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Original Article

Influence of Phosphate-Solubilizing Bacteria on Rice (*Oryza sativa* L.) Growth and Suppression of Sheath Blight Caused by *Rhizoctonia solani* Kühn

***[1]Shuaibu, A. M., [1]Belllo, I. M., [2]Jahun, B. M. and [1]Daudu, O. A. Y.**

[1] Department of Plant Biology, Federal University of Technology, Minna, Niger State, Nigeria.
[2] Department of Biology Education, Federal College of Education Technical, Bichi, Kano State, Nigeria

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ABSTRACT

Rice (*Oryza sativa* L.) remains one of the world's most critical staple crops, providing the main source of dietary calories for over half of the global population. In Nigeria, as in many developing nations, demand for rice continues to rise due to rapid population expansion and shifting dietary preferences. Despite this growing demand, rice yield is still limited by numerous biotic and abiotic constraints. This study assessed the effects of phosphate-solubilizing bacteria (PSB) on the growth performance and suppression of leaf sheath blight disease in rice varieties infected with *Rhizoctonia solani*, the pathogen responsible for the disease. Three rice varieties Kwandala, FARO 44, and FARO 52 were subjected to single and combined inoculations of *Pseudomonas fluorescens*, *Bacillus subtilis*, and *Bacillus thuringiensis*, in addition to negative and positive control treatments. Experiments were conducted under greenhouse conditions using a completely randomized block design. The findings revealed that *Pseudomonas fluorescens* consistently resulted in the greatest improvements in chlorophyll contents, plant height, and tiller number at 30, 60, and 90 days after sowing. All phosphate-solubilizing bacteria treatments significantly lowered disease incidence and severity relative to the control, with *Pseudomonas fluorescens* achieving the lowest disease incidence (16%) and severity (0.94 cm), second only to the fungicide (Benlate). Significant varietal variation was also observed, as FARO 52 recorded the highest chlorophyll contents, while FARO 44 exhibited the highest plant height. Overall, phosphate-solubilizing bacteria particularly *Pseudomonas fluorescens* substantially enhanced rice growth and effectively mitigated leaf sheath blight infection, demonstrating their promise as environmentally sustainable bio-fertilizers and bio-control agents against sheath blight for improved rice production.

Keywords: Bio-control**,** Phosphate-solubilizing bacteria and *Rhizoctonia solani*

*** Corresponding author's email:** shuaibu.abubakar@futminna.edu.ng, +2348134412110

INTRODUCTION

Rice (*Oryza sativa* L.) is both an economically important staple crop and a well-established model system for studying plant physiology, nutrient acquisition, and plant microbe interactions in cereals. Its well-characterized growth stages and responsiveness to rhizosphere processes make rice a suitable biological system for investigating microbial influences on plant growth and disease responses [1]

Phosphorus (P) is an essential macronutrient involved in photosynthesis, energy transfer, nucleic acid synthesis, and membrane formation [2]. However, phosphorus availability remains a major limitation in many agricultural soils, as less than 0.1% of total soil phosphorus is present in plant-available forms [3]. Most soil phosphorus is immobilized in inorganic complexes or organic forms resistant to mineralization, resulting in poor phosphorus use efficiency and reduced crop productivity [4]. Although chemical phosphate fertilizers are widely applied to overcome this limitation, their long-term use is constrained by finite phosphate rock reserves and environmental impacts such as eutrophication and disruption of soil microbial communities [5 and 6].

Phosphate-solubilizing bacteria (PSB) are key functional components of the rhizosphere that regulate phosphorus cycling through mechanistic processes, including organic acid secretion, proton extrusion, chelation, and phosphatase-mediated mineralization [7 and 8]. Common PSB genera such as Bacillus and Pseudomonas are abundant in the rice rhizosphere, where they actively interact with plant roots and influence nutrient availability and rhizosphere chemistry [9 and 10].

In addition to enhancing phosphorus availability, PSB exhibit multiple plant growth–promoting traits, including phytohormone production, improved nutrient uptake, and modulation of root architecture. Importantly, many PSB also suppress soil-borne pathogens through competition, antibiosis, and induction of plant defense responses, thereby linking nutrient acquisition with disease resistance [11 and 12]. This dual role positions PSB as important biological regulators of plant growth and health rather than merely commercial biofertilizers.

Sheath blight disease caused by *Rhizoctonia solani* Kühn is one of the most destructive biotic stresses in rice production. The pathogen infects the leaf sheath and blade, reduces photosynthetic efficiency, and leads to substantial yield and biomass losses. Due to its soil-borne nature, broad host range, and limited host resistance, management of *R. solani* remains challenging, and reliance on chemical fungicides offers only temporary control without addressing underlying rhizosphere interactions [13].

Comprehensive characterisation of phosphate-solubilizing bacteria requires an integrated approach, combining morphological, biochemical, and molecular techniques to accurately identify functional strains and evaluate their biofertilization potential [1]. This study was conducted to explore sustainable and environmentally friendly strategies for improving rice production and managing sheath blight disease caused by *Rhizoctonia solani*, thereby reducing reliance on chemical fertilizers and fungicides. The aim of this research was to evaluate the influence of phosphate-solubilizing bacteria on the growth performance of rice and their potential to suppress sheath blight disease, while also assessing the response of different rice varieties to bacterial inoculation and pathogen infection.

MATERIALS AND METHODS

Isolation and identification of *Rhizoctonia solani*

The pathogenic isolate of *Rhizoctonia solani* used in this study was obtained from rice plants showing typical sheath blight symptoms. The fungus was isolated using standard tissue isolation techniques on potato dexterous agar (PDA) and purified through hyphal tip culture. Identification was based on cultural and microscopic characteristics and molecular confirmation was performed through ITS region sequencing [14]

Phosphate-solubilizing bacteria isolates

The phosphate-solubilizing bacterial isolates used in this study were previously obtained from the IITA and characterized based on their biochemical and molecular traits as described by [14]. The isolates were maintained on nutrient agar slants and reactivated in nutrient broth prior to inoculation.

Agronomic Practices and Experimental Design

The experiment was conducted under greenhouse conditions at the department of Plant Biology, Bayero University Kano, following the agronomic practices and experimental design previously described by [14]. The treatment consisted of inoculation with phosphate-solubilizing bacteria (PSB), pathogen inoculation with *Rhizoctonia solani* and their combinations arranged in a completely randomized block design (CRBD) with three replications.

Application of Phosphate-Solubilizing Bacteria (PSB) as Seed Inoculant.

Before inoculation the seeds were sterilized. Treated seeds were coated with a slurry containing 40% gum Arabic and 10% sugar solution mixed with bacterial culture. Negative control contains seeds treated with gum Arabic and sugar solution only while Positive control contains Benlate at 1,000 ppm. For the other treatments bacterial suspensions containing approximately 10^8 CFU/ml were used to coat rice seeds at a rate of 50 ml Kg-1. In dual treatments, equal volumes of bacterial strains were mixed in the same proportion [15].

Rice varieties

Three different rice varieties were obtained from IITA Kano branch and used; Kwandala (which is suspected to be susceptible to *Rhizoctonia solani*, FARO 44 and FARO 52 (which are all improved varieties)

Growth parameters

The height of the plant were determined by using a standard meter scale by measuring aerial parts of the plant from the soil surface to the terminal node of the developing leaf. In each plot, five plants were randomly chosen to measure the plant height at 30, 60 and 90 DAS (Days after sowing). The average height of these five plants were calculated for determining the average plant height in each treatment and was expressed in cm. [16].

Number of tillers

The number of tillers per pot was recorded at 30, 60 and 90 DAS (Days after sowing) by normal counting from randomly selected 5 pots in each treatment [17].

Chlorophyll contents

The chlorophyll content of plant leaves was measured at 30, 60 and 90 DAS (Days after sowing) using chlorophyll meter. In each plot, three (3) plants were randomly chosen and the mean was recorded for each plot at (30, 60 and 90 respectively) days after sowing. [17].

Disease scoring

Number of infected tillers per pot was taken by counting the number of infected tillers per pot at 130 days after sowing (DAS) before harvesting and recorded. Number of infected grains per pot were taken by counting the infected grains per pot after harvesting and recording. Weight of infected grain per pot were measured in gram (g) after harvesting using the weighing balance [18].

Disease incidence

Disease incidence was taken 45 days after pathogen inoculation. Disease incidence was assessed as described by [18]. It was assessed by quantifying percentage symptomatic sheath infected and grains damage as chaffy, discolored and partially filled grains per pot in each treatment using the formula below:

$$D.I\% = \frac{\text{Number of infected plants}}{\text{Total number of plants}} \times 100$$

The disease incidence percentage (Least virulent: 10 – 29 %; moderately virulent: 30 – 49 %; Virulent: 50 – 69 %; highly virulent: 70 – 90 %) were used to determine the virulence of the fungus isolate [19].

Disease severity

Disease severity was assessed visually and scored using 1-5 disease severity index (DSI), where 1= <1 mm lesion; 2= 1- < 3 mm; 3=3- < 5 mm; 4=5- ¬ < 7 mm; 5= ≥ 7 mm or dead seedling. The fungus caused no symptoms or very mild symptoms (DSI = 0-0.3) were considered avirulent; the fungus showed mild symptoms (DSI = 0.4-1.9) were considered low virulent; fungus showed moderate symptoms (DSI = 2-2.9) were considered moderately virulent; fungus showed severe symptoms (DSI = 3-3.9) were considered virulent and fungus caused very severe symptoms (4-5 DSI) were considered strongly virulent [19].

Data analysis

The data collected was subjected to analysis of variance (ANOVA). Treatment means were compared through employing least significant difference (LSD) test at 5% probability level, using SPSS.

RESULTS

Isolation and identification of fungal pathogen (Rhizoctonia solani)

The pathogenic isolate of *Rhizoctonia solani* used in this study were previously characterized morphologically and molecularly [14].

Effects of Phosphate solubilizing bacteria on chlorophyll content

Notable variations were observed in chlorophyll contents at 30, 60 and 90 days after sowing across all treatment levels (Table 1). At 30 days after sowing, the least chlorophyll content was observed in Negative control (32.10) but was not significantly different ($P > 0.05$) from *Pseudomonas fluorescens* + *Bacillus thuriengensis* (32.16), *Bacillus subtilis* +

Bacillus thuriengensis (33.89) and *Pseudomonas fluorescens* + *Bacillus subtilis* + *Bacillus thuriengensis* (32.79). The significantly highest (P < 0.05) chlorophyll content at 30 days after sowing was recorded in *Pseudomonas fluorescens* (39.11) (Table 1). At 60 days after sowing, Negative control (40.09) had the significantly least (P < 0.05) chlorophyll content while the significant highest (P < 0.05) was recorded in *Pseudomonas fluorescens* (52.57). The least chlorophyll content at 90 days after sowing was recorded in Negative control (64.42) but was not significantly different (P > 0.05) from *Pseudomonas fluorescens* + *Bacillus thuriengensis* (66.94), *Bacillus subtilis* + *Bacillus thuriengensis* (66.59). Benlate was observed to have significantly higher (P < 0.05) chlorophyll content at 90 days after sowing (74.39) (Table 1).

In terms of varietal performance, Kwandala had significantly higher (P < 0.05) chlorophyll content at 30 days after sowing (39.72) while Faro 44 had the least (30.92) (Table I). At 60 and 90 days after sowing, Faro 52 had significantly higher (P < 0.05) chlorophyll content (51.33 and 73.92, respectively)

able 1: Effects of Phosphate solubilizing bacteria on chlorophyll content of three varieties of Rice at different number of days after sowing.

Treatment	30	60	90
T0	32.10 ±1.60^{a}	40.09±2.89^{a}	64.42±2.76^{a}
T1	39.11 ±1.20^{c}	52.57±2.03^{c}	76.87±1.84^{d}
T2	36.27 ±0.99^{ab}	48.56±1.53^{b}	73.20±1.56^{c}
T3	35.99 ±1.39^{ab}	47.24±1.18^{b}	70.55±1.52^{ab}
T4	35.00 ±1.48^{ab}	43.88±1.54^{ab}	69.58±0.52^{ab}
T5	32.16 ±1.57^{a}	43.61±1.60^{ab}	66.94±0.67^{a}
T6	33.89 ±1.41^{a}	43.19±0.78^{ab}	66.59±2.06^{a}
T7	32.79 ±1.71^{a}	43.42±0.86^{ab}	71.62±2.80^{ab}
T8	37.29 ±1.38^{b}	49.68±2.50^{b}	74.39±1.71^{c}
LSD 5%	4.10	6.63	6.78
Varieties			
Kwandala	39.72 ± 0.87^{c}	45.76±2.16^{b}	66.23±1.93^{a}
Faro 52	34.23 ± 2.41^{b}	51.33±2.90^{c}	73.92±4.20^{b}
Faro 44	30.92 ± 1.48^{a}	40.31±2.60^{a}	71.23±3.48^{ab}
LSD 5%	3.14	4.14	7.93
Interaction			

Treat x Var.	***	***	***

Values are mean ± standard error of mean. Mean along the same column with different superscripts are significantly different at $P < 0.05$ using Fischer's LSD.

NS= Not significant. *=Significant at 10%, **= Significant at 5%, ***= Significant at 1%, LSD=Least significant difference.

T0: Negative control, T1: *Pseudomonas fluorescens*, T2: *Bacillus subtilis,* T3: *Bacillus thuriengensis,* T4: *Pseudomonas fluorescens* + *Bacillus subtilis,* T5: *Pseudomonas fluorescens* + *Bacillus thuriengensis,* T6: *Bacillus subtilis* + *Bacillus thuriengensis,* T7: *Pseudomonas fluorescens* + *Bacillus subtilis* + *Bacillus thuriengensis,* T8: Positive control (benlate)

Interaction effect of treatment and varieties on chlorophyll content

Notable disparities were observed in chlorophyll contents of the three rice varieties at 30, 60 and 90 days after sowing at all treatment levels (Table 2). At 30 days after sowing, Kwandala showed the significantly least ($P < 0.05$) chlorophyll content at Negative control (37.94) while the significant highest ($P < 0.05$) chlorophyll content was recorded in *Pseudomonas fluorescens* (42.18) (Table II). Faro 52 showed the significantly least ($P < 0.05$) chlorophyll content at *Pseudomonas fluorescens* + *Bacillus thuriengensis* (28.89) while the highest was recorded in *Pseudomonas fluorescens* (40.65) but was not significantly different ($P > 0.05$) from *Bacillus subtilis* (34.58), *Bacillus thuriengensis* (35.66) and benlate (39.45). In Faro 44, the significantly least ($P < 0.05$) chlorophyll content was recorded in Negative control (27.08) while the highest was recorded in *Pseudomonas fluorescens* (34.50) but was not significantly different ($P > 0.05$) from *Bacillus subtilis* (34.13) (Table 2).

At 60 days after sowing, Kwandala showed the significantly least ($P < 0.05$) chlorophyll content at Negative control (40.02) while the significantly highest ($P < 0.05$) was recorded in *Pseudomonas fluorescens* (52.26) (Table 2). In Faro 52, *Bacillus subtilis* + *Bacillus thuriengensis* had the least chlorophyll content (44.53) but was not significantly different ($P > 0.05$) from *Pseudomonas fluorescens* + *Bacillus subtilis* + *Bacillus thuriengensis* (45.96). T1 had the highest chlorophyll content but was significantly different ($P > 0.05$) from benlate (58.02). In Faro 44, Negative control showed the significantly least ($P < 0.05$) chlorophyll content (30.16) while the highest was recorded in *Pseudomonas fluorescens* (45.79) but was not significantly different ($P > 0.05$) from *Bacillus subtilis* (45.15) (Table 2).

At 90 days after sowing, Kwandala showed the least chlorophyll content at Negative control (60.89) but was not significantly different ($P > 0.05$) from *Pseudomonas fluorescens* + *Bacillus subtilis* + *Bacillus thuriengensis* (60.51) (Table 2). The significantly highest ($P < 0.05$) chlorophyll content in kwandala was recorded in *Pseudomonas fluorescens* (70.54). In Faro 52, *Bacillus subtilis* + *Bacillus thuriengensis* (59.34) had the significantly less ($P < 0.05$) chlorophyll content while the significantly highest ($P < 0.05$) was recorded in *Pseudomonas fluorescens* (83.20). Faro 44 showed the significantly least ($P < 0.05$) chlorophyll content at Negative control (57.17) while the highest was recorded in *Pseudomonas fluorescens* (76.88) but was not significantly different ($P > 0.05$) from *Pseudomonas fluorescens* + *Bacillus subtilis* + *Bacillus thuriengensis* (76.82) (Table 2).

Table 2: Interaction effect of treatment and varieties on chlorophyll content

Treatment	Kwandala	Faro 52	Faro 44
		Chlorophyll at 30 days after sowing	
T0	37.94 ± 0.46^{a}	31.27 ± 0.48^{b}	27.08 ± 0.38^{a}
T1	42.18 ± 0.38^{e}	40.65 ± 0.63^{e}	34.50 ± 0.42^{d}
T2	40.11 ± 0.15^{bcd}	34.58 ± 0.71^{c}	34.13 ± 0.24^{d}
T3	40.83 ± 0.79^{de}	35.66 ± 0.48^{c}	31.50 ± 0.59^{c}
T4	38.73 ± 0.55^{abc}	37.05 ± 0.20^{d}	29.22 ± 0.23^{b}
T5	38.36 ± 0.55^{ab}	28.89 ± 0.40^{a}	29.24 ± 0.64^{b}
T6	39.30 ± 0.52^{abcd}	30.27 ± 0.20^{ab}	32.10 ± 0.90^{c}
T7	39.53 ± 0.40^{abcd}	30.28 ± 0.21^{ab}	28.57 ± 0.53^{ab}
T8	40.52 ± 0.81^{cde}	39.45 ± 0.38^{e}	31.91 ± 0.34^{c}
		Chlorophyll at 60 days after sowing	
T0	40.02 ± 0.58^{a}	50.07 ± 0.94^{b}	30.16 ± 0.39^{a}
T1	52.26 ± 0.83^{f}	59.65 ± 0.78^{d}	45.79 ± 0.15^{f}
T2	45.94 ± 0.51^{c}	54.60 ± 0.56^{c}	45.15 ± 0.36^{f}
T3	47.93 ± 0.75^{d}	50.79 ± 0.52^{b}	43.00 ± 0.45^{e}
T4	42.63 ± 0.57^{b}	49.59 ± 0.61^{b}	39.41 ± 0.78^{c}
T5	44.19 ± 0.44^{bc}	48.80 ± 0.33^{b}	37.82 ± 0.39^{b}
T6	44.73 ± 0.61^{c}	44.53 ± 0.36^{a}	40.30 ± 0.69^{cd}
T7	44.11 ± 0.15b^{c}	45.96 ± 0.40^{a}	40.19 ± 0.27^{cd}
T8	50.06 ± 0.79^{e}	58.02 ± 1.04^{d}	40.96 ± 0.46^{d}
		Chlorophyll at 90 days after sowing	
T0	60.89 ± 0.23^{a}	75.19 ± 0.57^{d}	57.17 ± 0.72^{a}
T1	70.54 ± 0.38^{d}	83.20 ± 0.59^{h}	76.88 ± 0.43^{d}
T2	68.04 ± 0.31^{c}	78.21 ± 0.56^{fg}	73.35 ± 1.65^{c}
T3	65.66 ± 0.70^{b}	76.04 ± 0.11^{de}	69.94 ± 0.20^{b}
T4	68.09 ± 0.87^{c}	71.36 ± 0.63^{c}	69.28 ± 0.37^{b}
T5	66.96 ± 0.29^{bc}	64.92 ± 0.06^{b}	68.94 ± 1.12^{b}
T6	67.36 ± 0.49^{c}	59.34 ± 0.33^{a}	73.06 ± 1.67^{c}
T7	60.51 ± 0.47^{a}	77.54 ± 0.98^{ef}	76.82 ± 0.45^{d}
T8	68.07 ± 1.06^{c}	79.47 ± 0.30^{g}	75.62 ± 0.31^{cd}

Values are mean ± standard error mean. Means with different superscripts along the same column are significantly different at $P < 0.05$. T0: Negative control, T1: *Pseudomonas fluorescens*, T2: *Bacillus subtilis,* T3: *Bacillus thuriengensis,* T4: *Pseudomonas fluorescens* + *Bacillus subtilis*, T5: *Pseudomonas fluorescens* + *Bacillus thuriengensis,* T6: *Bacillus subtilis* + *Bacillus thuriengensis,* T7: *Pseudomonas fluorescens* + *Bacillus subtilis* + *Bacillus thuriengensis,* T8: Positive control (benlate)

Effect of Phosphate solubilizing bacteria on Plant height (cm) of three varieties of Rice

Significant variations were observed in plant heights at 30, 60 and 90 days after sowing across all treatment levels (Table 3). At 30 days after sowing, the least plant height was recorded in Negative control (29.38 cm) but was not significantly different ($P > 0.05$) from *Pseudomonas fluorescens* + *Bacillus subtilis* (30.13 cm).

The highest plant height was recorded in *Pseudomonas fluorescens* (34.08 cm) but was not significantly different ($P > 0.05$) from benlate (33.41 cm) (Table 3).

At 60 days after sowing, Negative control (64.93 cm) had the significantly least ($P < 0.05$) plant height while the significant highest ($P < 0.05$) plant height was recorded in *Pseudomonas fluorescens* (74.57 cm) (Table 3).

At 90 days after sowing, Negative control (76.11 cm) had the least plant height but was not significantly different ($P > 0.05$) from T4 and T5 (77.41 cm and 78.27 cm, respectively) while *Pseudomonas fluorescens* (85.89 cm) had the significantly highest ($P < 0.05$) plant height (Table 3).

In terms of varietal performance, the significantly least ($P < 0.05$) plant height was recorded in Kwandala at 30, 60 and 90 days after sowing (28.50 cm, 63.50 cm and 76.68 cm, respectively) while Faro 44 had the significantly highest ($P < 0.05$) plant height at 30, 60 and 90 days after sowing (37.13 cm, 73.64 cm ad 85.67 cm, respectively) (Table 3).

Table 3: Effect of Phosphate solubilizing bacteria on plant height (cm) of three rice varieties at different number of days after sowing

Treatment	30	60	90
T0	29.38 ± 1.03^{a}	64.93 ± 1.61^{a}	76.11 ± 1.60^{a}
T1	34.08 ± 1.72^{b}	74.57 ± 1.46^{c}	85.89 ± 1.20^{c}
T2	32.13 ± 2.06^{ab}	68.89 ± 2.44^{ab}	80.31 ± 0.99^{ab}
T3	31.94 ± 1.46^{ab}	69.99 ± 1.38^{ab}	79.63 ± 1.39^{ab}
T4	30.13 ± 0.72^{a}	68.61 ± 0.97^{ab}	77.41 ± 1.48^{a}
T5	32.23 ± 1.21^{ab}	71.35 ± 2.17^{b}	78.27 ± 1.57^{a}
T6	31.66 ± 1.51^{ab}	68.30 ± 1.97^{ab}	81.64 ± 1.41^{ab}
T7	32.32 ± 1.52^{ab}	65.53 ± 1.19^{a}	81.78 ± 1.71^{ab}
T8	33.41 ± 1.46^{b}	73.13 ± 1.52^{bc}	85.60 ± 1.38^{b}
LSD 5%	2.44	5.38	5.71
Varieties			
Kwandala	28.56 ± 0.53^{a}	63.50 ± 1.50^{a}	76.68 ± 1.95^{a}
Faro 52	30.06 ± 1.32^{a}	71.30 ± 2.69^{ab}	79.87 ± 2.84^{b}
Faro 44	37.13 ± 1.75^{b}	73.64 ± 2.14^{b}	85.67 ± 2.64^{c}
LSD 5%	2.44	3.14	4.50
Interaction			

Treat x Var.	***	***	***

Values are mean ± standard error of mean. Mean along the same column with different superscripts are significantly different at $P < 0.05$ using Fischer's LSD.

NS= Not significant. *=Significant at 10%, **= Significant at 5%, ***= Significant at 1%, LSD=Least significant difference.

T0: Negative control, T1: *Pseudomonas fluorescens*, T2: *Bacillus subtilis*, T3: *Bacillus thuriengensis,* T4: *Pseudomonas fluorescens* + *Bacillus subtilis,* T5: *Pseudomonas fluorescens* + *Bacillus thuriengensis,* T6: *Bacillus subtilis* + *Bacillus thuriengensis,* T7: *Pseudomonas fluorescens* + *Bacillus subtilis* + *Bacillus thuriengensis*, T8: Positive control (benlate)

Interaction effect of treatment and varieties on plant height (cm)

Significant differences ($P < 0.05$) were observed in plant height of the three rice varieties across all treatment levels at 30, 60 and 90 days after sowing (Table 4). At 30 days after sowing, Kwandala showed the least plant height at *Bacillus subtilis* + *Bacillus thuriengensis* (27.84 cm) but was not significantly different ($P > 0.05$) from Negative control (27.83 cm) and *Bacillus subtilis* (27.90 cm). The highest plant height was recorded in Benlate (29.73 cm) but was not significantly different ($P > 0.05$) from *Pseudomonas fluorescens* + *Bacillus thuriengensis* (29.67 cm). In Faro 52 and Faro 44, the significantly least ($P < 0.05$) plant height was recorded in Negative control (27.71 cm and 32.60 cm, respectively) while the highest was recorded in *Pseudomonas fluorescens* (33.47 cm and 40.30 cm, respectively) (Table 4).

At 60 days after sowing, Kwandala variety had the significantly least ($P < 0.05$) plant height at *Pseudomonas fluorescens* + *Bacillus subtilis* + *Bacillus thuriengensis* (59.28 cm) while the significantly highest ($P < 0.05$) was recorded in Benlate (67.20cm) (Table 4). In Faro 52 variety, the significantly least ($P < 0.05$) plant height was recorded in *Pseudomonas fluorescens* + *Bacillus subtilis* + *Bacillus thuriengensis* (64.97 cm) while the highest was recorded in *Pseudomonas fluorescens* (77.97 cm). Faro 44 showed the significantly least ($P < 0.05$) plant height at Negative control (67.50 cm) while the significant highest ($P < 0.05$) was recorded in *Pseudomonas fluorescens* (79.47 cm) (Table 4).

At 90 days after sowing, Kwandala showed the least plant height at Negative control (72.01 cm) but was not significantly different ($P > 0.05$) from *Bacillus subtilis* (72.13 cm) while the significantly highest ($P < 0.05$) was recorded in *Pseudomonas fluorescens* (80.50 cm) (Table IV). In Faro 52, *Pseudomonas fluorescens* had the highest plant height (87.09 cm) but was not significantly different ($P > 0.05$) from Benlate (87.09 cm) while *Pseudomonas fluorescens* + *Bacillus thuriengensis* (71.27 cm) had the significantly least ($P < 0.05$) plant height. Faro 44 was observed to have the least plant height at Negative control (78.64 cm) but was not significantly different ($P > 0.05$) from *Pseudomonas fluorescens* + *Bacillus subtilis* (79.83 cm) (Table 4), while the significant highest ($P < 0.05$) was recorded in *Pseudomonas fluorescens* (90.07cm) but was not significantly different ($P > 0.05$) from Benlate and *Bacillus subtilis* + *Bacillus thuriengensis* having (89.87cm and 89.33cm respectively) (Table 4).

Table 4: Interaction effect of treatment and varieties on plant height (cm)

Treatment	Kwandala	Faro 52	Faro 44

		<u>Plant height at 30 days after sowing</u>	
T0	27.83 ± 0.44^{a}	27.71 ± 1.65^{a}	32.60 ± 1.45^{a}
T1	28.47 ± 0.29^{ab}	33.47 ± 0.41^{c}	40.30 ± 0.35^{d}
T2	27.90 ± 0.21^{a}	28.41 ± 1.70^{ab}	40.08 ± 0.70^{cd}
T3	28.43 ± 0.32^{ab}	29.70 ± 0.44^{ab}	37.67 ± 0.41^{bcd}
T4	28.50 ± 0.29^{ab}	29.57 ± 1.22^{ab}	32.33 ± 0.88^{a}
T5	29.67 ± 0.33^{b}	30.30 ± 1.31^{abc}	36.71 ± 0.82^{b}
T6	27.84 ± 0.43^{a}	29.67 ± 1.67^{ab}	37.47 ± 0.93^{bc}
T7	28.67 ± 0.33^{ab}	30.20 ± 1.22^{abc}	38.10 ± 0.76^{bcd}
T8	29.73 ± 0.82^{b}	31.55 ± 0.87^{bc}	38.94 ± 0.54^{bcd}
		<u>Plant height at 60 days after sowing</u>	
T0	61.50 ± 0.55^{ab}	65.80 ± 0.20^{ab}	67.50 ± 1.25^{a}
T1	66.28 ± 0.51^{de}	77.97 ± 0.15^{e}	79.47 ± 0.35^{e}
T2	62.34 ± 1.22^{bc}	71.05 ± 1.19^{d}	73.27 ± 1.64^{bcd}
T3	62.57 ± 1.14^{bc}	70.73 ± 0.96^{cd}	76.67 ± 0.88^{de}
T4	64.55 ± 0.41^{cd}	70.51 ± 0.29^{cd}	70.77 ± 0.94^{ab}
T5	64.65 ± 0.33^{cd}	75.80 ± 0.92^{e}	73.61 ± 0.64^{bcd}
T6	63.10 ± 0.38^{bc}	68.20 ± 1.33^{bc}	73.61 ± 0.64^{bcd}
T7	59.28 ± 0.68^{a}	64.97 ± 0.73^{a}	72.33 ± 1.94^{bc}
T8	67.20 ± 1.01^{e}	76.63 ± 1.11^{e}	75.57 ± 1.37^{cd}
		<u>Plant height at 90 days after sowing</u>	
T0	72.01 ± 0.45^{a}	77.67 ± 0.88^{b}	78.64 ± 1.21^{a}
T1	80.50 ± 0.66^{e}	87.09 ± 0.63^{c}	90.07 ± 0.88^{c}
T2	72.13 ± 1.04^{a}	80.27 ± 1.39^{b}	88.54 ± 1.00^{b}
T3	75.52 ± 1.25^{bc}	79.03 ± 0.55^{b}	84.33 ± 1.20^{b}
T4	74.33 ± 0.88^{ab}	78.07 ± 1.21^{b}	79.83 ± 1.09^{a}
T5	78.91 ± 0.31^{d}	71.27 ± 1.19^{a}	84.64 ± 3.18^{b}
T6	77.83 ± 1.32^{cd}	77.77 ± 0.82^{b}	89.33 ± 0.24^{c}
T7	79.00 ± 0.58^{d}	80.57 ± 1.22^{b}	85.77 ± 1.57^{b}
T8	79.83 ± 0.61^{de}	87.09 ± 0.63^{c}	89.87 ± 0.41^{c}

Values are mean ± standard error mean. Means with different superscripts along the same column are significantly different at $P < 0.05$. T0: Negative control, T1: *Pseudomonas fluorescens*, T2: *Bacillus subtilis*, T3: *Bacillus thuriengensis*, T4: *Pseudomonas fluorescens* + *Bacillus subtilis*, T5: *Pseudomonas fluorescens* + *Bacillus thuriengensis, T6: Bacillus subtilis* + *Bacillus thuriengensis*, T7: *Pseudomonas fluorescens* + *Bacillus subtilis* + *Bacillus thuriengensis*, T8: Positive control (benlate)

Effect of Phosphate solubilizing bacteria on number of Tillers of three Rice varieties

Notable disparities were observed in number of tillers per plant at 30, 60 and 90 days after sowing across all the treatment levels (Table 5). At 30 days after sowing, the least number of tillers was observed in *Pseudomonas fluorescens* + *Bacillus subtilis* (10.11) but was not significantly different ($P > 0.05$) from Negative control (10.33) and *Pseudomonas fluorescens* + *Bacillus thuriengensis* (10.56). *Pseudomonas fluorescens* (13.67) was observed to have the highest number of tillers at 30 days after sowing but was not significantly different ($P > 0.05$) from *Bacillus subtilis* (13.00) (Table 5).

At 60 days after sowing, Negative control had the least number of tillers (18.00) while *Pseudomonas fluorescens* had the significantly ($P < 0.05$) highest number of tillers (23.78) (Table 5). The significantly highest ($P < 0.05$) number of tillers per plant at 90 days after sowing was recorded in *Pseudomonas fluorescens* (34.00).

In terms of varietal performance, Faro 44 had the significantly least ($P < 0.05$) number of tillers per plant at 30 days after sowing (10.56) while the highest was recorded at Faro 52 (12.33) but was not significantly different ($P > 0.05$) from kwandala (11.63) (Table 6). Kwandala showed the significantly highest ($P < 0.05$) number of tillers per plant at 60 days after sowing (21.74) while no significant differences ($P < 0.05$) was observed in all the varieties at 90 days after sowing (Table 5).

Table 5: Effect of Phosphate solubilizing bacteria on number of tillers of three rice varieties at different number of days after sowing.

Treatment	30	60	90
T0	10.33 ± 0.44^{a}	18.00 ± 0.58^{a}	27.78 ± 0.66^{a}
T1	13.67 ± 0.44^{c}	23.78 ± 0.46^{b}	34.00 ± 0.44^{c}
T2	13.00 ± 0.58^{c}	21.22 ± 0.70^{ab}	32.56 ± 0.80^{bc}
T3	12.00 ± 0.47^{b}	20.22 ± 0.60^{ab}	29.33 ± 0.62^{ab}
T4	10.11 ± 0.31^{a}	18.00 ± 0.82^{a}	29.00 ± 0.73^{ab}
T5	10.56 ± 0.50^{a}	19.44 ± 0.58^{a}	28.44 ± 0.50^{a}
T6	11.00 ± 0.55^{ab}	19.44 ± 0.78^{a}	28.44 ± 0.44^{a}
T7	11.00 ± 0.33^{ab}	19.11 ± 0.45^{a}	28.44 ± 0.38^{a}
T8	11.89 ± 0.35^{ab}	21.11 ± 0.42^{ab}	30.56 ± 0.67^{b}
LSD 5%	2.06	3.05	3.50
Varieties			
Kwandala	11.63 ± 1.16^{b}	21.74 ± 1.01^{b}	30.52 ± 1.61^{a}
Faro 52	12.33 ± 0.89^{b}	19.78 ± 1.46^{a}	29.48 ± 1.61^{a}
Faro 44	10.56 ± 0.63^{a}	18.59 ± 1.14^{a}	29.52 ± 1.31^{a}
LSD 5%	1.42	1.29	-
Interaction			
Treat x Var.	**	NS	NS

Values are mean ± standard error of mean. Mean along the same column with different superscripts are significantly different at $P < 0.05$ using Fischer's LSD.
NS= Not significant. *=Significant at 10%, **= Significant at 5%, ***= Significant at 1%, LSD=Least significant difference.
T0: Negative control, T1: *Pseudomonas fluorescens*, T2: *Bacillus subtilis*, T3: *Bacillus thuriengensis*, T4: *Pseudomonas fluorescens* + *Bacillus subtilis*, T5: *Pseudomonas fluorescens* + *Bacillus thuriengensis*, T6: *Bacillus subtilis* + *Bacillus thuriengensis*, T7: *Pseudomonas fluorescens* + *Bacillus subtilis* + *Bacillus thuriengensis*, T8: Positive control (benlate)

Interaction of treatment and varieties on number of tillers at 30 days after sowing

Significant differences ($P < 0.05$) were observed in number of tillers per plant at 30 days after sowing in the three rice varieties across all treatment levels (Table 6). The least number of tillers per plant in Kwandala variety was observed in Negative control (9.00) but was not significantly different ($P > 0.05$) from *Pseudomonas fluorescens* + *Bacillus subtilis* and *Pseudomonas fluorescens* + *Bacillus thuriengensis* (10.00 and 9.33, respectively), while the significantly highest ($P < 0.05$) was recorded in *Bacillus subtilis* (14.00) (Table 6).

In Faro 52 variety, *Pseudomonas fluorescens* + *Bacillus subtilis* (10.67) had the significantly least ($P < 0.05$) number of tillers per plant while the significantly highest ($P < 0.05$) was recorded in *Pseudomonas fluorescens* (15.00). *Bacillus subtilis* + *Bacillus thuriengensis* had the significantly least ($P < 0.05$) number of tillers per plant in Faro 44 while the significantly highest number of tillers ($P < 0.05$) was recorded in *Pseudomonas fluorescens* (12.33) (Table 6).

Table 6: Interaction of treatment and varieties on number of tillers at 30 days after sowing

Treatment	Kwandala	Faro 52	Faro 44
T0	9.00 ± 0.58^{a}	11.67 ± 0.33^{ab}	10.33 ± 0.33^{abc}
T1	13.67 ± 0.33^{bc}	15.00 ± 0.58^{d}	12.33 ± 0.33^{d}
T2	14.00 ± 0.58^{c}	14.00 ± 0.58^{cd}	11.00 ± 0.58^{bc}
T3	13.00 ± 0.58^{bc}	12.67 ± 0.33^{bc}	10.33 ± 0.33^{abc}
T4	10.00 ± 0.58^{a}	10.67 ± 0.67^{a}	9.67 ± 0.33^{ab}
T5	9.33 ± 0.88^{a}	12.00 ± 0.58^{ab}	10.33 ± 0.33^{abc}
T6	12.67 ± 0.67^{b}	11.00 ± 0.58^{ab}	9.33 ± 0.33^{a}
T7	10.67 ± 0.33^{ab}	12.00 ± 0.58^{ab}	10.33 ± 0.33^{abc}
T8	12.33 ± 0.33^{b}	12.00 ± 0.58^{ab}	11.33 ± 0.88^{cd}

Values are mean ± standard error mean. Means with different superscripts along the same column are significantly different at $P < 0.05$.
T0: Negative control, T1: *Pseudomonas fluorescens*, T2: *Bacillus subtilis*, T3: *Bacillus thuriengensis*, T4: *Pseudomonas fluorescens* + *Bacillus subtilis*, T5: *Pseudomonas fluorescens* + *Bacillus thuriengensis*, T6: *Bacillus subtilis* + *Bacillus thuriengensis*, T7: *Pseudomonas fluorescens* + *Bacillus subtilis* + *Bacillus thuriengensis*, T8: Positive control (benlate)

Effect of Phosphate Solubilizing Bacteria on Disease severity and Disease incidence (%) of three Rice varieties

Significant differences were observed in disease severity and disease incidence across all treatment levels (Table 7). The significantly highest ($P < 0.05$) disease severity was recorded in Negative control (3.50cm) while the least was recorded in Benlate (0.66cm) but was not significantly different ($P > 0.05$) from *Pseudomonas fluorescens* (0.94cm). The significantly highest ($P < 0.05$) disease incidence was recorded in Negative control (63.11%) while the least was recorded in Benlate (9.89%) (Table 7).

In terms of varietal performance, the significantly highest ($P < 0.05$) disease severity was recorded in Kwandala (2.32) while the significantly highest ($P < 0.05$) disease incidence was recorded in Faro 52 (33.41%). Faro 44 had the significantly least ($P < 0.05$) disease incidence (25.33%) (Table 7).

Table 7: Effect of Phosphate Solubilizing Bacteria on Disease severity and Disease incidence of three Rice varieties

Treatment	Disease incidence (%)	Disease severity (cm)
T0	63.11 ± 1.16^{e}	3.50 ± 0.15^{c}
T1	16.00 ± 4.11^{b}	0.94 ± 0.26^{a}
T2	23.89 ± 2.00^{c}	1.39 ± 0.18^{ab}
T3	29.67 ± 2.52^{c}	1.94 ± 0.22^{ab}
T4	27.89 ± 2.17^{c}	1.89 ± 0.20^{ab}
T5	31.11 ± 1.65^{d}	2.26 ± 0.11^{b}
T6	32.00 ± 2.17^{d}	2.27 ± 0.18^{b}
T7	36.89 ± 1.89^{d}	2.62 ± 0.12^{b}
T8	9.89 ± 3.05^{a}	0.66 ± 0.18^{a}
LSD 5%	5.17	0.43
Varieties		
Kwandala	31.41 ± 7.90^{b}	2.32 ± 0.46^{b}
Faro 52	33.41 ± 8.06^{c}	1.88 ± 0.41^{a}
Faro 44	25.33 ± 10.80^{a}	1.62 ± 0.71^{a}
LSD 5%	7.02	0.57
Interaction		
Treat x Var.	***	***

Values are mean ± standard error of mean. Mean along the same column with different superscripts are significantly different at $P < 0.05$ using Fischer's LSD.
NS= Not significant. *=Significant at 10%, **= Significant at 5%, ***= Significant at 1%, LSD=Least significant difference.
T0: Negative control, T1: *Pseudomonas fluorescens*, T2: *Bacillus subtilis*, T3: *Bacillus thuriengensis*, T4: *Pseudomonas fluorescens* + *Bacillus subtilis*, T5: *Pseudomonas fluorescens* + *Bacillus thuriengensis*, T6: *Bacillus subtilis* + *Bacillus thuriengensis*, T7: *Pseudomonas fluorescens* + *Bacillus subtilis* + *Bacillus thuriengensis*, T8: Positive control (benlate)

Interaction effect of treatment and varieties on Disease Severity and Incidence

Notable variations were observed in disease severity and disease incidence across all treatment levels in the three rice varieties (Table 8).

In Kwandala variety, Benlate had the least disease severity (1.17cm) but was not significantly different ($P > 0.05$) from *Pseudomonas fluorescens* (1.47cm) (Table 8). The significantly least ($P < 0.05$) disease severity in Faro 52 was recorded in Benlate (0.80cm) while the least disease severity in Faro 44 was recorded in *Pseudomonas fluorescens* (0.00cm) but was not significantly different ($P > 0.05$) from Benlate (0.00cm). Negative control had the significantly highest ($P < 0.05$) disease severity in Kwandala, Faro 52 and Faro 44 (3.60cm, 3.23cm and 3.67cm, respectively) (Table 8).

The significantly least ($P < 0.05$) disease incidence was recorded on Benlate in Kwandala (19.67%) and Faro 52 (10.00%) (Table VIII). But in Faro 44 the significantly least ($P < 0.05$) disease incidence was recorded on *Pseudomonas fluorescens* (0.00%) but was not significantly different ($P > 0.05$) from Benlate (0.00). Negative control had the significantly highest ($P < 0.05$) disease incidence in the three rice varieties viz Kwandala (66.67%), Faro 52 (61.675%) and Faro 44 (61.00%) (Table 8)

Table 8: Interaction effect of treatment and varieties on Disease Severity and Incidence (%)

Treatment	Kwandala	Faro 52	Faro 44
		Disease Severity	
T0	3.60 ± 0.35^{c}	3.23 ± 0.15^{e}	3.67 ± 0.29^{f}
T1	1.47 ± 0.26^{a}	1.37 ± 0.23^{ab}	0.00 ± 0.00^{a}
T2	1.67 ± 0.29^{a}	1.67 ± 0.22^{bcd}	0.83 ± 0.12^{b}
T3	2.50 ± 0.12^{b}	2.10 ± 0.25^{d}	1.23 ± 0.28^{bc}
T4	2.53 ± 0.15^{b}	1.47 ± 0.24^{bc}	1.67 ± 0.28^{cd}
T5	2.43 ± 0.26^{b}	2.07 ± 0.12^{cd}	2.27 ± 0.15^{de}
T6	2.67 ± 0.20^{b}	1.93 ± 0.18^{bcd}	2.20 ± 0.42^{de}
T7	2.87 ± 0.12^{b}	2.27 ± 0.15^{d}	2.73 ± 0.18^{e}
T8	1.17 ± 0.18^{a}	0.80 ± 0.15^{a}	0.00 ± 0.00^{a}
		Disease Incidence %	
T0	66.67 ± 1.67^{e}	61.67 ± 1.67^{e}	61.00 ± 1.00^{e}
T1	24.33 ± 1.33^{ab}	23.67 ± 1.33^{b}	0.00 ± 0.00^{a}
T2	25.67 ± 1.33^{abc}	28.00 ± 1.51^{bc}	18.00 ± 1.73^{b}
T3	32.67 ± 1.40^{d}	35.00 ± 1.89^{cd}	21.33 ± 2.96^{b}
T4	24.00 ± 1.08^{ab}	35.00 ± 1.89^{cd}	24.67 ± 2.40^{bc}
T5	30.33 ± 1.03^{bcd}	31.67 ± 1.41^{bcd}	31.33 ± 2.96^{cd}
T6	27.00 ± 1.08^{bcd}	35.67 ± 1.53^{cd}	33.33 ± 4.41^{d}
T7	32.33 ± 1.45^{cd}	40.00 ± 1.73^{d}	38.33 ± 4.63^{d}
T8	19.67 ± 0.60^{a}	10.00 ± 0.89^{a}	0.00 ± 0.00^{a}

Values are mean ± standard error of mean. Means with different superscripts along the same column are significantly different at $P < 0.05$.

T0: Negative control, T1: *Pseudomonas fluorescens*, T2: *Bacillus subtilis*, T3: *Bacillus thuriengensis*, T4: *Pseudomonas fluorescens* + *Bacillus subtilis*, T5: *Pseudomonas fluorescens* + *Bacillus thuriengensis*, T6: *Bacillus subtilis* + *Bacillus thuriengensis*, T7: *Pseudomonas fluorescens* + *Bacillus subtilis* + *Bacillus thuriengensis,* T8: Positive control (benlate)

DISCUSSION

Effect of Phosphate solubilizing bacteria on growth of rice

The chlorophyll content of *Pseudomonas fluorescens* was significantly ($P < 0.05$) greater at 30, 60 and 90 (39.11, 52.57, 76.87 SPAD unit respectively) days after sowing compared with the control (30.10, 40.09 64.42 SPAD unit respectively). This might be due to the higher possession of indole acetic acid, phytase enzymes and higher phosphate solubilizing index by the *Pseudomonas fluorescens* which resulted in higher chlorophyll content. The result is in agreement with the finding of [20] and also agrees with the result of [21] who reported that foliar application of indole acetic acid and salicylic acid increased the chlorophyll content of the plants. Chloroplasts are oxidized by the production of super oxides and other reactive oxygen species (ROS) resulting in severe decrease in chlorophyll contents [22]. Results showed that application of Phosphate solubilizing bacteria especially *Pseudomonas fluorescens* resulted in significant improvement in chlorophyll pigments. Indole acetic acid production (IAA) resulted in increased photosynthetic activity due to the improved hormonal balance and reduced ethylene production, thus prevented the breakdown of chlorophyll proteins and resulted in higher chlorophyll content [21].

The plant height (cm) in *Pseudomonas fluorescens* was significantly ($P < 0.05$) greater at 30, 60 and 90 (34.08, 74.57 and 85.89 respectively) days after sowing compared with control (29.38, 64.93 and 76.11 respectively). These findings were in accordance with [23, 24 and 17] also recorded that application of *Pseudomonas fluorescens* both at 30, 60 and 90 days after sowing increased the plant height. This happened may be due to the production of Indole acetic acid (IAA) by the PSB leading to increase in plant height or may be the capability of the PSB for fixing nitrogen from air and enhanced metabolism process resulted in more energy and growth improvement. This growth promoter effect could be attributed to the potential of these PSB to increase the availability of nutrients, such as phosphorus, and siderophore and phytohormone production [15], as well as to their capacity to colonize the root system and interact positively with the plant. Similar results of inoculation with strains of the genera *Pseudomonas* and *Bacillus* on several crops under controlled conditions have been reported [25, 26, 27, and 28].

At 30 days after sowing number of tillers is significantly increased by *Pseudomonas fluorescens* (13.67) compared to control that had (10.33) but the control was significantly higher than the *Pseudomonas fluorescens* + *Bacillus subtilis* that has (10.11). While at 60 days after sowing *Pseudomonas fluorescens* + *Bacillus subtilis* has the same mean with the control (18.00) respectively. *Pseudomonas fluorescens* has the mean of (23.78) and is significantly higher. At 90 days after sowing *Pseudomonas fluorescens* has the higher mean of (34.00) compared to control that have (27.78). [29], reported similar result on aerobic rice treated with *Pseudomonas* striata and also [30] reported similar results in wheat, where the rock phosphate treatment with Phosphate solubilizing bacteria (*Pseudomonas striata)* Inoculation gave higher results and enhanced the crop yield.

In all the treatments *Pseudomonas fluorescens* were significantly higher which may be due to higher Indole acetic acid production of 4.56 mgl^{-1}, higher phosphate solubilizing index, sand higher phosphatase enzymes production although all the isolates were able to produce IAA without tryptophan, phosphatase enzymes and also ability to solubilize phosphate. This is in agreement with the finding of [31] that phosphate solubilizing bacteria produced IAA and have prominent effect on plant growth and development and a similar finding of [32] that isolated PSB strains have the ability to produce IAA and N_2 fixing ability to increase the growth of plant. [33] Reported that application of *Pseudomonas fluorescens* significantly increased plant height. This growth promoter effect could be attributed to the potential of these strains to increase the availability of nutrients, such as phosphorus, and siderophore and phytohormone production [15]. [34] Reported maize growth promotion by inoculating two phosphate-solubilizing bacteria, *Serratia marcescens* and *Pseudomonas sp*., isolated from compost. [35] Showed that *Pantoea agglomerans* effectively promoted rice growth and increased the yield.

Pseudomonas fluorescens has the great ability to adapt to plant rhizosphere as reported by [36, 37] may be this will be among the reason for its increase in the growth parameters of the rice and other crops. The success of *Pseudomonas fluorescen* as a plant growth promoter bacteria (PGPB) is poorly understood but it has been demonstrated that the species carries many genes that are expressed only in the rhizosphere, which may be determinants to its environmental fitness [38].

Varietal effect on the chlorophyll content showed that FARO 52 (73.92) had the highest significant mean then FARO 44 (71.23) and Kwandala (66.23). While on Plant height FARO 44 (85.67cm) has the highest significant difference compared to FAR0 52 and Kwandala having (79.87cm and 76.68cm respectively), plant height depend on the variety of rice. The significant differences among genotypes for plant height indicate appreciable amount of variability among the genotypes. The result is similar with the finding of [39] and also in agreement with the result of [40] where Faro 44 differed significantly in plant height, number of leaves per plant, total biomass, harvest index and grain yield. Kwandala has the highest number of tillers (30.52) then followed by FARO 44 (29.52) and then FARO 52 (29.48). This result is not in agreement with the finding of [40] who reported FARO 44 differed significantly from NERICA 2 and FARO 15 at all the parameters under study.

Effect of phosphate solubilizing bacteria on disease incidence and severity

Seed treatment of Phosphate solubilizing bacteria has an effect to the disease incidence and severity compared to control. Apart from the checked treatment *Pseudomonas fluorescens* has the lowest disease incidence of 16% then followed by *Bacillus subtilis* with 23.89%, which are all in the range of least virulent compared to control of having 63.11% which falls within the range of virulent. This result is in agreement with the result of [41]

Pseudomonas fluorescens effectively controlled sheath blight of rice when it is applied as seed treatment and he add that bacteria appeared to move epiphytically from seed to roots, stems and leaves. The result is also similar with the finding of [42] who record 60.67% disease incidence by inoculating non sclerotial *Rhizoctonia solani* on rice and level it as virulent, but it is not in agreement with the research of [43] who recorded 12.28% disease incidence and also [44] by using non sclerotial *Rhizoctonia solani* and consider it least virulent.

The production of siderophore from the phosphate solubilizing bacteria is the one that is capable to suppress the growth of the *Rhizoctonia solani*/soil borne disease. The siderophore production is the one capable for the antagonistic effect of *Rhizoctonia solani* from the findings of [45] that isolated PSB strains from the rhizosphere of Chinese cabbage were found to solubilize Phosphorus in the media and besides this, they were able to produce siderophores and IAA. [46] Have previously reported same observation that PSB strains (*Pseudomonas spp.*) exhibited the best antagonistic properties against *R. solani* among the all isolates collected from paddy location in Seberang Perai, Penang, Malaysia. Several studies indicated that the antagonistic potential of *Pseudomonas fluorescens* against various soil borne plant pathogens is correlated with production of lytic enzymes [47]. [48] Had earlier stated that, antifungal compounds like HCN, salicyclic acid and 2-hydroxyl phenazine produced by bacterial biocontrol agents has suppressed the plant pathogenic fungi.

The isolate obtained was found to be more virulent with 63.11% disease incidence and 49.72% yield loss percentage, the result is in agreement with the finding of [42] which record 60.67% disease incidence and is not in agreement with the finding of [43] who recorded 12.28% disease incidence and also [44] mentioned non sclerotial *Rhizoctonia solani* produced poor diseased symptoms expression in pathogenicity test.

Pseudomonas fluorescens and *Bacillus subtilis* has the lowest disease severity of (0.94cm and 1.39cm respectively) compared to control (3.50cm), this happens due to higher siderophore and hydrogen cyanide production. The dual inoculation of the isolates has the least impact compared to the single inoculation this happens may be due to synergistics effects amongst them, but all the isolates has the least disease incidence and severity compared to control, this is in line with the finding of [49] The result is also in agreement with the research of U.B. [50]. Seed treatment of phosphate solubilizing bacteria has a greater impact on yield loss as it reduced it significantly. *Pseudomonas fluorescens* reduced the yield loss as it have 3.72% then followed by *Bacillus subtilis* that have 12.25% compared to control that have 49.72%.

CONCLUSION

This study demonstrates that phosphate solubilizing bacteria (PSB) significantly improved rice growth and reduced sheath blight disease caused by *Rhizoctonia solani*. Among the tested isolates, *Pseudomonas fluorescens* consistently showed superior performance, recording the highest chlorophyll content, plant height and number of tillers at different growth stages, it also substantially reduced disease incidence (16%) and severity (0.94 cm) compared with the untreated control, which recorded the highest disease incidence (63.11%) and severity (3.50 cm). Varietal differences were observed, with FARO 52 showing higher chlorophyll content and FARO 44 producing taller plants, while Kwandala exhibited relatively higher disease susceptibility. Overall, the result indicate that PSB, particularly *Pseudomonas fluorescens,* can serve as effective biofertilizers and biocontrol agents for sustainable rice production. Further field studies are recommended to validate these findings under natural conditions.

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Authors' contribution

Abubakar Shuaibu: Conceived and designed the study, conducted the research, wrote the entire manuscript and also funded the research. Bashir Jahun: critically reviewed the manuscript and provided substantial corrections throughout the work. Ismaila Bello: Conceptualization; Resources; Investigation and Project administration. Oladipupo Daudu: Visualization and Writing-review & editing.

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