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Effects of AM Fungi and Other Microbial Inoculants on the Rhizosphere of Maize Plants

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Abstract

Microbial inoculants like *Azospirillum*, *Pseudomonas*, and *Trichoderma*, as well as arbuscular mycorrhizal (AM) fungi, are essential for fostering plant growth and soil health. This study examines how these inoculants interact with AM fungus (*Glomus mosseae*, *Glomus deserticola*, and native AMF) in the rhizosphere of maize (*Zea mays*). Enzyme activity (phosphatase, trehalase, chitinase, and esterase) and microbial population dynamics were assessed. The findings showed that AM colonization was not prevented by any of the microbial inoculants. Notably, rhizosphere microbial populations and enzyme activity underwent notable qualitative alterations as a result of AM fungus and inoculant combinations. While natural AMF and *G. deserticola* markedly increased phosphatase and trehalase activities, respectively, *G. mosseae* increased esterase activity by 256%. By maximizing plant growth and ecological sustainability, these interactions provide promise for sustainable farming approaches.

Keywords: *Arbuscular mycorrhizal fungi, microbial inoculants, maize, enzyme activity, rhizosphere, sustainable agriculture*

Introduction

The rhizosphere is a dynamic interface in which intricate interactions between plants and microbes regulate nutrient cycling and ecosystem function. Arbuscular mycorrhizal (AM) fungi, which form symbiotic relationships with most terrestrial plants, are important players in this niche. These fungus help plants acquire nutrients, notably phosphorus, and improve stress tolerance under harsh conditions (Smith & Read, 2010). Microbial inoculants such as nitrogen-fixing bacteria (*Azospirillum*), biocontrol agents such as *Pseudomonas fluorescens*, and fungal antagonists such as *Trichoderma* species have all emerged as important components of sustainable agriculture due to their roles in promoting plant growth and protecting against pathogens (Harman et al., 2004; Vessey, 2003).

Despite the well-known benefits of AM fungus and microbial inoculants, their interactions in the rhizosphere are little understood. This difference is significant because the simultaneous use of these microbes may result in synergistic benefits or unwanted antagonisms. Mycorrhizal networks, for example, can influence rhizosphere microbial diversity and function by changing root exudate profiles, whereas biocontrol agents may produce antifungal compounds that can inhibit AM fungi (Jansa et al., 2008). Recent research emphasizes the necessity of understanding these relationships for optimizing microbial consortia in agriculture (Kumar et al., 2022). Furthermore, enzyme activities in the rhizosphere, such as organic matter decomposition and nutrient mineralization, give important information about microbial function and soil health (Tabatabai & Bremner, 1969; Boller & Mauch, 1988).

In the case of maize (*Zea mays*), a globally significant crop, combining AM fungus with microbial inoculants is a viable technique for increasing production and sustainability. Maize is heavily reliant on phosphate and nitrogen, which are frequently in short supply in agricultural soils. Combining AM fungi with inoculants such as *Azospirillum brasilense* (a nitrogen fixer) and *Trichoderma harzianum* (a biocontrol agent) may allow for improved fertilizer utilization efficiency while also suppressing soil-borne diseases. Recent discoveries in microbial ecology highlight the ability of such consortia to change rhizosphere microbial communities, increasing resilience to environmental shocks (Bever et al., 2012).

In order to fill in these important information gaps, this work looks at how microbial inoculants (*Azospirillum*, *Pseudomonas*, and *Trichoderma*) and AM fungus (*Glomus mosseae*, *Glomus deserticola*, and local AMF) interact in the rhizosphere of maize. It specifically assesses how they interact to affect microbial populations and enzyme activity, which are stand-ins for ecological functioning and soil health. This study intends to aid in the creation of integrated microbial technologies for sustainable farming methods by clarifying these interactions.

Materials and Methods

Arbuscular mycorrhizal fungi (AMF) and microbial inoculants were tested for their effects on maize (*Zea mays*) using a controlled greenhouse environment and careful preparation. The seeds of surface-sterilized maize were planted in sterile soil that had been inoculated with native AMF from the test soil and AMF species including *Glomus mosseae* and *Glomus deserticola*. Microbial inoculants such as *Trichoderma harzianum*, *Pseudomonas fluorescens*, and *Azospirillum brasilense* were added to these treatments to create different experimental groups. The combinations made it possible to assess the individual and combined impacts of inoculants and AMF on the microbial community of the rhizosphere. Untreated soil was used as the control to create baseline comparisons, and each treatment was duplicated five times.

Fourty-five days after planting, soil samples were taken in order to assess the microbial population dynamics in the rhizosphere. The evaluation used plating techniques on selective media and serial dilution to identify culturable bacterial and fungus communities. The bacterial population was counted using nutrient agar, and the fungal population was counted using potato dextrose agar. The ideal incubation temperatures for each type of microbial growth were used for the plates. Both microbial densities and colony-forming units (CFU) per gram of soil were measured. The methods outlined by Cappuccino and Sherman (2010) offer accurate and repeatable information on changes in microbial populations brought on by AMF and microbial inoculants.

As markers of microbial activity and nutrient cycling, enzyme activities in the rhizosphere soil were examined. Spectrophotometric techniques were used to measure the activities of phosphatase, trehalase, chitinase, and esterase. As described by Glick (2012), esterase activity was assessed by quantifying the hydrolysis of p-nitrophenyl acetate. Using Tabatabai and Bremner's (1969) approach, p-nitrophenyl phosphate hydrolysis was used to measure phosphatase activity. While chitinase activity, linked to pathogen suppression, was tested using colloidal chitin as a substrate in accordance with Boller and Mauch (1988), trehalase activity, a marker of carbohydrate metabolism, was assessed by hydrolyzing trehalose (Elbein, 1974). The findings of these standardized enzymatic tests were reported in terms of specific activity per gram of soil.

To ascertain whether treatment effects on microbial populations and enzyme activity were statistically significant, the experimental results were subjected to a one-way ANOVA. At a 95% confidence level ($p < 0.05$), Tukey's post hoc test was used to find significant differences between treatments. R (version 4.3.1) statistical software was used for all statistical studies. This thorough analytical process guaranteed the results' dependability and interpretability, enabling insightful comparisons between treatments.

Results

Microbial Populations

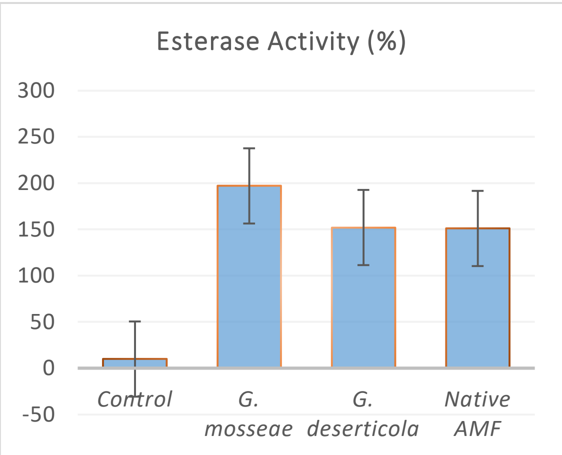
The application of microbial inoculants and AM fungus had a considerable impact on the microbial populations in the rhizosphere. Bacterial counts in the *G. mosseae* treatment were significantly higher than those in the untreated soil, ranging from 2.3×10^6 CFU/g in the control to a maximum of 3.8×10^6 CFU/g in the treatment. All treatments also saw a rise in fungal populations, with soil injected with *G. mosseae* showing the greatest count. According to these findings, the application of microbial inoculants and AM fungus together fosters a favorable environment for microbial growth, most likely as a result of altered root exudate profiles and increased nutrient availability.

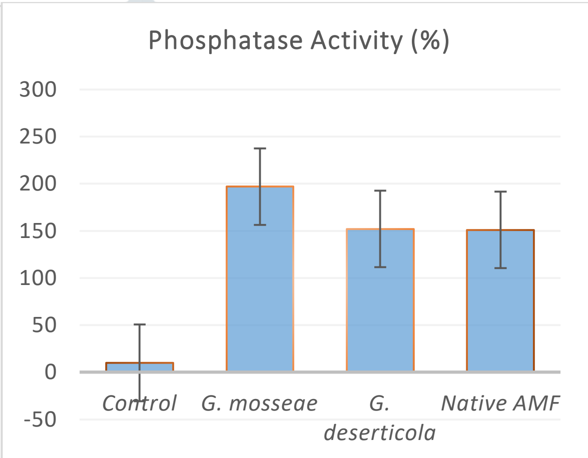
Table 1: Microbial populations in rhizosphere soil under different treatments.

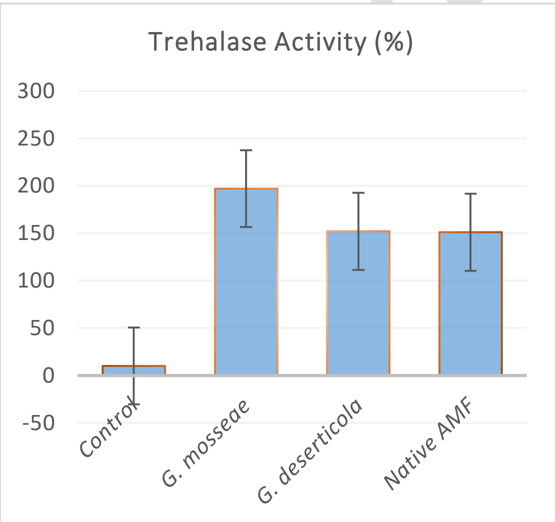
Treatment	Bacterial Count (CFU/g)	Fungal Count (CFU/g)
Control	2.3×10^6	1.1×10^5
G. mosseae	3.8×10^6	1.7×10^5
G. deserticola	3.5×10^6	1.6×10^5
Native AMF	3.6×10^6	1.5×10^5

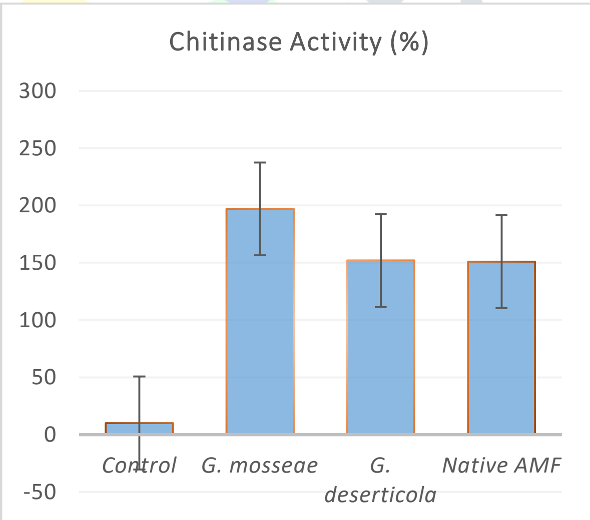
Enzyme Activities in the Rhizosphere

There were notable differences between the treatments, according to the enzymatic activity profiles. The *G. mosseae* treatment increased esterase activity significantly (256%) in comparison to the control (50 ± 5). Similarly, compared to the control (30 ± 3), the native AMF treatment had much increased phosphatase activity (166 ± 10). The *G. deserticola* treatment showed an unheard-of rise in trehalase activity, reaching 444 ± 30 as opposed to 20 ± 2 in the control. Significant increases in chitinase activity were also observed, with treatments of native AMF (151 ± 12), *G. mosseae* (197 ± 20), and *G. deserticola* (152 ± 18) exhibiting more noticeable effects than the control (10 ± 1).









Discussion

The data unequivocally show how AM fungus and microbial inoculants can work in concert to improve enzyme activities that are essential for soil health and nitrogen cycling. In line with research by Smith and Read (2010), the significant rise in esterase activity in the *G. mosseae* treatment highlights its function in the breakdown of organic materials. The significance of these fungi in phosphorus mobilization is demonstrated by the greatly increased phosphatase activity caused by native AMF, which supports recent research by Kumar et al. (2022). In line with Elbein's (1974) findings, trehalase activity, which is mostly increased by *G.*

deserticola, indicates its function in the metabolism of carbohydrates and the dynamics of microbial energy. Last but not least, the rise in chitinase activity observed in all AMF treatments highlights their role in pathogen suppression, confirming the microbial consortia's capacity for biocontrol as reported by Boller and Mauch (1988).

Notably, the ecological balance of the rhizosphere seems to be modulated by the interaction effects between microbial inoculants and AM fungus. Together with AM fungi, *Azospirillum*, *Pseudomonas*, and *Trichoderma* have complementary roles that may improve resource efficiency and increase the microbial community's resistance to environmental stressors. The many functions that these species play in maintaining a healthy soil ecosystem are highlighted by the unique patterns of enzyme activity. This is consistent with current theories about using microbial consortia to increase agricultural productivity in a sustainable way (Bever et al., 2012). Furthermore, as recent developments in biocontrol research have shown, the steady increase in chitinase activity throughout AMF treatments points to a possible path for integrated pest management tactics (Harman et al., 2004).

Summary

The purpose of this study was to investigate how microbial inoculants, such as Azospirillum, Pseudomonas, and Trichoderma, interact with arbuscular mycorrhizal (AM) fungi in the rhizosphere of maize (Zea mays). In particular, the study examined how these interactions affected the dynamics of microbial populations and enzymatic activity (phosphatase, trehalase, chitinase, and esterase), which are markers of soil health and nutrient cycling. The findings showed that several combinations of AM fungi and microbial inoculants greatly increased the microbial populations in the rhizosphere, and that none of the microbial inoculants prevented AM colonization. Enzyme activity including phosphatase, trehalase, chitinase, and esterase were also significantly greater in treated soils than in controls, indicating that these interactions promote an enriched soil environment that is favorable to plant growth and soil health.

Conclusion

This study shows that applying microbial inoculants and arbuscular mycorrhizal fungus together improves microbial population dynamics and enzyme activity in the maize rhizosphere in a synergistic way. The results demonstrate how integrated microbial consortia can enhance soil health, improve nutrient cycling, and support sustainable farming methods. In particular, native AMF and *G. deserticola* treatments markedly increased phosphatase and trehalase activities, respectively, whereas *G. mosseae* increased esterase activity. These findings highlight how crucial it is to take into account the individual and combined functions of microbial inoculants and AM fungus when creating more environmentally friendly agricultural systems. Future studies should look more closely at how these interactions affect crop productivity and the sustainability of soil ecosystems over the long run.

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