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Effect of potassium solubilizing bacteria and foliar application of potassium on soil nutrient status and soil biological properties in paddy (*Oryza sativa*) in coastal acid soils of Karnataka

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Abstract

A field experiment was conducted to study the “Effect of potassium solubilizing bacteria and foliar application of potassium on uptake and nutrient use efficiency in paddy (*Oryza sativa*) in coastal acid soils of Karnataka” during the *Kharif* 2021 at Zonal Agricultural and Horticultural Research Station (ZAHRS), Brahmavar, Udipi, KSNUAHS, Shivamogga. The experiment was laid out in Randomized Complete Block Design with eleven treatments replicated thrice. The experimental treatments included combinations of recommended doses of nitrogen, phosphorus, and potassium along with soil application of KSB and foliar KCl. Results showed significant improvements in soil chemical properties in the treatment with a recommended dose of N and P₂O₅, 75% K₂O, KSB at 5 kg ha⁻¹, and 2% KCl foliar spray at 30 and 60 DAT (T10). Organic carbon increased to 1.56%, with available nitrogen, phosphorus, and potassium reaching 275.85 kg ha⁻¹, 65.76 kg ha⁻¹, and 129.10 kg ha⁻¹, respectively. Micronutrient availability also improved, with iron (20.53 mg kg⁻¹), manganese (4.80 mg kg⁻¹), zinc (2.63 mg kg⁻¹), and copper (4.47 mg kg⁻¹) significantly higher than the control. Biological properties were enhanced, with bacterial (30.07 cfu × 10⁵ g⁻¹ soil), fungal (43.75 cfu × 10³ g⁻¹ soil), and actinomycetes (19.80 cfu × 10² g⁻¹ soil) populations reaching their highest levels in T10. Potassium solubilizing bacteria populations were also maximized (42.78 cfu × 10² g⁻¹ soil), reflecting improved potassium availability. This study highlights the synergistic role of KSB and foliar potassium in enhancing soil fertility and microbial activity, offering a sustainable strategy for reducing chemical input dependency and improving paddy yield in acidic soils.

Keywords: Potassium solubilizing bacteria, farm yard manure and coastal acid soils

Introduction

Rice (*Oryza sativa*) is a staple crop, feeding over 2.5 billion people globally and contributing significantly to food security. In India, rice occupies 43.79 million hectares, with an annual production of 118.87 million tonnes and productivity of 2,434 kg ha⁻¹ (USDA, 2019) [28]. In Karnataka, rice is cultivated across 1.45 million hectares, producing 3.72 million tonnes annually (GOI, 2019) [7]. However, sustaining productivity while preserving soil health has become a critical challenge, particularly in nutrient-deficient coastal acid soils. These soils are characterized by high rainfall, which leads to nutrient leaching, low organic matter, and deficiencies in essential nutrients, especially potassium (K). Such imbalances adversely affect soil fertility and crop yields, necessitating sustainable nutrient management strategies.

Potassium plays a pivotal role in plant physiology, including water absorption, stomatal regulation, enzyme activation, and photosynthate translocation (Yang *et al.*, 2015; Hussain *et al.*, 2016) [9, 11]. However, 90–98% of soil potassium exists in fixed or mineral forms, unavailable for plant uptake (Sparks & Huang, 1985) [26]. The reliance on imported K-fertilizers such as muriate of potash (MOP) has economic and environmental implications. Additionally, intensive agriculture has accelerated K depletion, making nutrient management a pressing issue for sustainable rice cultivation.

Potassium solubilizing bacteria (KSB) offer an eco-friendly solution to address potassium deficiency. KSB are rhizospheric microorganisms that solubilize fixed potassium from insoluble

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sources like feldspar, mica, and illite, using mechanisms such as acidolysis, chelation, and organic acid production (Parmar & Sindhu, 2013) [19]. These microbes not only enhance potassium availability but also improve soil biological properties by stimulating microbial diversity and activity. Studies have shown that KSB inoculation significantly increases bacterial, fungal, and actinomycetes populations, thereby enhancing nutrient cycling and organic matter decomposition (Meena *et al.*, 2014; Gundala *et al.*, 2013) [16, 8]. This dual benefit of improving nutrient status and fostering a biologically active soil ecosystem makes KSB an integral component of sustainable agriculture. The inclusion of KSB in nutrient management programs can transform soil fertility by increasing nutrient availability and microbial activity. KSB contribute to the release of potassium into soil solution, making it readily available for plant uptake while simultaneously promoting microbial-driven processes like decomposition and mineralization. These effects improve not only potassium availability but also the overall nutrient status of soils, including nitrogen, phosphorus, and secondary nutrients. Enhanced soil biological activity further ensures long-term soil health by creating a balanced ecosystem that supports plant growth.

Complementing KSB with foliar application of potassium offers additional advantages. Foliar potassium ensures efficient nutrient absorption, particularly during critical growth stages, and mitigates potassium losses caused by leaching in high-rainfall areas. This integrated approach optimizes nutrient uptake, supports physiological processes like stomatal regulation and stress tolerance, and ultimately improves paddy yield and quality. Moreover, it reduces the dependency on costly chemical fertilizers, making it a cost-effective and environmentally sustainable practice for farmers.

Despite its potential, the combined impact of KSB and foliar potassium on soil nutrient status and biological properties remains underexplored in coastal acid soils. Addressing these gaps is essential for developing resilient cropping systems that ensure high productivity without compromising soil health. By enhancing microbial populations and nutrient dynamics, KSB and foliar potassium can create a synergistic effect, fostering sustainable agricultural practices tailored to the specific challenges of acid soils.

Materials and Methods

The experiment was conducted at Seed Farm, Zonal Agricultural and Horticultural Research Station, Brahmavar, Udupi district, Karnataka. The experimental site is situated between 130 25' N latitude and 740 45' E longitude with an altitude of 10 meters above mean sea level. It comes under the coastal zone (agro-climatic zone 10) of Karnataka. Composite soil samples were drawn at a depth of 0 to 15 cm soil layer and a representative sample was obtained by standard procedures. The soil was analyzed for its chemical properties viz., pH, EC, organic carbon, available nitrogen, phosphorus and potassium and for biological properties viz., Bacteria, Fungi, Actinomycetes and K-solubilizers. The results of the analysis are given in Table 1. Experimental design is RCBD with eleven treatment and three replication. The cropping season is *kharif* with spacing 20 × 10 cm, seed rate 25 kg acre⁻¹ and variety MO-4. Treatment details are T1: Recommended dose of nutrients (60: 30: 60 kg per ha) + 5 tonnes of FYM, T2: T1 + soil application of KSB @ 5 kg per ha, T3: T1+ 2% KCl @ 30 and 60 DAT, T4: T1 + soil application of KSB @ 5 kg per ha + 2% KCl @ 30 and 60 DAT, T5: Recommended dose of N and P2O5 + 50% K2O + soil application of KSB @ 5 kg per ha, T6: Recommended dose of N and P2O5 + 50% K2O + 2% KCl @ 30 and 60 DAT, T7: Recommended dose of N and P2O5 + 50% K2O + soil

application of KSB @ 5 kg per ha + 2%KCl @ 30 and 60 DAT, T8: Recommended dose of N and P2O5 + 75% K2O + KSB @ 5 kg per ha, T9: Recommended dose of N and P2O5 + 75% K2O + 2% KCl @ 30 and 60 DAT, T10: Recommended dose of N and P2O5 + 75% K2O + soil application of KSB @ 5 kg per ha + 2% KCl @ 30 and 60 DAT and T11: Absolute control. Note: FYM: Farm yard manure, KSB: Potassium solubilizing bacteria, KCl: Muriate of potash, Urea, rock phosphate and muriate of potash were used as inorganic source of N, P and K fertilizers. Five hills were selected randomly from the net plot and labelled for recording the observations in each treatment. Fisher's method of analysis of variance was applied for analysis and interpretation of data as given by Panse and Sukhatme (1967). The level of significance used in 'F' and 't' tests was P=0.05. Critical difference values were calculated wherever the 'F' test was significant.

Soil samples were collected prior to treatment application and at harvest to assess changes in soil properties. These samples were air-dried in shade, finely powdered using a wooden mallet, sieved through a 2 mm mesh, and stored in polythene bags for subsequent analysis. Chemical properties of the soil, including pH, electrical conductivity, organic carbon, available nitrogen, phosphorus, potassium, exchangeable calcium and magnesium, available sulfur, and DTPA-extractable micronutrients (iron, manganese, zinc, and copper), were analyzed following standard protocols.

The soil pH was measured using a 1:2.5 soil-to-water suspension and a digital pH meter with a combined electrode (Jackson, 1973) [12]. Electrical conductivity was determined using a conductivity bridge on a similar suspension, with results expressed as dS m⁻¹ at 25 °C. Organic carbon was quantified via Walkley-Black's wet oxidation method. Available nitrogen was measured by distilling soil with potassium permanganate and sodium hydroxide, trapping the released ammonia in boric acid, and titrating against sulfuric acid). Available phosphorus was extracted using Bray's No.1 extractant and quantified by the chlorostannous-reduced molybdophosphoric acid blue color method at 660 nm (Bray and Kurtz, 1945) [4]. Available potassium was measured using a flame photometer after ammonium acetate extraction. Exchangeable calcium and magnesium were estimated by titration with EDTA, and available sulfur was measured turbidometrically using calcium chloride as an extractant (Jackson, 1973) [12]. DTPA-extractable micronutrients were determined using an atomic absorption spectrophotometer (Lindsay and Norwell, 1978) [13].

Biological properties, including bacterial, fungal, and actinomycetes populations, were assessed using the serial dilution plate count method. Soil samples were diluted in sterile water up to the appropriate dilution factors (10⁵ for bacteria, 10⁴ for fungi, and 10³ for actinomycetes) and plated on specific nutrient media. Plates were incubated, and colony-forming units (CFU) per gram of soil were calculated using the formula:

$$\text{CFU per gram of soil} = \frac{\text{No. of microbial count} \times \text{Dilution factor}}{\text{ml taken for dilution} \times \text{Weight of soil}}$$

K-solubilizing bacteria were similarly enumerated using Aleksandar media to determine the population of potassium-solubilizers in the soil (Skinner *et al.*, 1952) [25].

Results and Discussion

Effect of KSB and Foliar Application of 2% KCl on Soil Chemical Properties

Soil pH

The application of potassium solubilizing bacteria (KSB) and foliar application of 2% potassium chloride (KCl) did not

significantly alter soil pH among treatments. However, the highest pH (5.60) was recorded in T10, which included the recommended dose of N and P₂O₅, 75% K₂O, KSB (*Bacillus mucilaginosus*) @ 5 kg/ha, and foliar KCl at 30 and 60 DAT. This was closely followed by T9 (50% K₂O with similar applications, 5.54), while the lowest pH (5.29) was observed in T1 (recommended dose of nutrients + FYM @ 5 t/ha). The stabilization of pH in T10 may be attributed to microbial respiration generating CO₂ and the subsequent consumption of H⁺ ions during reduction reactions, as reported by Ponnamperna *et al.* (1966)^[20] and Adenawoola and Adejoro (2005)^[1]. The slight reduction in pH with KSB application could be attributed to the release of organic acids such as oxalic, citric, and gluconic acids, consistent with findings by Sheng and He (2006)^[24] and Prajapati *et al.* (2012)^[21] (Table 2).

Electrical Conductivity (EC)

Among all 11 treatments there is no significant differences in EC were observed. The values ranged between 0.054 dS/m in T1 and 0.127 dS/m in T9 (50% K₂O + KSB + 2% KCl). The higher EC in T7 (recommended dose of N and P₂O₅ + 50% K₂O + KSB + 2% KCl) could be due to the addition of salts through fertilizers and manures, as noted by Subramanian and Kumaraswamy (1989)^[27]. Similar increases in EC with combined biofertilizer and inorganic applications were observed by Deshmukh *et al.* (2005)^[5] (Table 2).

Organic Carbon (OC)

Organic carbon content showed significant variation among treatments. T10 recorded the highest OC (1.56%), followed by T8 (75% K₂O + KSB, 1.54%). The lowest OC was observed in T1 (0.92%) and T3 (FYM alone, 1.09%) (Table 2). The increase in OC in T10 is likely due to microbial degradation of organic residues and biomass accumulation, as reported by Gaurishankar *et al.* (2002)^[6] and Meshram *et al.* (2004)^[18]. Enhanced microbial activity under KSB treatments further accelerated organic matter decomposition.

Available Nitrogen (N)

Available nitrogen levels were significantly higher in T10 at all stages, with values of 379.75 kg/ha at 30 DAT and 275.85 kg/ha at harvest. This was followed by T8 and T7. The lowest N levels were observed in T1 (330.79 kg/ha at 30 DAT and 236.20 kg/ha at harvest) (Table 3). The improved nitrogen availability in KSB-treated soils may be attributed to enhanced mineralization and growth-promoting hormone secretion, as noted by Meena *et al.* (2012)^[15].

Available Phosphorus (P)

The highest available phosphorus was recorded in T10 (75.69 kg/ha at 30 DAT and 65.76 kg/ha at harvest), followed by T8 and T9. The control (T1) showed the lowest P levels (53.84 kg/ha at harvest) (Table 3). Enhanced P solubilization through organic acids produced by KSB contributed to the observed increases, as corroborated by Manna *et al.* (2006)^[14] and Boateng *et al.* (2006)^[3].

Available Potassium (K)

T10 exhibited significantly higher available potassium levels, with 152.98 kg/ha at 30 DAT and 129.10 kg/ha at harvest, followed by T8 and T7. The lowest potassium availability was observed in T1 (101.62 kg/ha at harvest) (Table 3). KSB-mediated solubilization of potassium-bearing minerals, facilitated by organic acids such as citric and tartaric acids,

likely accounted for these improvements. These findings align with the work of Meena *et al.* (2014)^[17].

DTPA-Extractable Micronutrients

1. **Iron (Fe):** Iron availability was significantly enhanced in T10, which recorded the highest Fe content (20.53 mg/kg) compared to T1 (10.18 mg/kg) (Table 4). This increase can be attributed to the production of organic acids by KSB, such as citric and gluconic acids, which effectively chelate and mobilize iron from soil reserves. The acids lower the soil pH in microenvironments, facilitating the dissolution of Fe and increasing its availability to plants. Prasad *et al.* (2010)^[22] supported these findings, demonstrating the role of microbial organic acids in Fe solubilization and nutrient enhancement in acidic soils. This mechanism underscores the potential of integrating KSB for improved micronutrient management and soil fertility.
2. **Manganese (Mn):** T10 exhibited the highest Mn availability (4.80 mg/kg), significantly higher than the control (T1, 2.29 mg/kg) (Table 4). This increase can be attributed to microbial activity facilitated by potassium-solubilizing bacteria, which enhances Mn solubility through organic acids and nutrient cycling documented similar microbial contributions to Mn availability in soil systems.
3. **Zinc (Zn) and Copper (Cu):** Zinc availability in T10 reached 2.63 mg/kg, compared to 0.94 mg/kg in T1, demonstrating the effectiveness of organic acids produced by KSB in solubilizing zinc (Table 4). These acids, such as citric and oxalic acids, release Zn from its bound forms, improving plant uptake. Similarly, copper availability was significantly higher in T10 (4.47 mg/kg) than T1 (1.11 mg/kg). Organic acids enhance Cu solubility by chelating it and releasing it from soil minerals. This dual improvement in Zn and Cu reflects enhanced nutrient cycling and microbial contributions, aligning with the findings of Ahmad *et al.* (2010).

Effect of KSB and Foliar Application of 2% KCl on Soil Biological Properties

The integration of potassium solubilizing bacteria (KSB) and foliar potassium (2% KCl) significantly enhanced the biological properties of soil, as evidenced by increased microbial activity across bacterial, fungal, actinomycetes, and KSB populations. These improvements were attributed to the synergistic effects of biofertilizers and potassium application, which enhanced nutrient cycling, organic matter decomposition, and overall soil health.

Bacterial Population

The bacterial population in soil significantly increased in treatments that included KSB and foliar KCl. The highest population was recorded in the T10 treatment (Recommended dose of N and P₂O₅ + 75% K₂O + soil application of KSB @ 5 kg ha⁻¹ + 2% KCl foliar spray), with 22.79 cfu × 10⁵ g⁻¹ soil at 60 DAT and 30.07 cfu × 10⁵ g⁻¹ soil after harvest. This was followed by treatments T8 (KSB + 75% K₂O) and T7 (50% K₂O + KSB), which recorded 27.36 and 27.15 cfu × 10⁵ g⁻¹ soil after harvest, respectively (Table 5). The lowest bacterial population (13.38 cfu × 10⁵ g⁻¹ soil after harvest) was observed in treatments with FYM only. The significant increase in bacterial populations under T10 is due to the enhanced availability of potassium through KSB-mediated solubilization and the improved microbial environment created by foliar potassium

application. As Meena *et al.* (2013) ^[15] noted, KSB can solubilize potassium, enhancing microbial activity and soil nutrient dynamics. The findings also corroborate, who observed similar results with biofertilizer applications in other crops.

Fungal Population

The fungal population was highest in T10, with $29.09 \text{ cfu} \times 10^3 \text{ g}^{-1}$ soil at 60 DAT and $43.75 \text{ cfu} \times 10^3 \text{ g}^{-1}$ soil after harvest, followed closely by T8 ($41.67 \text{ cfu} \times 10^3 \text{ g}^{-1}$ soil) and T7 ($38.78 \text{ cfu} \times 10^3 \text{ g}^{-1}$ soil). The lowest fungal population was recorded in FYM-only treatments ($16.79 \text{ cfu} \times 10^3 \text{ g}^{-1}$ soil after harvest) (Table 5). Fungi are vital for decomposing organic matter and facilitating nutrient availability, and their proliferation in KSB-treated soils underscores the role of biofertilizers in enhancing soil health. The organic acids secreted by KSB, such as oxalic and citric acids, contribute to organic matter breakdown and create a conducive environment for fungal activity. Bagyalakshmi *et al.* (2012) ^[2] supported this observation, highlighting the role of KSB in increasing fungal proliferation and nutrient availability.

Actinomycetes Population

Actinomycetes populations, essential for degrading complex organic compounds, were significantly higher in KSB-treated soils. The T10 treatment recorded $12.61 \text{ cfu} \times 10^2 \text{ g}^{-1}$ soil at 60 DAT and $19.80 \text{ cfu} \times 10^2 \text{ g}^{-1}$ soil after harvest, followed by T8 ($18.15 \text{ cfu} \times 10^2 \text{ g}^{-1}$ soil). FYM-only treatments showed the lowest actinomycetes populations ($12.52 \text{ cfu} \times 10^2 \text{ g}^{-1}$ soil after harvest) (Table 5). The combined use of KSB and foliar potassium created a favorable environment for actinomycetes proliferation by improving soil structure and nutrient availability, consistent with the findings of, who reported enhanced microbial activity with biofertilizers in potassium-deficient soils.

Potassium Solubilizing Bacteria (KSB) Population

The highest KSB population was observed in T10, with $33.97 \text{ cfu} \times 10^2 \text{ g}^{-1}$ soil at 60 DAT and $42.78 \text{ cfu} \times 10^2 \text{ g}^{-1}$ soil after harvest, followed by T8 ($37.99 \text{ cfu} \times 10^2 \text{ g}^{-1}$ soil) and T7 ($37.62 \text{ cfu} \times 10^2 \text{ g}^{-1}$ soil). FYM-only treatments recorded the lowest KSB populations ($18.64 \text{ cfu} \times 10^2 \text{ g}^{-1}$ soil after harvest) (Table 5). KSB enhances potassium availability by solubilizing fixed potassium through organic acid production. These results are consistent with findings by Sheng and He (2006) ^[24] and Prajapati *et al.* (2016) ^[21], who demonstrated that KSB application improves nutrient availability and microbial diversity.

Synergistic Effects of KSB and Foliar Potassium

The integration of KSB and foliar potassium in T10 significantly enhanced microbial populations across all categories, demonstrating a synergistic effect. Biofertilizers provide a continuous nutrient supply through microbial activity, while foliar potassium ensures nutrient availability during critical growth stages. This dual approach improved root exudation, serving as a carbon source for microorganisms, and enhanced soil microbial colonization. The findings align with studies by Prajapati *et al.* (2016) ^[21], which highlighted the importance of combining biofertilizers with inorganic nutrients for sustainable soil fertility management.

Key Observations

- Enhanced Microbial Activity:** The T10 treatment demonstrated the highest microbial populations, showcasing

the potential of biofertilizers combined with foliar potassium in boosting soil biological properties.

- Nutrient Cycling and Decomposition:** Enhanced microbial activity facilitated organic matter decomposition and nutrient cycling, essential for maintaining soil fertility.
- Sustainability:** The integrated use of KSB and reduced potassium inputs offers a sustainable solution to chemical fertilizer dependency, improving soil health and crop productivity.

Table 1: Initial soil chemical and biological properties

Chemical properties of soil	
pH (1:2.5)	5.62
EC (1:2) (dS m ⁻¹) at 25 °C	0.058
Organic carbon (per cent)	1.14
Available nitrogen (kg ha ⁻¹)	272.00
Available P ₂ O ₅ (kg ha ⁻¹)	60.30
Available K ₂ O (kg ha ⁻¹)	110.25
Exchangeable calcium [cmol (p+) kg ⁻¹]	0.98
Exchangeable magnesium [cmol (p+) kg ⁻¹]	0.29
Available sulphur (mg kg ⁻¹)	11.46
DTPA Fe (mg kg ⁻¹)	14.31
DTPA Mn (mg kg ⁻¹)	4.12
DTPA Zn (mg kg ⁻¹)	1.45
DTPA Cu (mg kg ⁻¹)	1.92
Biological properties of soil	
Bacteria (cfu ×10 ⁵ g ⁻¹ of soil)	13.15
Fungi (cfu ×10 ⁴ g ⁻¹ of soil)	18.72
Actinomycetes (cfu ×10 ² g ⁻¹ of soil)	12.45
K Solubilizers (cfu ×10 ² g ⁻¹ of soil)	4

Table 2: Chemical properties of soil after harvest of paddy as influenced by soil application of KSB and foliar application of 2% KCl

Treatments	pH	EC (dS m ⁻¹)	OC (per cent)
T ₁	5.24	0.064	1.09
T ₂	5.29	0.054	1.49
T ₃	5.46	0.060	1.36
T ₄	5.38	0.064	1.41
T ₅	5.41	0.078	1.42
T ₆	5.45	0.065	1.39
T ₇	5.54	0.127	1.46
T ₈	5.53	0.084	1.54
T ₉	5.27	0.075	1.32
T ₁₀	5.60	0.071	1.56
T ₁₁	4.98	0.068	0.92
S.Em.±	0.31	0.033	0.13
C.D. at 5%	NS	NS	0.38

Table 4: DTPA extractable micronutrients status of soil after harvest of paddy as influenced by soil application of KSB and foliar application of 2% KCl

Treatments	Fe	Mn	Zn	Cu
	mg kg ⁻¹			
T ₁	15.08	3.50	1.41	1.96
T ₂	17.94	4.29	2.37	3.99
T ₃	15.38	3.23	1.68	2.36
T ₄	16.26	3.53	1.82	3.06
T ₅	17.11	3.88	2.00	3.55
T ₆	16.80	3.85	1.96	3.31
T ₇	17.52	4.03	2.25	3.69
T ₈	19.95	4.52	2.45	4.25
T ₉	16.56	3.56	1.88	3.13
T ₁₀	20.53	4.80	2.63	4.47
T ₁₁	10.18	2.29	0.94	1.11
S. Em.±	0.81	0.22	0.27	0.54
C.D. at 5%	2.41	0.65	0.8	1.6

Table 3: Available nitrogen, phosphorus and potassium content of paddy soil at different growth stage as influenced by soil application of KSB and foliar application of 2% KCl

Treatments	Available N (kg ha ⁻¹)				Available P ₂ O ₅ (kg ha ⁻¹)				Available K ₂ O (kg ha ⁻¹)			
	30 DAT	60 DAT	90 DAT	At harvest	30 DAT	60 DAT	90 DAT	At harvest	30 DAT	60 DAT	90 DAT	At harvest
T ₁	330.79	283.71	241.27	236.20	66.20	52.53	54.83	53.84	121.17	95.71	104.21	101.62
T ₂	366.21	319.53	271.73	266.03	71.93	64.72	61.58	60.46	127.84	132.66	128.41	127.74
T ₃	335.04	301.81	256.75	247.67	70.41	50.16	51.69	50.75	136.64	110.11	109.94	107.21
T ₄	337.06	303.31	256.66	252.52	69.09	53.28	52.98	52.02	139.69	116.17	120.56	118.04
T ₅	347.41	307.61	261.59	256.11	71.46	60.42	62.46	61.33	141.21	127.48	120.64	119.41
T ₆	345.68	304.31	258.79	253.36	71.40	55.49	54.95	53.95	144.56	126.95	122.45	117.28
T ₇	357.74	314.83	267.73	262.11	71.51	61.25	61.16	60.06	140.27	129.61	123.61	120.54
T ₈	371.13	328.16	279.07	273.22	74.33	69.22	66.04	64.84	145.97	135.44	129.87	126.64
T ₉	337.80	301.91	257.93	251.36	72.24	76.81	57.80	56.75	152.98	124.18	117.51	114.60
T ₁₀	379.75	331.34	281.78	275.86	75.69	69.54	66.97	65.76	149.04	138.84	132.39	129.10
T ₁₁	322.40	197.47	167.93	164.40	61.19	53.54	52.40	51.45	105.32	81.24	73.81	66.25
S.Em.±	11.13	7.63	7.86	7.08	1.77	4.59	2.39	1.74	3.03	3.43	2.99	2.86
C.D. at 5%	33.17	22.74	23.43	21.09	5.28	13.68	7.12	5.21	9.04	10.24	8.91	8.54

Table 5: Population of bacteria and fungi actinomycetes and KSB after harvest of paddy as influenced by soil application of KSB and foliar application of 2% KCl.

Treatments	Bacteria (CFU × 10 ⁵ g ⁻¹ of soil)		Fungi (CFU × 10 ³ g ⁻¹ of soil)		Actinomycetes (CFU × 10 ² g ⁻¹ of soil)		KSB (CFU × 10 ² g ⁻¹ of soil)	
	60 DAS	Harvest	60 DAS	Harvest	60 DAS	Harvest	60 DAS	Harvest
T ₁	14.02	13.38	8.92	12.52	8.92	12.52	15.52	18.64
T ₂	18.11	25.62	11.58	17.89	11.58	17.89	31.34	37.62
T ₃	14.25	20.58	9.14	16.23	9.14	16.23	20.03	27.77
T ₄	14.54	19.37	9.23	16.51	9.23	16.51	20.25	26.72
T ₅	18.15	27.15	11.00	17.53	11.00	17.53	26.77	30.93
T ₆	15.62	22.98	10.31	17.00	10.31	17.00	24.55	27.07
T ₇	16.49	24.66	11.29	16.69	11.29	16.69	23.74	30.93
T ₈	20.31	27.36	9.50	17.67	9.50	17.67	30.64	37.99
T ₉	14.86	20.86	12.42	18.15	12.42	18.15	26.94	32.35
T ₁₀	22.79	30.07	12.61	19.80	12.61	19.80	33.97	42.78
T ₁₁	9.11	10.48	5.39	7.74	5.39	7.74	9.29	11.15
S.Em.±	1.94	2.76	1.09	1.51	1.09	1.51	3.07	4.15
C.D. at 5%	5.77	8.22	3.24	4.49	3.24	4.49	9.14	12.36

Conclusion

The combined application of potassium solubilizing bacteria (KSB) and foliar potassium significantly improved soil chemical and biological properties. Enhanced nutrient availability, including potassium, nitrogen, and phosphorus, was observed alongside increased microbial populations such as bacteria, fungi, and actinomycetes. These improvements facilitated better nutrient cycling, organic matter decomposition, and overall soil fertility. Integrating KSB with foliar potassium provided a sustainable approach to addressing nutrient deficiencies in soils, reducing dependence on chemical fertilizers, and promoting long-term soil health. This strategy offers a cost-effective and eco-friendly solution to enhance crop productivity while maintaining soil ecological balance and sustainability.

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