds. Prusiński (2005) said that the effectiveness of foliar fertilization of plants with urea and microelements will depend on the availability of macro- and microelements and symbiotic intensity.

Analysis of variance showed no significant effect of starting dose of nitrogen on the protein content in dry matter of seeds. Foliar feeding increased the content of this component by 0.15% as compared to the control (Table 4.). What's more Prusiński (2005) obtained a significant increase in total protein content in the seeds of the foliar treatment.

Table 4. Yield components of white lupin and protein content in seeds (mean in years)

Tabela 4. Elementy struktury plonu łubinu białego i zawartość białka w nasionach (średnia z lat)

Initial nitrogen feeding	Foliar feeding	Number of pods per plant	Number of seeds per pod	Weight of one thousand seeds (g)	Total protein (%)
Control	Control	4.62	3.41	297	32.70
	Basfoliar 6-12-6	4.71	3.46	299	32.95
30 N kg·ha^{-1}	Control	4.80	3.42	301	32.90
	Basfoliar 6-12-6	4.82	3.44	303	32.95
Mean for factor					
Control		4.67	3.44	298	32.83
30 N kg·ha^{-1}		4.81	3.43	302	32.93
LSD I $_{0.05}$		0.135	ns	0.356	ns
Control		4.71	3.42	299	32.80
Basfoliar 6-12-6		4.77	3.45	301	32.95
LSD II $_{0.05}$		ns	ns	ns	0.132
LSD IxII $_{0.05}$		ns	ns	ns	ns
Mean		4.74	3.43	300	32.88

ns – non – significant differences

Statistical analysis of the research results proved that the initial nitrogen feeding contributes to a significant increase in seed yield. With reference to the control plots, the obtained increase was 0.15 Mg·ha^{-1}, i.e. 3.9% (Table 5). Ekolist significantly affected white lupin seed yield. Foliar feeding did not influence the average seed yield. In the years of research, seed yield was 3.95 Mg·ha^{-1}, and was significantly higher that the research of Podleśny (2005). Prusiński (2002b, 2005) in his research showed that the traditional type of white lupin yielded higher than the indeterminate type. In the research of Borowska and Prusiński (2005) foliar feeding with a high dose of Ekolist influenced significantly on yielding of white lupin.

Table 5. Seed yield in years 2009-2011 ($Mg \cdot ha^{-1}$)

Tabela 5. Plon nasion w latach 2009-2011 (($Mg \cdot ha^{-1}$)

Initial nitrogen feeding	Foliar feeding	2009	2010	2011	2009-2011
Control	Control	4.25	2.97	4.17	3.80
	Basfoliar 6-12-6	4.35	3.23	4.25	3.94
30 $kg \cdot ha^{-1}$	Control	4.38	3.28	4.29	3.98
	Basfoliar 6-12-6	4.51	3.32	4.36	4.06
	Mean for factor				
Control		4.25	3.10	4.21	3.87
30 $kg \cdot ha^{-1}$		4.45	3.30	4.33	4.02
LSD I $_{0.05}$		0.179	0.165	ns	0.142
Control		4.32	3.13	4.23	3.89
Basfoliar 6-12-6		4.43	3.28	4.31	4.00
LSD II $_{0.05}$		ns	0.235	ns	ns
LSD IxII $_{0.05}$		ns	0.259	ns	0.125
Mean		4.38	3.20	4.27	3.95

ns – non – significant differences

Conclusions

1. Initial nitrogen increased the lodging of plants of 1.25° and the maturity stage became 4.5 days longer as compared to the control. Vegetation period of was on average 127.75 days. Vegetation period of Boros varieties approximately to 128 days.
2. Number of pods per plant and the weight of one thousand seeds were considerably higher after the using of initial dose of nitrogen. Foliar feeding with Basfoliar 6-12-6 did not modify the yield components.
3. The yield was changeable during research years and on average amounted to 3.95 $Mg \cdot ha^{-1}$. The initial nitrogen feeding increased yielding. Foliar feeding did not influence the average seed yield but it increased considerably the amount of total protein in seeds.

References

Borowska, M., Prusiński J. (2005) IBA and Ekolist in white lupin seed production. Biuletyn Instytutu Hodowli i Aklimatyzacji Roślin, 237/238, 207-221.

Erbas, M., Certel, M., Uslu, M. K. (2005) Some chemical properties of white lupin seeds (*Lupinus albus* L.). Food Chemistry, 89, 341-345. doi:10.1016/j.foodchem.2004.02.040

Faluyi, M. A., Zhou, X. M., Zhang, F., Leibovitch, S., Migner, P., Smith, D. L. (2000) Seed quality of sweet white lupin (*Lupinus albus*) and management practice in eastern Canada. European Journal of Agronomy, 13, 7-37. doi:10.1016/S1161-0301(00)00057-5

Huyghe, C. (1997) White lupin (*Lupinus albus L*.). Field Crops Research, 53, 147-160. doi:10.1016/S0378-4290(97)00028-2

Jarecki, W., Bobrecka-Jamro, D. (2012) Reaction of white lupine (*Lupinus albus* L.) to seed inoculation with Nitragina. Acta Scientiarum Polonorum, Agricultura, 11 (2), 19-26.

Podleśny J. (2005) The effect of sowing method and row spacing on the growth, development and yielding of determinate type of white lupine. Pamiętnik Puławski, 140, 199-214.

Podleśny J. (2006) Suitability of point sowing in cultivation of selected species of leguminous plants. Inżynieria Rolnicza, 13, 385-392.

Prusiński J. (2002a) Yield analysis of traditional and self-completing white lupin (*Lupinus albus L.*) varieties in relation to plant density. Biuletyn Instytutu Hodowli i Aklimatyzacji Roślin, 221, 175-187.

Prusiński J. (2002b) Impact of foliar plant fertilization and chemical control on yielding of traditional and self-completing white lupin (*Lupinus albus* L.) cultivars. Acta Scientiarum Polonorum, Agricultura, 1 (1), 37-47.

Prusiński J. (2005) Traditional and self-completing white lupin (*Lupinus albus L*.) cultivars yielding depending on foliar plant fertilization and chemical protection. Electronic Journal of Polish Agricultural Universities, 8 (3), 41. http://www.ejpau.media.pl/volume8/issue3/art-41.html