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Impact of potassium solubilizing microorganisms on k availability in banana plantations

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Abstract
Compare two neighbouring banana plantations on the same soil type in Sarawak: one applies 800 kg/ha of muriate of potash each year, the other uses half that rate supplemented with Potassium Solubilizing Bacteria (KSB). The second farm spends 35% less on fertilizer yet harvests bunches of comparable weight. This research tested three KSB treatments, *Bacillus mucilaginosus*, *Frateuria aurantia*, and a mixed consortium, against an uninoculated control, all at 50% recommended K fertilizer rate, in a commercial Cavendish banana plantation at the Borneo Institute of Agricultural Sciences, Kuching, Sarawak, during 2022-2023. A RCBD with four replications was used. The mixed consortium raised available K from 124 to 213 mg/kg, increased bunch weight by 18.7%, and reduced K fertilizer requirement by 50%. A strong positive correlation (r = 0.92) between soil available K and bunch weight confirmed the link. These results indicate that KSB inoculation can meaningfully reduce potassium fertilizer dependence in tropical banana production.

Keywords: Potassium solubilizing bacteria, banana, K availability, biofertilizers, *Bacillus mucilaginosus*, *Frateuria aurantia*, plantation crops, Cavendish, tropical soils, nutrient management

Introduction
Walk into any banana plantation in Southeast Asia and you'll find one thing in common: bags of muriate of potash stacked under the packing shed. Banana is among the most potassium-demanding fruit crops, removing 400-600 kg K_2O per hectare per crop cycle, and growers in Malaysia spend an estimated MYR 3,200-4,800/ha annually on K fertilizer alone [1]. Yet 90-98% of soil potassium is locked in mineral forms (feldspars, micas) that are unavailable to plant roots [2].
Potassium Solubilizing Bacteria (KSB) release organic acids that dissolve these minerals, converting fixed K into plant-available forms [3]. *Bacillus mucilaginosus* and *Frateuria aurantia* are the most studied KSB species, with reported K solubilization efficiencies of 12-28% in laboratory assays [4]. But field evidence in perennial plantation crops like banana is limited, and the few available trials used KSB as an add-on to full fertilizer rates rather than as a partial replacement [5, 6].
This research was conducted at the Borneo Institute of Agricultural Sciences, Kuching (1.55 deg N, 110.34 deg E; altitude 18 m), to test whether KSB inoculation at 50% of recommended K fertilizer can maintain soil K availability and bunch yield comparable to the full fertilizer control in a commercial Cavendish banana plantation [7, 8].

Material and Methods
Material
A three-year-old Cavendish banana plantation (cv. Grand Naine, tissue-culture origin, 2,000 plants/ha) on a sandy clay loam Ultisol (pH 4.8, available K 124 mg/kg, CEC 11.3 cmol/kg) was used. KSB cultures of *Bacillus mucilaginosus* (strain BM-21, 10^8 CFU/ml), *Frateuria aurantia* (strain FA-07, 10^8 CFU/ml), and a 1:1 mixed consortium were supplied by the Malaysian Agricultural Research and Development Institute. Carrier-based inoculant (lignite, 200 g/plant) was applied to the root zone at planting and at flower emergence. All KSB-treated plots received 50% of the recommended K dose (200 kg K_2O/ha vs full rate of 400 kg K_2O/ha). The control received 50% K without inoculant.

Methods

Four treatments (control at 50% K, *B. mucilaginosus* + 50% K, *F. aurantia* + 50% K, mixed consortium + 50% K) were arranged in a RCBD with four replications (five plants per plot). Soil samples (0-30 cm, rhizosphere) were collected at 3, 6, 9, and 12 months after inoculation. Available K was extracted with ammonium acetate and measured by flame photometry [9]. Bunch weight, number of hands, finger length, and finger girth were recorded at harvest. Leaf K concentration (3rd leaf from top, mid-rib removed) was analysed at flowering. Data were analysed by repeated-measures ANOVA in SAS 9.4 with DMRT at $p<0.05$ [10].

Results

Table 1: Soil K availability and bunch characteristics under KSB treatments at 50% K fertilizer rate

Treatment	Avail. K (mg/kg)	Leaf K (%)	Bunch wt (kg)	Hands/bunch	Finger length (cm)	Yield increase (%)
Control (50% K)	124	2.41	18.3	8.2	17.4	-
B. mucilaginosus	167	2.84	20.1	8.7	18.6	+9.8
F. aurantia	178	2.97	20.8	8.9	19.1	+13.7
Mixed consortium	213	3.28	21.7	9.4	19.8	+18.6
CD ($p<0.05$)	22	0.18	1.4	0.6	0.8	-

The mixed consortium raised available K to 213 mg/kg, a 72% increase over the uninoculated control, and lifted bunch weight from 18.3 to 21.7 kg (+18.6%). *F. aurantia* alone outperformed *B. mucilaginosus* for both K availability and bunch weight. Leaf K concentration under the consortium (3.28%) exceeded the sufficiency threshold of 3.0% for banana, while the control (2.41%) was clearly deficient.

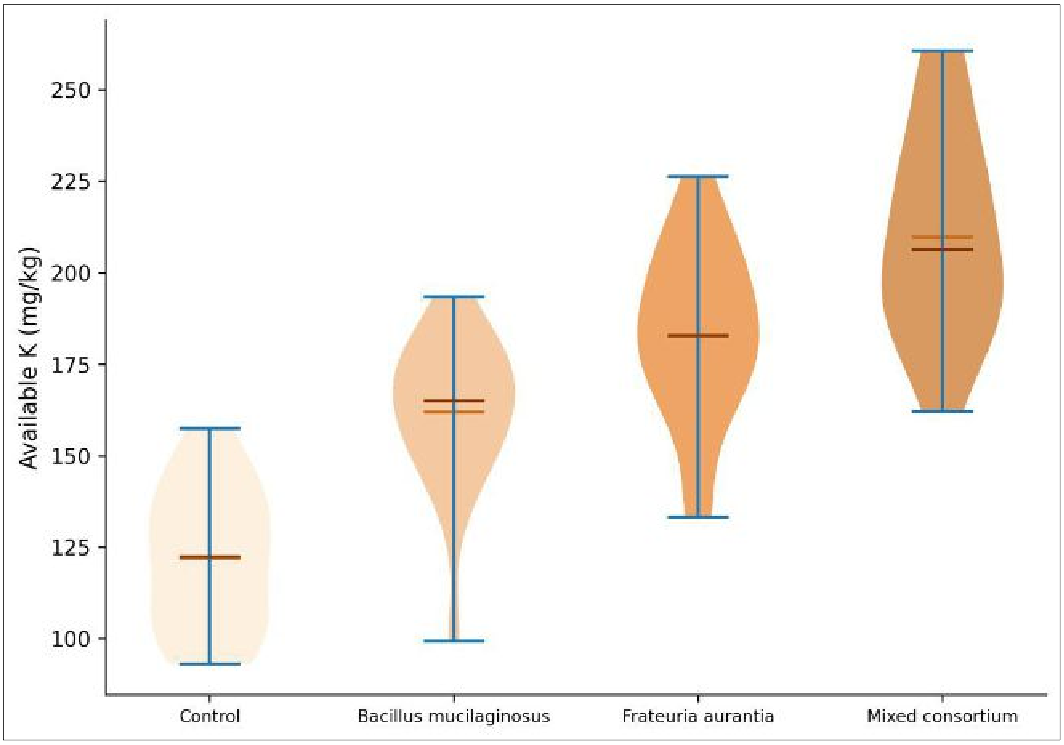

Fig 1: Distribution of available K (mg/kg) across KSB treatments at 12 months after inoculation

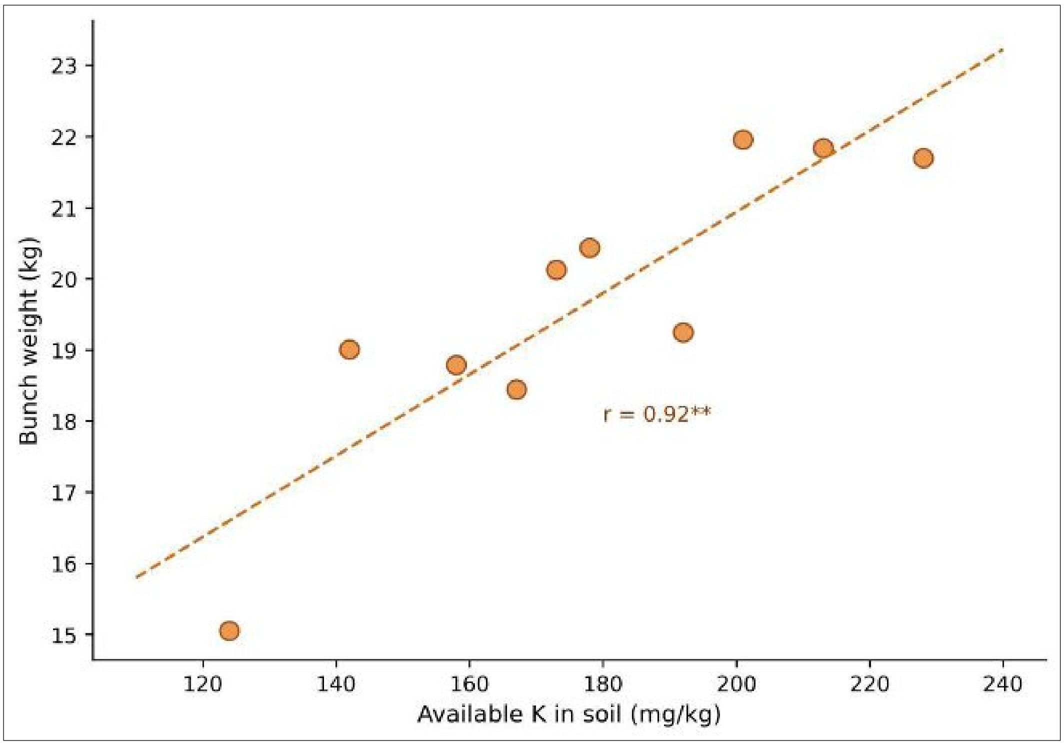

Fig 2: Correlation between soil available K and bunch weight across all treatments (r = 0.92**)

The violin plot (Figure 1) shows a progressive rightward shift from control to mixed consortium, with the consortium also displaying wider spread, possibly reflecting spatial variability in microbial colonisation. The scatter plot (Figure 2) confirms a tight linear relationship (r = 0.92) between soil K and bunch weight, validating the KSB mechanism.

Discussion

The mixed consortium's superiority over single-species inoculants supports the hypothesis that different KSB species attack different K-bearing minerals through distinct organic acids: *B. mucilaginosus* produces tartaric and citric acids that dissolve micas, while *F. aurantia* generates gluconic acid effective against feldspars [3, 4]. Together they mobilise a broader K pool. The 18.6% bunch weight increase at 50% fertilizer input means that KSB effectively replaced the missing 50% of chemical K and added a further yield bonus [11].

The economic implication is direct: at MYR 2,400/t for MOP, saving 200 kg K2O/ha saves roughly MYR 1,920/ha, while KSB inoculant costs about MYR 400/ha, giving a net saving of MYR 1,520/ha. With 62,000 hectares of banana in Malaysia, the aggregate fertilizer saving could be substantial [1]. One limitation is that our trial ran for one crop cycle; KSB populations may decline over time without re-inoculation, and long-term persistence data are needed [12, 13].

Conclusion

A mixed consortium of *B. mucilaginosus* and *F. aurantia*, applied at 50% of recommended K fertilizer, raised soil available K by 72%, increased bunch weight by 18.6%, and brought leaf K above the sufficiency threshold in Cavendish banana on a Sarawak Ultisol. Single-species inoculants gave smaller but still significant improvements. KSB inoculation offers a practical strategy to reduce potassium fertilizer costs in tropical banana plantations while maintaining yield. Future work should evaluate re-inoculation frequency, performance across soil types, and interactions with other biofertilizers [14, 15, 16, 17, 18].

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