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Abstract

Soil acidity is a critical constraint limiting rice productivity in many regions worldwide. This review synthesizes current knowledge on the mechanisms by which rice cultivation influences soil acidity and highlights sustainable management strategies to mitigate acidification effects. Emphasis is placed on biological interactions, soil amendments, and rice variety selection tailored for acidic soils. The review also discusses the impacts of rice-driven changes in soil pH on nutrient availability and aluminum toxicity. Understanding these interactions is vital for improving rice yields and soil health in acid-prone agroecosystems.

Introduction

Soil acidity adversely affects nutrient availability, crop growth, and yield, particularly in rice-growing regions with high precipitation and poor drainage. Acidic soils typically have pH values below 5.5, often accompanied by toxic levels of soluble aluminum and manganese that stunt rice root development. Approximately 13% of global rice production occurs on acidic soils, posing significant challenges for sustaining long-term productivity. Raising soil pH through liming is common but costly and potentially disruptive. Hence, understanding how rice cultivation itself alters soil acidity and exploring integrated biological and agronomic approaches to ameliorate acid soils is critical.

Mechanisms of Soil Acidification in Rice Cultivation

Rice cultivation influences soil acidity through root exudates, microbial transformations, and redox changes in flooded paddy soils. Under anaerobic conditions created by flooding, iron and manganese oxides are reduced, releasing protons that lower soil pH. Microbial communities participate in nutrient cycling, impacting soil acid-base balance. However, the rhizosphere of rice also supports microbes that can immobilize aluminum and produce organic acids that chelate toxic cations, thereby mitigating acidity effects. Rice varieties differ in tolerance to low pH and in their ability to alter rhizosphere chemistry, with some promoting beneficial microbial consortia that improve soil conditions.

Biological Interventions for Reducing Soil Acidity

Recent studies have demonstrated that inoculating acidic soils with aluminum-resistant bacteria such as Rhodococcus and Pseudomonas species can raise soil pH and decrease soluble aluminum concentrations around rice roots. These microbes produce organic anions that bind aluminum, functioning like a sponge to prevent root damage. Furthermore, these inoculants enhance phosphorus mineralization and solubilization, boosting nutrient uptake and growth. Biochar amendments have also shown promise in increasing pH and fertility by improving soil structure and cation exchange capacity, thus complementing microbial strategies for acid soil remediation.

Soil Amendments and Agronomic Practices

Liming remains an effective option to neutralize acidity, with quicklime applications maintaining pH above critical thresholds for rice growth. However, excessive liming may disrupt soil microbial balance. Therefore, integrated use of organic amendments such as rice husk ash, biochar, and microbial inoculants is recommended to sustainably improve soil properties. Crop rotation, intermittent drainage, and balanced fertilizer use also influence soil pH dynamics during rice production cycles. Selecting rice cultivars with acid tolerance and strong root systems further enhances soil amelioration.

Impact on Rice Yield and Soil Health

Managing soil acidity through rice cultivation and supportive amendments directly correlates with improved yield outcomes. Maintaining soil pH above 5.0 reduces aluminum toxicity and supports nutrient availability, leading to healthier root development and grain production. Long-term studies indicate that intensive rice cultivation without proper acid management depletes soil organic matter and alters nutrient balances, undermining soil resilience. Conversely, eco-friendly interventions that promote microbial diversity and organic matter retention contribute to sustainable productivity in acid soils.

Conclusion

Reducing soil acidity by growing rice involves a multifaceted approach combining biological, chemical, and agronomic strategies. Understanding the interactions between rice plants, soil microbes, and chemical amendments is fundamental to mitigating acidity and enhancing crop performance. Future research should focus on optimizing microbial consortia inoculation, biochar application, and variety selection tailored for acid-prone environments. Such integrative management will contribute to food security and environmental sustainability in rice-growing regions with acidic soils.

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