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ELECTRONIC JOURNAL OF POLISH AGRICULTURAL UNIVERSITIES

2000
Volume 3
Issue 1
Series
AGRONOMY

PRZEMYSŁAW BARŁÓG, WITOLD GRZEBISZ 2000. IMPACT OF kieserite AND NITROGEN FERTILISATION ON THE YIELD AND SEED CHEMICAL COMPOSITION OF NARROW-LEAFED LUPIN **Electronic Journal of Polish Agricultural Universities**, Agronomy, Volume 3, Issue 1.
Available Online http://www.ejpau.media.pl/

IMPACT OF kieserite AND NITROGEN FERTILISATION ON THE YIELD AND SEED CHEMICAL COMPOSITION OF NARROW-LEAFED LUPIN

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ABSTRACT

A three-year field experiment researched the impact of 60 kg-Mg ha^{-1} kieserite fertilisation and 75 kg-N ha^{-1} nitrogen fertilisers on the yield and seed chemical composition of three narrow-leafed lupin cultivars. It was observed that kieserite fertilisation did not have a significant effect on the straw and seed yields. The cross-cultivar differences depended mostly on the weather conditions over the vegetation period. The high-alkaloid cultivar, 'Mirela', gave higher and more-stable-over-the-years seed yield than the low-alkaloid cultivars, 'Emir' and 'Sur'. A fertilisation with ammonium nitrate and calcium nitrate significantly increased, as compared with the control and the object fertilised with N in its ammonium form, the yields of straw and of digestible protein, however it did not influence the seed yield considerably.

Key words: narrow-leafed lupin cultivars, kieserite, nitrogen fertilisers – nitrogen form, seed yield, yield structure, macroelement content.

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INTRODUCTION

Not only does the narrow-leafed lupin show a capability to fix atmospheric nitrogen, but it also assimilates nitrogen from soil [20]; the optimum content of that element in soil enhances lupin yielding [16]. However the literary coverage does not answer fully and unanimously whether or not it is justifiable to apply a nitrogen fertiliser at all or, if so, at which doses, which may be due to a much-varied mineral nitrogen content in soil and often considerably exceeds the commonly applied pre-sowing dose [4]. One should also bear in mind that nitrogen is present in soil in two basic forms, $N\text{-}NO_3$ and $N\text{-}NH_4$, which show a different impact on plant growth and development. In the wild there are species with their individual preferences for one of the forms or show a maximum development whenever the two forms are available [1,6].

The narrow-leafed lupin requires the crop-rotation position rich in available magnesium [7]. Fertilisation with kieserite at 'regeneration' dose (60-150 kg · ha^{-1} of Mg) aims not only at supplying the plant with an adequate amount of magnesium but, first of all, enhancing the soil fertility [17]. A high dose of magnesium can cause an antagonism and synergy of ions due to which Mg^{2+} will have a negative effect on the uptake of $N\text{-}NH_4$ and a positive effect on the uptake of $N\text{-}NO_3$ [9]. Magnesium fertilisation can also enhance the uptake of certain nitrogen forms due to the effect on lupin nodulation processes as well as on the metabolism of nitrogen compounds [11].

The present research presents a hypothesis that due to the interaction of magnesium and different nitrogen forms, there emerge differences in yielding and chemical composition of narrow-leafed lupin seeds.

MATERIALS AND METHODS

The field experiments were conducted over 1994-1996 at the Swadzim Agricultural Experiment Station of the Poznań Agricultural University, on lessive soil of the IVb soil valuation class and a good rye soil suitability complex, of a slight acid reaction, a high content of available potassium and phosphorus and an average of magnesium. The content of mineral nitrogen in early spring in the layer of 0-40 cm ranged from 19 to 26 kg · ha^{-1} of $N\text{-}NO_3$ and from 4.5 to 6.0 kg · ha^{-1} of $N\text{-}NH_4$.

The field experiment was set as a split-split-plot design.

The factors researched included:

1. two doses of magnesium fertilisation: non-fertilised and kieserite-fertilised ($MgSO_4 \cdot H_2O$) at 60 kg·ha^{-1} of Mg;
2. three narrow-leafed lupin cultivars (*Lupinus angustifolius* L.) – high-alkaloid 'Mirela' and two low-alkaloid cultivars, 'Emir' and 'Sur';
3. nitrogen forms: $Ca(NO_3)_2$, $(NH_4)_2SO_4$, NH_4NO_3, $CO(NH_2)_2$ at the dose of 75 kg· ha^{-1} of N.

The experiment was carried out in 4 replications on plots, 20 m^2 each.

Lupin was sown onto the after-corn position, for a list of basic agronomic practices and their timing, see Table 1. The dose of phosphorus and potassium fertilisers amounted to 60 kg· ha^{-1} of P_2O_5 and 80 kg·ha^{-1} of K_2O, respectively. The amount of the sowing material was adjusted to the post-emergence plant density planned, 90 plants per sq. m, at the 15 cm row spacing at the sowing depth of 3 cm. Prior to sowing, the seeds were treated with *Bradyrhizobium lupini* and dressed with Funaben T (thiram, 200 g·100 kg^{-1} of seeds).
The total and protein nitrogen, having been precipitated with the 2.5% trichloroacetic acid was defined with the Kjeldahl method, while phosphorus with the calorimetric vanadate-molybdate method. The other macroelements were defined with the AAS method, the material having been mineralised at 450°C and ash having been solved in 3M HCl solution.
The data was analysed with the ANVAR software designed by Toboła, Poznań Agricultural University.

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Table 1. Typical agronomic practices and their timing

Agronomic practice	Timing		
	1994	1995	1996
Fertiliser application	March, 31	March, 23	April, 13
Pre-sowing cultivation	March, 31	March, 23	April, 13
Seeding and harrowing	April, 1	March, 24	April, 15
Soil-applied herbicide (Azotop, 1.25 kg· ha^{-1})	April, 2	March, 25	April, 16
Couch-grass spraying (Fusilade Super, 1.5 l·ha^{-1})	May-June	May-June	June, 5
Desiccation (Reglone, 4 kg· ha^{-1})	July, 17	July, 14	M* August, 5 E,S August, 19
Seed harvest	July, 22	July, 21	M August, 20 E,S September, 18

***Cultivars: M - 'Mirela', E - 'Emir', S – 'Sur'**

RESULTS

Over 1994-1995 lupin maturity stages, weather conditions were similar; high air temperature and low rainfall, while the July of 1996 rainfall was very high and amounted to 216.2 mm (Table 2).

Magnesium fertilisation did not show a significant effect on the narrow-leafed lupin straw and seed yields (Table 3). The cross-cultivar differences depended, most of all, on the weather conditions over the vegetation period. In 1994 significant differences were observed in straw yield, only. 'Emir' lupin plants gave a higher straw yield than the other cultivars. In 1995 the straw yields of 'Emir' and 'Mirela' was significantly higher than that of 'Sur'. That year all the three cultivars gave different seed yields; 'Mirela' gave the highest yield, 8% and 11% higher than the respective values obtained for Emir and 'Sur'. Similarly its total protein yield was significantly higher, as compared with 'Sur'. The high 1996 rainfall at the beginning of the maturity stage led to an excessive growth of the sweet-cultivar vegetative mass, hence a significantly higher straw yield at the expense of generative yield. Only 'Mirela' yielded similarly as in 1994 and 1995; a 3-year-mean seed yield amounted to 2.5 t·ha^{-1}. Despite some yielding variability over years, the average highest seed yield was observed for 'Mirela', and the lowest for 'Sur'.

Table 2. 1994-1996 Swadzim Agricultural Experiment Station weather conditions

Month/Decade	1994		1995		1996	
	Temperature °C	Rainfall mm	Temperature °C	Rainfall mm	Temperature °C	Rainfall mm
April	9.1	47.5	7.6	12.0	8.3	13.8
May	12.0	66.4	13.1	77.6	12.7	74.2
June	15.9	34.3	16.4	89.1	16.4	33.8
July/1	18.8	63.1	20.0	0.2	15.9	134.4
July/2	21.8	0.4	21.4	9.6	14.8	29.3
July/3	24.8	0.0	21.5	6.5	16.3	52.5
August	17.9	54.2	17.5	60.6	18.5	48.7
September	13.3	55.1	13.4	83.3	11.3	56.6

Nitrogen fertilisation showed a higher impact on straw yield than on the seed yield. Lupin fertilised with NH_4NO_3 and $Ca(NO_3)_2$ produced a higher straw yield, as compared with the control, and as compared with $(NH_4)_2SO_4$ and $CO(NH_2)_2$ fertilisation (Fig. 1). The highest seed yield was obtained fertilising lupin also with the NH_4NO_3 and Ca $(NO_3)_2$ (Fig. 2). However, the yields did not differ significantly from those obtained for the control. As compared with all the above-specified objects, fertilising with $(NH_4)_2$ SO_4 decreased the seed yield. The research did not reveal a significant correlation of nitrogen and magnesium forms, yet there was observed such a trend. The object without kieserite yielded highest with NH_4NO_3 having been applied, while the object

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with kieserite – $Ca(NO_3)_2$. Magnesium fertilisation did not decrease the seed yield whenever $Ca(NO_3)_2$ was applied (Fig. 2). Narrow-leafed lupin fertilisation with NH_4NO_3 and $Ca(NO_3)_2$ increased digestible protein yield significantly (Fig. 3).

Table 3. Narrow-leafed lupin straw, seed and digestible protein yields

Magnesium fertilisation	1994				1995				1996			
	Mirela	Emir	Sur	LSD	Mirela	Emir	Sur	LSD	Mirela	Emir	Sur	LSD
Straw yield, t·ha^{-1}												
- Mg	4.1	5.1	4.4		5.7	6.0	4.8		5.9	8.0	9.7	
+ Mg	4.2	5.9	4.5		5.4	5.0	4.3		5.6	8.0	9.5	
Mean	4.2	5.5	4.4	0.8	5.6	5.5	4.6	0.4	5.8	8.0	9.6	1.4
Seed yield, t·ha^{-1}												
- Mg	2.64	2.42	2.43		2.69	2.51	2.40		2.41	1.22	1.08	
+ Mg	2.58	2.59	2.49		2.54	2.31	2.29		2.55	0.98	1.13	
Mean	2.61	2.51	2.46	n.s.	2.61	2.41	2.34	0.20	2.48	1.10	1.10	0.21
Digestible protein yield, kg·ha^{-1}												
- Mg	691	645	669		716	686	664	.	765	367	354	
+ Mg	660	686	682		732	660	607		851	292	356	
Mean	675	665	676	n.s.	724	672	636	56	808	330	355	66

n.s. - non-significant difference

Fig.1. Effect of kieserite and nitrogen fertilisation on the narrow-leafed lupin straw yield

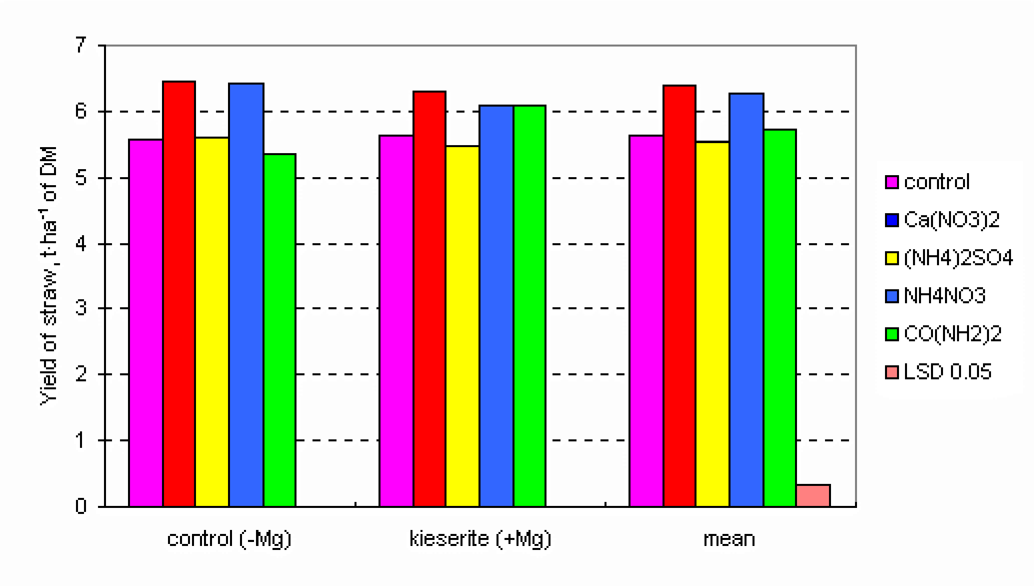


Fig. 2. Effect of fertilisation with kieserite and nitrogen on the narrow-leafed lupin seed yield

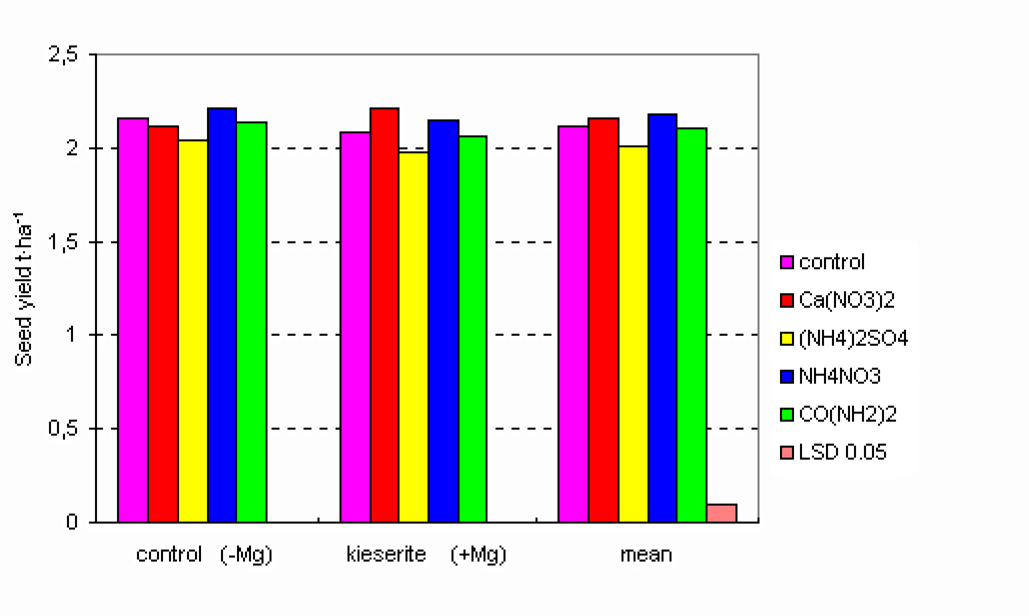
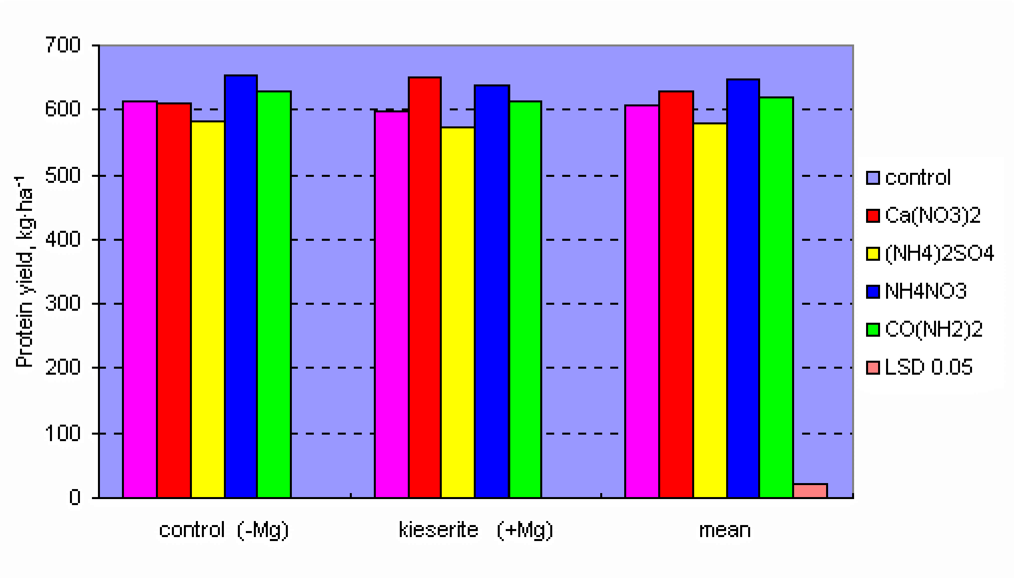


Fig.3. Effect of kieserite and nitrogen fertilisations on the yield of digestible protein



The value of HI calculated for Ca $(NO_3)_2$-fertilised object was significantly lower, as compared with the control and the carbamide-fertilised object. $(NH_4)_2$ SO_4 fertilisation decreased the number of seeds per pod, however it increased the number of pods per plant. The non-Mg fertilised object showed that the fertiliser significantly decreased the weight of 1000 seeds as compared with the values obtained for Ca $(NO_3)_2$, NH_4NO_3 and the control. In the object fertilised with Mg, $(NH_4)_2SO_4$ acted similarly to Ca $(NO_3)_2$ (Table 5).

The seeds of the cultivars differed, first of all, in their contents of phosphorus and potassium (Table 6). The seeds of the sweet cultivars, 'Emir' and 'Sur', showed their much higher contents than 'Mirela'. The seeds of these cultivars were also noted to have slightly higher contents of Mg and Ca. The sweet cultivar, 'Sur' showed the highest content of total nitrogen, while the bitter cultivar, 'Mirela', the highest percentage of protein nitrogen in the total nitrogen content. kieserite fertilisation slightly increased the contents of total nitrogen and its content of protein nitrogen in the seeds of the cultivars, 'Emir' and 'Mirela' as well as slightly decreased the concentration of the other elements. Nitrogen fertilisation showed a considerable impact on the content of the total nitrogen (Table 7). The highest content of the total nitrogen was observed as a result of lupin fertilisation with carbamide followed by NH_4NO_3 fertilisation. The difference between the values obtained for the objects

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and the control amounted to 0.14% and 0.10%, respectively. The content of nitrogen in the seeds of lupin fertilised with $(NH_4)_2SO_4$ was similar to the value obtained for the control. The application of NH_4NO_3 increased slightly the share of protein nitrogen in the total nitrogen content.

Table 4. Yield structure of narrow-leafed lupin cultivars

Year	Cultivar	Harvest index %	Weight of 1000 seeds g	Number of pods per plant	Number of seeds per pod	Number of seeds per plant
1994	Mirela	36.46	126.8	8.75	5.10	44.8
	Emir	31.62	131.2	9.98	2.56	25.4
	Sur	30.88	120.2	9.48	2.88	27.0
	$LSD_{0.01}$	1.31	1.27	n.s.	1.14	8.8
1995	Mirela	31.51	112.1	4.38	5.68	25.1
	Emir	31.28	107.4	6.95	3.54	24.9
	Sur	34.52	111.3	5.53	4.32	24.4
	$LSD_{0.01}$	n.s.	n.s.	0.98	0.78	n.s.
1996	Mirela	30.76	159.4	8.11	3.78	29.6
	Emir	12.65	146.4	4.75	3.61	17.2
	Sur	10.82	140.8	4.94	3.11	15.4
	$LSD_{0.01}$	2.12	5.98	1.28	0.41	4.6

n.s.- non-significant difference

Table 5. Effect of nitrogen fertilisers on narrow-leafed lupin yield structure

Nitrogen form	Harvest index %	Number of pods per plant	Number of seeds per pod	Number of seeds per plant	Weight of 1000 seeds, g	
					-Mg	+Mg
Control	28.8	6.8	3.82	26.1	127.9	129.3
$Ca(NO_3)_2$	26.5	7.1	3.88	27.2	129.1	129.9
$(NH_4)_2SO_4$	27.6	7.3	3.55	25.9	125.9	129.9
NH_4NO_3	27.7	7.0	4.04	27.7	128.8	128.9
$CO(NH_2)_2$	28.7	6.9	3.89	26.8	127.6	127.4
$LSD_{0.05}$	1.9	n.s.	0.29	n.s.	1.86	

n.s. - non-significant difference

Table 6. Content of macronutrients in seeds and percentage of protein nitrogen in the total nitrogen content, % of d.m.

Macronutrient	Cultivar								
	Mirela			Emir			Sur		
	- Mg	+ Mg	Mean	- Mg	+ Mg	Mean	- Mg	+ Mg	Mean
Total N	5.20	5.36	5.28	5.23	5.31	5.27	5.46	5.41	5.44
% of protein N	88.8	90.0	89.4	87.8	88.2	88.0	88.5	88.3	88.4
P	0.508	0.504	0.506	0.580	0.567	0.574	0.577	0.559	0.568
K	0.917	0.870	0.894	1.135	1.132	1.134	1.105	1.060	1.083
Ca	0.301	0.296	0.299	0.311	0.322	0.317	0.318	0.307	0.313
Mg	0.141	0.136	0.139	0.153	0.151	0.152	0.153	0.149	0.151

Table 7. Effect of nitrogen fertilisations on the content of seed macronutrients and percentage of protein nitrogen in the total nitrogen content, % of d.m.

Nitrogen forms	Macronutrient					
	Total N	% of protein N	P	K	Ca	Mg
Control	5.27	88.6	0.561	1.041	0.309	0.149
$Ca(NO_3)_2$	5.34	88.6	0.542	1.024	0.312	0.147
$(NH_4)_2SO_4$	5.27	88.2	0.544	1.040	0.314	0.146
NH_4NO_3	5.37	88.9	0.548	1.046	0.309	0.147
$CO(NH_2)_2$	5.41	88.6	0.551	1.032	0.300	0.147

DISCUSSION

Narrow-leafed lupin seed yield under average soil and climatic conditions amounts to 1.5-2.5 $t \cdot ha^{-1}$ [8]. As reported by the Research Centre for Cultivars (COBORU), the seed yield of 'Mirela', 'Emir' and 'Sur' over 1987 - 1990 amounted to 2.32; 2.30 and 2.06 $t \cdot ha^{-1}$, respectively [14], while narrow-leafed lupin straw yield from 3 to 6 $t \cdot ha^{-1}$ [3,18] and the present results obtained fall into the category of 'average values'. The exception was 1996 when the straw yield of sweet cultivars exceeded the average values at a very low seed yield. 1994 lupin maturing phase coincided with very high temperature and no rainfall; hence no cross-cultivar differences in yielding. Similar weather conditions were observed in 1995, while in 1996 heavy rainfall at the beginning of pod maturing caused an excessive growth of the vegetative mass in 'Emir' and 'Sur' at the expense of seed yield. As known from literature, a regular lupin development can be disturbed whenever the pre-maturity period is accompanied by a heavy rainfall which can trigger the vegetation and production of 3rd - and 4th -layer branching. Over the moisten years, narrow-leafed lupin can seed-yield 50% lower [12,13]. In 1996 'Mirela' completed plant flowering three days earlier as compared with the plants of 'Emir' and 'Sur' which could have been one of the main reasons for such considerable cross-cultivar differences.

The present attempt to evaluate the impact of kieserite fertilisation did not allow us to conclude that the fertiliser enhances the seed yield of narrow-leafed lupin. A tendency observed towards decreasing the seed yield in kieserite-fertilised objects could have been due to a negative impact on the soil reaction [11], which is indirectly confirmed by higher seed yields of lupin fertilised with $Ca(NO_3)_2$ in the kieserite-fertilised object.

Numerous research show that an increased intake of nitrogen, either as a result of an enhanced assimilation or an increase in the content of its available forms in soil enhances the production of lupin vegetative mass [5]. The present research confirmed earlier observations, yet it should be stressed that the impact of nitrogen depended on the fertiliser chemical form. The mineral nitrogen forms researched singled out the $N\text{-}NO_3$ form which showed the greatest impact on the straw yield, while the lowest - $N\text{-}NH_4$. A negative effect of nitrogen fertilisation with $N\text{-}NH_4$ is explained differently, e.g. by triggering shortages of potassium or calcium or causing a photosynthesis slow-down due to changes in chlorophyll activity [10]. The latest hypotheses show that the root intake of $N\text{-}NH_4$ ions disturbs energy conversion processes considerably. A high root demand for assimilates leads to a decrease in the over-the-ground plant mass [6]. According to Ruszkowska et al. [1986] the differences in the activity of nitrogen forms are mostly due to their varied impact on the soil pH. Researching the impact of different nitrogen forms on the bean growth showed in objects fertilised with $N\text{-}NO_3$ – an increase in the rhisosphere reaction by 0.4 units and with $N\text{-}NH_4$ – a decrease by 0.6 [19]. A decrease in the soil pH can limit the availability of molybdenum which is part of nitrogenase as well as lupin nodulation [2,5]. Differently that carbamide, a negative impact of $(NH_4)_2$ SO_4 on lupin plants could have been also due to the antagonistic effect of SO_4^{-2} on MoO_4^{-2} intake. The optimum mineral nitrogen content in soil at the beginning of nodule formation accelerates the formation of photosynthetic organs of an adequate size. The area of photosynthesis at the same time enhances the potential for the production of assimilates and the seed yield. According to Szukała [1994], on the soils of very good and good rye suitability complexes, the optimum pre-sowing dose of nitrogen in the form of ammonium nitrate applied for narrow-leafed and white lupins amounted to 32-34 $kg \cdot ha^{-1}$ of N. A further increase in the nitrogen dose (up to 60 $kg \cdot ha^{-1}$ of N) showed a positive effect on the straw yield only. Similarly the present research shows that a high nitrogen dose enhanced the yield of vegetative mass only. However the literary coverage includes reports on the increase in seed yield due to fertilisation, exceeding 30 $kg \cdot ha^{-1}$ of N; e.g. a narrow-leafed lupin seed yield increase by 0.2 $t \cdot ha^{-1}$ at 70 $kg \cdot ha^{-1}$ of N [5]. One shall bear in mind that the plants on the $(NH_4)_2SO_4$ – fertilised object seed-yielded lower as compared with the objects fertilised with nitrates and the control, which could have been due to a negative impact of the fertiliser on the vegetative mass and a lower mobility of assimilates into seeds as compared with the control.

CONCLUSIONS

1. Cross-cultivar narrow-leafed yielding differences depended on the weather conditions over the vegetation period. The high-alkaloid cultivar, ‘Mirela’, seed-yielded higher and more stable over the research years than the low-alkaloid cultivars, ‘Emir’ and ‘Sur’.
2. A high Mg dose in kieserite did not increase the narrow-leafed lupin seed and protein yields.
3. Fertilisation with Ca $(NO_3)_2$ and NH_4NO_3 at 75 $kg \cdot ha^{-1}$ of N enhanced the vegetative mass as well as the yield of digestible protein yet it did not show an impact on the narrow-leafed lupin seed yield.

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