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Nickel Forms in Calcareous Soils and Influence of Ni Supply on Growth and N Uptake of Oats Grown in Soil Fertilized with Urea

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ABSTRACT

Laboratory and pot studies were conducted to investigate nickel (Ni) distribution among different fractions in nine calcareous soils and the influence of Ni supply on the response of oats to urea application on a calcareous soil. Total Ni in the nine soils ranged from 31 to 94 mg kg^{-1} with an average content of 74 mg Ni kg^{-1} soil. Majority of the Ni (6 to 72 %) was in residual form. The DTPA extractable Ni ranged from 0.5 to 1.0 mg Ni kg^{-1} soil. Application of urea to Rasulpur series at the rate of nil, 50 and 150 mg N kg^{-1} with nil and 25 mg Ni kg^{-1} soil had a significant ($p < 0.01$) effect on shoot growth and N uptake of Oats. Application of urea @ 50 and 150 mg N kg^{-1} soil significantly ($p < 0.01$) improved shoot growth and N uptake of oats as compared to control. Nickel supply did not influence the response of oats to urea application due to sufficient bio-available Ni in the original soil required by urease for urea hydrolysis.

Key Words: Urea hydrolysis; Ni supply; Calcareous Soils; Ni fractions

INTRODUCTION

Oats (*Avena sativa* L.) is an important fodder crop in Pakistan, which is fertilized by urea as a N source to realize maximum green fodder production. At the same time urea, being a high analysis fertilizer, is a major N fertilizer in Pakistan like several other countries of the world. Urea is hydrolysed by the urease enzyme before its uptake by plants (Tisdale *et al*., 1985; Mengel & Kirkby, 1987). Recently, Marschner (1995) has listed nickel (Ni) as an essential micronutrient, which is required by urease for hydrolysing urea. Singh *et al*. (1990) have observed improvement in plant growth and N uptake of wheat from urea by Ni application on a calcareous soil. Several investigators have also shown beneficial effects of Ni on urease activity and improving N use efficiency by plants in hydroponic studies (Gerendas & Sattelmacher, 1999; Gerendas *et al*., 1999). However, deficiency of Ni in soils has rarely been reported (Dalton *et al*., 1985).

The present laboratory and pot study was, therefore, designed to investigate the distribution of Ni in different fractions in several calcareous soils and to evaluate the significance of Ni supply on growth and N uptake of oats in a calcareous soil fertilized with urea.

MATERIALS AND METHODS

Soils. Bulk representative surface (0-15 cm) soil samples were collected for Bhalwal series (Ustollic Haplargid), Gujranwala series (Udic Haplustalf), Kotli series (Entic Chromustert), Peshawar series (Udic Haplustalf), Pindorian series (Udic Haplustalf), Rajar series (Typic Ustorthent), Rasulpur series (Ustochreptic Camorthid), Shahdara series (Typic Torrifluvent), and Warsak series (Udic Ustochrept) (Ahmad *et al*., 1985). Soils were air-dried and ground to pass through a 2-mm sieve. Their detailed physico-chemical properties have been reported previously (Rahmatullah *et al*., 1994). The soils were alkaline calcareous in nature with # 1% organic matter. They were mostly medium textured except heavy textured Kotli series.

Pot study. A bulk surface (0-15 cm) sample collected for Rasulpur series was air-dried and ground to pass through 2-mm sieve. The soil was sandy loam (sand 65.4%; silt 27.5% and clay 7.1%) with pH_s 8.00; CEC 3.6 $cmol_c kg^{-1}$; organic matter 0.36% and $CaCO_3$ 1%. Two-kg sub-samples of sieved Rasulpur series filled each in 24 polyethylene lined plastic pots were supplied with nil and 25 mg Ni kg^{-1} as $NiCl_2.6H_2O$ and nil, 50 and 150 mg N kg^{-1} as urea. Uniform basal doses of various nutrients added to all pots were 90 mg P kg^{-1} as KH_2PO_4, 50 mg Ca kg^{-1} as $CaSO_4.2H_2O$, 25mg Mg kg^{-1} as $MgSO_4.7H_2O$, 25F mol B (H_3BO_3), 2Fmol Mn ($MnSO_4$), 2 Fmol Zn ($ZnSO_4$), 0.5 Fmol Cu ($CuSO_4$), 0.5 Fmol Mo (H_2MoO_4) and 50 Fmol Fe (Fe-EDDHA) in solution form. Soil in all the pots was moistened with distilled water, dried and mixed thoroughly twice to establish equilibrium. Samples for laboratory analyses were collected from each pot before sowing seeds of oats (*Avena Sativa*). Nine uniform plants per pot were allowed to grow after germination. Moisture contents in all pots were maintained with distilled water at 25% (W/W) water content by weighing during the plants' growth period. Whole plant tops were harvested seven weeks after sowing. Plant samples were washed with distilled water, blotted in filter paper sheets, and dried to a constant weight at 65ºC in a forced-air oven. The plant samples were ground in Wiley mill fitted with stainless steel blades.

Chemical analyses. Fine-ground plant samples were digested first with concentrated HNO_3 and thereafter with a di-acid mixture (1:4) $HNO_3 : HClO_4$ (Jackson, 1962). Nickel in the plant digest was determined by atomic absorption spectroscopy. The DTPA was used to extract bioavailable Ni in the soils (Lindsay & Norvell, 1978). Total Ni in soils was determined by digestion with HNO_3, $HClO_4$, H_2SO_4 and HF

(Follett & Lindsay, 1970). Detailed procedures used to estimate different forms of Ni in soils are outlined by Tessier *et al*. (1979). Fractionation of Ni involved sequential extractions with (a) distilled water to remove water soluble Ni, (b) 1 M $MgCl_2$ to extract exchangeable Ni, (c) 0.5 M NaOAc and 0.5 M HOAc to remove Ni held by carbonates, (d) 0.175 M $(NH_4)_2C_2O_4$-0.100 M $H_2C_2O_4$ to remove Ni held by Fe and Al oxides and (e) 30% H_2O_2 to remove Ni held by soil organic matter. Residual form of Ni in soil was estimated by subtracting sum of various Ni forms from total Ni.

Statistical analysis. Variance of plant dry matter yield and plant Ni content was analysed assuming a complete randomized design. Least significant difference (Steel & Torrie, 1980) was used for mean separation. Linear correlation/regression analysis for extractable Ni in soil and Ni in different fractions in soils was carried out (Steel & Torrie, 1980).

RESULTS AND DISCUSSION

Plant growth. Application of N as urea significantly ($p<0.01$) improved shoot dry matter yield of oats (Table I). Nickel application had no significant effect on shoot growth of oats. Maximum shoot dry matter yield was produced by urea applied at the rate of 150 mg N kg^{-1}. Nitrogen supply at the rate of 50 and 150 mg N kg^{-1} either with or without Ni addition statistically had similar effect on shoot growth of oats. These results differ from those of Singh *et al*. (1990) who had observed improvement in wheat growth by Ni supply when urea was the N source on a calcareous soil.

Table I. Shoot growth and nitrogen uptake of oats fertilized with urea and nickel (means of 4 replications)

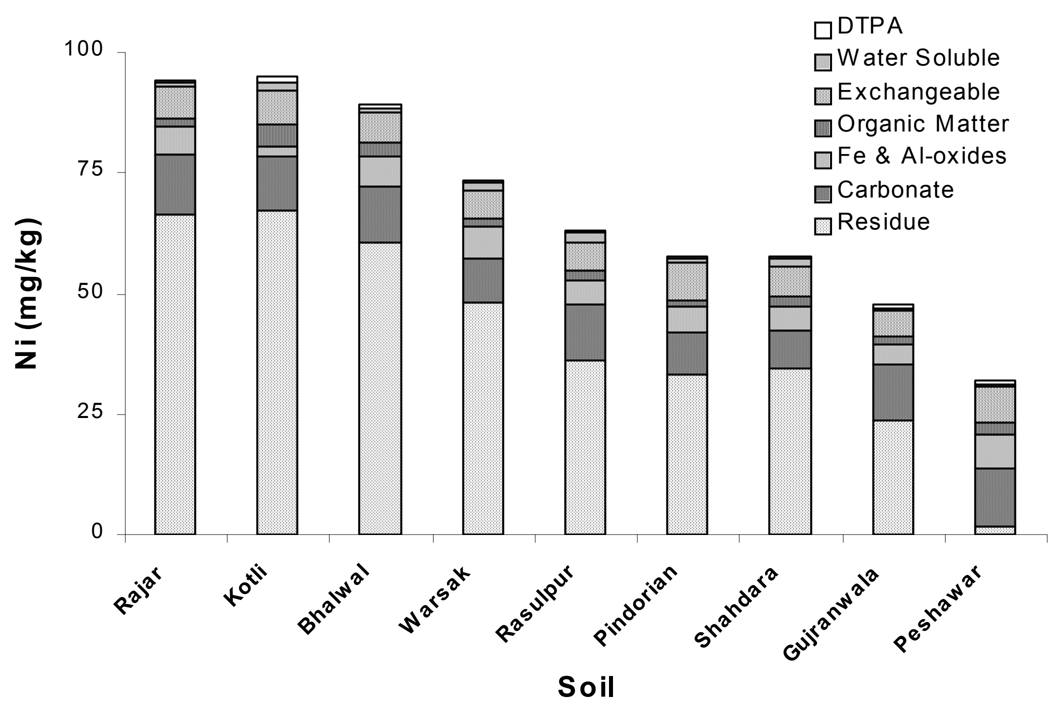
Urea N applied ($mg\ kg^{-1}$)	Shoot dry wt. ($g\ pot^{-1}$)		N conc. in Shoot (%)		Total N in shoot ($mg\ pot^{-1}$)	
	-Ni	+ Ni @ 25 mg kg^{-1}	-Ni	+ Ni @ 25 mg kg^{-1}	-Ni	+ Ni @ 25 mg kg^{-1}
0	0.65	0.60	5.35	4.77	34.78	28.62
50	1.12	1.08	6.25	6.04	70.00	65.23
150	1.19	1.26	6.82	6.71	81.16	84.55
$LSD_{0.01}$	0.41		1.00		25.76	

N uptake. There was an evident increase in per cent N concentration in plant shoot (Table I). Per cent N concentration in shoot varied from 4.77 to 6.82%. It was adequate when compared to its sufficiency level in oats as reported by Reuter and Robinson (1986).

Application of urea either with or without Ni supply had a significant ($p< 0.01$) effect on total N content in oat shoots (Table I). Total N content in shoot followed the trend of shoot dry matter yield. Total N content in oat shoot did not differ significantly among 50 and 150 mg N kg^{-1} rate of urea application. Maximum N content in oat shoot was yielded by urea applied either with or without Ni supply at the rate of 150 mg N kg^{-1}. Nickel supply had no effect on total N uptake by oats.

Nickel fractions. Total Ni in the nine soils ranged from 31.25 mg Ni kg^{-1} in Peshawar series to 93.75 mg Ni kg^{-1} in Kotli series and Rajar series. It was with in the range reported in

Fig.1. Distribution of nickel among different fraction in nine calcareous soils (Figures given on the top of each bar is the DTPA extractable Ni (mg kg-1) in the soil)



literature for total Ni in soils (Lindsay, 1979; Uren, 1992). A major proportion of 6 to 72% of total Ni in the soils was in residual form, which included Ni present in mineral structures. It explained 98.6% variation in total Ni is soils. Quantitatively, it was followed by Ni precipitated with carbonates in the present calcareous soils of arid and semi-arid regions. A 12 to 38% proportion of total Ni in these soils was associated with carborates. Exchangeable Ni estimated by $MgCl_2$ extraction was 7 to 24% of total Ni in the soils. Nickel in exchangeable and soluble form is considered available for plant uptake. A very small fraction of < 1 to 3% of total Ni was present in soluble form. The plant available Ni was extracted by DTPA. It ranged from 0.5 to 1.0 mg Ni kg^{-1} soil. It was # 1% of total Ni in the soils. It was negatively correlated ($r = -0.73$, $n = 9$, $p < 0.05$) with Ni held by Fe and Al-oxides. The DTPA extractable Ni had positive relationship ($r=0.64$, $n=9$, $p< 0.05$) with Ni held by soil organic matter.

Nickel has been listed as an essential micronutrient (Marschner, 1995). It is required for the urease enzyme, which hydrolyses urea. Urea has been the major nitrogenous fertilizer manufactured and used in Pakistan like several other parts of the world. Application of urea at the rate of 50 mg N kg^{-1} in the present study significantly ($p<0.01$) improved shoot dry matter yield and N uptake by oats. Low organic matter and hence, low available N in the present soils favoured significant plant response to N application (Iqbal *et al*., 1998). However, single application of 150 mg N kg^{-1} did not produce significant increase in shoot dry matter yield and N uptake of oats possibly due to heavy N losses at high rate of single application of urea which are particularly accentuated under alkaline calcareous soil conditions (Tisdale *et al*., 1985). Application of Ni did not affect plant responses to urea application at either rate. It conforms earlier reports of no clear evidence of Ni deficiency in soil grown plants (Dalton *et al*., 1985). Also urease requires, a small amount of Ni (Uren, 1992), which was present in the original soils. However, influence of Ni application on agronomic efficiency and N recovery of oats were remarkable (Fig. 1).

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