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SOME EFFECTS OF NICKEL TOXICITY ON RYE GRASS*

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KEY WORDS

Iron Manganese Nickel toxicity Rye grass Zinc

SUMMARY

Rye grass (*Lolium perenne*, cv. S-23) was grown for 4 weeks in a non-calcareous Seaton loam soil with varying amounts of Ni as $NiSO_4$. The purpose of this investigation was to study the Ni toxicity and the relationship of Ni with other essential elements. Nickel depressed shoot yield at all levels except at the lowest level *viz* 30 μg Ni/g soil. Nickel concentration of 50 μg/g in shoots did not reduce the dry matter production in rye grass although slight chlorosis did appear at this level. The Ni and Fe concentration of the shoots increased and that of Mn and Zn decreased with increasing rates of Ni application. Uptake of Mn and Zn decreased at all level of Ni. But Fe uptake showed a slight increase at the first two levels and a profound depression at the subsequent levels. The pattern of Ni uptake is different, being highest at the middle level and decreasing on both sides which showed that the increase of Ni concentration of shoots is not proportional to the reduction in the yield. The Ni–Fe ratio rather than Ni and Fe concentration in plants has shown better relationship with the toxic effects of Ni. The implications of Ni phytotoxicity are discussed with particular reference to serpentine soils.

INTRODUCTION

Nickel is often associated with serpentine soils[15,18]. Analysis of plant material from these soils have shown considerably higher Ni content in comparison with non-serpentine sites[3,8,11]. Excess of Ni is one of the important factors causing reduced growth on these soils[9,10,15]. Nickel phytotoxicity varies with concentration of Ni in soil solution as well as with the plant species[13]. Some plant species are tolerant to the nickeliferrous soils so much so that accumulation of large quantities of Ni in their aerial parts produce no adverse effect[12,17]. Stimulatory effects of Ni at low concentration have also been reported in some species[2], but as soon as the concentration increases beyond a critical limit, which may vary

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from species to species, the adverse effects on plants become apparent. Toxic levels of Ni may depress yield and disturb the pattern of nutrient uptake, resulting in reduced uptake of some nutrient elements and increased supply of the others[7,11,14]. However, like other heavy metals, Ni when supplied in excess is believed to interfere with Fe uptake and metabolism causing chlorosis and necrosis[4,12,19]. Inspite of these investigations the interrelationship of Fe with Ni is still controversial[13,14,19]. Moreover, very little information is available on interrelationship of Zn and Ni concentration in plants. The present studies were therefore, designed to elucidate the toxic level of Ni for rye grass. In addition, the studies have also provided useful information on the relationship of Ni with other essential trace elements.

MATERIALS AND METHODS

Rye grass (*Lolium perenne*, cv. S-23) was grown in 200 g Seaton loam soil; non-calcareous pH 4.7. Prior to sowing, $NiSO_4$ at the rate of 0, 30, 90, 180 and 270 μg Ni/g soil was blended with the soil. The 0.3 g seeds were sown in each pot. The plants were grown for 4 weeks in a glass house under controlled temperature and humidity. The plant material was harvested, with stainless steel scissors, 1 cm above the soil level and dried at 70°C for 24 hours and then weight of the dry matter was recorded in g/pot. Oven dried plant material was ground in 'Grindex' boll mill, using capsule and bolls made of tungston carbide to avoid contamination from metals. The plant material was digested with diacid mixture of HNO_3 and $HClO_4$ (2:1). Analyses for Ni, Fe, Mn and Zn were performed with Atomic Absorption Spectrophotometer[1].

RESULTS AND DISCUSSION

Symptoms of Ni toxicity started appearing few days after germination and increased in severity with time and rate of Ni application. Some of the leaves showed slight chlorosis with 30 μg Ni/g soil. The reduction in growth with 90 and 180 μg Ni/g soil was associated with chlorosis and necrosis while in case of 270 μg Ni/g soil the growth was very much stunted and leaves showed severe chlorosis and necrosis.

Nickel depressed the dry matter yield (shoots) at all levels except at 30 μg Ni/g soil (Table 1). The dry matter Leaf concentration of 50 μg/g was not sufficient to reduce the yield, although slight chlorosis did appear at this level. The levels 180 and 270 μg Ni/g soil reduced the relative yield to 34% and 14% respectively.

The Ni and Fe concentration increased and that of Mn and Zn decreased with increasing rate of Ni application. Uptake of Mn and Zn decreased at all levels whereas Fe uptake increased at the first two levels and decreased thereafter. Nickel uptake showed a different pattern, being highest at 90 μg Ni/g soil and decreasing on either side, indicating that the increase in Ni concentration is not

Table 1. Yield and elemental composition of rye grass (shoots) grown in Seaton loam soil amended with nickel. Contents (μg/g) and uptake (μg/pot)

Ni added μg/g soil	Yield shoot g/pot	Relative yield	Toxic symptoms*	Ni		Mn		Fe		Zn		Ni/Fe ratio
				Content	Uptake	Content	Uptake	Content	Uptake	Content	Uptake	
0	0.73	100	O	8	6	480	350	80	58	46	34	0.10
30	0.73	100	sC	50	37	480	350	92	67	28	20	0.54
90	0.63	86	C	154	97	360	227	101	64	27	17	1.53
180	0.25	34	SC	321	80	350	88	150	38	31	8	2.14
270	0.10	14	VSC	470	47	350	35	175	18	33	3	2.68
LSD .05	0.10	–	–	26	22	56	45	16	20	4	5	–

* Healthy (O), Chlorotic (C), Slight (s), Severe (S) and Very Severe (VS).

Table 2. Correlation matrix between the yield and concentration of metals

	Yield	Ni	Mn	Fe
Ni	−0.98			
Mn	0.79	−0.84		
Fe	0.94	0.99	−0.78	
Zn	0.22	−0.33	0.49	−0.83

Table 3. Correlation matrix between the yield and uptake of metals

	Yield	Ni	Mn	Fe
Ni	−0.32			
Mn	0.98	−0.50		
Fe	0.94	−0.08	0.90	
Zn	0.89	−0.60	0.92	0.76

proportional to the depressions in yield. It is interesting to note that the Ni concentration showed a linear relationship with the rate of Ni applied, an addition of 30 μg Ni/g soil produced an increase of about 50 μg/g dry matter.

Correlation matrix for the dry matter yield *vs* concentration of Ni, Mn, Fe and Zn is shown in Table 2. Nickel and iron have shown negative correlation with yield whereas the positive correlations exhibited by Mn and Zn are not significant. Nickel showed a positive and strong correlation with Fe while Mn and Zn are negatively correlated and the coefficients are not high enough to be significant.

Correlation matrix between the dry matter yield *vs* total uptake of metals is presented in Table 3. Manganese, Fe and Zn are positively correlated with the yield, Mn gave the highest coefficient of correlation. Again Ni has shown positive correlation with Fe and Zn.

The increased Fe level as a result of Ni toxicity may be in part related to the stunted growth of the plants and, therefore a concentration effect. Moreover Fe utilization may be affected due to Ni toxicity and hence the symptome very much similar to Fe deficiency appeared in the presence of sufficient Fe[14,20]. The Fe uptake rather than Fe concentration in the shoots is a better indicator of toxic effects because Fe content increased due to reduction in yield. Chlorotic symptoms are not related to Fe and Ni content of the plant but the Ni–Fe ratio in plant has afforded a good relationship with Ni phytotoxicity[3]. It is observed that the Ni–Fe ratio of more than 1.0 is associated with the toxic effects of Ni. A ratio of more than 2.0 in plant has produced higher degree of necrosis and chlorosis[4].

The Zn and Mn content and their uptake were depressed due to Ni application at all levels, showing that these elements are synergistic[19]. The levels of Ni which caused toxicity are helpful in explaining the effects of serpentine soils where reduced growth often occur with lower Ni concentration in plants than in this study[3,5,8,9]. This suggests that besides the higher levels of Ni, some other factors such as low P and high Mg are also responsible for poor growth in serpentine soils[10,15,18].

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