Biosciences
reports

JOURNAL OF BIOSCIENCES REPORTS

VOL: 01 ISSUE: 01

http://biosciencesreports.com

MAIZE GROWTH AND YIELD PERFORMANCE WITH THE APPLICATION OF PLANT GROWTH-PROMOTING RHIZOBACTERIA

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Abstract. *Plant growth-promoting rhizobacteria (PGPR) play a pivotal role in improving the crop productivity and soil health through several mechanisms, counting nutrient solubilization, hormone production and improved soil structure. This research trial intended to appraise the effects of diverse PGPR strains on maize progression, yield and soil properties. Field experimentations were carried out to assess the impact of Pseudomonas fluorescens, Pseudomonas putida, Azospirillum lipoferum, Bacillus polymyxa and Bacillus fimosus on key agronomic parameters. The results validated that PGPR application significantly improved root and shoot biomass, plant height and maize yield equated to control. Among the tried strains, Pseudomonas fluorescens, Pseudomonas putida and Azospirillum lipoferum were the most effective leading to substantial upsurges in maize productivity. Additionally, PGPR treatments boosted soil porosity and reduced bulk density signifying their role in improving soil structure. These outcomes advocate that PGPR can function as a justifiable alternative to conventional fertilizers, promoting maize growth while maintaining soil health.*

Keywords: *PGPR (Plant Growth-Promoting Rhizobacteria), maize growth, soil health, sustainable agriculture, microbial inoculants*

INTRODUCTION

Maize (*Zea mays L.*) is imperatice cereal crop worldwide, ranking third after wheat and rice in terms of production and consumption. Maize yields have significantly declined due to various factors, including nutrient depletion and declining soil fertility [1]. The continuous degradation of soil quality, coupled with limited access to chemical fertilizers, has posed a major challenge for smallholder farmers, who form the backbone of maize production in the region. Sustainable agricultural practices are therefore essential to enhance maize productivity while maintaining soil health.

PGPR have emerged as a promising biological alternate to synthetic fertilizers for improving crop yield and soil fertility [2]. PGPR are valuable bacteria that inhabit plant roots and augment plant growth through various mechanisms, comprising nutrient solubilization, hormone production and biological control of pathogens [3,4]. Although the particular mechanisms underlying PGPR-mediated plant growth promotion are not fully implicit [5], several studies have demonstrated their ability to enhance nutrient uptake by facilitating nitrate assimilation, phosphate solubilization and iron chelation [4,6].

Previous studies have reported that maize seeds immunized with *Pseudomonas cepacia*, *P. fluorescens* and *Streptomyces aurantiacus*, in combination with nitrogen fertilization (120 kg/ha), resulted in a 25% yield increase compared to non-inoculated controls [7]. Additionally, the synergistic effect of PGPR and nitrogen fertilization was found to enhance maize yield by 60% compared to PGPR inoculation alone [8]. This suggests that PGPR not only improve nutrient availability but also contribute to the production of beneficial ancillary metabolites i.e. antibiotics, enzymes and antifungal compounds, which enhance plant resilience against biotic and abiotic stresses [6,7,9].

Despite the potential of PGPR as biofertilizers, their application in maize cultivation under field conditions in Benin remains largely unexplored. The lack of field-based studies has limited the ability of local scientists and farmers to harness PGPR for sustainable maize production. Given the financial constraints faced by smallholder farmers in Benin, PGPR-based biofertilizers offer an economical and environmentally friendly substitute to straight fertilizers.

This study aims to bridge this knowledge gap by (i) characterizing maize-specific PGPR and (ii) identifying the most effective PGPR inoculation strategies for improving maize growth and productivity in soils. The outcomes of this exploration will contribute to the development of sustainable agricultural practices and provide valuable insights into the potential of PGPR as a biofertilization strategy for maize production.

Materials and Methods

Study Area and Experimental Site

This trial was conducted at the experimental fields of the Arid Zone Research Center in southern KP. The site experiences arid climate with monson rainy and dry seasons, receiving an average annual precipitation of 250 mm. Rainfall is distributed over two months (July to August), with peak precipitation in July. The mean annual temperature is approximately 32°C. The soil is characterized as calcareous with a pH of 8.2. Organic matter content is 0.59% and available phosphorus is 12.5 ppm. Exchangeable cations include potassium (108 ppm), calcium (7.7 meq/100 g) and magnesium (2.7 meq/100 g).

Rhizobacterial Inoculum Preparation and Maize Seed Treatment

The Plant Growth-Promoting Rhizobacteria (PGPR) used in the investigation are enumerated in Table 1. PGPR inoculum was prepared in Luria-Bertani (LB) growth medium and incubated under optimal conditions for each bacterial strain: *Pseudomonas* spp. at 28–30°C, *Bacillus* spp. at 37°C and *Azospirillum* spp. at 30°C. Bacterial cultures were grown for 24 hours to reach a final concentration of approximately 10^8 CFU/ml before use for maize seed inoculation.

Maize seeds of the variety Shahenshaw were used for the experiment. The field research was organized in a randomized block design with three replicates. The treatments comprised of 06 PGPR-inoculated maize seed groups and an uninoculated control, making a total of 07 treatment groups. Each field plot measured 4 m × 3.2 m (12.8 m^2), with four planting rows per plot. Maize seeds were inoculated by immersing them in the prepared bacterial suspensions before sowing. Double seeds were planted per hole at a depth of 5 cm, with a row space of 0.75 m and an intra-row space of 0.40 m, resulting in a planting density of 31,250 plants/ha.

Table 1. PGPRs Used in The Investigation

PGPR Strains
Pseudomonas putida
Pseudomonas aeruginosa
Pseudomonas fluorescens
Azospirillum lipoferum
Bacillus polymyxa
Bacillus fimosus

3.4 Data Collection and Measurement

To evaluate the effects of PGPR inoculation on maize progression and yield, plant height and the quantity of leaves were recorded. Ten arbitrarily selected plants per treatment were measured. At harvest (87 DAS), root and shoot biomass were also noted.

- **Plant Height Measurement:** Height was measured from the soil surface to the tip of the highest fully emerged leaf (>50% exposure).
- **Biomass Measurement:** Roots and shoots were separated, oven-dried at 70°C for 72 hours and weighed to determine dry biomass.

3.5 Statistical Analysis

Statistical scrutiny was executed using analysis of variance (ANOVA), bearing in mind inoculum treatment as a static factor and replication as a arbitrary factor. Least square means were extracted for each of the 06 PGPR treatments, followed by numerical classification [10] to group rhizobacteria based on their morphological growth effects on maize.

Results

Effect of PGPR on Root Fresh Weight

The application of different PGPR pointedly influenced root fresh weight (Figure 1). Compared to the control (CTRL), all PGPR-treated maize plants exhibited an increase in root fresh weight. Among the bacterial treatments, *Pseudomonas* sp. demonstrated the highest root fresh weight, followed closely by *Azospirillum lipoferum*. Treatments with *Bacillus polymyxa* and *Bacillus* *fimosus* resulted in moderate increases, while the control group had the bottommost root fresh weight.

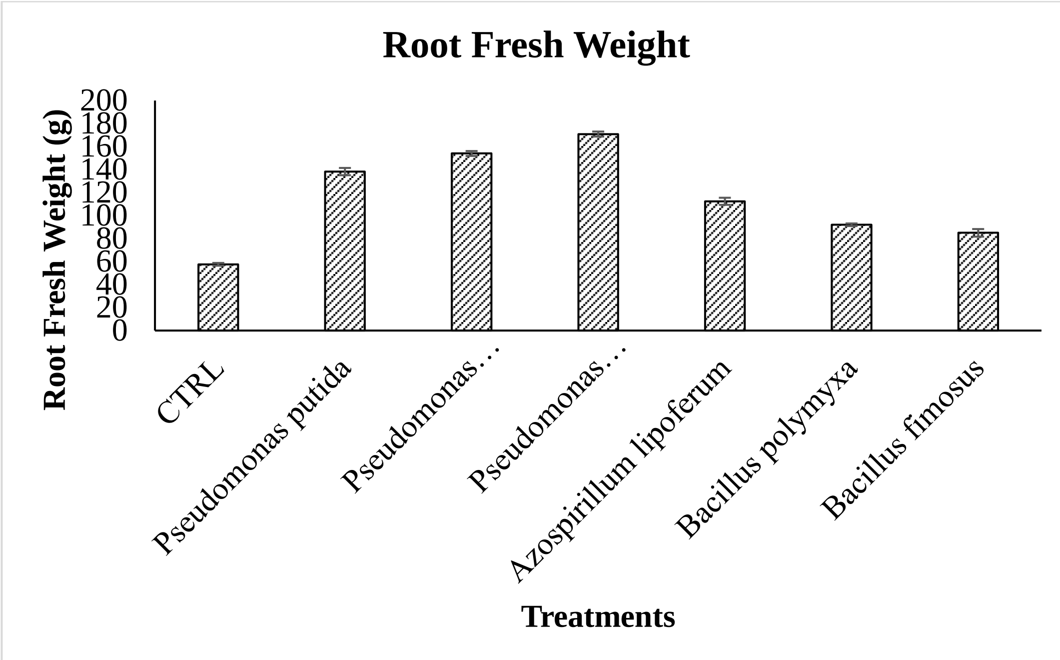

Figure 1. Effect of PGPR on Root Fresh Weight

Effect of PGPR on Shoot Fresh Weight

PGPR treatments had a positive impact on shoot fresh weight (Figure 2). Maize plants inoculated with *Pseudomonas fluorescens* exhibited the highest shoot fresh weight, surpassing the control significantly. *Azospirillum lipoferum* and *Pseudomonas putida* also demonstrated notable increases in shoot fresh weight, while *Bacillus polymyxa* and *Bacillus fimosus* treatments showed relatively moderate improvements compared to the control.

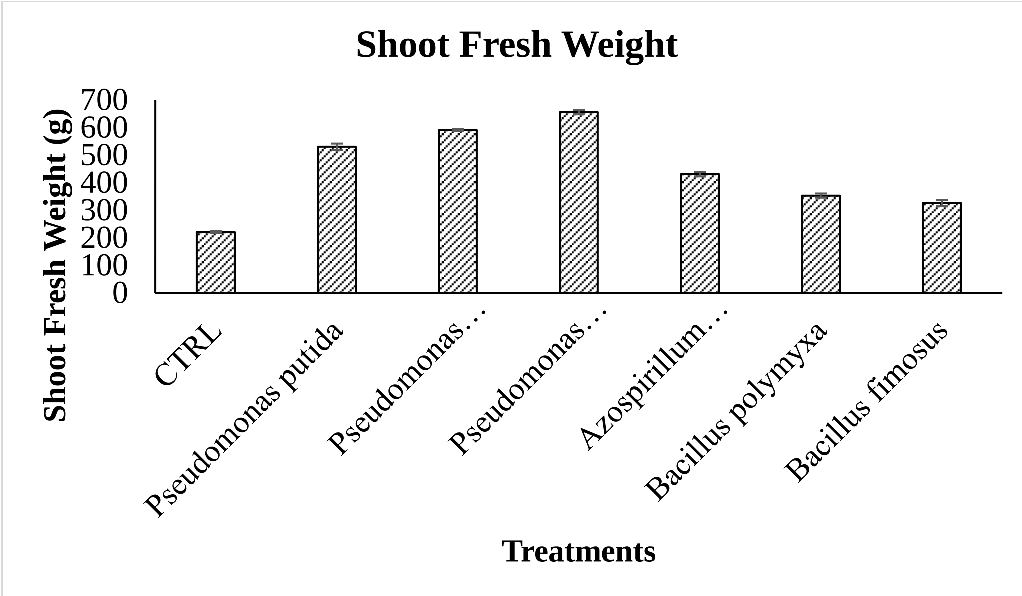

Figure 2. Effect of PGPR on Shoot Fresh Weight

Effect of PGPR on Plant Height

A momentous increase in maize plant height was observed in PGPR-inoculated plants equated to the control (Figure 3). *Pseudomonas fluorescens* and *Pseudomonas putida* treatments resulted in the tallest plants, followed by *Azospirillum lipoferum*. *Bacillus polymyxa* and *Bacillus fimosus* treatments produced shorter plants, although they were still taller than the control group.

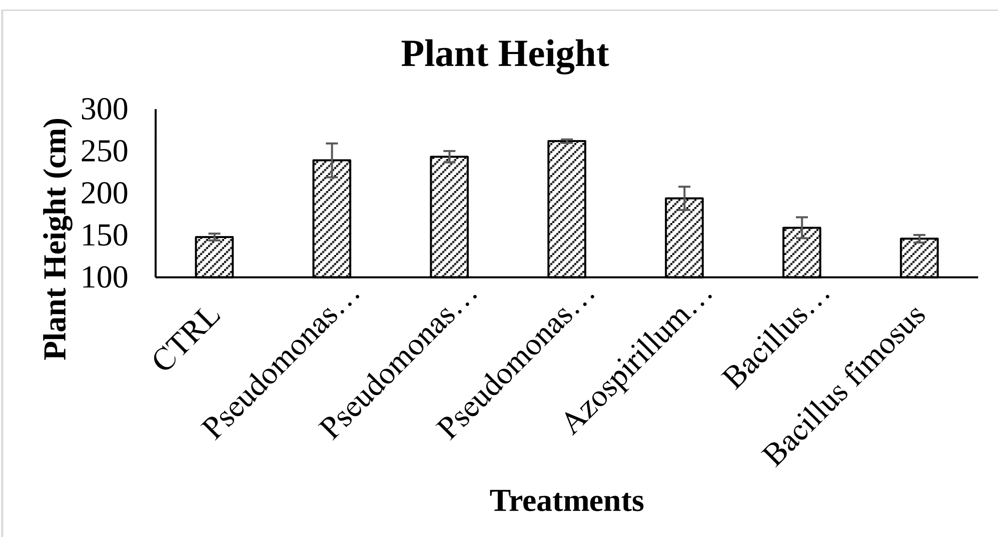

Figure 3. Effect of PGPR on Plant Height

Effect of PGPR on Maize Yield

Maize yield was significantly influenced by PGPR treatments (Figure 4). The highest maize yield was noted in plants treated with *Pseudomonas fluorescens*, trailed by *Pseudomonas putida* and *Azospirillum lipoferum*. While *Bacillus polymyxa* and *Bacillus fimosus* resulted in moderate yield increases, the control group exhibited the lowest yield.

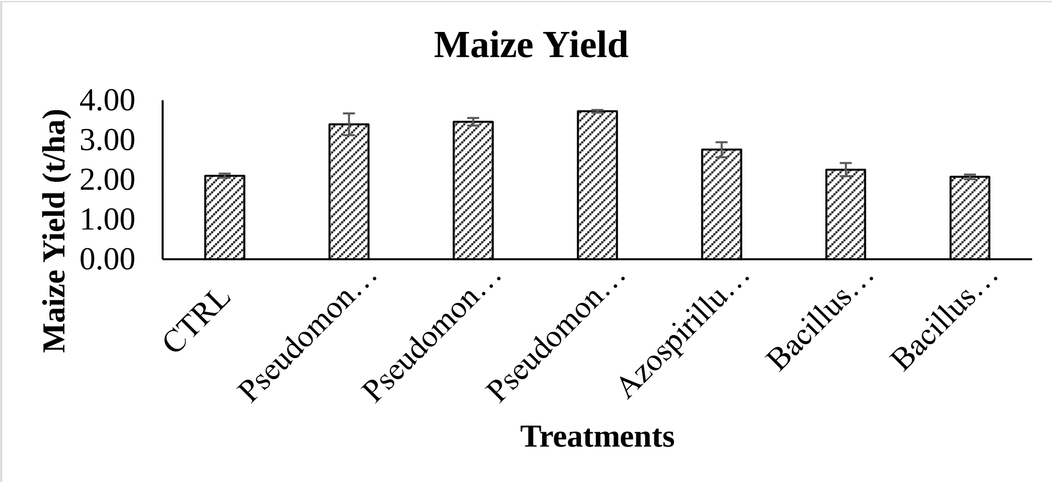

Figure 4. Effect of PGPR on Maize Yield

Effect of PGPR on Soil Porosity

Soil porosity was significantly enhanced by PGPR application (Figure 5). The control treatment had the lowest soil porosity, while inoculation with *Pseudomonas* sp. and *Azospirillum lipoferum* resulted in the highest porosity values. *Bacillus polymyxa* and *Bacillus fimosus* also improved soil porosity, albeit to a lesser extent compared to *Pseudomonas* sp. and *Azospirillum lipoferum*.

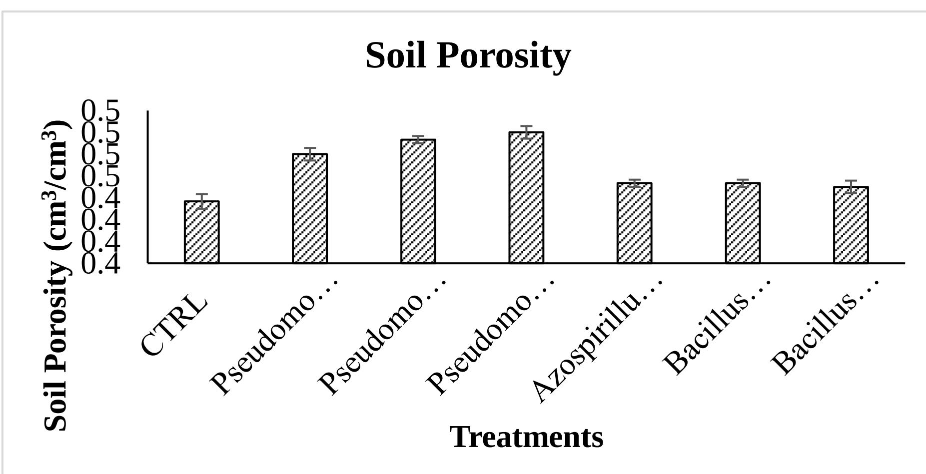

Figure 5. Effect of PGPR on Soil Porosity

Effect of PGPR on Soil Bulk Density

Soil bulk density was significantly reduced by PGPR treatments (Figure 6). The control plot exhibited the highest bulk density, whereas treatments with *Pseudomonas fluorescens*, *Pseudomonas putida* and *Azospirillum lipoferum* resulted in the lowest bulk density values. *Bacillus polymyxa* and *Bacillus fimosus* also contributed to a reduction in soil bulk density but were less effective compared to *Pseudomonas* sp. and *Azospirillum lipoferum*.

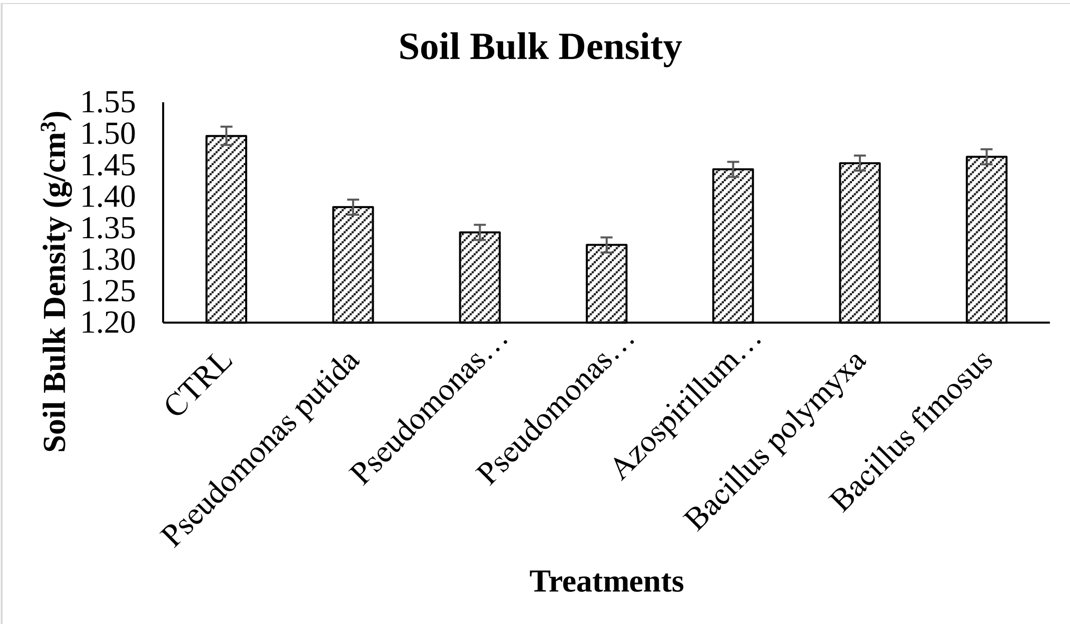

Figure 6. Effect of PGPR on Soil Bulk Density

Discussion

The outcomes of this study demonstrate the weighty role of PGPR in enhancing maize growth, yield and soil properties. Inoculation of maize with PGPRs, particularly *Pseudomonas fluorescens*, *Pseudomonas putida* and *Azospirillum lipoferum*, resulted in substantial improvements in root and shoot biomass, plant height and overall crop productivity. These results align with previous research indicating that PGPRs facilitate plant growth over numerous mechanisms, counting nutrient solubilization, phytohormone production and improved soil structure [4,11,12].

Effect of PGPR on Maize Performance

A noteworthy upsurge in plant growth parameters observed in PGPR-treated plants suggests that these bacteria play a central role in promoting maize development. The highest values noted for these parameters in *Pseudomonas fluorescens, Pseudomonas putida* and *Azospirillum lipoferum* treatments suggest that these strains are particularly effective in upsurging maize growth. These outcomes are dependable on reports by Mohanty et al. [13], who demonstrated the positive special effects of *Azospirillum lipoferum* and Pseudomonas spp. on maize biomass production.

Maize yield increase following PGPR inoculation further supports them as potent biofertilizers. The significant yield enhancement observed in plants treated with *Pseudomonas fluorescens*, *Pseudomonas putida* and *Azospirillum lipoferum* highlights their capability to improve nutrient uptake particularly nitrogen, phosphorus and potassium that are essential for crop productivity [14,15]. These results confirm that specific PGPRs have a species-dependent effect on crop improvement emphasizing the importance of selecting appropriate bacterial strains for targeted applications.

Impact of PGPR on Soil Properties

The observed improvements in soil porosity and reductions in soil bulk density indicate that PGPRs contribute to better soil structure. *Pseudomonas fluorescens*, *Pseudomonas putida* and *Azospirillum lipoferum* treatments resulted in the highest soil porosity and lowest bulk density values, suggesting their role in enhancing soil aeration and water infiltration. These outcomes are in settlement with Mahapatra et al. [16], who reported that PGPR application improves soil health by altering soil texture and structure.

Treatments with Bacillus polymyxa and Bacillus fimosus showed moderate improvements in soil properties indicating that not all PGPRs isolated from maize rhizosphere add equally to soil conditioning. This finding supports a notion that PGPR effects are strain-specific and that careful selection is required to optimize benefits for both plant and soil health [17].

Mechanisms of PGPR-Induced Growth Promotion

The positive effects of *Pseudomonas fluorescens*, *Pseudomonas putida* and *Azospirillum lipoferum* on maize growth and yield attributed to several contrivances, comprising nitrogen fixation, phosphorus solubilization and manufacture of plant growth regulators i.e. auxins and gibberellins. *Azospirillum* sp. has been previously reported to enhance plant height and biomass by producing indole-3-acetic acid (IAA) that promotes root elongation and nutrient absorption [18]. Similarly, *Pseudomonas* spp. have been shown to increase nutrient obtainability by solubilizing phosphate and increasing nitrogen uptake efficiency [19].

Interestingly, certain PGPR strains such as *Bacillus fimosus* and *Bacillus polymyxa* exhibited limited or negative impacts on shoot biomass and root development. These outcomes propose that while some PGPRs promote plant growth, others may compete with the plant for resources or produce metabolites that hinder plant development.

Conclusion and Future Implications

This study provides strong evidence supporting the role of *Pseudomonas fluorescens*, *Pseudomonas putida* and *Azospirillum lipoferum* as effective PGPRs for maize crop improvement. The observed enhancements in growth parameters, yield and soil properties highlight their potential as sustainable alternatives to chemical fertilizers. However, further exploration is desired to investigate the long-term impacts of PGPR application under diverse agro-climatic conditions and soil types.

Future studies should also explore the synergistic effects of PGPR combinations to enhance their efficacy. Additionally, the development of commercial biofertilizers incorporating these beneficial strains could contribute to sustainable agriculture and food security by reducing reliance on synthetic fertilizers while maintaining high crop productivity.

These findings pave the way for broader application of PGPRs in maize production systems and reinforce the need for targeted microbial inoculants that cater to specific crop and soil requirements.

References

- Galani YJH, Ligowe IS, Kieffer M, Kamalongo D, Kambwiri AM, Kuwali P, Thierfelder C, Dougill AJ, Gong YY, Orfila C. Conservation agriculture affects grain and nutrient yields of maize (Zea mays L.) and can impact food and nutrition security in Sub-Saharan Africa. Front. Nutr. 2022;8:804663.
- Basu A, Prasad P, Das SN, Kalam S, Sayyed RZ, Reddy MS, El Enshasy H. Plant growth promoting rhizobacteria (PGPR) as green bioinoculants: recent developments, constraints and prospects. Sustainability. 2021;13(3):1140.
- Aloo BN, Tripathi V, Makumba BA, Mbega ER. Plant growth-promoting rhizobacterial biofertilizers for crop production: the past, present and future. Front. Plant Sci. 2022;13:1002448.
- Chandran H, Meena M, Swapnil P. Plant growth-promoting rhizobacteria as a green alternative for sustainable agriculture. Sustainability. 2021;13(19):10986.
- Shah A, Nazari M, Antar M, Msimbira LA, Naamala J, Lyu D, Rabileh M, Zajonc J, Smith DL. PGPR in agriculture: A sustainable approach to increasing climate change resilience. Front. Sustain. Food Syst. 2021;5:667546.
- Hasan A, Tabassum B, Hashim M, Khan N. Role of plant growth promoting rhizobacteria (PGPR) as a plant growth enhancer for sustainable agriculture: A review. Bacteria. 2024;3(2):59-75.
- Mun BG, Hussain A, Park YG, Kang SM, Lee IJ, Yun BW. The PGPR *Bacillus aryabhattai* promotes soybean growth via nutrient and chlorophyll maintenance and the production of butanoic acid. Front. Plant Sci. 2024;15:1341993.
- Dhayalan V, Karuppasamy S. Plant growth promoting rhizobacteria in promoting sustainable agriculture. Glob. J. Environ. Sci. Manag. 2021;7(3):1-18.
- Upadhyay SK, Rajput VD, Kumari A, Espinosa-Saiz D, Menendez E, Minkina T, Dwivedi P, Mandzhieva S. Plant growth-promoting rhizobacteria: a potential bio-asset for restoration of degraded soil and crop productivity with sustainable emerging techniques. Environ. Geochem. Health. 2023;45(12):9321-44.
- Zdaniuk B. Ordinary least-squares (OLS) model. In: Encyclopedia of quality of life and well-being research. Cham: Springer Int. Publ.; 2024. p. 4867-69.
- Chaudhary P, Xu M, Ahamad L, Chaudhary A, Kumar G, Adeleke BS, Verma KK, Hu DM, Širić I, Kumar P, Popescu SM. Application of synthetic consortia for improvement of soil

fertility, pollution remediation and agricultural productivity: a review. Agronomy. 2023;13(3):643.

- Masmoudi F, Alsafran M, Jabri HA, Hosseini H, Trigui M, Sayadi S, Tounsi S, Saadaoui I. Halobacteria-based biofertilizers: a promising alternative for enhancing soil fertility and crop productivity under biotic and abiotic stresses—a review. Microorganisms. 2023;11(5):1248.
- Mohanty P, Singh PK, Chakraborty D, Mishra S, Pattnaik R. Insight into the role of PGPR in sustainable agriculture and environment. Front. Sustain. Food Syst. 2021;5:667150.
- Hyder S, Rizvi ZF, los Santos-Villalobos SD, Santoyo G, Gondal A, Khalid N, Fatima SN, Nadeem M, Rafique K, Rani A. Applications of plant growth-promoting rhizobacteria for increasing crop production and resilience. J. Plant Nutr. 2023;46(10):2551-80.
- Malik L, Sanaullah M, Mahmood F, Hussain S, Siddique MH, Anwar F, Shahzad T. Unlocking the potential of co-applied biochar and plant growth-promoting rhizobacteria (PGPR) for sustainable agriculture under stress conditions. Chem. Biol. Technol. Agric. 2022;9(1):58.
- Mahapatra S, Yadav R, Ramakrishna W. Bacillus subtilis impact on plant growth, soil health and environment: Dr. Jekyll and Mr. Hyde. J. Appl. Microbiol. 2022;132(5):3543-62.
- Adeniji A, Huang J, Li S, Lu X, Guo R. Hot viewpoint on how soil texture, soil nutrient availability and root exudates interact to shape microbial dynamics and plant health. Plant Soil. 2024:1-22.
- Cruz-Hernández MA, Mendoza-Herrera A, Bocanegra-García V, Rivera G. Azospirillum spp. from plant growth-promoting bacteria to their use in bioremediation. Microorganisms. 2022;10(5):1057.
- Dasila H, Sah VK, Jaggi V, Kumar A, Tewari L, Taj G, Chaturvedi S, Perveen K, Bukhari NA, Siang TC, Sahgal M. Cold-tolerant phosphate-solubilizing Pseudomonas strains promote wheat growth and yield by improving soil phosphorous (P) nutrition status. Front. Microbiol. 2023;14:1135693.