Nutrient Bioavailability under Aerobic Condition in Rice

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ABSTRACT

Many factors that determine bioavailability of essential elements are expected to change after a shift to aerobic system of rice cultivation. Soil pH is an important characteristic and controls the availability of most essential plant nutrients and there by the growth and yield of rice. Flooding overcomes both acid and alkaline (sodic) conditions in soil. The pH of an acid soil changed from 3.5 to near 6.0 and that of an alkaline soil changed from 8.1 to near 7.3 on submergence for a period of 2 weeks due to the dilution of H+ or Na+ ions and reverted back to its original pH when flooding was withdrawn. In aerobic rice, as the concept of flooding the paddy fields is abandoned, bulk soil pH may either increase or decrease depending on the original soil pH. In an aerobic rice study at Philippines, the pH of soil increased from 7.0 at seeding to near 8.0 at flowering in 2007 and was reported to be responsible for micronutrient deficiency.

INTRODUCTION

One of the most prominent micronutrient deficiencies in rice, affecting both lowland and upland varieties grown under aerobic conditions, is zinc deficiency (Kreye *et al.*, 2009). Zinc deficiency symptoms were observed in aerobic rice in North China, 2 or 3 years after fields were shifted from flooded to aerobic conditions (Wang *et al.*, 2002). Next to phosphate and nitrogen deficit, zinc deficit is an important issue that affects up to 50% of all lowland rice soil.

Nutrient bioavailability

Zinc variation, or the distribution of zinc in soil across several chemical forms, affects the availability of zinc to plants. There are four ways that zinc can be found in soil: (1) suspended in soil solution; (2) bound as exchangeable zinc to negatively charged compounds, like organic matter or metal oxides; (3) incorporated as insoluble zinc in clay minerals or metal oxides; or (4) held in primary minerals like ZnS and $Zn(OH)_2$. Only the first, the dissolved fractions are directly available for plant uptake. Adsorption-desorption processes and solubility connections between the solution and solid phases seem to be the main factors controlling zinc bioavailability in soil. The main factors influencing the adsorption-desorption reactions of zinc in soils, and consequently controlling the amount of zinc dissolved in soil solution, are the features of the soil, such as pH, redox potential, organic matter, and pedogenic oxides. The transition from lowland to aerobic farming is anticipated to alter these characteristics.

Nutrient bioavailability under aerobic condition

Due to aerobic production, the pH of the bulk soil may return to its initial value after being flooded, which can lead the soil to become neutral. Under aerobic conditions, the redox potential will rise, leading to the creation of Fe and Mn oxides, which may then be adsorbed with Zn. Zinc precipitation when ZnSO4 falls in an aerobic environment. According to Chen *et al*. (2008), switching to aerobic culture may also result in a rise in the variety and quantity of Fe-oxidizing/reducing bacteria, which could have an impact on the concentration and speciation of zinc in the soil solution. Oxidation can cause the organic matter level to drop in aerobic conditions.

The rates at which Zn is absorbed by crops may also be significantly impacted by the differences in transpiration and diffusion between aerobic and wet fields. Low rates of zinc dissolution and diffusion in soils may limit zinc transport to the plant root in aerobic fields. Lower transpiration rates in aerobic fields as opposed to flooded ones may also reduce the mass transfer of zinc from the soil to plants, which in turn reduces plant uptake of zinc and its allocation to grains.

For crops cultivated on low zinc soils, root-induced pH shifts in the rhizosphere and the release of exudates with varying molecular weights are crucial for zinc acquisition. Rhizosphere acidification can improve the uptake of Zn and P in lowland rice. One possible method of lessening zinc shortage in lowland rice is the excretion of organic acids or phytosiderophores that can raise the bioavailability of zinc in the rhizosphere. Low molecular weight organic acids (LMWOAs), respiration-induced changes in CO2, and the excretion of protons (H+) and hydroxyl (OH−) or bicarbonate (HCO3−) ions all contribute to changes in the pH of the rhizosphere. The primary factor affecting the cation/anion absorption ratio and, consequently, the pH of the rhizosphere is the kind of nitrogen (N) input. O2 emitted from the roots of plants growing in anaerobic soil may boost H+ extrusion and increase the bioavailability of zinc for plants. Furthermore, rice roots absorb N mostly in the form of NH 4+, which causes the roots to emit H+ and lower the pH of the rhizosphere. It is anticipated that in aerobic rice cultivation, the transition of the predominant type of N uptake from NH 4+ to NO 3− will cause OH− to exude into the rhizosphere, raising its pH and lowering Zn availability in the process.

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Reduced zinc uptake in rice cultivated in aerobic fields as different to flooded fields on calcareous soil may be due to a shift in rhizosphere pH brought on by altered N dynamics. Six rice genotypes were used in a field experiment by Gao *et al*. (2006) to investigate the bioavailability of zinc under aerobic and flooded conditions. The results showed that the concentration of zinc in rice plants during the tillering and physiological maturity stages was lower in aerobic conditions than in flooded conditions.

CONCLUSION

However, rice varieties studied showed difference in their tolerance to Zn deficiency. Moreover, it was found that zinc application neither affected grain yield nor grain Zn content. So, applying zinc fertilizers in sufficient quantities to overcome the zinc deficiency will not serve the purpose but places considerable burden on resource poor farmers and it was therefore suggested that breeding efforts should be intensified to improve the tolerance to zinc deficiency in rice cultivars.

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