Perspective

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Microbial Strategies for Enhancing Phosphorus Availability and Sustainability in Tea Cultivation

Afonso Ilva*

Department of Chemistry, NOVA University Lisbon, Caparica, Portugal

Corresponding author: Afonso Ilva, Department of Chemistry, NOVA University Lisbon, Caparica, Portugal, E-mail: AfonsoIlva45@edu.au

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Description

Tea is not only one of the most significant industrial crops but also the most widely consumed non-alcoholic beverage globally. From cultivation to consumption, tea plays a vital role in global trade, cultural practices and economic development. Given the limited scope for expanding cultivation areas, enhancing tea productivity is essential to meet rising consumer demands. One of the primary constraints on tea productivity is the insufficient availability of Phosphorus (P) due to the binding of a significant portion of applied is it phosphorus to metal ions in the soil. Phosphorus is a critical nutrient for plant growth, playing a vital role in energy transfer, photosynthesis and the synthesis of nucleic acids. However, the availability of phosphorus in soil, particularly in tea plantations, is often limited. Tea plants thrive in acidic soils, which significantly influences the availability of nutrients, especially phosphorus. In acidic environments, phosphorus tends to bind strongly to Aluminum (Al) and Iron (Fe) oxides, forming insoluble compounds such as Aluminum Phosphate (Al-P) and iron phosphate (Fe-P). This binding reduces the availability of phosphorus to tea plants, as a considerable amount of inorganic phosphorus applied as fertilizers becomes inaccessible due to rapid conversion into these complex forms.

The role of soil acidity

The acidic soil conditions required for tea cultivation contribute to the problem of phosphorus availability. Tea plants prefer soil pH levels between 4.5 and 5.5. At this pH range, the solubility of aluminum and iron increases, leading to the formation of insoluble phosphorus compounds. Studies have shown that in such conditions, a significant portion of the phosphorus applied as fertilizer binds to aluminum and iron, rendering it unavailable to the plants. For instance, research by Dutta and Thakur highlights that acidic soils lead to the rapid immobilization of phosphorus, posing a significant challenge for maintaining adequate P levels in tea plantations. To address the issue of phosphorus availability, microbial interventions have emerged as promising solutions. Soil microorganisms possess various mechanisms to solubilize inorganic phosphorus and make it more readily available to plants. These mechanisms include the production of organic acids, secretion of phosphatases and the release of siderophores that bind to iron, freeing phosphorus from iron complexes. Phosphate-Solubilizing Bacteria (PSB) are capable of converting insoluble phosphorus compounds into forms that plants can absorb. These bacteria produce organic acids such as gluconic acid and citric acid, which lower the pH in the vicinity of the root zone, thereby increasing the solubility of phosphorus. PSB can significantly enhance phosphorus availability in the soil, leading to improved growth and yield of tea plants. The use of biofertilizers containing phosphorus-solubilizing microorganisms has gained attention as an effective strategy to enhance phosphorus availability. Several studies and practical applications have demonstrated the effectiveness of microbial interventions in improving phosphorus availability in tea cultivation. In India, where tea is a major agricultural product, research has focused on integrating phosphate-solubilizing bacteria into tea cultivation practices. Field trials have shown that inoculating tea plants with PSB can increase phosphorus uptake and enhance yield. This approach has the potential to reduce reliance on chemical fertilizers, promoting more sustainable agricultural practices. In Sri Lanka, mycorrhizal fungi have been used to improve phosphorus uptake in tea plantations. Farmers have adopted mycorrhizal inoculants to enhance nutrient availability and improve plant resilience to environmental stressors.

Microbial diversity

The diversity of phosphorus-solubilizing microorganisms and their specific roles in different soil types can provide insights into optimizing microbial interventions for tea plantations. Integrating microbial interventions with traditional agricultural practices can enhance their effectiveness and ensure broader adoption by farmers. This includes developing tailored biofertilizer formulations and providing training on their application. Conducting long-term studies to assess the sustainability and environmental impact of microbial interventions is vital. This has resulted in healthier plants and increased productivity. China, one of the largest tea producers globally, has seen significant advancements in the use of biofertilizers. The incorporation of phosphorus-solubilizing microorganisms in biofertilizer formulations has led to better nutrient management in tea plantations. This approach not only boosts phosphorus availability but also contributes to soil health

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and sustainability. Enhancing phosphorus availability through microbial interventions holds great promise for tea cultivation. Future research should focus on the following areas. This will help in understanding the cumulative effects on soil health, crop productivity and ecosystem stability. Phosphorus availability is a critical factor influencing tea productivity, especially in the acidic soils where tea plants thrive. Addressing this challenge through microbial interventions offers a promising solution. Phosphate-solubilizing bacteria, mycorrhizal fungi and biofertilizers have shown significant potential in enhancing phosphorus availability, improving plant growth and promoting sustainable tea cultivation. By integrating these microbial strategies with traditional agricultural practices, tea producers can optimize phosphorus management, increase yields and contribute to the overall sustainability of the tea industry.