SOIL TEMPERATURE AND NITROGEN EFFECTS ON RESPONSE OF FLOODED AND NONFLOODED RICE TO ZINC

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KEY WORDS
Ammonium sulphate Crowley soil Fixation Flooding Mixed application Rice Surface application Urea

SUMMARY
Response of direct seeded rice (cv. Bluebelle) to Zn was studied in flooded and nonflooded (field capacity) Crowley soil (pH 7.6) maintained at soil temperatures of 18 and 30°C. Urea and (NH₄)₂SO₄ were compared as sources of N to determine their effect on plant uptake of Zn from ZnSO₄ either mixed or surface applied to the soil. Grain yields were slightly higher from nonflooded than from flooded soil. Higher dry matter production at 30 than at 18°C was not related to Zn nutrition. Urea and (NH₄)₂SO₄ resulted in similar yields and Zn uptake by flooded rice, but (NH₄)₂SO₄ was superior for nonflooded rice in the absence of applied Zn. More fixation of mixed Zn by the limed Crowley soil probably caused its lower effectiveness, as compared to surface-applied Zn.

INTRODUCTION
Cool soil conditions which often prevail during early spring after crop emergence can enhance Zn deficiency where native soil supplies are low. Mikkelson⁸ and Sharma et al.¹⁰ found that dry matter yield of rice and Zn uptake were depressed at low soil temperatures (15 to 16°C); addition of Zn had little effect on Zn concentration. Giordano and Mortvedt⁷ also observed that growth and Zn uptake by corn in the greenhouse were significantly less at 16 than at 32°C. Accordingly, uptake of Zn and P was less at the lower soil temperature, suggesting that growth retardation sometimes attributed to Zn deficiency during cool weather may also be related to P uptake. In the field, soil warming to 27°C with thermostatically controlled heating cables resulted in slightly higher accumulation of Zn by several vegetable species grown on sewage sludge-amended soil³. Chaudhry et al.¹ have shown that N application increases the Zn content of
flooded rice on calcareous soil, especially when urea and \((\text{NH}_4)_2\text{SO}_4\) are the sources of N. The proposed mechanism involves, in addition to growth response to N, an increased Zn solubility and root efficiency for Zn absorption rather than pH reduction or soluble Zn–NH\(_3\) complex formation which occurs for upland crops. Yoshida et al.\(^{12}\) noted similar yields of immature rice and Zn content with \((\text{NH}_4)_2\text{SO}_4\), \(\text{NH}_4\text{Cl}\), and urea applied for flooded rice. In contrast, Giordano et al.\(^5\) found that dry matter production and Zn uptake by corn grown in greenhouse pots were significantly higher with \((\text{NH}_4)_2\text{SO}_4\) than with anhydrous \(\text{NH}_3\) or urea. An increase in solubility of both native and applied Zn was attributed to lower soil pH associated with \((\text{NH}_4)_2\text{SO}_4\) treatment.

The purpose of this study was to determine (1) to what extent soil temperature influences response of flooded and nonflooded rice to Zn, and (2) influence of N source on dry matter production and Zn uptake.

**METHODS**

Crowley soil, a typic albaqualf from Louisiana, was limed to pH 7.6 with 15 g of a 4:1 mixture of CaCO\(_3\) and MgCO\(_3\) per 5 kg of soil. In addition, 1,000 mg of N, 1,000 mg of P, and 600 mg of K were mixed with the soil in each pot as urea or \((\text{NH}_4)_2\text{SO}_4\), concentrated superphosphate, and \(\text{K}_2\text{SO}_4\), respectively. Zinc sulfate was mixed full depth with the soil or applied to the soil surface at a rate of 40 mg Zn per pot. Extra pots of limed soil were included which received 100 g of a dry municipal sewage sludge as a mixed treatment, but no additional nutrients. The sludge provided 2,100 mg of N, 1,300 mg of P, 100 mg of K, and 180 mg of Zn.

Three-week-old Bluebelle rice seedlings (12 per pot) were transplanted and the soil was either flooded or adjusted to approximately 0.3 atm moisture tension. Soil temperature was maintained at either 18 or 30°C by immersing the pots in thermostatically controlled water baths. An additional 1,000 mg of N as urea or \((\text{NH}_4)_2\text{SO}_4\) was applied during the growth period in several increments to each pot except those which received sludge. All pots (three replicates of each treatment) were harvested when the grain was mature. Yields of straw and grain were recorded after oven drying and the tissues were analyzed for Zn, N, and P. Soil samples were taken from each pot after harvest for determination of soil pH and available Zn by the DTPA method.

**RESULTS**

In general total dry matter production was higher at 30 than at 18°C with differences being greater under flooding (Table 1). This response to soil heating was entirely a reflection of increased grain yields; straw production was little affected by this difference in temperature. Total dry matter production at 18°C was higher from soils at field capacity than from the flooded pots, again a result of higher grain yields. Within a particular temperature or moisture regime, yield responses to applied Zn were comparable with urea and \((\text{NH}_4)_2\text{SO}_4\). However, extreme Zn deficiency occurred in nonflooded rice with no applied Zn and with