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Evaluation of Rhizosphere Bacteria Associated with *Spinacia oleracea* for Plant Growth-Promoting Potentials in Bida, Niger State, Nigeria

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Abstract

The study aimed to assess the rhizosphere bacteria of the spinach plant (Spinacia oleracea) for their growth-promoting potentials. Rhizosphere soil samples were collected from three different farmlands within Bida metropolis, namely Bangaie, Wuya, and Tako Wasa. The samples were isolated for bacteria growth, and the isolated bacteria were identified for their potential to promote plant growth using standard procedures. A total of four distinct bacteria were isolated with their frequency of occurrence as Bacillus cereus (37.5%), Klebsiella pneumoniae and Bacillus specie (25% each), and Micrococcus luteus (12.5%). The results showed that the isolated bacteria were able to produce various plant growth-promoting substances such as ammonia, phosphatase solubilization, proteolytic enzyme activity, and amylase activity. These findings suggest that rhizosphere bacteria of Spinacia oleracea have great potential as biofertilizers, which could contribute to sustainable agriculture practices. This study provides valuable insights into the potential of rhizosphere bacteria in promoting plant growth and highlights the importance of further studying their role in sustainable crop production.

Keywords: Rhizosphere, Spinach Plant, Bacteria, Growth Promoting Potentials

INTRODUCTION

The current climate conditions and modern agricultural practices are continuously and severely modifying and polluting the natural ecosystems (Yang *et al.*, 2024). Green leafy vegetables such as Spinach *(Spinacia oleracea)* are rich sources of many nutrients and form a major category of vegetable groups that have been designated as 'nature anti-aging wonders and medicinal value (Sarma and TR, 2024). Spinach *(Spinacia oleracea)* is a valuable crop for food and medicinal purposes with production of over 26 million tons on about 921000 ha in the world (Kaur *et al.*, 2022). Spinach *(Spinacia oleracea)* derived phytochemicals and bioactive compounds are able to scavenge reactive oxygen species and prevent macromolecular oxidative damage, modulate expression and activity of genes involved in metabolism, proliferation, inflammation, and antioxidant defense, and also curb food intake by inducing secretion of satiety hormones (Ibrahim *et al.*, 2025).

Medicinally, spinach (*Spinacia oleracea*) has been traditionally used as an anti-inflammatory, anti-convulsant, antifungal, analgesic, and anticancer agent (Varela *et al.*, 2023). The mucilaginous liquid from the leaves and stalks is used as a remedy for headaches (Islambulchilar, 2024).

Growing spinach as well as other vegetables is particularly suitable for small-scale farmers and their families, because it requires moderate difficulty and limited expenditure for production (Krishna *et al.*,2024). Farmers earn their living through using limited farm inputs in their production (Touch *et al.*, 2024). Spinach and other vegetables are the most constantly and extensively cultivated food and income-generating crops in many parts of Nigeria (Ayinde *et al.*, 2025). Spinach can give a high yield per unit area of land; hence, it generates high income for the farmers (Sharma et al., 2024). Poor dissemination of technological information has resulted in low farm income, weak financial position, and inadequate funding of small-holder farmers' economic activities (Vasavi et al., 2025). The level of commercial spinach production is perceived to be low, scarce, and expensive in the local Nigerian markets where it is available (Okoma et al.,

2025). The plant is called *Efo* in Yoruba (literally, a cool appetizer to the stomach), *Akwukwonri* in Igbo, Alayfo in Nupe and Gbagyi, and *Ganye alayyafo* in Hausa.

The rhizosphere is the zone of soil surrounding a plant root where the root influences the biochemistry of the soil and this zone is about 1 mm wide, but has no distinct edge, rather, it is an area of intense biochemical activity influenced by compounds exuded by the root, and by microorganisms feeding on the compounds (David and Rengel, 2024). Soil microbial communities are often difficult to characterize, mainly because of their immense phenotypic and genotypic diversity (Tariq *et al.*, 2025). Bacterial populations in upper layers of the soil can contain as many as 10^9 cells per gram of soil (Karimzadeh *et al.*, 2024).

Rhizobacteria are root-colonizing bacteria that form a symbiotic relationship with many plants, especially legumes (Uyi *et al.*, 2024). Though parasitic varieties of rhizobacteria exist, the term usually refers to the bacteria that form a relationship beneficial for both parties (mutualism) (Ammar, 2024). The bacteria grow at the expense of carbohydrates from the host and, in turn, provide fixed nitrogen for amino acid biosynthesis (Kaltenpoth *et al.*,2025). This symbiosis is a prime example of an intimate mutual relationship between the soil bacterium and its host plant and illustrates the concept behind the term 'Plant Growth Promoting Rhizobacteria (PGPR)' (Anas *et al.*, 2025). Plant Growth-Promoting Rhizobacteria (PGPR) are considered to be an alternative to the use of chemicals (Agbodjato and Babalola, 2024). Plant Growth-Promoting Rhizobacteria are a group of organisms that have a close association with plants and can help plants to establish properly in degraded ecosystems, protect plants from diseases and promote plant growth (Ansabayeva *et al.*, 2025). They are a group of heterogeneous bacteria that are found in the rhizosphere, that is, at the root surface and in association with roots, and can improve the quality of plant growth directly or indirectly (Mukherjee et al., 2024). Plant Growth-Promoting Rhizobacteria activity has been reported in species belonging to several genera, such as *Azotobacter, Azospirillum, Pseudomonas, Acetobacter, Burkholderia, Bacillus,* and *Serratia* (Sharma and Chandra, 2024). Plant Growth-Promoting Rhizobacteria have important beneficial effects on plant health and growth, suppress disease-causing microbes, and accelerate nutrient availability and assimilation (Hasan *et al.*, 2024).

The study aims to assess the Rhizosphere bacteria of Spinach *(Spinacia oleracea)* for growth-promoting potentials.

MATERIAL AND METHODS

Study area

This study was carried out in Bangaie (BYG), an urban district within Kyari ward, part of Bida LGA, Tako Wasa (TWS), a district in Bida LGA, with coordinates of 9.08 ^{0}N, 6.01 ^{0}E and Wuya (WYA) is a town or locality situated near Mokwa Local Government Area in Niger State with coordinates of 9.1393^{0}N, 5.8228^{0}E.

Collection of soil samples

Top soil samples were collected at a depth of 0-20 cm from three agricultural areas used for spinach cultivation in 2022. From each of the three main sites, three sub-sites were taken for the purpose of random sampling. Finally, three soil bulk samples, one from each of the stated areas, were transferred into polythene bags and transported to the Federal Polytechnic Bida Microbiology laboratory for further analysis.

Material Sterilization and Media Preparation

Using standard operating procedures, all the glassware was properly washed, dried, and sterilized in the oven at 160 °C for one hour. The entire working surfaces were also disinfected with ethanol. This was done to avoid contamination during the media preparation as well as the sample processing.

All the media (Nutrient Agar) used was weighed, prepared and sterilized according to the manufacturer's instruction. Distilled water was measured using a measuring cylinder, mixed, and weighed using a weighing balance before being added to a sterile conical flask with the agar powder. The medium was then put into a conical flask, well-sealed, and autoclaved at 121 °C for 15 minutes to sterilize it. After the sterile media had cooled to around 45 °C, it was dispensed into a sterile petri dish and given time to harden (Albu *et al.*, 2024).

Serial Dilution and Isolation of Rhizosphere Bacteria

Ten grams (10g) of rhizosphere soil sample was added into a 250ml clean conical flask containing 200ml sterile distilled water and was shake on a magnetic stirrer for 15minutes, then**serialdilutionsof**10^{-2} to 10^{-6} are prepared and 1ml each of dilutions 10^{-4} to 10^{-6} is

transferred to sterile petri plates (3 replicates each for 10^{-4} to 10^{-6} dilutions and 6 replicates for 10^{-5} dilution). The melted and cooled Nutrient's Agar was poured into various plates. The Nutrient's Agar plates were incubated at 25 °C in an inverted position for 7 days (Ekobol *et al.*, 2025).

Total Bacteria Count

The representative petri dish incubated was visualized under a colony counting machine and was used to count the total bacterial count (lab tech, India), and the result was expressed as colony-forming unit per milliliter (cfu/ml) at the end of the count.

Characterization of Rhizobacteria Isolates

The characterization of isolated rhizobacteria consisted firstly in macroscopic (colony morphology, pigmentation) and microscopic (Gram reaction, mobility, cell shape, spores' position) observations. Several biochemical and enzymatic tests followed this first identification. The performed tests were the production of oxidase, catalase growth on Nutrient

Gram's staining

A drop of distilled water was placed on a clean glass slide and a loop of the bacterial isolate was smeared on the water which was then allowed to dry and was then passed through a flame twice in order to heat fix it, two drops of crystal violet were added and was left for 60seconds before washing it with distilled water, then lugol's iodine was added and washed away with distilled water after 1minute and it was flooded with 75 % or 95% of alcohol (ethanol) and washed with distilled water after 30seconds and then counterstained with safranin which was also washed with distilled water after 1 minute or 2 minutes which the glass slide was left to dry and was examined under the microscope with oil immersion lens (Sana *et al.*, 2023).

Biochemical Identification

Catalase Test

On a clean glass slide, a smear of the bacterial isolates was made in a drop of normal saline with aflame aflame-sterilized wire loop. A drop of hydrogen peroxide was transferred using a pipette on the smeared bacteria, and the slide was observed for bubbles forming (Sana *et al.*, 2023).

Oxidase Test

A piece of filter paper was soaked in tetra-methyl-p-phenylenediamine dihydrochloride, and the paper was placed in a clean, sterilized petri-dish. A smear was made on the filter paper, adding a few drops of normal saline, and the mixture was left for 30 seconds to observe the color change from white to purple (Sana *et al.*, 2023).

Indole Test

The tryptophan broth was inoculated with broth culture, and the tube was inoculated aseptically by taking the growth from 18 to 24 hours of culture. The tube was incubated at 37°C for 24-28 hours, then 0.5 ml of Kovac's reagent was added to the broth culture, and observations were made (Sana *et al.*, 2023).

Methyl Red Test

Methyl Red broth was prepared in test tubes then the broth was inoculated aseptically with 2 loopful of respective bacterial culture and the test tubes were labelled with name of organism inoculated and incubated at 37°C for 48-72 hours, then Few drops of methyl red indicator were added into the incubated tubes the reactions was observed (Sana *et al.*, 2023).

Urease Test

A heavy inoculum was used from an 18- to 24-hour pure culture to streak the entire slant surface. Then the tubes were incubated with loosened caps at 35 ºC, the slant was observed for a colour change at 6 hours, 24 hours, and every day for up to 6 days and urease production was indicated by a bright pink (fuchsin) color on the slant that may extend into the butt that is, any degree of pink was considered a positive reaction (Sana *et al.*, 2023).

Coagulase Test

The test was performed by preparing a suspension of bacterial cells mixed into a drop of rabbit plasma on a microscope slide. If bound coagulase is present on the bacterial cells, then the presence of plasma will cause the bacterial cells to clump, which indicates a positive reaction (Sana et *al.*, 2023).

Voges Proskauer

Tubes of peptone broth were inoculated and incubated at 37°C for 48 hours. Then, 1ml of 40% KOH and 3ml of a 5% solution of 2-naphthol in absolute ethanol were added to each tube. A

positive result gives a crimson color in 30 minutes (Sana et al., 2023).

Screening of Bacteria Isolates for Plant Growth Promoting Potential

Ammonia Production

Production of ammonia by the isolates was tested in peptone medium (Soponputtaporn *et al.*, 2024). Freshly grown pure cultures of the isolates were grown for 48–72 hours at 28 °C, and Nesseler's (0.5ml) reagent was added (Mesele *et al.*, 2025). The reaction was observed for color change to yellow (Kumar and Chae, 2024).

Phosphate Solubilization Test

All isolates were tested for the solubilization of phosphate (Bakki *et al.*, 2024). The test isolates were inoculated in 25ml Pikovskaya's (PVK) broth and incubated for 48–72 hours at room temperature (Samal and Sukla, 2024). Thereafter, the bacterial cultures were centrifuged at 15000 rpm for 30 minutes (Li et *al.*, 2024). The supernatant of 1ml was mixed with 10ml of chloromolibidic acid, and the volume was made up to 45ml with distilled water (Youseif, 2018). Chlorostannous acid (0.25ml) was added, and the volume was made up to 50ml with distilled water. The reaction was observed for colour change to blue (Rathod *et al.*,2024).

Protease (Caseinase) Activity

The qualitative assay for protease production was performed on sterile skim milk agar plates (Panc. digest of casein 5.0, Yeast extract 2.5, Glucose 1.0, Agar 15.0, Distilled water 1000 ml, Skim milk 7% was added as inducer (Prajapati *et al.*, 2022). Isolates were spot inoculated and followed by incubation at 30°C, and a zone of clearance around the colony indicated the enzymatic degradation of protease (Afrin et al., 2024).

Amylase (Starch Hydrolysis) Activity

The bacterial isolates were spot inoculated on starch agar (Beef extract 3.0, Peptone 5.0, soluble starch 2.0, Agar 15.0, Distilled water 1 liter) medium plates and incubated at 30°C for 48 h (Woo *et al.*, 2024). At the end of the incubation period, the plates were flooded with iodine solution, kept for a minute, and then poured off. Iodine reacts with starch to form a blue colour compound (Marma *et al.*, 2025). This blue colour fades rapidly. Hence the colourless zone surrounding colonies indicates the production of amylase (Alzahran *et al.*, 2024).

RESULTS

Table 1 shows the Total Bacteria Count (TBC) (cfu/ml) of the rhizosphere vegetable (spinach) collected from three agricultural sites: Wuya, Bangaie, and Tako Wasa. The result reveals that rhizosphere vegetable (spinach) from Wuya has the highest microbial count (2.1 x 10^4 cfu/ml), followed by rhizosphere vegetable (spinach) from Bangaie (1.1 x 10^4), while rhizosphere vegetable (spinach) from Tako Wasa has the lowest microbial count (1.3 x 10^3cfu/ml).

Table 1: Average Total Plate Count per ml for the Samples

S/N	Samples	TBC (cfu/ml)
1.	RVB	1.1 x 10^4
2.	RVW	2.1 x 10^4
3.	RVT	1.3 x 10^3

Key: RVB = Rhizosphere Vegetable (Spinach) from Bangaie
RVW = Rhizosphere Vegetable (Spinach) from Wuya
RVT = Rhizosphere Vegetable (Spinach) from Tako Wasa,
TBC = Total Bacteria Count

Table 2 shows the morphological characteristics of recovered isolates from three agricultural sites: Wuya, Bangaie, and Tako Wasa, including their form, colour, and mode of growth. To identify the suspected bacteria organism, each isolate's colonial morphology was recorded. Three (3) Vegetable (Spinach) samples obtained yielded a total of eight (8) bacteria isolates.

Table 4 shows the percentage frequency of occurrence of bacterial isolates obtained from the rhizosphere vegetable (spinach) samples obtained from the farm in Wuya, Bangaie, and Tako Wasa, respectively. The result shows that *Bacillus cereus* was the most predominant (37.5%), followed by *Klebsiella pneumoniae* and *Bacillus specie* (25%), while *Micrococcus Luteus* (12.5%), which is recorded as the lowest prevalence. The prevalence of bacteria might be due to environmental conditions, including the temperature at which fertilizer is applied, humidity, farming practices, etc.

Table 2: Morphological Identification and Characterization of Bacterial Isolates

Isolate Code	Macroscopic Characteristics	Microscopic Characteristics	Inferences
RVW_1	Milky colour	Rod shape in chains, some are singly	*Bacillus cereus*
RVT_1 A 001	Milky colour	Rod shape	*Klebsiella pneumoniae*
RVT_2	Creamy colour	Regular	*Bacillus cereus*
RVW_2	Milky colour	Cocci	*Bacillus specie*
RVB_1 A 001	White colour	Oval shape in bunch	*Micrococcus Luteus*
RVB_1 B 002	Milky colour	Rod shaped	*Klebsiella pneumoniae*
RVB_2	Milky colour	Rod shape in chains	*Bacillus specie*
RVT_1 B 002	Creamy colour	Regular shape	*Bacillus cereus*

Key: RVW = Rhizosphere Vegetable (Spinach) from Wuya; RVB = Rhizosphere Vegetable (Spinach) from Bangaie; RVT = Rhizosphere Vegetable (Spinach) from Tako Wasa

Table 3: Biochemical Analysis of Bacterial Isolates

Sample Code	Catalase	Coagulase	Methyl Red	Indole	Urease	Oxidase	Voges-Proskauer	Possible Organisms
RVW_1	+	_	_	_	_	_	_	*Bacillus cereus*
RVT_1 001	+	_	_	_	+	_	_	*Klebsiella pneumoniae*
RVT_2	+	_	_	_	_	_	_	*Bacillus cereus*
RVW_2	+	_	_	_	_	_	+	*Bacillus specie*
RVB_1 001	+	_	_	_	_	_	_	*Micrococcus Luteus*
RVB_1 002	+	_	_	_	+	_	+	*Klebsiella pneumoniae*
RVB_2	+	_	_	_	_	_	+	*Bacillus specie*
RVT_1 002	+	_	+	_	_	_	_	*Bacillus cereus*

Key: + = Present, - = Not present, RVW = Rhizosphere Vegetable (Spinach) from Wuya, RVB = Rhizosphere Vegetable (Spinach) from Bangaie, RVT = Rhizosphere Vegetable (Spinach) from Tako Wasa

Table 4: Percentage Frequency Occurrence of Bacteria Isolates

Isolates	Frequency	Percentage Occurrence (%)
Bacillus cereus	3	37.5%
Klebsiella pneumonia	2	25%
Bacillus specie	2	25%
Micrococcus luteus	1	12.5%
Total	**8**	**100%**

Table 5: Screening of the microbial Isolates for Growth Promoting Potential

Organism	Sample code	NH_4	PHO_4	PROT	AMYL
Bacillus cereus	RVW_1	+++	+++	+++	+++
Klebsiella pneumonia	RVT_1 A001	++	_	++	+++
Bacillus cereus	RVT_2	+++	+++	+++	+++
Bacillus specie	RVW_2	_	_	_	_
Micrococcus Luteus	RVB_1 A001	_	_	_	+++
Klebsiella pneumoniae	RVB_1 B002	+++	+++	+++	+++
Bacillus specie	RVB_2	_	_	_	_
Bacillus cereus	RVT_1 B002	++	_	_	_

Key: NH_4 = Ammonia Production; PHO_4 = Phosphate Solubilization; PROT = Proteolytic Enzyme Activity; AMYL = Amylase Activity; - = not detected; + = low; ++ = medium; +++ = high; RVW = Rhizosphere Vegetable (Spinach) from Wuya; RVB = Rhizosphere Vegetable (Spinach) from Bangaie; RVT = Rhizosphere Vegetable (Spinach) from Tako Wasa

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DISCUSSION

The results, as shown in Table 1, indicated a flora of bacterial isolates from the sample sites (Bangaie, Wuya, and Tako Wasa). This might be due to favorable environmental variables, such as the temperature at which fertilizer is applied, humidity levels, farming practices, etc. The three (3) rhizospheres of vegetable (spinach) had bacterial counts that ranged from 1.1 x 10^4 to 2.1 x 10^4cfu/mL, with vegetable (spinach) from Wuya having the highest count and vegetable (spinach) from Bangaie having the lowest, according to further analysis of the samples. In Wuya, microorganisms can grow more readily. This implies that Wuya's soil will be better suited for farming and other agriculturally related activities. This result is in line with the findings of Kumata *et al.* (2017), who found that soils with high bacterial load prevalence experience increased growth.

The microorganisms isolated from three (3) samples of spinach in the current investigation (Table 2) were morphologically classified by their form, color, and mode of growth into four (4) bacteria (*Bacillus cereus, Klebsiella pneumoniae, Bacillus specie,* and *Micrococcus luteus*). *Bacillus cereus, Klebsiella pneumoniae, Bacillus specie*, and *Micrococcus luteus* could have been present in the samples due to favorable environmental conditions for microbes, such as the temperature at which fertilizer is applied, humidity levels, agricultural methods, etc. The findings of this study are consistent with those of Al-Khayri (2012), who conducted bacterial strain isolation on vegetable rhizosphere soil and showed a high frequency of *Bacillus specie* and *Klebsiella pneumoniae*. Soil bacteria are essential for decomposing organic matter and recycling old plant material. Some soil bacteria and fungi form relationships with plant roots that provide important nutrients like nitrogen or phosphorus.

Table 3 shows that *Bacillus cereus, Klebsiella pneumoniae, Bacillus specie*, and *Micrococcus luteus* are among the bacteria strains that the biochemical tests also identified, and these findings are consistent with research done by Ali *et al.,* (2017) in an effort to identify bacteria present in the rhizosphere soil of vegetable plants (Spinach) with *Bacillus specie* dominating the frequency of occurrence. This can be because of favorable environmental factors like temperature and humidity that promote the growth of microorganisms. Bacteria perform many essential ecological tasks in the soil, including improving soil aggregation and structure, recycling soil nutrients, and recycling water. Soil bacteria produce small aggregates in the soil that boost soil fertility by using their secretions to bind soil particles together (Andreote and Pereira, 2017). Additionally, the bacteria isolated from this study (B*acillus cereus, Klebsiella pneumoniae, Bacillus specie*, and *Micrococcus luteus*) from the three (3) sample sites in Bangaie, Wuya, and Tako Wasa are comparable to those isolated from vegetable (Spinach) rhizosphere soil by Altaf *et al.,* (2019), with *Bacillus cereus* and *Klebsiella pneumoniae* being the dominant bacteria isolates. These could be a reflection of the quality of the soil and its properties.

Table 4 indicates the bacteria isolates with their frequency of occurrence. A total of four (4) different bacteria were isolated. From the result, *Bacillus cereus* (37.5%) has the highest frequency of occurrence, occurring 3 times, followed by *Klebsiella pneumoniae* (25%) and *Bacillus specie* (25%), occurring 2 times respectively where whereas *Micrococcus luteus* (12.5%) with the lowest frequency of occurrence (1 time). Similar results were reported by Arunachalam *et al.* (2017), who found that *Bacillus cereus* predominated in prevalence in the rhizosphere soil of vegetable plants (Spinach). The presence of *Bacillus cereus, Klebsiella pneumoniae, Bacillus specie*, and *Micrococcus luteus* (Table 4), however, shows that the soils are suitable for agricultural techniques. Soil microorganisms greatly aid the biogeochemical cycles and the practice of crop production. By producing specific chemicals for plants, aiding the uptake of specific nutrients from the soil, and reducing or avoiding plant diseases, free-living soil bacteria are helpful for plant growth (Wei *et al.,* 2016).

Table 5 displays the results of tests on the ability of bacterial isolates (*Bacillus cereus, Klebsiella pneumoniae, Bacillus specie,* and *Micrococcus luteus*) to promote growth. The generation of ammonia, which indirectly affects plant growth, is the most significant characteristic of a rhizosphere that promotes plant growth. All of the bacterial isolates except for Micrococcus luteus and Bacillus species tested positive for ammonia production. This is likely due to the fact that these bacteria commonly cause food poisoning and are found in the environment (soil, water, and air). This finding is in agreement with Ahmad *et al.,* (2014) study on the potential of tomato soil to promote plant growth. The ability of isolated bacteria to promote plant growth was tested, and a variety of results were seen. *Bacillus cereus, Klebsiella pneumoniae,*

Bacillus specie, and *Micrococcus luteus* isolates were able to solubilize phosphate in the plate-based assay by exhibiting a clear halo zone around the colony. This result is consistent with the work of Alessa *et al.* (2017), who conducted a study and found that *Klebsiella pneumoniae* was observed negatively. This is because *Klebsiella pneumoniae* insoluble forms predominate, making them less easily available for plant uptake. All isolates, with the exception of *Micrococcus luteus and Bacillus specie*, were found to be positive for proteolytic enzyme. The pace at which plant residues break down and release nutrients that are accessible to the plant is accelerated by proteolytic enzymes (Arunachalam *et al.*, 2017). The outcome of the current investigation supports Imade & Babalola (2021) findings that *Klebsiella pneumoniae* produces a proteolytic enzyme that promotes plant development. *Bacillus cereus and Klebsiella pneumoniae* both produced the enzyme amylase in tests. *Bacillus cereus*, which is a spore-forming, ash-tolerant bacterium and is mostly connected to the bioremediation process, may be the cause of this. Soil amylase is in charge of the main breakdown of complex polysaccharides, including starch, to a readily usable form of glucose.

CONCLUSION AND RECOMMENDATIONS

Conclusion

Conclusively, the results of the present study have revealed that the rhizosphere is a habitat for soil bacteria that favors agricultural practices. The isolated bacteria were also tested for plant growth-promoting potentials, and the results show that the rhizosphere soil of vegetable (Spinach) contained bacteria that have plant growth-promoting potentials, hence the reason for the favorable and fast growth of plants in those areas. The presence of these bacteria is significant to plants. Soil bacteria are essential for decomposing organic matter and recycling old plant material. Some soil bacteria and fungi form relationships with plant roots that provide important nutrients like nitrogen or phosphorus.

Recommendations

From the research, to add valuable knowledge to the existing basis of information on rhizosphere soil, it is recommended that;

i. Future studies are required to prove the nature of bacteria isolates to harness their potential as bio-inoculants in agriculture.
ii. For plant pathologists and rice farmers in the sampling sites to benefit from the good impacts of the rhizosphere microbiota and to take the required phytosanitary precautions to control the phytopathogenic genera and consequently promote plant growth, more research should be conducted.
iii. Finally, more study is required to comprehend the interactions, including antagonistic relationships and other types of interactions, between the rhizosphere microflora and root exudates in relation to the physical-chemical properties of the soil.

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