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# The Absorption Characteristics of Nickel Chloride applied to Alfalfa and Smooth Brome grass

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## Introduction

Nickel is included in the crust about 0.8 ppm, and almost all of that exists in the igneous rock. On the other hand, the content of that in soil is about 0.5 ppm. Also, the concentration of nickel in plants was reported to be about 0.05-5.00 ppm[6]. Generally, plants absorp nickel through the soil.

Nickel is not an essential element for higher plant nutrition, but there is sufficient evidence to suggest that nickel and tin are probably essential for dairy cattle[3]. With usual practical feeding conditions there is no reason to suspect that chromium, vanadium, tin, or nickel levels will be high enough in feeds to adversely affect the performance of dairy cattle, because nickel constitutes urease or CO-dihydrogenase, and also, occurs in the cofactor $F_{430}$ of methanogenic bacteria in nickeloplasmin, and in the interaction with Fe absorption. $(NH_2)_2CO + H_2O \xrightarrow[\text{urease}]{} CO + 2NH_3$

Nickel deficiency symptom do not appear in higher plants, but cause poor growth, thickened legs, dermatitis, and swollen mitochondria in animals. For example, more than 62 ppm of nickel was needed to adversely affect the growth in dairy calves[2].

Higher levels of nickel in cows progressively decreased feed intake and weight gains. Performance of lactating cows was not depressed by 100 ppm in the total dyr matter ration. These amounts of nickel are far higher than normally found in feeds.

We reported that the absorption of some selenium compound and cobalt chloride by alfalfa and smooth bromegrass existed by means of the soil[4,5]. We reported also that those elements were absorbed to relate homologous series ions, and the relationship was a negative correlation between those elements[1].

In the present paper, we report the results of the relations between nickel concentrations in alfalfa (*Medicago sativa* L.) and smooth bromegrass (*Bromus inermis* Leyss) and the nickel contents in the soil, especially, for the fertilization to of the soil or for the stages of growth and parts of the plants.

## Materials and Methods

The soil used in this study was Nopporo diluvial soil. The chemical characteristics of the soil prior to the experimental initation were shown in Table 1.

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**Table 1.** Chemical characteristics of soil used

| Soil | pH | | EC | T-N | Available $P_2O_5$ | Exchangeable bases | | | | Trace elements | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | $K_2O$ | $Na_2O$ | CaO | MgO | Zn | Mn | Cu | B | Ni |
| | $H_2O$ | KCl | mmho | % | mg/100 g soil | mg/100 g soil | | | | ppm Dry matter basis | | | | |
| Diluvial soil | 6.0 | 4.9 | 0.60 | 0.39 | 5.4 | 8.5 | 0.5 | 159.0 | 14.0 | 1.8 | 30.0 | 0.3 | 0.26 | 2.08 |

**Table 2.** Amount of fertilizers and nickel chloride

a. Fertilizers

| Type of fertilizer | g/m$^2$ | g/m$^2$ |
|---|---|---|
| Super phosphate | 100 | 20 as $P_2O_5$ |
| Potassium sulfate | 40 | 20 $K_2O$ |
| Calcium carbonate | 89 | 50 CaO |
| Magnesium carbonate | 21 | 10 MgO |

b. Amount of nickel chloride and urea

| Type of addition | Chemical formula | Amounts of Ni or N g/m$^2$ |
|---|---|---|
| Nickel addition | $NiCl_2$ | 0, 3, 9, and 27 as Ni |
| Urea addition | $(NH_2)_2CO$ | 0, 10, 30, and 90 as Urea |

The soil had pH ($H_2O$) 6.0 and (KCl) 4.9. The percentage of nitrogen was 0.39 per cent, and available phosphorous was a lower content of 5.4 mg/100 g dry soil. Also, the copper content of microelements was a low value of 0.3 ppm on a dry soil basis. Soluvul (0.1 N HCl) nickel content of the soil was $2.08 \pm 0.82$ ppm.

This study was carried out in the field. The amount of basic fertilizers and nickel chloride added to the plots were shown in Table 2. Fertilization was done using chemical fertilizer. The size of each plot was 1 m$^2$, and the treatments were in three repetitions.

Alfalfa (*Medicago sativa* L.) (variety : Bartas) and smooth bromegrass (*Bromus inermis* Leyss) (variety : Salatoga) were grown on these soils plots with same fertilization and four levels of nickel and urea.

Both plants were harvested at the first-flower stage of the alfalfa. The herbage and soils were analyzed for nickel and other nutrients. The determination of nickel in the plants and soils was carried out using the Hitachi 207 atomic absorption spectro-photometer, as was the analysis of nitrate in the plants, was carried out using the Dionex ion chromatography.

## Results and Discussion

Dry matter yield of alfalfa and smooth bromegrass ;

The dry matter yield of the plants are shown in Tables 3 a and 3 b. The dry matter yield of alfalfa and smooth bromegrass in 30 g plot of urea is related to the levels of nickel added to soil. That is, the dry matter yield of the 1st cutting of both plants decreased by the increase of nickel added from 521 g with 3 g to 111 g with 27 g/m² of nickel chloride for alfalfa, and, also, from 262 g to 102 g for smooth bromegrass.

Concentrations of nickel in the alfalfa and smooth bromegrass;

Nickel concentrations in the forage of alfalfa and smooth bromegrass are shown in Tables 4 a and 4 b. The concentrations of nickel in the plants increased with

**Table 3-a.** Dry matter yield of alfalfa

| | | Nickel addition g/m² | | | |
|---|---|---|---|---|---|
| | | 0 | 3 | 9 | 27 |
| Urea addition g/m² | 0 | 242.6 | 238.8 | 212.8 | 155.7 |
| | 10 | 255.6 | 313.7 | 316.4 | 38.6 |
| | 30 | 325.2 | 521.8 | 136.2 | 111.8 |
| | 90 | 139.3 | 303.8 | 288.0 | 63.8 |

**Table 3-b.** Dry matter yield of smooth bromegrass

| | | Nickel addition g/m² | | | |
|---|---|---|---|---|---|
| | | 0 | 3 | 9 | 27 |
| Urea addition g/m² | 0 | 85.1 | 143.7 | 157.8 | 52.7 |
| | 10 | 88.5 | 251.5 | 278.6 | 75.9 |
| | 30 | 179.4 | 262.0 | 300.0 | 101.5 |
| | 90 | 312.5 | 276.6 | 287.6 | 93.1 |

**Table 4-a.** Concentration of nickel in the alfalfa

| Treatment | Ni/m² | | ppm Dry matter basis |
|---|---|---|---|
| Plots without Ni | 0 g/m² | Leaves | 0.66±0.21 |
| | | Stems | 0.19±0.03 |
| Plots with Ni | 3 g/m² | Leaves | 0.80±0.07 |
| | | Stems | 0.23±0.03 |
| | 9 g/m² | Leaves | 1.35±0.17 |
| | | Stems | 0.58±0.06 |
| | 27 g/m² | Leaves | 2.98±1.20 |
| | | Stems | 1.19±0.52 |

**Table 4-b.** Concentration of nickel in the smooth bromegrass

| Treatment | Ni/m² | ppm Dry matter basis |
|---|---|---|
| Plots without Ni | 0 g/m² | 0.43±0.17 |
| Plots with Ni | 3 g/m² | 0.69±0.42 |
| | 9 g/m² | 0.96±0.25 |
| | 27 g/m² | 2.02±0.55 |

the increment of nickel chloride applied to the soil. The nickel concentrations in the leaves alfalfa were from 0.80±0.07 ppm to 2.98±1.20 ppm, and the concentration in the stems were from 0.23±0.03 to 2.98±1.20 ppm. Also, the nickel concentration of the forage of the smooth bromegrass were from 0.69±0.42 to 2.02±0.55 ppm. In plots without nickel, the concentration were 0.66±0.21 ppm in the leaves, and 0.19±0.03 ppm in the stems of the alfalfa. On the other hand, the concentration in the smooth bromegrass was 0.43±0.17 ppm.

Interspecific difference of nickel absorption ;

The interspecific difference of nickel absorption in both plants is shown in Table 5. Also, the concentrations of nickel in the parts of alfalfa were shown in Fig. 1. The distributions of nickel concentrations of alfalfa with nickel were 0.43±0.12 ppm, and of smooth bromegrass were the same, 0.43±0.17 ppm. The concentrations of alfalfa with nickel were 1.19±0.81 ppm, and that of smooth bromegrass with nickel were 1.22±0.70 ppm.

The nickel concentrations of the leaves was higher than that of the stems.

The relationships between nickel and nitrate concentration in plant added urea ;

The concentrations of nitrate in alfalfa and smooth bromegrass were shown

**Table 5.** Interspecific difference of nickel absorption by plant

| | Alfalfa (ppm) | Smooth bromegrass (ppm) |
|---|---|---|
| Average without Ni | 0.43±0.12 | 0.43±0.17 |
| Average with Ni | 1.19±0.81 | 1.22±0.70 |

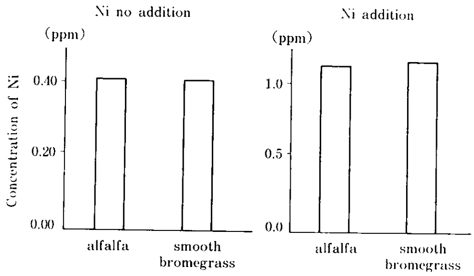


**Fig. 1.** Concentrations of nickel in alfalfa and smooth bromegrass.

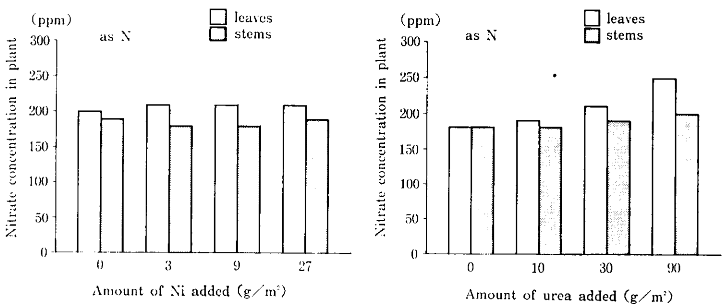


**Fig. 2.** Nitrate concentration in alfalfa.

Fig. 2, and 3. That is, the nitrate concentration was not increased with the rising of the urea or nickel levels in the stems of the alfalfa, but it increased for the leaves. The nitrate concentration was increased with the rising of the urea level and was decreased with the rising of the nickel level in the smooth bromegrass.

The relationships between nickel and nitrate concentrations in smooth bromegrass were related to the increase of urea or nickel added to the soils. Namely,

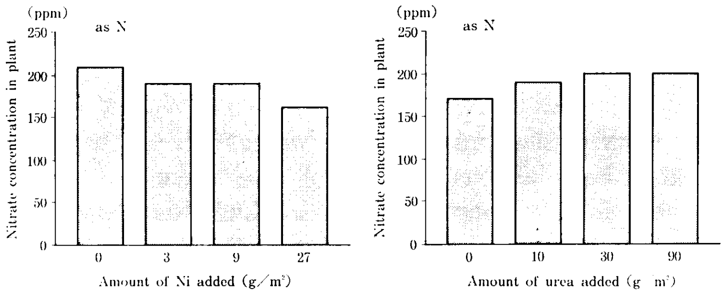


**Fig. 3.** Nitrate concentration in smooth bromegrass.

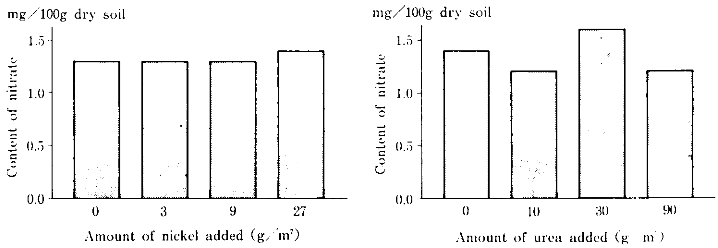


**Fig. 4.** Nitrate content in the soil after the harvest of alfalfa.

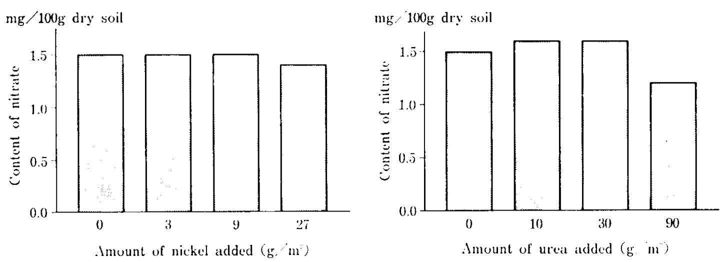


**Fig. 5.** Nitrate contents in the soil after the harvest of smooth bromegrass.

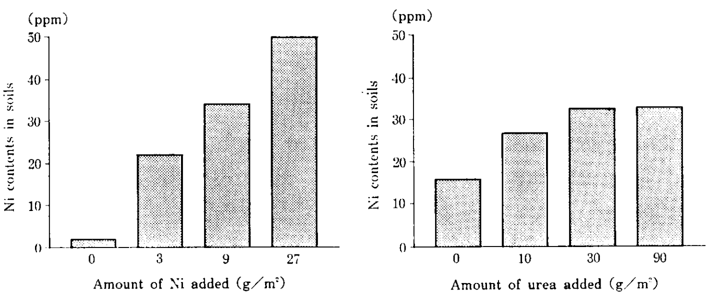


**Fig. 6.** Nickel contents in the soils after the harvest of smooth bromegrass.

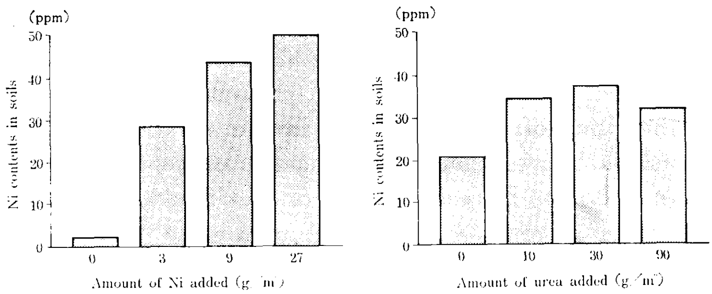


**Fig. 7.** Nickel contents in the soils after the harvest of alfalfa.

when there was an increase of nickel, these was a decrease in the nitrate in the plants, on the other hand, for on increase of urea there was an increase in the nitrate concentration in the plants. But for alfalfa, those relationships were not found.

The increase of nickel added to the soils decreased the nitrate concentration in the 1st cutting of the smooth bromegrass, that is, the coefficient of correlation between nickel and nitrate concentration was significant, ($r = -0.712$). But for alfalfa, the significant relationship between them was not found.

The contents of nickel and nitrate in the soils after the harvest of the alfalfa and smooth bromegrass;

The contents of nickel and nitrate in the soils after the harvest of the alfalfa and smooth bromegrass were shown in Fig. 4–7. The content of nickel in the soils after cutting the alfalfa and smooth bromegrass was related to the increment of nickel levels added to the soils, but the increase of the nitrate content was not by related to the nickel addition of nickel.

The content of nitrate in the soils after cutting the alfalfa and smooth bromegrass was related to the increment of urea, but the content of nickel in the soils increased with the urea addition.

## Summary

Nickel is not an essential element for higher plant nutrition, but there is sufficient evidence to suggest that nickel is probably essential for dairy cattle, because nickel constitutes urease or CO-dihydrogenase, and also, occurs in the cofactor $F_{430}$ of methanogenic bacteria in nickeloplasmin and in the interaction with Fe absorption.

$$(NH_2)_2CO + H_2O \underset{\text{urease}}{\longrightarrow} CO_2 + 2NH_3$$

Nickel deficiency symptoms appear not for higher plants, but appear as poor growth, thickend legs, dermatitis and swollen mitochondria in animals.

Alfalfa (*Medicago sativa* L.) and smooth bromegrass (*Bromus inermis* Leyss) were grown on Nopporo diluvial soil, with nickel chloride and urea applied to the soil. The plants were harvested, were determined for forage yield, and were analysed for nickel and nitrate.

The main results were as follows;

1) The forage yield of alfalfa and smooth bromegrass was related to the level of nickel chloride added to soil. That is, the dry matter yield of the 1st cutting of both plants decreased with the increase of added nickel from 521 g with 3 g to 11.8 g with 27 $g/m^2$ of nickel chloride for alfalfa and also, from 261 g to 101 g for smooth bromegrass.

2) The concentration of nickel in the plants increased with the increment of nickel chloride applied to the soil.

3) The concentrations of nickel in the leaves or stems of the alfalfa and smooth bromegrass without nickel were $0.66 \pm 0.21$, $0.19 \pm 0.03$ and $0.43 \pm 0.17$ ppm, respectively. The interspecific difference of nickel absorption did not appear.

4) The increase of nickel added to the soils decreased the nitrate concentration in 1st cutting of smooth bromegrass, that is, the cofficient of correlation between nickel and nitrate concentration ($r = -0.712$) was significant. But for alfalfa, the significant relationship between them was not found.

5) The content of nitrate in the soils after cutting the alfalfa and smooth bromegrass did not relate with the increment of urea added, but the content of nickel in the soils increased with the urea addition, and also, with the nickel addition of course.

## References

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## 要　　約

ニッケルは高等植物栄養のためには必須であるとは認められていない。しかし乳牛のためには必要であるという十分な証明がなされている。それはニッケルがウレアーゼあるいは CO-デヒドロゲナーゼの構成要素であり，またニッケロプラスミンのメタン生成細菌の補酵素 $F_{430}$ や鉄吸収との相互作用にもかかわっているからである。

$$(NH_2)_2CO + H_2O \xrightarrow[urease]{} CO_2 + 2NH_3$$

高等植物のニッケル欠乏症は明白ではないが，しかし動物においては成育が弱まり，肥大不足や皮膚炎を発症し，そしてミトコンドリヤを膨潤させることが明らかとなっている。

アルファルファ (*Medicago sativa* L.) とスムースブロムグラス (*Bromus inermis* Leyss) が塩化ニッケルとウレアを施用した野幌洪積性土壌に栽培された。その植物体は収穫されニッケルと硝酸態窒素が分析された。

その主要な結果は以下のようであった。

1) 両牧草の乾物生育量はニッケル施用量の増加に伴い減少し，ウレア 30 g 施用区ではアルファルファでニッケル 3 g 施用の 521 g から 27 g/m$^2$ の 111 g まででであった。またスムースブロムグラスでは 262 g から 102 g であった。

2) 土壌に施用された塩化ニッケルの増加に伴ない植物体中ニッケル含有率は増大した。

3) ニッケル無施用のアルファルファ葉部と茎部のニッケル含有率とスムースブロムグラスのそれはそれぞれ 0.66±0.21, 0.19±0.03 および 0.43±0.17 ppm であった。またその種間差は明瞭でなかった。

4) 土壌に加えられたニッケルとスムースブロムグラスのニッケル含有率との間に有意な負の相関 (r＝－0.712) が認められた。しかし，アルファルファではこのような関係は見い出されなかった。

5) この両牧草の刈取り跡地の硝酸含量は施用されたウレアの量には関係しなかったが，しかし土壌のニッケル含量はウレアの施用量の増加で増大した。また当然ニッケル施用量の増大に伴ない増加した