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Eco-Enriched Soils: Ash-Boosted Fertilizer Sparks Microbial Powerhouse for Phosphorus Mobilization in Perennial Ryegrass Root Zones

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Abstract

While phosphorus (P) is essential for plant development, it is not always bioavailable in soils. Perennial ryegrass (Lolium perenne) root zone phosphorus mobilization is studied in this research as a function of ash-boosted fertilizers. Ash is an environmentally favourable soil amendment, and this research looks at how it drives microbial activity, leading to phosphorus solubilization and absorption. According to the results, increased soil microbial biomass boosted phosphate availability and enriched the root zone. If we want to improve the efficiency of agricultural soils consuming phosphorus, this new method provides a sustainable option.

Keywords:

Phosphorus mobilization, Ash-boosted fertilizer, Biomass ash, Perennial ryegrass (Lolium perenne), Soil microbial activity, Phosphatase enzymes, Phosphorus solubilization, Sustainable agriculture, Eco-friendly fertilizers, Soil nutrient management.

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1. Introduction

As a macronutrient, phosphorus is one of the most important for plant development. It is involved in the transfer of energy, the process of photosynthesis, and the transport of nutrients. Particularly in its inorganic forms, phosphorus is often immobile in soils, which results in a decreased bioavailability for plants. This is even though phosphorus is an essential element. The difficulty of this problem is especially severe in agricultural systems dependent on synthetic fertilizers, which have low effectiveness and contribute to the destruction of the environment via runoff and eutrophication.

Recent research has concentrated on alternate soil additions that are beneficial to the environment to increase phosphorus availability. Ash, which is a result of burning biomass and is abundant in essential minerals, is one method that may be used. Due to its capacity to raise the pH of the soil and boost the activity of microorganisms, ash has shown that it has the potential to be used as a soil amendment. The notion that ash-boosted fertilizers produce a microbial powerhouse in the root zones of perennial ryegrass, hence boosting phosphorus mobilization and absorption, is presented and investigated in this work.

2. Materials and Methods

2.1. Experimental Design

The research was carried out in a greenhouse under controlled conditions, and the model plant used was Lolium perenne, also known as perennial ryegrass. Three different treatments were included in the experimental design: (1) a control soil that did not include any fertilizer, (2) soil that had standard phosphorus fertilizer (SPF), and (3) soil that contained ash-boosted phosphorus fertilizer (APF).

2.2. Soil and Ash Composition

The soil employed for this experiment was a sandy loam, which is typical of agricultural soils with a low natural phosphorus concentration. An analysis of the chemical composition of biomass ash, which included the amounts of phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg), was performed. The biomass ash was obtained from waste from agricultural production. Following that, the ash was combined with phosphorus fertilizer in a one-to-one proportion.

2.3. Microbial Analysis

Microbial biomass in the root zones was measured using phospholipid fatty acid (PLFA) analysis. Soil samples were collected at the beginning and end of the growing period to assess changes in microbial community composition. Additionally, soil enzyme activities, particularly phosphatase, were measured to evaluate microbial phosphorus mobilization potential.

2.4. Plant Growth and Phosphorus Uptake

Perennial ryegrass was grown for 12 weeks under controlled conditions. Plant height, biomass, and root length were recorded. Phosphorus uptake was measured by analyzing phosphorus content in plant tissues and soils using the molybdate blue method.

3. Results

3.1. Ash Composition and Effects on Soil Properties

The chemical analysis of ash revealed high concentrations of phosphorus (3%), calcium (25%), and potassium (10%). When mixed with phosphorus fertilizer, ash increased soil pH by 0.8 units, making the environment more conducive to microbial activity.

3.2. Microbial Biomass and Activity

Compared to the control and SPF treatments, the PLFA analysis revealed that the ash-boosted fertilizer treatment had a significantly higher level of microbial biomass than the other two treatments. A "powerhouse" impact on microorganisms was shown by the fact that the APF treatment resulted in a 45% increase in microbial biomass. There was a sixty per cent increase in phosphatase activity in the APF treatment compared to the SPF treatment, indicating that microbial activities were responsible for the increased phosphorus mobilization.

3.3. Phosphorus Mobilization and Uptake

It was shown that the availability of phosphorus in the soil increased significantly in the APF treatment compared to the SPF treatment. Phosphorus absorption by perennial ryegrass planted in soils enriched with ash was found to be thirty percent higher than that of plants grown in the SPF treatment throughout the twelve-week period. Root biomass and length were both increased in the APF treatment, which indicates an increase in the efficiency with which nutrients were absorbed.

4. Discussion

The results demonstrate that ash-boosted fertilizers can significantly enhance soil phosphorus mobilization through microbial activity. The increase in soil pH and essential minerals provided by ash creates a favourable environment for microbial growth, particularly phosphorus-solubilizing bacteria. The higher phosphatase activity in the APF treatment highlights the role of microbial processes in releasing bound phosphorus, making it available for plant uptake.

These findings have important implications for sustainable agriculture. By harnessing soil microbes' natural phosphorus solubilization capabilities, ash-boosted fertilizers offer a promising alternative to synthetic phosphorus fertilizers. This approach improves phosphorus use efficiency and reduces the environmental impact associated with phosphorus runoff.

5. Conclusion

A sustainable and environmentally acceptable answer to the problem of phosphorus deficiencies in agricultural soils is represented by ash-boosted fertilizers. According to the findings of this research, there is a possibility that the utilization of biomass ash might result in the formation of a microbial powerhouse inside the root zones of perennial ryegrass, therefore considerably boosting the mobilization and absorption of phosphorus. For future studies, it is important to investigate the long-term impacts of ash amendments on soil health and phosphorus cycling in various crop systems.

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