SHORT COMMUNICATION

Mechanism of nitrogen effect on zinc nutrition of flooded rice*

Summary

Nitrogen application increased Zn contents of flooded rice on two calcareous soils. Urea and (NH₄)₂SO₄ being better N carriers than NH₄NO₃ resulted in higher increase. Nitrogen enhanced Zn contents partly through growth promotion but mainly by increasing soil Zn solubility and root efficiency for Zn absorption. Zinc solubility rose by an enigmatic mechanism and not from pH reduction or soluble Zn–H₂N₃ complex formation as occurs for upland plants. Nitrogen aggravated Zn retention in upland plant roots as immobile Zn-protein complex was not important for rice. Bicarbonate inhibition of Zn uptake by rice from CO(NH₂)₂ application or its stimulation by lower redox potential from NH₄NO₃ addition were not involved.

Introduction

Submerged rice (Oryza sativa L.) usually responds to N and Zn fertilizers on calcareous soils. Nature of their mutual interaction was never studied critically. Nitrogen often depresses Zn concentration in upland plants causing severe yield reduction. Ozanne suggested this to result from higher Zn retention in roots as immobile Zn-protein complex.

Nitrogen, sometimes, also increases total Zn contents in upland plants. This occurs mainly by growth promotion or soil pH depression. Thus NH₄NO₃ being more efficient for plant growth than other fertilizers, especially on calcareous clayey soils resulted in higher Zn increase. On light textured soils (NH₄)₂SO₄ caused more increase due to pH reduction. Nitrogen effect on per se Zn uptake or on root efficiency for its absorption is yet unknown.

Nitrogen effect on Zn uptake may strongly differ for flooded rice. It is sown on buffered calcareous clay soils where pH changes from normal doses of acidic N fertilizers may not be involved. Moreover, pH of acidic and alkaline flooded soils usually equilibrate at 7.0. Nitrogen sources may also exhibit differential effect on growth and thus on Zn uptake by rice. By contrast in upland plants, (NH₄)₂SO₄ was double efficient for rice than NH₄NO₃ due to severe NO₃-N loss in reduced soils from denitrification. Bicarbonate inhibition of Zn uptake from CO(NH₂)₂ application or its stimulation by lower soil redox potential from NH₄NO₃ addition may also be important for rice. The current experiments were conducted to evaluate these hypotheses.

* No. V in the series Micronutrient availability to cereals from calcareous soils.
Materials and methods

(a) Zinc uptake by rice from soils. Sub-portion of 4.5 kg of two calcareous (CaCO$_3$ 0.5, 2%) clay soils of Pakistan, Gujranwala and Miranpur (pH 8.4, 8.6, organic matter 1%) was filled in plastic pots. Basal fertilizer consisted of 13 ppm P as KH$_2$PO$_4$ and treatments included in triplicate were 0, 37, 75 and 150 ppm N as CO(NH$_2$)$_2$, (NH$_4$)$_2$SO$_4$ or NH$_4$NO$_3$ in the presence of 0, 5 and 25 ppm Zn, all mixed with soil before planting. Six 20-days nursery seedlings, cv. Basmati 370 rice, were transferred in pots and grown for another 36 days under flooding. After which shoots were harvested, dried, ground and their one g portions digested with H$_2$NO$_3$-HClO$_4$ (4:1) mixture. Zinc in the diluted digest was determined by atomic absorption system. Total Zn contents equalled Zn conc. x plant yield.

(b) Kinetics of soil Zn solubility. Sub-samples of Miranpur soil at 4.5 kg in plastic pots received a basal P dose of 13 ppm and various treatments in triplicate at 150 ppm N as CO(NH$_2$)$_2$, (NH$_4$)$_2$SO$_4$, and (NH$_4$)$_2$NO$_3$. Pots flooded with 5 cm standing deionized water were placed near those sown under rice during main rice growing months of August and September. Aliquots from 150 ml soil percolate collected by gravity each week from side holes of pots under N gas atmosphere were analysed for pH in all especially designed O-free cell and for HCO$_3^-$ by acid titration. The remaining percolates were preserved against oxidation by adding six drops of conc. H$_2$SO$_4$ and later on analysed for Ca, Cu, Zn, Mn, and Fe by atomic absorption spectroscopy.

(c) Zinc absorption from solutions by N pretreated and untreated rice seedlings. Earlirose rice seedlings were grown for 10 days in silica sand on solutions of 250 $\mu$M CaSO$_4$ or Ca(NO$_3$)$_2$. Both the treatments had identical plant growth but untreated plants exhibited N deficiency just by 10th day. The seedlings in quadruplicate were then transferred to 300 ml glass tubes containing aerated solutions of 500 $\mu$M CaCl$_2$ and 5 $\mu$M $^{65}$ZnCl$_2$ (activity 9000 cpm/ml) at pH 5.6. Absorption time was 48 hours after which the solutions were replaced with 10$^{-8}$M Na$_2$EDTA for one hour to eliminate adsorbed root $^{65}$Zn. The plants were then washed and radioactivity of its roots and shoots counted in a well-scintillation counter. Zinc absorbed was calculated from specific activity relationship.

Results and discussion

Nitrogen exhibited no effect on Zn concentration except in 150 ppm N as (NH$_4$)$_2$SO$_4$ and 25 ppm Zn treatment on Miranpur soil where Zn concentration in rice shoots increased ($P < 0.01$, Table 1) These results failed to support N depression of Zn concentration in upland plants causing severe yield decline.

Nitrogen enhanced total Zn contents in rice on both soils ($P < 0.05$, 0.01, Table 1, 2). Growth promotion appears at least partly responsible. Thus, Zn contents in plant paralleled with plant yield exhibiting high correlation coefficient both on Gujranwala and Miranpur soils ($r$ 0.81, 0.78 $P < 0.01$). Urea and (NH$_4$)$_2$SO$_4$ increasing rice growth more than NH$_4$NO$_3$ ($P < 0.1$) also