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Effect of various nitrogen doses on chromium and nickel content, accumulation and translocation in yellow lupine

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Abstract. The aim of the study in the field experiment was to determine the effect of different nitrogen fertilization and growth phases on the nickel and chromium content, accumulation and translocation in yellow lupine. The test factors included nitrogen doses (0, 30, and 120 kg ha^{-1}) introduced into the soil prior to seed sowing, as well as growth stages (BBCH 65 and 90) of tested plant. Mineral nitrogen was introduced to the soil as ammonium sulphate $(NH_4)_2SO_4$. Plants harvested at 65 BBCH were divided into roots, steams, leaves and flowers, whereas those harvested at 90 BBCH were divided into roots, steams, leaves, pods and seeds. 30 kg N ha^{-1} application did not significantly impact on the content and uptake of Cr and Ni by lupine. The content of these heavy metals in lupine decreased after fertilization with 120 kg N ha^{-1}. This N dose did not significantly affected the amounts of Cr and Ni taken up by tested plants. Cr bioaccumulation coefficient did not significantly depend on N fertilization used, while the increase of N doses decreased the value of this coefficient for Ni. Under the conditions of growing lupine on soil with a natural chromium and nickel content, no tendency to hyperaccumulate these heavy metals was found.

Keywords: heavy metals, *Lupinus luteus* L., nitrogen fertilization, growth stage

INTRODUCTION

Heavy metals are naturally present in soil at quantities considered to be trace and rarely toxic. However, human activity can lead not only to an increase in heavy metal content in the environment, but also to a change in the rate of natural changes occurring in it, and, as a result, to a threat of the mobilization of these elements. In view of the hazards that may result from high concentrations of heavy metals in feed or food, their mobility should be monitored (Chang et al., 2014; Bhalerao et al., 2015; Doabi et al., 2018; Yang et al., 2018). Numerous factors affecting the bioavailability of heavy metals include nitrogen fertilizers, which can affect the uptake of certain elements by plants by stimulating the processes of organic matter mineralization, as well as changing the pH value of the soil in the root zone of plants (Violante et al., 2010; Czarnecki, During, 2015).

Nickel is an essential element for crops, for legumes in particular (Lopez, Magnitskiy, 2011; Bhalerao et al., 2015). It is part of enzymes that play an important role in the metabolism of nitrogen, and its deficiency interferes with the metabolism of carbon, affecting the uptake of nutrients. It is necessary, starting from seed germination, through vegetative growth phase, ultimately culminating with seed development (Lopez, Magnitskiy, 2011; Yusuf et al., 2011). However, due to the low demand for this element, phytotoxic effects are noted more often than deficiency. Sources of nickel for plants can include soil reserves, waste, but also pesticides and fertilizers (Chen et al., 2009; Bhalerao et al., 2015). High content of this metal in growth medium may exert adverse effects on plants (Leskova et al., 2017 and 2019). In addition, nickel administered in excessive amounts to animals and humans induces genotoxicity, carcinogenicity, immunotoxicity and toxicity in various other metabolically active tissues (Das et al., 2018).

In case of chromium, its significant usefulness for plant growth has not been demonstrated. However, abnormally high chromium concentrations in growth medium are detrimental to plant growth and development (Singh et al., 2013). In addition to the natural presence in soils, an increase in chromium levels can be attributed to the use of fertilizers and wastes as fertilizer (Gambuś, Wieczorek, 2012). Chromium enters the subsequent links in the food chain through consumption of plant material. Chromium is an essential nutrient, yet exposure to high levels via ingestion may have adverse effects on animal and human health. The estimated safe daily dose for chromium is 50 to

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200 micrograms (Tulasi, Rao, 2014). Jaison and Muthukumar (2017) emphasize the need for investigating plants for the presence of Cr even when collected from non-contaminated soils.

The literature lacks studies containing uptake, accumulation and translocation of chromium and nickel to various parts of yellow lupine harvested for green fodder (in the flowering stage) and seeds (in the full maturity stage).

The aim of the study was to determine the effect of various doses of nitrogen fertilization and of the development stage on the content, bioaccumulation and translocation of chromium and nickel in yellow lupine (*Lupinus luteus* L.).

MATERIAL AND METHODS

The field experiment was conducted in Siedlce (N52°10'12.04'' E22°17'15.40'') in 2008 and 2011. The experiment was conducted on slightly acidic soil with granulometric composition of loamy sand. The content of selected elements in this soil before the experiment was set up is shown in Table 1. According to IUNG-PIB guidelines (Siebielec et al., 2012), the soil on which the study was carried out in both years have natural chromium and nickel content. Plots 1 m^2 in size were delineated in a field of yellow lupine of the cultivar 'Mister'. Two-factorial experiment repeated in two years was set up in the randomized block design, in three replications. Nitrogen fertilization was the first factor: a) control treatment – without nitrogen fertilization; b) with nitrogen applied at a rate equivalent to 30 kg N ha^{-1}; c) with nitrogen applied at a rate equivalent to 120 kg N ha^{-1}. The time of harvest was the second factor: a) full flowering stage, 65 BBCH; b) full maturity stage, 90 BBCH.

Mineral nitrogen was introduced to the soil as ammonium sulphate $(NH_4)_2SO_4$ before yellow lupine was sown. The amounts of phosphorus and potassium were established on the basis of the amounts of the available element forms in soil. Potassium was introduced to the soil in all plots at 100 kg K ha^{-1} as potassium salt. Because of a very high amount of phosphorus as available forms (Table 1), no phosphorus fertilization was applied. Before sowing, seeds of yellow lupine were inoculated with a vaccine containing *Bradyrhizobium* sp. Sowing was performed in early April at 100 germinating seeds per 1 m^2. Soil was sprayed with the herbicide Stomp 330 EC at a rate of 4 dm^3 ha^{-1} on the day following the sowing of lupine. Lupine plants was sprayed with Amistar 250 SC at 1.0 dm^3 ha^{-1} against anthracnose at the beginning of the budding phase; this procedure was repeated after 10 days. The plant was harvested manually by digging it up from the soil with a spade to depth 0.25 m. Lupine plants harvested during the flowering stage were divided into roots, steams, leaves and flowers, whereas those harvested during the full maturity stage were divided into roots, steams, leaves, stripped pods and seeds.

The total rainfall in individual months and mean monthly air temperature during the growing season for yellow lupine is shown in Table 2. It shows that both growing seasons were rather favourable for the growth, development and yielding of yellow lupine. The total rainfall during the 2008 and 2011 growing seasons satisfied the plants needs in full. However, it was not properly distributed over the months of growing. The amount of rainfall in June 2008 and in May and June 2011 was lower than required for yellow lupine, as reported by Dzieżyc et al. (1987). In addition to the greater water deficit during the period of intensive growth of lupine (May–June) in 2011, higher temperatures were recorded during the period than in 2008, which probably exacerbated the water deficit.

The content of chromium and nickel in soil and in plant material was determined by inductively coupled plasma atomic (optical) emission spectrometry (ICP-AES/OES)

Table 1. Selected properties of soil in humus layer prior used to the field experiments in 2008 and 2011 years.

Soil properties	Unit	Years of foundation experiment	
		2008	2011
pH_{KCl}	–	5.90	5.80
C_{tot}	g kg^{-1}	25.7	23.8
N_{tot}		2.04	1.92
P_{tot}		1.10	1.15
K_{tot}		0.85	0.81
Mg_{tot}		0.96	0.93
S_{tot}		0.448	0.56
P_{av}	mg kg^{-1}	369.0	314.0
K_{av}		67.0	59.0
Cr		7.52	11.20
Ni		5.34	4.95

P_{av}, K_{av} – available forms for plants; X_{tot} – total content

Table 2. Rainfall and air temperatures during the test crop, date from IMGW-PIB Warszawa.

Weather parameter	Month	Study period		Long-term mean (1981–2007)
		2008	2011	
Sum monthly rainfall [mm]	IV	43.5	38.1	32.9
	V	72.7	55.6	54.2
	VI	56.7	44.3	68.8
	VII	108.8	204.2	64.9
	VIII	85.1	55.4	61.8
Average monthly temperature [°C]	IV	8.7	9.8	7.9
	V	12.5	13.5	13.7
	VI	17.0	18.1	16.1
	VII	18.1	18.1	18.3
	VIII	18.3	18.1	17.6

on a spectrometer Optima 8300 (Perkin Elmer, Tulsa, USA) in the bulk solution obtained by mineralisation of samples at 450 °C. The ash obtained by mineralisation was dissolved in HCl 6 mol dm^{-3} in order to degrade carbonates and evaporated to dryness on a sand bath. A 10% solution of HCl was used to transfer chlorides to volumetric flasks. The analysis were performed in triplicate. The spectrometer was calibrated using the STD GEOCHEM CUSTOM 4 standard (PE #: N9307113). The determinations were made at wavelengths [nm]: Ni 231.604 and Cr 267.716. The detection limits were 0.1 mg kg^{-1} and 0.06 mg kg^{-1} respectively.

The results were subjected to three-factor analysis of variance (years, N doses, growth stages). Conclusions regarding the significance of an effect of the factors under study on individual features were based on the Fisher-Snedecor F-test, and the $LSD_{0.05}$ for comparison of the means were calculated by the Tukey test. To these calculations the Statistica 13 PL software package (StatSoft, Tulsa, USA) was used. In addition, the uptake and the bioaccumulation and translocation coefficient of Cr and Ni were calculated.

The uptake was calculated by multiplication the element content in the plant (Tables 3 and 4 respectively) and its yield (Wysokiński, 2013).

Bioaccumulation factor (BAF) presents the ratio of a metal content in a plant to its amount in the soil (Rezvani, Zaefarian, 2011).

$$BAF = \frac{Cp}{Cs}$$

BAF_x – bioaccumulation factor
Cp – content of Cr and Ni in the plant
Cs – content of Cr and Ni in the soil

The translocation factor (TF) was calculated as a ratio of the elements contents in the above-ground parts to the content in the roots (Rezvani, Zaefarian, 2011).

$$TF = \frac{Cpbs}{Cpr}$$

TF – translocation factor
Cpbs – content of Cr and Ni in the above-ground parts of the plant
Cpr – content of Cr and Ni in the roots

RESULTS AND DISCUSSION

No significant effect of nitrogen fertilization on the content of chromium in leaves and flowers of yellow lupine (Table 3), and of nickel in flowers and seeds (Table 4) was demonstrated in the performed experiment. The roots of lupine fertilized with both nitrogen doses had less content of both heavy metals than in the control object. The content of chromium in pods and seeds, and nickel in leaves was higher after the application of 30 kg N ha^{-1} than without nitrogen fertilization, while the application of 120 kg N ha^{-1} did not significantly affect this parameter. The content of chromium in stems, nickel in pods, as well as both heavy metals, on average, in whole lupine mass was similar without nitrogen fertilization and after application of 30 kg N ha^{-1}, while significantly lower when 120 kg N ha^{-1} was introduced into the soil. The content of chromium and nickel in roots and leaves, as well as their average content in whole lupine plant was higher at full maturity than at flowering. The concentration of chromium in the stems was not dependent on the development phase of the test plant, while a higher nickel content was obtained in this part of the lupine harvested in phase 90 than 65 BBCH. Higher chromium content in all separated parts and on average in whole lupine plant was obtained in the first than in the second year of the study. In the case of nickel, this relationship was obtained only in roots and seeds. The concentration of this heavy metal in leaves and flowers was not significantly dependent on year of study. The nickel content in stems, stripped pods and the mean content in whole lupine plant was lower in the first than the second year of the study.

The content of heavy metals in different plant organs decreases in the order of: root > leaves > stem > flowers > seeds (Ociepa-Kubicka, Ociepa, 2012), generally most often: roots > aboveground parts (Bielecka, Królak, 2019). In our own research, the content of chromium and nickel in the organs of lupine harvested at full maturity decreased in the order: root > leaves > stripped pods > stems > seeds.

Nickel is considered to be high mobile in the environment and plants, and its minimally excessive amounts are very phytotoxic (Naik et al., 2010; Bhalerao et al., 2015). Literature data indicate that 10, 50 and 1000 mg kg^{-1} dry matter of plants are critical levels of Ni toxicity recognized in sensitive, moderately tolerant and hyperaccumulative species, respectively (Chen et al., 2009; Hussain et al., 2013). In our own research, nickel concentrations exceeding the level designated as critical for sensitive species was found only in the roots and leaves separated at full maturity phase. Mean content of this heavy metals in whole biomass of lupine and in whole aboveground parts did not exceed the first level of toxicity – for sensitive plants. Toxicity of chromium for very sensitive plants occurs at its content above 2 mg kg^{-1} dry matter, and for medium resistant plants below 20 mg kg^{-1} d.m. (Kabata-Pendias, Pendias, 1999). As in the case of nickel, the content of chromium in the roots also slightly exceeded the toxic level for very sensitive plants, to which legumes do not belong. The mean content of this heavy metal in whole lupine plant was much lower than the specified level.

The uptake of chromium by all parts of yellow lupine and accumulation in whole mass was higher in the first than in the second year of the study (Table 5). Yellow lupine cultivated in first year accumulated in roots, stems and stripped pods less nickel than in second year, but for

Table 3. Chromium content in yellow lupine [mg Cr kg^{-1} DM], (n = 36).

Investigated factor		Part of plant						Meanly in plant (weighted average)
		roots	stems	leaves	flowers	stripped pods	seeds	
N dose [kg ha^{-1}]	0	2.731 *b*	0.683 *b*	1.648 *a*	0.584 *a*	0.702 *a*	0.537 a	1.264 *b*
	30	2.228 *a*	0.642 *ab*	1.685 *a*	0.649 *a*	0.922 *b*	0.681 *b*	1.199 *ab*
	120	2.177 *a*	0.594 *a*	1.643 *a*	0.608 *a*	0.719 *a*	0.556 *a*	1.089 *a*
Growth stage (BBCH)	65	2.147 *a*	0.628 *a*	1.164 *a*	0.613	-	-	1.143 *a*
	90	2.610 *b*	0.651 *a*	2.153 *b*	-	0.781	0.591	1.225 *b*
Year of study	1st	2.612 *b*	0.828 *b*	2.015 *b*	0.787 *b*	0.844 *b*	0.760 *b*	1.368 *b*
	2nd	2.145 *a*	0.451 *a*	1.302 *a*	0.439 *a*	0.717 *a*	0.422 *a*	1.000 *a*

a, b – means with different letters in the columns are significantly different

Table 4. Nickel content in yellow lupine [mg Ni kg^{-1} DM], (n = 36).

Investigated factor		Part of plant						Meanly in plant (weighted average)
		roots	stems	leaves	flowers	stripped pods	seeds	
N dose [kg ha^{-1}]	0	29.43 *b*	4.24 *c*	10.27 *a*	3.47 *a*	4.21 *b*	1.46 *a*	8.81 *b*
	30	24.67 *a*	3.36 *b*	12.21 *b*	3.84 *a*	5.29 *b*	1.49 *a*	8.29 *b*
	120	24.55 *a*	1.96 *a*	11.33 *a*	4.02 *a*	3.90 *a*	1.41 *a*	7.10 *a*
Growth stage (BBCH)	65	17.24 *a*	2.44 *a*	7.63 *a*	3.77	-	-	7.50 *a*
	90	35.20 *b*	3.94 *b*	14.91 *b*	-	4.47	1.45	8.63 *b*
Year of study	1st	35.58 *b*	3.34 *a*	11.79 *a*	4.03 *a*	2.64 *a*	1.74 *b*	7.34 *a*
	2nd	28.19 a	3.86 *b*	10.75 *a*	3.52 *a*	6.29 *b*	1.16 *a*	8.79 *b*

a, b – means with different letters in the columns are significantly different

Table 5. Chromium uptake by yellow lupine [g Cr ha^{-1}], (n = 36).

Investigated factor		Part of plant						Total by plant
		roots	stems	leaves	flowers	stripped pods	seeds	
N dose [kg ha^{-1}]	0	1.22 *b*	0.74 *a*	2.66 *a*	0.06 *a*	0.73 *a*	0.65 *a*	5.33 *a*
	30	1.03 *a*	0.76 *a*	2.79 *a*	0.09 *b*	1.09 *b*	0.98 *b*	5.65 *a*
	120	1.00 *a*	0.79 *a*	3.00 *a*	0.07 *a*	0.93 *b*	1.03 *b*	5.81 *a*
Growth stage (BBCH)	65	1.19 *b*	0.66 *a*	1.59 *a*	0.07	-	-	3.51 *a*
	90	0.97 *a*	0.87 *b*	4.04 *b*	-	0.91	0.89	7.68 *b*
Year of study	1st	1.15 *b*	1.03 *b*	3.76 *b*	0.09 *b*	1.12 *b*	1.19 *b*	7.14 *b*
	2nd	1.01 *a*	0.50 *a*	1.87 *a*	0.06 *a*	0.71 *a*	0.58 *a*	4.05 *a*

a, b – means with different letters in the columns are significantly different

Table 6. Nickel uptake by yellow lupine [g Ni ha^{-1}], (n = 36).

Investigated factor		Part of plant						Total by plant
		roots	stems	leaves	flowers	stripped pods	seeds	
N dose [kg ha^{-1}]	0	12.73 *b*	4.82 *c*	16.48 *a*	0.40 *a*	4.21 *a*	1.78 *a*	37.21 *a*
	30	10.81 *a*	3.93 *b*	19.88 *b*	0.50 *b*	5.83 *b*	2.13 *b*	38.85 *a*
	120	10.49 *a*	2.58 *a*	20.27 *b*	0.49 *b*	4.42 *a*	2.57 *c*	37.08 *a*
Growth stage (BBCH)	65	9.47 *a*	2.43 *a*	10.26 *a*	0.46	-	-	22.61 *a*
	90	13.22 *b*	5.12 *b*	27.50 *b*	-	4.82	2.16	52.81 *b*
Year of study	1st	10.14 *a*	3.17 *a*	22.23 *b*	0.47 *a*	3.40 *a*	2.71 *b*	38.84 *a*
	2nd	12.54 *b*	4.38 *b*	15.52 *a*	0.45 *a*	6.24 *b*	1.60 *a*	36.59 *a*

a, b, c – means with different letters in the columns are significantly different

leaves and seeds this observation was opposite (Table 6). Total uptake of this heavy metal by whole tested plant was similar in both years of study. The amount of both heavy metals accumulated in whole yellow lupine plant were not significantly dependent on nitrogen fertilization. However, significant differences were obtained in the amount of these metals accumulated in individual organs of lupine fertilized with different doses of nitrogen. Lupine not fertilized with nitrogen accumulated the most chromium and nickel in the roots. Plants harvested from this object accumulated less of both tested heavy metals in seeds, as well as less chromium in stripped pods than after applying both doses of nitrogen. The amount of chromium accumulated in stems and leaves was not significantly differentiated under the influence of different nitrogen fertilization. The amount of nickel accumulated in the stems decreased with increasing nitrogen doses, while in leaves and flowers it was higher after applying both nitrogen doses than in the control object. The amount of chromium accumulated in flowers and nickel in stripped pods was higher after application 30 kg N ha^{-1} than on the control object and after fertilization with 120 kg N ha^{-1}. The amount of both tested heavy metals accumulated in the stems, leaves and the total amount in whole yellow lupine mass, as well as nickel in the roots, was higher in the full maturity phase than in the flowering phase. Only the amount of chromium accumulated in the roots was greater in phase 65 than 90 BBCH.

The amount of heavy metals taken up by the root system of plants most often depends on their content and availability in growth medium (Chen et al., 2009; Ociepa-Kubicka, Ociepa, 2012; Kasowska et al., 2018). Plants take up the metals found in the soil in the form of free ions with particular ease. Fertilization with fertilizers which acidify the soil, such as ammonium sulphate, increased the content of phyto-available forms of heavy metals. An increase in the accumulation of these elements in plants was observed as a result of this process (Sady, Smoleń, 2004). In our study, a nitrogen dose of 30 kg N ha^{-1}, applied in the form of ammonium sulphate, did not significantly change the content of both heavy metals in yellow lupine. However, after applying 120 kg N ha^{-1}, there was a decrease of both metal content in the test plant. Sulfur was also introduced into the soil as ammonium sulphate, which promotes legume nodulation, and its compounds (as glutathione – GSH and phytochelatins – PCs) can form durable high-strength complexes with heavy metals, thus playing a protective role against heavy metals present in the plant nutrient environment (Matraszek et al., 2017). Both applied doses of nitrogen did not significantly differentiate the amount of chromium and nickel, which were took up by the whole yellow lupine plant. The relationships obtained above indicate the effect of diluting the concentration of these heavy metals in the mass of lupine fertilized with the largest (120 kg N ha^{-1}) nitrogen dose. In addition, they do not indicate increased bioavailability of chromium and nickel as a result of using physiologically acid fertilizer.

Table 7. The values of bioaccumulation and translocation factor, (n = 36).

Investigated factor		Bioaccumulation factor		Translocation factor	
		Cr	Ni	Cr	Ni
N dose [kg·ha^{-1}]	0	0.12 *a*	1.24 *b*	0.40 *a*	0.23 *a*
	30	0.13 *a*	1.18 *b*	0.49 *b*	0.30 *b*
	120	0.11 *a*	1.03 *a*	0.47 *b*	0.28 *b*
Growth stage (BBCH)	65	0.13 *a*	1.03 *a*	0.47 *a*	0.33 *b*
	90	0.12 *b*	1.28 *b*	0.44 *a*	0.21 *a*
Year of study	1st	0.15 *b*	1.37 *b*	0.49 *b*	0.28 *a*
	2nd	0.09 *a*	0.93 *a*	0.42 *a*	0.26 *a*

a, b – means with different letters in the columns are significantly different

The BAF and TF coefficients were calculated to assess the mobility of chromium and nickel between the soil and the plant and in the test plant itself. The BAF value indicates plant's potential to absorb metal from soil. In authors' own research conducted on soils not contaminated with chromium and nickel, the value of the biological accumulation coefficient of chromium by yellow lupine grown in the 1st year of experiment was 0.15, with 0.09 in the 2nd year (mean 0.12, Table 7). The values of BAF for nickel were much higher than for chromium. In the first year of research the BAF value of Ni was 1.37, with 0.93 in the second year (mean 1.15). The values of chromium BAF were similar in the flowering and full maturity stages of lupine, while for the nickel they were smaller in the flowering phase than in the full maturity phase. The values of this coefficient for chromium were similar in the control object and after applying both doses of nitrogen. Each dose of nitrogen reduced the value of the nickel BAF. Symanowicz et al. (2015), in studies conducted on *Galega orientalis* did not demonstrate the effect of different nitrogen fertilization on the availability of heavy metals.

Nickel is a highly mobile trace metal and tends to accumulate in newly formed plant parts as well as seeds (Yusuf et al., 2011). In opposite to this study, accumulation of this metal was more pronounced in roots rather than aboveground parts of plants (Antonkiewicz et al., 2016; Stoikou et al., 2017; Jan et al., 2019). In general, chromium is largely retained in the roots of plants (Smith et al., 2008; Syam et al., 2016). Authors' own studies have shown that during full flowering and full maturity, yellow lupine accumulated 66.1% and 87.4% of chromium, as well as 58.1% and 75.0% of nickel in the aboveground parts, respectively. 33.9% and 12.6% of chromium, and 41.9% and 25.0% of nickel were found in the roots of the tested plant in phases 65 and 90 BBCH, respectively. 75.8% of chromium and 70.9% of nickel absorbed by the entire plant were accumulated in aboveground organs constituting crop residues of lupine harvested at full maturity (stems + leaves + pods). 11.6% of the total amount of chromium uptake and 4.1% of nickel uptake were found in the yield of seeds obtained in

the full maturity phase. The conducted study indicates that larger amounts of these heavy metals may reach further links in the food chain if the green mass of yellow lupine harvested in the flowering phase is used for animal feed, compared to feed made with seeds harvested at full maturity. When growing this plant for seeds, only a small part of chromium and nickel is found in these organs (crops), while the vast majority, 88.4% Cr and 95.9% Ni, respectively, goes back to the soil in the form of crop residues.

The susceptibility to movement of heavy metals from the roots to the aerial parts of plants is indicated by the translocation factor (Rezvani, Zaefarian, 2011; Ociepa et al., 2014). Among the tested metals, chromium was easier to move than nickel, as evidenced by the higher values of translocation coefficients obtained in both years of the study. In case of both heavy metals tested, no translocation factor above 1 was obtained that would indicate a hyperaccumulative potential for lupine in relation to these metals.

Heavy metals block water transport from roots to the aboveground parts of plants (Yusuf et al., 2011; Rucińska-Sobkowiak, 2016). This may result in dehydration of shoots and reduction of ion transport. In our research, the content, accumulation and translocation of chromium was higher in the year with more favorable precipitation and temperature conditions (1st) than in the year with less rainfall and higher air temperature (2nd). It was observed despite the lower content of this heavy metal in the soil in the first year (7.52 mg Cr kg^{-1}) in comparison to the second year (11.2 mg Cr kg^{-1}). In the case of nickel, the bioaccumulation coefficient was also higher in the first than the second year of the study (under condition of similar content of this heavy metal in soil of 5.34 and 4.95 mg Ni kg^{-1} respectively), while the translocation coefficient was similar in both years.

CONCLUSIONS

1. The content of chromium and nickel in whole yellow lupine plant decreased after applying 120 kg N ha^{-1}, while the dose of 30 kg N ha^{-1} did not significantly affect this parameter. Both doses of nitrogen fertilization did not affect the uptake of tested heavy metals by lupine significantly.
2. The averages content and total uptake of nickel and chromium by yellow lupine were higher in the full maturity phase than in the full flowering phase.
3. The value of chromium BAF did not significantly depend on the nitrogen fertilization used, while after applied with 120 kg N ha^{-1} a decrease in the value of this coefficient for nickel was noted.
4. Under the conditions of growing lupine on soil with a natural chromium and nickel content, no tendency to hyperaccumulate these heavy metals was found.

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