*Original Research Article*

# Impact of Potassium Inoculants and Biotite on Soil Microbial Population and Enzymatic Activity under Maize (*Zea Mays* L.) Cultivation in Gangetic Plains


## Abstract

The study explores the impact of potassium inoculants and black mica on soil microbial populations and enzymatic activity in maize cultivated soils. Microbial communities fueled by root exudates play essential roles in nutrient cycling, plant health, and soil structure. This study investigates the effects of potassium-solubilizing bacteria (KSB) and mineral potassium on microbial populations and enzymatic activity across different growth stages of maize. The experiment was conducted in randomized block design with 14 treatments, including combinations of KSB isolates, mineral potassium, and inorganic potassium. Microbial populations (bacteria, fungi, actinomycetes, and KSB) were quantified using serial dilution and plating techniques. Enzymatic activities (dehydrogenase, phosphatase, and urease) were assessed to understand nutrient interactions and microbial influences. The findings indicate that all treatments exhibited increased microbial populations compared to the control. Notably, treatment $T_{13}$ (75% recommended potassium dose + 25% potassium from Biotite + OVPS 05) consistently demonstrated the highest microbial growth. The presence of KSB appeared crucial in enhancing bacterial and fungal populations. Additionally, enzymatic activities were significantly influenced by treatments, with $T_{13}$ showing the highest dehydrogenase, alkaline phosphatase, and urease activities. These results suggest that the combination of KSB isolates and mineral potassium contributes to enhanced microbial populations and soil enzymatic activities, offering insights into sustainable agriculture practices that balance productivity and soil health. The study sheds light on the intricate relationships between microorganisms, nutrients, and soil biochemical processes, providing valuable guidance for future agricultural strategies.



**Keywords:** Dehydrogenase; microorganisms; root exudates andsustainable agriculture.


## Introduction

In the context of modern agriculture's pursuit of sustainability, understanding the intricate dynamics within the rhizosphere – the soil region influenced by plant roots – has become a focal point [1]. This microcosmic realm is a hub of activity, driven by microbial communities fueled by root exudates. These microorganisms play a crucial role in nutrient cycling, plant health, and soil structure [2]. Among the various factors shaping rhizosphere dynamics, the application of beneficial microorganisms and essential nutrients has garnered attention. Maize, a global staple crop with intricate root systems, offers insights into rhizosphere interactions. The rhizosphere acts as a dynamic interface where biochemical exchanges occur between roots and soil [3]. This dynamic interaction shapes microbial communities that impact nutrient availability, disease resistance, and plant growth. Notably, potassium-solubilizing bacteria (KSB) play a significant role by liberating fixed potassium from soil minerals, enhancing its accessibility to plants. Additionally, mineral potassium, a vital macronutrient, influences plant growth and soil enzyme activities. Microbial

communities and soil biochemical processes in the rhizosphere are far from static, changing with the plant's growth stages [4]. As maize progresses through germination, vegetative growth, reproduction, and maturation, shifts in root exudate composition trigger changes in microbial diversity and enzymatic activities. These shifts have profound implications for nutrient cycling, organic matter decomposition, and overall soil health. Within the rhizosphere's microbial tapestry, KSB form a niche community with a substantial impact on nutrient availability. These microorganisms release potassium ions from mineral structures, facilitating its uptake by plants. KSB's activities might indirectly influence other microbes by altering the rhizosphere's chemical environment through metabolic processes. Simultaneously, mineral potassium affects soil enzymatic activities through its influence on microbial metabolic processes. Enzymes, pivotal for nutrient cycling, are influenced by the availability of mineral potassium [5]. Maize's journey through growth stages introduces physiological and metabolic shifts that echo through the rhizosphere. Each stage contributes varying root exudate compositions, offering substrates for microbial utilization. These inputs trigger dynamic shifts in microbial communities and enzymatic activities, shaping nutrient cycling, soil structure, and organic matter decomposition.

The study's aim is to unravel the effects of KSB isolates and mineral potassium on microbial populations and soil enzymatic activity in the maize rhizosphere across growth stages. This exploration seeks to elucidate the relationships between microorganisms, nutrient availability, and soil biochemical processes. The implications extend to sustainable agriculture, where fine-tuning microbial interventions and nutrient management could enhance productivity and soil health [6]. The maize rhizosphere serves as a dynamic stage where microbial communities, potassium availability, and soil enzymatic activities interact, influencing plant health and ecosystem dynamics [7,8]. This study investigates the interplay of KSB isolates, mineral potassium, microbial populations, and enzymatic processes as maize progresses through growth phases. The outcomes hold promise for redefining our understanding of plant-soil-microbe interactions, offering new pathways for sustainable agricultural approaches that balance productivity and environmental stewardship.

## MATERIALS AND METHODS

An experiment with potassium solubilizing bacteria and doses of inorganic K as well as mineral K (Biotite) was being carried out at Agricultural Research Farm, BHU during the *Kharif* season taking Maize as a test crop. The experiment was carried out with 14 treatments (table 1) and replicated thrice in randomized block design. The initial status of soil properties was given in table 2. In order to assess the microbial population in the soil, composite samples were created by combining soil samples from different treatment plots. The quantification of total bacteria, fungi, actinomycetes, and KSB was carried out through a serial dilution and plating method [9]. Initially, the soil was serially diluted, and then each dilution was plated onto petri plates containing appropriate growth media. After incubation, microbial colonies were counted based on distinct morphological characteristics. Bacterial colonies with slimy, shiny, and smooth characteristics were considered as bacteria, while fungal colonies were identified by their cottony appearance. Actinomycetes colonies

displayed concentric rings with a star-like pattern. KSB colonies were recognized by the halo zone around them.

**Table 1. Detail of Treatments**

| Treatment combinations | Notation |
|---|---|
| Control | $T_1$ |
| OVPS 05 | $T_2$ |
| OVPS 07 | $T_3$ |
| 50% RDK | $T_4$ |
| 75% RDK | $T_5$ |
| 100% RDK | $T_6$ |
| 50% RDK + 50% RDK through Biotite | $T_7$ |
| 75% RDK + 25% RDK through Biotite | $T_8$ |
| 50% RDK + 50% RDK through Biotite + OVPS 05 | $T_9$ |
| 50% RDK + 50% RDK through Biotite + OVPS 07 | $T_{10}$ |
| 50% RDK + 25% RDK through Biotite + OVPS 05 | $T_{11}$ |
| 50% RDK + 25% RDK through Biotite + OVPS 07 | $T_{12}$ |
| 75% RDK + 25% RDK through Biotite + OVPS 05 | $T_{13}$ |
| 75% RDK + 25% RDK through Biotite + OVPS 07 | $T_{14}$ |

The counts were expressed as colony-forming units (CFUs) per gram of oven-dried soil, calculated by multiplying the CFUs with the dilution factor. This method provided insights into the density of microbial populations in the soil across different treatment conditions. Soil enzymatic activities in the context of microbial dynamics and nutrient availability.

**Table 2. Initial physico-chemical properties of experimental field soil**

| Soil properties | Initial values |
|---|---|
| pH | 6.7 |
| EC ($dSm^{-1}$) | 0.33 |
| Organic carbon (%) | 0.37 |
| Available N ($kg\ ha^{-1}$) | 188.12 |
| Available P ($kg\ ha^{-1}$) | 14.92 |
| Available K ($kg\ ha^{-1}$) | 244.48 |

Three specific enzyme activities were investigated: dehydrogenase, phosphatase, and urease. Dehydrogenase, a catalyst in respiration, was evaluated through the Triphenyl Tetrazolium Chloride (TTC) method. Air-dried soil samples were combined with TTC and water, incubated at 37°C for 24 hours, and the resultant Triphenyl Tetrazolium Formazan (TTF) was quantified spectrophotometrically at 485 nm. Phosphatase activity, indicating phosphomonoesterase function, was determined by measuring p-nitrophenol release when soil was incubated with a sodium p-nitrophenyl phosphate solution at pH 11. The $CaCl_2$-NaOH treatment stopped enzymatic activity and enabled accurate p-nitrophenol recovery. Lastly, urease activity, relating to urea hydrolysis, was gauged by comparing added and

recovered urea concentrations after soil incubation. These enzymatic assessments collectively illuminate soil biochemical processes, microbial influences, and nutrient interactions.Statistical analysis of data was carried out using ANOVA and further comparisons were made with the critical difference (CD) at 5% degree of significance to draw the valid differences among the treatments[10].

## Result and Discussion

### *Soil bacterial population*

The study evaluates the effects of KSB isolates and mineral potassium on bacterial populations during distinct growth phases of maize cultivation (figure 1), reveal that all treatments yield higher bacterial populations compared to the control. Notably, treatment $T_{13}$ (75% RDK + 25% RDK *via* Biotite + OVPS 05) consistently exhibits the most substantial bacterial increase at 30 DAS, 60 DAS, and harvest stages, outperforming other treatments. Moreover, bacterial populations follow an increasing trend from 30 DAS to 60 DAS before declining at harvest. The presence of KSB appears pivotal in achieving improved outcomes, potentially due to biotite potassium solubilization, corroborating earlier studies [11,12, 13].

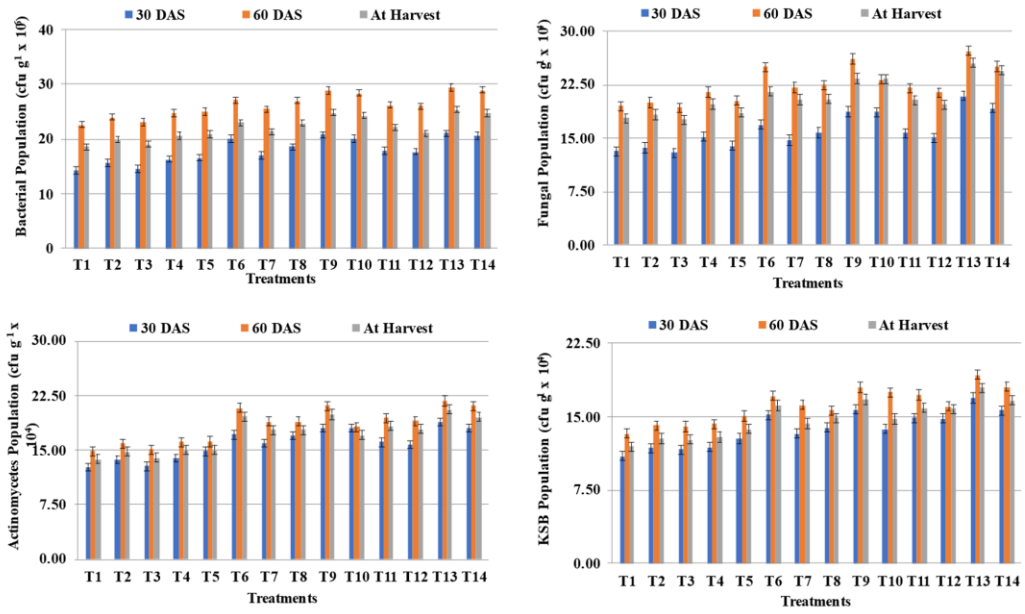


**Fig. 1: Effect of potassium inoculants and biotite on soil microbial population of maize cultivated soils**

### *Soil fungal population*

All treatments exhibited higher fungal populations than the control, with $T_{13}$ (75% RDK + 25% RDK through Biotite + OVPS 05) and $T_{14}$ (75% RDK + 25% RDK through Biotite + OVPS 07) consistently showing the highest populations (figure 1). Fungal populations increased from 30 to 60 days after sowing and then decreased at harvest. Notably, T13 stood out as the most effective treatment throughout the maize growth periods, emphasizing the

role of mineralization in enhancing eukaryotic cell proliferation in rhizospheric soil, which aligns with [14,15].

***Soil actinomycetes population***

All treatments exhibit higher actinomycetes populations than the control, with $T_{13}$ (75% RDK + 25% RDK through Biotite + OVPS 05) consistently showing the most significant enhancement across growth stages (Figure 1). Notably, at 30 DAS, $T_{13}$ and $T_9$ (50% RDK + 50% RDK through Biotite + OVPS 05) stand out; at 60 DAS and harvest, $T_6$, $T_9$, $T_{13}$, and $T_{14}$ demonstrate higher populations. Actinomycetes populations peak at 60 DAS and decline by harvest. The synergistic KSB co-inoculation effect in $T_{13}$ promotes heightened microbial density, paralleling findings by [16]

**Population of KSB**

The application of $T_{13}$ (75% RDK + 25% RDK through Biotite + OVPS 05) consistently displaying superior results across stages like 30 DAS, 60 DAS, and harvest (Fig. 1). Notably, the KSB population showed an increasing trend from 30 DAS to 60 DAS, followed by a decline at harvest, consistent with findings by [17,18] highlighting the potential benefits of waste mica bio-intervention in enhancing rhizosphere effects.

**Soil enzymatic activity**

**Dehydrogenase activity**

The influence of KSB isolates and mineral potassium on dehydrogenase activity in the rhizospheric soil of maize plants during different growth periods (Fig. 2). Across these stages, all treatments exhibit higher dehydrogenase activity compared to the control.

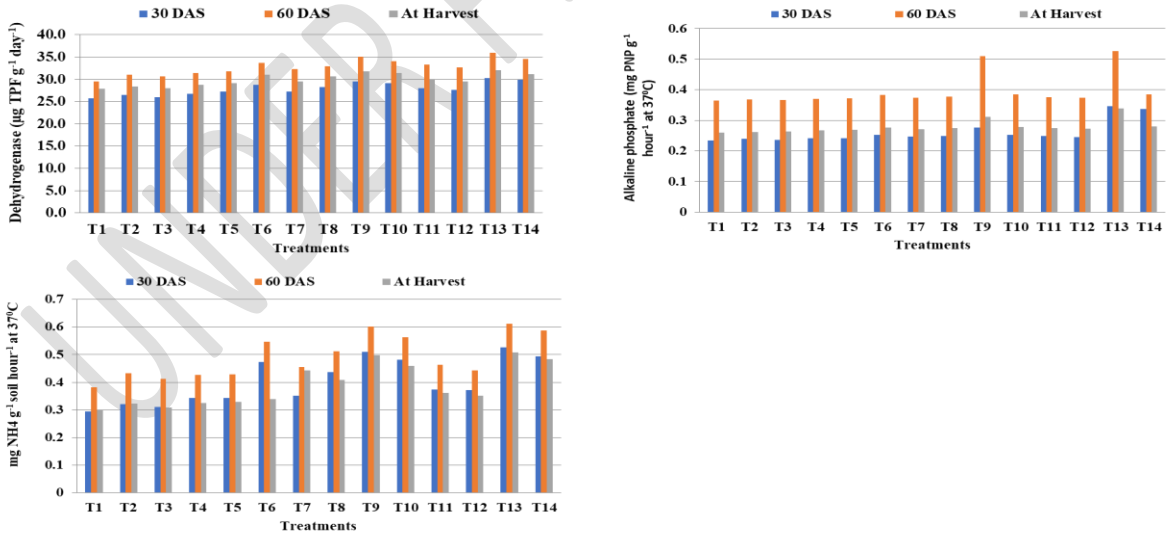


**Fig. 2: Effect of potassium inoculants and biotite on soil enzymatic activity of maize cultivated soils**

Particularly noteworthy is treatment $T_{13}$, involving a combination of 75% recommended potassium dose, 25% potassium from Biotite, and OVPS 05, which demonstrates the highest

dehydrogenase activity at various stages, suggesting increased microbial activity due to enhanced potassium fertilizer doses. This parallels findings from [19,20] on microbial impacts on rhizospheric dehydrogenase activity. At 60 DAS, $T_{13}$ and $T_9$ showcase notable activity, and dehydrogenase activity generally increases from 30 DAS to 60 DAS before declining at maize crop harvest. Additionally, the findings correlate with [21] observations regarding dehydrogenase activity variations in different farming systems. Overall, the study underscores the role of KSB and potassium in influencing soil microbial activities and nutrient transformations, as indicated by dehydrogenase enzyme activity [22].

**Phosphatase activity**

The treatments involving potassium application through biotite led to increased alkaline phosphate activity, with treatment $T_{13}$ (75% recommended potassium dose + 25% potassium through Biotite + OVPS 05) consistently exhibiting the highest activity throughout the growth periods (fig.2). This effect was attributed to microbial-induced root exudates and biochemical changes. The observed trend of increasing alkaline phosphate activity from 30 to 60 days after sowing, followed by a decline at harvest, aligns with previous research findings in maize rhizospheric systems [23].

**Urease activity**

All the treatments exhibit higher urease activity compared to the control, with treatments involving RDK fertilizer through biotite and K-solubilizing bacteria showing the highest activity (fig. 2). Notably, $T_{13}$ and $T_{14}$ treatments at harvest display the greatest urease activity, attributed to increased root exudate secretion fostering heightened microbial activity in the rhizosphere. This study underscores the significant impact of experimental treatments on rhizosphere enzyme activity and microbial dynamics, emphasizing the role of nutrient supply and root exudates in enhancing soil microorganism populations [24].

**Conclusion**

In the study investigating the impact of potassium inoculants and black mica on soil microbial population and enzymatic activity in maize cultivated soils, significant findings emerged. The experiment examined 14 treatments, including different potassium sources, and evaluated microbial populations and enzymatic activities across distinct growth stages. Notably, treatments incorporating potassium-solubilizing bacteria and mineral potassium through biotite consistently displayed elevated microbial populations compared to the control. Treatment $T_{13}$, involving 75% recommended potassium dose, 25% potassium via biotite, and KSB, stood out as particularly effective. This treatment exhibited enhanced bacterial, fungal, actinomycetes, and KSB populations. Dehydrogenase, alkaline phosphate, and urease activities were significantly higher in treatments involving biotite and KSB, with $T_{13}$ showing superior enzyme activity. These findings underscore the interconnectedness of microbial dynamics, nutrient availability, and enzymatic processes in the rhizosphere, offering insights for advancing sustainable agricultural practices.

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