International Journal of Bio-resource and Stress Management https://ojs.pphouse.org/index.php/IJBSM

Crossref

IJBSM July 2026, 17(7): 01-10

Article AR7107

Research Article

Natural Resource Management

DOI: HTTPS://DOI.ORG/10.23910/1.2026.7107

Appraisal of Dual-mode Application of Potassium Solubilizing Bacteria (*Bacillus amyloliquefaciens*) in K-rich Sandy Loam Soil: Insights from Sweet Corn

Santanu Kundu[1], S. K. Sudhakar[1], K. R. Gade[2], S. Vijay Kumar[1], S. K. Banoth[1] and M. K. Goud[1]

[1]Dept. of Agronomy, Professor Jayashankar Telangana Agricultural University, Hyderabad (500 030), India
[2]Dept. of Soil Science, AICRP on Integrated Farming System, Professor Jayashankar Telangana Agricultural University, Hyderabad (500 030), India

Open Access

Corresponding santanukundu120@gmail.com

0009-0001-4182-6939

ABSTRACT

An experiment was undertaken during the winter season (November, 2022–February, 2023) at the college farm of the Professor Jayashankar Telangana Agricultural University (PJTAU), Rajendranagar, Hyderabad, India. In this study, dual-mode application of potassium (K) solubilizing and plant growth promoting bacteria (KSB) strain *Bacillus amyloliquefaciens* was used to substitute chemical K-fertilizer for high K demanding sweet corn, in K-rich sandy loam soil to improve sweet corn yield, quality and profitability. Overreliance on chemical fertilizers in agriculture jeopardized human, plant, and soil health, leading to deterioration of agricultural productivity and soil functions despite continued fertilizer use. Hence, integrated use of chemical and biofertilizers may address these problems. Present experiment showed non-significant differences in plant performance up to knee-height stage (30 DAS). However, complete avoidance of recommended chemical-K (RDK_0)±KSB was inferior to other treatments. From 60 DAS onward, significantly higher leaf area and biomass accumulation plant^{-1} were recorded with all 100% RDK (basal or split application)±KSB treatments and 75% RDK+KSB. Consequently, 30.5–19.2% higher green cob yield, 27.4–16.76% higher stover yield, and 49.6–28.6% higher net returns were observed, along with increased total soluble solids, N and K content, and crude protein in kernels compared to 0% RDK. However, kernel and fodder P content was significantly higher with KSB application irrespective of fertilizer dose. Crop growth rate significantly varied from knee-height to tasseling stage, while micronutrient content in kernels remained unaffected. Thus, KSB substituted recommended potassium fertilizer dose by 25% without compromising crop performance and sweet corn quality.

KEYWORDS: Kernel quality, seed treatment, soil drenching, plant performance

Citation* (VANCOUVER)*: Kundu et al., Appraisal of Dual-mode Application of Potassium Solubilizing Bacteria (*Bacillus amyloliquefaciens*) in K-rich Sandy Loam Soil: Insights from Sweet Corn. *International Journal of Bio-resource and Stress Management,* 2026; 17(7), 01-10. HTTPS://DOI.ORG/10.23910/1.2026.7107.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, author have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The author has declared that no conflict of interest exists.

RECEIVED on 03rd April 2026 RECEIVED in revised form on 20th June 2026 ACCEPTED in final form on 04th July 2026 PUBLISHED on 10th July 2026

1. INTRODUCTION

India accounts for nearly 17.7% of the global population and has achieved self-sufficiency in food grain production. However, India's rank remained 105th in the Global Hunger Index (GHI), primarily due to food quality and nutritional inadequacy (Kundu et al., 2025). The Food and Agriculture Organization (FAO) emphasized that nutritional security was an integral component of food security (Hwalla et al., 2016). Therefore, ensuring both quality and quantity of agricultural produce through sustainable production technologies has become imperative. Agriculture is the backbone of the Indian economy, with 42.3% of the population directly dependent on it and contributing 18.2% to the national GDP (Anonymous, 2024). Under such circumstances, profitability of production systems must be prioritized along with yield and quality enhancement, particularly in high-value crops like sweet corn. Sweet corn, a specialty type of maize treated as a vegetable, has gained popularity due to its fresh consumption and superior palatability (Anonymous, 2022). Corn was found to be responsive to higher dose of potassium (K) fertilization due to its optimum physiological function (Biswas et al., 2023; Mohamed et al., 2025). Sweet corn possesses the sugary-1 (su1) gene, which facilitates sugar accumulation in the endosperm by suppressing starch synthesis (Ruanjaichon et al., 2021). Additionally, sweet corn is valued for its rich phytonutritional profile, including dietary fibre, vitamins, and essential minerals (Revilla et al., 2021). Important role of potassium (K) was found in the plant metabolism, enzyme activation, and assimilate translocation, which directly influence crop productivity and produce quality (Olaniyan et al., 2022). In Telangana (Rajendranagar), recommended dose of K for sweet corn is 50 kg ha^{-1}, even in medium to high K soil (Reddy et al., 2023). Because, maize/sweet corn was found to be responsive to higher dose of chemical K fertilizer (Gnanasundari et al., 2019; Biswas et al., 2023), and a substantial K-uptake by sweet corn was also observed (Lavanya et al., 2024). Potassium solubilizing bacteria (KSB) strains have been recognized for their dual functionality like plant growth enhancing rhizobacteria (secretes plant growth promoting hormones like auxins, gibberellin and cytokinin) and nutrient (K) mobilizing bacteria, capable of solubilizing native unavailable soil K (generally unavailable soil K accounts for 90–98% of total soil K) into plant-available forms (Etesami et al., 2017; Kumar et al., 2024), through the process of acidolysis, chelation, complexolysis, and ion-exchange reactions (Olaniyan et al., 2022). Hence, KSB integration with chemical fertilizers may offers a promising strategy to enhance crop performance, while reducing environmental pollution and chemical fertilizer input costs (Sattar et al., 2019). Therefore, it had been hypothesized that application KSB strain through seed treatment and soil drenching would improve the sweet corn performance and also improve the quality of the produce in a lucrative way with a meagre dose of recommended chemical K fertilizer in K-rich soil. In order to analyse the hypothesis, a novel experiment had been undertaken with dual-mode application of KSB strain *Bacillus amyloliquefaciens* in conjunction with chemical K-fertilizer in sandy loam soil of semi-arid tropic. The aim of our study was to evaluate the effects of dual-mode application of potassium-solubilizing bacteria (KSB) coupled with different doses of chemical K-fertilizer, on the growth, productivity, and economics of sweet corn. This study also assessed the effects of these treatments on primary macronutrient content in stover and on the quality of sweet corn kernels.

2. MATERIALS AND METHODS

2.1. Climate and study location

An experiment was undertaken during the winter season of (November, 2022–February, 2023) at the college farm (Location- 17°19'18" N, 78°24'31" E) of the Professor Jayashankar Telangana Agricultural University (PJTAU), Rajendranagar, Hyderabad, India, for evaluating the proposed hypothesis in sweet corn. Initial soil physio-chemical properties were analysed by duly following the standard procedures (Table 1). During the crop growth period, weather parameters such as maximum-minimum temperature was ranged between 30.4–14.7°C and relative humidity was conducive for crop growth and development. There was no rainy day in entire cropping period, crop was grown completely under irrigated condition.

Table 1: Soil properties of the exact location of the experiment (samples were collected before starting of the experiment)

Soil parameters	Initial status	Adopted method and instrument used	References
Soil texture	Sandy loam	Hydrometer method	Piper (1966)
pH	7.45	Soil: Water -1:2.5 (pH meter)	Jackson (1973)
Organic Carbon (%)	0.41	Wet digestion method	Walkley and Black (1934)
Av. Nitrogen (ppm)	79.11	Hot alkaline $KMnO_4$ Method (Kjeldahl apparatus)	Subbiah and Asija (1956)
Av. Phosphorous (ppm)	11.69	0.5 M $NaHCO_3$ extract (Spectrophotometer)	Olsen et al. (1954)
Av. K (ppm)	188.3	Neutral N NH_4OAc extract (Flame photometer)	Jackson (1973)

2.2. Experiment details

The experiment with 10 potassium management practices, was evaluated in randomized block design (RBD) and 3 replications were there for each treatment. The 10 treatments included: RDK_0: 0% Recommended dose of potassium, RDK_{100}: 100% RDK (Basal) (i.e., 50 kg K ha^{-1}), RDK_{50}: 50% RDK (Basal), RDK_{75}: 75% RDK (Basal), RDK_{50+50}: 50% RDK (Basal)+50% RDK at 25 DAS, RDK_0+KSB: RDK_0+potassium solubilizing bacteria (KSB) (Seed treatment+Soil drenching at 25 DAS), RDK_{100}+KSB: RDK_{100}+KSB (Seed treatment+Soil drenching at 25 DAS) , RDK_{50}+KSB: RDK_{50}+KSB (Seed treatment+Soil drenching at 25 DAS), RDK_{75}+KSB: RDK_{75}+KSB (Seed treatment+Soil drenching at 25 DAS), RDK_{50+50}+KSB: RDK_{50+50} +KSB (Seed treatment+soil drenching at 25 DAS). RDK was given based on regional guideline of College of Agriculture (PJTAU), Rajendranagar, Hyderabad. Seeds of "Madhuri" variety of sweet corn were treated with KSB strain (*Bacillus amyloliquefaciens*) (procured from Department of Microbiology, PJTAU) at 10 ml kg^{-1} seed. Seed treatment was done with sugar solution. For this, 200 g sugar was added in 1 l of water and solution was boiled for 5 min and left to get cool for 1 hr, then KSB solution was mixed with sugar solution at 10 ml kg^{-1} seed and sprinkled over the seed and mixed thoroughly so that KSB solution got adhered to the seed surface then treated seeds were dried. This seed treatment was accomplished at night and next day early morning sowing was done as per treatment allocation. In case of soil drenching, KSB was added in fresh water at 2.5 ml l^{-1} and applied to root zone by battery operated power sprayer (nozzle was kept loose for making bigger droplet size), drenching was done when soil was moist. The total dose of N (i.e., 200 kg ha^{-1}) for sweet corn was applied through urea in three equal splits at sowing, 25 DAS and at 60 DAS. Whereas total dose of P (i.e., 60 kg ha^{-1}) was supplied as basal through SSP (Reddy et al., 2023), and chemical K-fertilizer (MOP) was administrated as per the treatments.

2.3. Plant response and performance assessment

In each plot, five plants (representative plant) were selected randomly and tagged from the middle portion of the plot to record no. of leaves $plant^{-1}$ and quality of sweet corn kernel and fodder. After harvesting of green cobs (from 1 m^2 area and 3 random places of the net plot area) at dough stage, the plants from same area were cut at the base and the weight of stover was recorded in kg m^{-2}. Destructive sampling was done (at knee height stage -30 DAS, tasseling -60 DAS, and at harvest) from penultimate two rows of the plots to record leaf area (cm^2 $plant^{-1}$) in leaf area meter (Model CI-203) and above ground plant biomass accumulation (g $plant^{-1}$) (plant samples were initially shade dried followed by in a hot air oven at 60±2°C until a constant weight was reached). In specific time interval, plant performance was calculated based on the following formulae (Eq. 1), adopted from Barman et al. (2025).

Crop growth rate (CGR) (g $plant^{-1}$) day^{-1})=$(W_2-W_1)/(T_2-T_1)$..(1)

[Where, W_1, T_1 and W_2, T_2 are the consecutive dry weights and sampling time, respectively]

2.4. Produce quality assessment

Green cobs (dough stage), harvested from representative plants, were taken to the laboratory and some kernels were separated from each cob. Kernels were crushed with mortar and pestle and the paste was squeezed to place 1 or 2 drops of kernel sap on the refractometer and TSS values were recorded as percentage (Kinge et al., 2024). After drying, kernels (collected from representative plants) were finely powdered in Willey's mill and the powdered samples were used to determine crude protein content and micronutrient content. Nitrogen content was estimated by the Kjeldahl method. A 1 g ground grain sample was digested with concentrated H_2SO_4 and a catalyst mixture (K_2SO_4 and $CuSO_4$), followed by distillation and titration of liberated ammonia against standard 0.02 N H_2SO_4 to determine N percentage (Rawal et al., 2024). By multiplying 6.25 with N %, crude protein content was calculated (Kabir et al., 2019), whereas prior to distillation of plant samples (leaf and stem together) were digested with concentrated H_2SO_4 on hot plate.

For phosphorous, potassium and micronutrients estimation, 1 g of powdered grain sample was digested with the di- acid mixture (HNO_3: $HClO_4$ in the proportion of 3:1), filtered and diluted to 100 ml with distilled water. The di-acid digested grain samples were analysed for Zn, Fe, Mn, Cu content by using Inductively Coupled Plasma Optical Emission Spectroscopy (Instrument model- ICP-OES-5110 VDV) method (Senila, 2024) and the results were noted in mg kg^{-1}. P and K content were estimated using spectrophotometer and flame-photometer, respectively (Barman et al., 2025).

2.5. Cost of cultivation and profitability assessment

The economics of the experiment were calculated on a large scale (i.e., per hectare) basis to obtain a broader understanding of its economic returns. Treatment-wise cost of cultivation and economic returns were estimated considering the operational cost of each treatment, cost of production, and the prevailing market price of the produce at the time of sale. Details cost of cultivation of different treatments has been mentioned in Table 4.

Gross returns were obtained from the income came from the sale of green cobs based on market value. Net returns were obtained by subtracting total cost of cultivation from the gross returns [Net returns (₹ ha^{-1})= Gross returns (₹ ha^{-1}) – Cost of cultivation (₹ ha^{-1})]. Benefit cost ratio (B:C) (Eq. 2) and economic efficiency (Eq. 3) (Bhargavi et al., 2019) were computed by using the following formula:

B:C=(Gross returns (₹ ha^{-1})/(Cost of cultivation (₹ ha^{-1}) ..(2)

Economic efficiency (₹ ha^{-1} day^{-1})=(Net returns (₹ ha^{-1})/(Crop duration (days) .... (3)

2.6. Statistics

Statistical comparisons of the measured parameters were carried out using ANOVA for a Randomized Block Design. All treatment means were compared by the LSD test at p=0.05. Correlation analysis was also carried out to estimate the degree of association between plant growth parameters, yield and primary macro nutrient content in economic and vegetative plant part. Data analysis and visualization were carried out in R-software (version R-4.5.2).

3. RESULTS AND DISCUSSION

3.1. Crop performance and yield

The role of potassium management practices was insignificant with respect to leaves $plant^{-1}$ in sweet corn at different growth stages. At knee height stage (30 DAS), tasseling stage (60 DAS) and at harvest, average no. of leaves $plant^{-1}$ were 4.5, 10.8 and 12.7, respectively (Table 3). No. of leaves might have been influenced by the plant genetic character; hence this parameter did not differ significantly across the treatments. However, leaf area $plant^{-1}$ was responsive to bacterial inoculation and higher dose of chemical K-fertilizers (Table 2). Biomass accumulation $plant^{-1}$ was significantly lower with 0% RDK irrespective of KSB treatments, and remaining treatments were equivalent at knee height stage (30 DAS). However, from tasseling stage (60 DAS) onward all 100% RDK treatments+KSB and 75% RDK+KSB were significantly superior till the harvest. As a result, significantly higher green cob yield (1.97–1.80 kg m^{-2}) and stover yield (2.28–2.09 kg m^{-2}) were also recorded with the same treatments (Table 2). It was noteworthy that substitution of 25% RDK without KSB or further reduction of RDK to the extent of 50% irrespective of KSB treatment could not confer significant impact on sweet corn performance. Except the treatments having 0% RDK, crop growth rate (CGR) was not significantly varied across the treatments up to 30 DAS. Thereafter, within 30-60 DAS, significantly higher CGR was found with all 100% RDK (irrespective of KSB treatment) and 75% RDK+KSB. Then, interestingly, in subsequent stage (60–90 DAS), significant difference in CGR was not observed owing to the treatment imposition (Table 2). Hence, crop growth within 30 to 60 DAS was very crucial and a determining factor in ultimate variation in sweet corn performance. Moreover, absolute values of plant growth attributes were numerically higher with split application of 100% RDK+KSB in sandy loam soil due to steady and optimum availability of plant nutrient within 30–60 DAS.

Response of maize to chemical K supplement was also reported by Biswas et al. (2023), Mohamed et al. (2025), and Fadhil et al. (2025). It might be due to the higher and steady requirement K for corn (Gnanasundari et al., 2019; Mohamed et al., 2025). KSB also performed as a PGPR and released the plant growth promoting hormones (auxin,

Table 2: Individual plant performance and yield of sweet corn as influenced by dual-mode application of KSB strain (*Bacillus amyloliquefaciens*) and chemical fertilizers in sandy loam soil

Treatments†	Number of leaves $plant^{-1}$			Leaf area (cm^2) $plant^{-1}$		
	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest
RDK_0	4.4	10.8	12.9	372.1	3852.2	3828.3
RDK_{100}	4.7	10.7	12.5	624.2	5904.4	5772.0
RDK_{50}	4.4	10.9	12.7	576.0	3972.1	3936.2
RDK_{75}	4.5	10.7	12.5	612.3	4920.2	4812.2
RDK_{50+50}	4.7	10.7	12.9	588.3	6000.2	5736.1
RDK_0+KSB	4.6	11.0	12.7	384.2	3948.3	3876.3
RDK_{100}+KSB	4.7	10.8	12.7	636.2	5940.1	5856.2
RDK_{50}+KSB	4.4	10.7	12.5	600.1	4668.0	4584.0
RDK_{75}+KSB	4.4	11.0	12.9	624.0	5424.4	5376.0
RDK_{50+50}+KSB	4.5	10.7	12.7	600.2	6240.7	6144.7
SEm±	0.1	0.1	0.2	28.2	310.9	279.0
LSD (p=0.05)	ns	ns	ns	83.7	923.7	828.9

Table 2: Continue...

Treatments†	Dry matter accumulation (g plant^{-1})			Crop growth rate (g plant^{-1} day^{-1})			Stover yield (kg m^{-2})	Green cob yield (kg m^{-2})
	30 DAS	60 DAS	Harvest	0–30 DAS	30–60 DAS	60–90 DAS		
RDK_0	4.61	83.84	171.58	0.15	2.64	2.92	1.79	1.51
RDK_{100}	5.71	108.78	206.23	0.19	3.44	3.25	2.22	1.91
RDK_{50}	5.45	84.19	172.99	0.18	2.62	2.96	1.83	1.55
RDK_{75}	5.64	96.44	183.72	0.19	3.03	2.91	1.88	1.61
RDK_{50+50}	5.46	110.22	206.52	0.18	3.49	3.21	2.26	1.95
RDK_0+KSB	4.74	83.93	171.90	0.16	2.64	2.93	1.79	1.52
RDK_{100}+KSB	5.76	109.32	206.34	0.19	3.45	3.23	2.24	1.93
RDK_{50}+KSB	5.58	95.88	178.96	0.19	3.01	2.77	1.85	1.58
RDK_{75}+KSB	5.66	107.84	196.54	0.18	3.41	2.96	2.09	1.80
RDK_{50+50}+KSB	5.60	110.40	206.93	0.19	3.49	3.22	2.28	1.97
SEm±	0.23	4.34	6.97	0.01	0.14	0.17	0.09	0.08
LSD (p=0.05)	0.70	12.91	20.72	0.02	0.412	ns	0.26	0.22

DAS: Days after sowing; ns: Nonsignificant, †Treatment details have been mentioned in materials and methods section

Table 3: Quality parameters of sweet corn kernel as influenced by dual-mode application of KSB strain (Bacillus amyloliquefaciens) and chemical fertilizers in sandy loam soil

Treatments†	Quality parameters					
	TSS (%)	Crude protein (%)	Micronutrient content (mg kg^{-1}) in kernel			
			Fe	Mn	Zn	Cu
RDK_0	11.8	7.4	30.2	6.0	23.7	4.5
RDK_{100}	15.8	10.1	30.6	6.2	24.7	4.7
RDK_{50}	12.0	7.5	30.8	5.9	24.1	4.6
RDK_{75}	13.8	8.9	29.8	6.1	24.3	4.6
RDK_{50+50}	16.2	10.4	30.7	6.2	25.3	4.6
RDK_0+KSB	11.9	7.5	31.1	6.5	23.8	4.8
RDK_{100}+KSB	16.1	10.2	31.6	7.2	24.9	5.1
RDK_{50}+KSB	13.5	8.4	32.2	6.8	24.1	4.8
RDK_{75}+KSB	15.1	9.5	31.8	7.1	24.6	4.9
RDK_{50+50}+KSB	16.5	10.5	32.4	7.2	25.4	5.1
SEm±	0.6	0.4	1.3	0.4	1.2	0.3
LSD (p=0.05)	1.7	1.1	ns	ns	ns	ns

TSS: Total soluble solid; ns: Nonsignificant; †Treatment details have been mentioned in materials and methods section.

cytokinin) in plant rhizosphere, thereby, it accentuated the plant shoot and root proliferation (Etesami et al., 2017; Kumar et al., 2024). Apart from that, proper dose of K fertilizer influenced the N acquisition positively (Figure 1, 2), which also augmented protein synthesis, overall plant metabolism (Cui and Tcherkez, 2021) and photosynthetic activity (Chen et al., 2021), and eventually the effect was reflected in plant performance. Moreover, Amanullah et al. (2016) and Wang et al. (2025) also reported that split application of 100% RDK in sandy loam soil was more beneficial than that of 100% RDK as basal in terms of growth and yield of maize and wheat.

3.2. Primary macro nutrient (N, P, K) Content (%) in kernel and stover

Among the primary macro nutrient content in sweet corn kernel and stover, a synergistic interaction was found in between N and K. Application of 100% RDK (either split or basal)±KSB and 75% RDK+KSB resulted in higher K content in kernel (0.811–0.801%) and stover (1.219–1.205%), which further augmented the N content in kernel and fodder (Figure 1). However, in case of higher P content in kernel (0.085–0.088%) and stover (0.057–0.058%), treatments with KSB were found to be superior regardless of chemical K fertilizer dose (Figure 1).

This result was found due to the vital role of potassium in nitrate reductase activity and nitrogen assimilation in leaves (Cao et al., 2025). The synergistic interaction between N and K in improving plant performance of oil seed crop was also observed by Li et al. (2023). Additionally, the release of organic acids by KSB also facilitated the P solubilization process and subsequent acquisition by plant, thereby, accessibility to fixed nutrients also enhanced (Olaniyan et al., 2022; Tian et al., 2024).

3.3. Total soluble solid (TSS), crude protein, and micronutrient content in kernel

TSS indicated the sweetness of the kernel, "Madhuri"

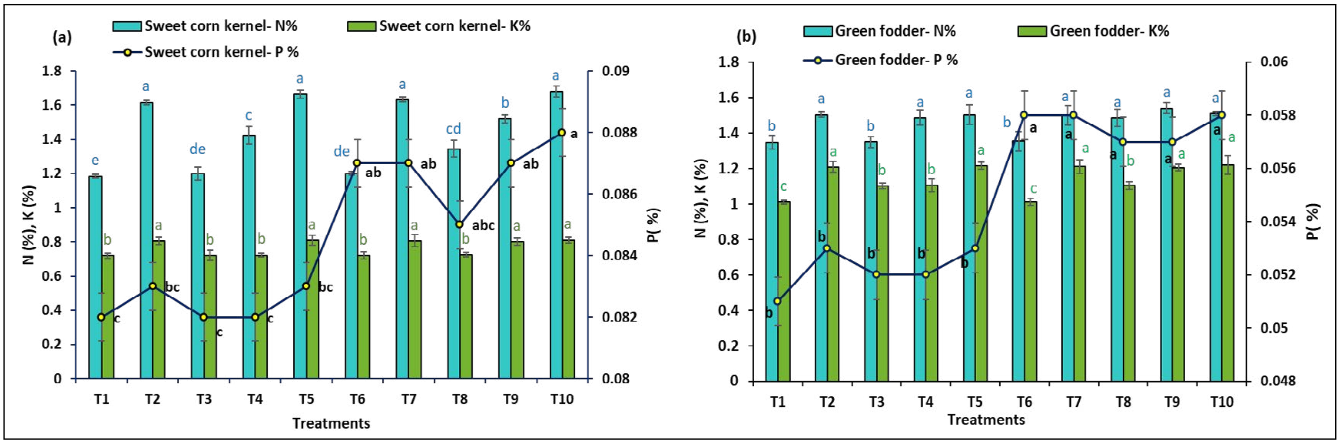

Figure 1: Effect of dual-mode application of KSB and chemical K fertilizer on N, P, K content (%) in sweet corn kernel (a) and stover (b) during the time of harvest. Similar lowercase letter atop the bar indicates no significant difference between the treatments at p=0.05 by the LSD test. T_1: RDK_0, T_2: RDK_{100}, T_3: RDK_{50}, T_4: RDK_{75}, T_5: RDK_{50+50}, T_6: RDK_0+KSB (Seed Treatment+Soil Drenching at 25 DAS), T_7: RDK_{100}+KSB, T_8: RDK_{50}+KSB, T_9: RDK_{75}+KSB, T_{10}: RDK_{50+50}+KSB

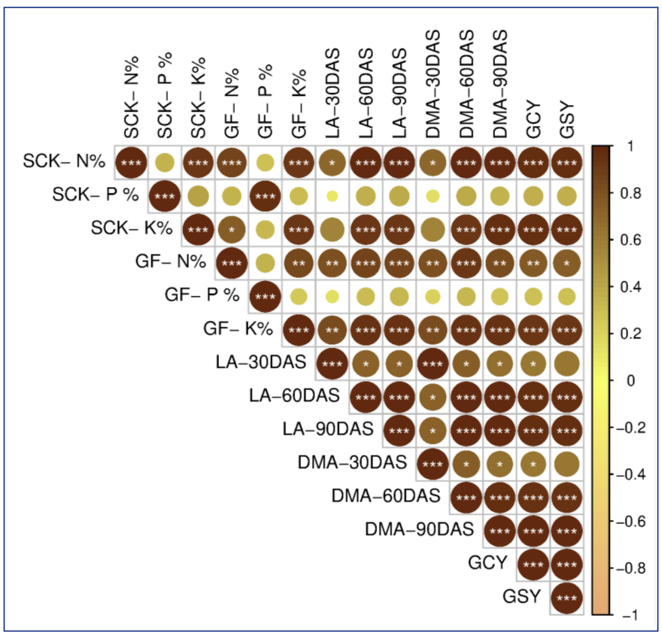

Figure 2: Correlation matrix between sweet corn kernel and stover nutrient content, growth attributes, green cob and stover yield. DAS: Days after sowing, SCK: Sweet corn kernel, GF: Green fodder/stover, LA: Leaf area, DMA: Dry matter accumulation, GCY: Green cob yield, GSY: Stover yield, *Significant at $p \leq 0.05$; **Significant at $p \leq 0.01$; ***Significant at $p \leq 0.001$

variety of sweet corn had average TSS content of 14.3% in this experiment with a highest value of 16.5%. However, similar result was recorded with all 100% RDK±KSB and with 75% RDK+KSB treatment. Lowest TSS content (11.8%) was observed with 0% RDK treatment (Table 3). This emphasized the role of external application of K for sweetness in kernel. Interestingly, when KSB was involved as treatment component with K fertilizer irrespective of the doses, it caused increment in TSS. Proper translocation of photosynthates and accumulation of sugar (upregulation of "*su 1*" gene) in sweet corn kernel as mediated by K^+ ions might have resulted into this increment in TSS content (Okumura et al., 2013; Wang et al., 2024).

The crude protein content was ranged between 7.4% (RDK_0) and 10.5% (RDK_{50+50}+KSB) with an average of 9.0%. The highest value was comparable with all RDK_{100}±KSB and RDK_{75}+KSB. Lowest crude protein content was recorded with 0% RDK (Table 3). Adequacy of K might have influenced nitrogen assimilation process in leaves as described by Hu et al. (2016), that ultimately reflected in crude protein content in kernels. This finding was in close agreement with Anees et al. (2016), where spraying of 0.1% K_2SO_4 significantly influenced the crude protein content in maize kernel.

Micronutrient (viz., Fe, Mn, Zn, Cu) content in sweet corn kernel was found to be insignificantly varied owing to potassium management practices (Table 3). However, KSB application resulted in numerically higher micronutrient content in grain. Release of organic acid by KSB might have slightly hastened the availability of micronutrient in soil and that reflected in result (Maurya et al., 2014; Tian et al., 2024).

3.4. Economics

In this study, application of different doses of chemical K-fertilizer with or without KSB treatment altered the cost of cultivation for different treatments. Because of more expenditure for 100% RDK and KSB seed treatment and soil drenching, highest cost of cultivation was recorded with RDK_{50+50}+KSB and RDK_{100}+KSB (₹ 58004 ha^{-1}) followed by RDK_{75}+KSB (₹ 57544 ha^{-1}) and RDK_{50}+KSB (₹ 57086 ha^{-1}). Lowest cost of cultivation (₹ 53590 ha^{-1}) was noted with RDK_0 (Table 4). However, all 100% RDK (either split or basal application) treatments irrespective of integration of KSB and 75% RDK+KSB fetched higher and comparable gross returns. Further reduction in RDK fetched less gross return (Table 5). Because of yield inferiority, lowest gross return was recorded with RDK_0 (₹ 120800 ha^{-1}). It implied that KSB could potentially substitute the 25% RDK as a result better economic yield fetched statistically similar gross return with RDK_{75}+KSB.

Among all treatments, highest net return (Rs.100573 ha^{-1}) was observed with RDK_{50+50}. However, statistical equivalence was established among all 100% RDK±KSB (Table 5). Reduction of RDK without any additional intervention resulted into curtailed monetary returns. Whereas, 25% reduction of RDK with KSB fetched comparable net return (₹ 86456 ha^{-1}) with respect to 100% RDK±KSB. It implied that, in sandy loam soil, in order to get high monetary returns, application of 100% RDK

Table 4: Cost of cultivation (₹ ha^{-1}) of different treatments

Treatments	Common cost of cultivation*	MOP cost (K-fertilizer)	KSB cost		Total cost of cultivation
			Seed treatment	Soil drenching	
RDK_0	53590	0	-	-	53590
RDK_{100}	53590	1837	-	-	55427
RDK_{50}	53590	919	-	-	54509
RDK_{75}	53590	1377	-	-	54967
RDK_{50+50}	53590	1837	-	-	55427
RDK_0+KSB	53590	0	35	2542	56167
RDK_{100}+KSB	53590	1837	35	2542	58004
RDK_{50}+KSB	53590	919	35	2542	57086
RDK_{75}+KSB	53590	1377	35	2542	57544
RDK_{50+50}+KSB	53590	1837	35	2542	58004

*Common cost of cultivation included expenditure made on cost on man power, land preparation, irrigation, FYM, pesticide application, and fertilizers application except K. Cost on KSB soil drenching includes KSB input cost and application charge.
†Treatment details have been mentioned in materials and methods section

Table 5: Sweet corn economics as influenced by dual-mode application of KSB strain (*Bacillus amyloliquefaciens*) and chemical fertilizers in sandy loam soil

Treatments†	Economics				
	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio	Economic efficiency (₹ ha^{-1} day^{-1})
RDK_0	53590	120800	67210	2.3	747
RDK_{100}	55427	152800	97373	2.8	1082
RDK_{50}	54509	124000	69491	2.3	772
RDK_{75}	54967	128800	73833	2.3	820
RDK_{50+50}	55427	156000	100573	2.8	1117
RDK_0+KSB	56167	121600	65433	2.2	727
RDK_{100}+KSB	58004	154400	96396	2.7	1071
RDK_{50}+KSB	57086	126400	69314	2.2	770
RDK_{75}+KSB	57544	144000	86456	2.5	961
RDK_{50+50}+KSB	58004	157600	99596	2.7	1107
SEm±	-	5818	5818	0.1	67
LSD (p=0.05)	-	17288	17288	0.3	199

†Treatment details have been mentioned in materials and methods section. B:C ratio: Benefit-cost ratio

as basal/two equal splits±KSB treatment or application of 75% RDK+KSB was imperative.

The data pertaining to benefit cost (B:C) ratio portrayed that highest B:C ratio (2.8) was recorded with two equal split applications of RDK (RDK_{50+50}) and with 100% RDK as basal (RDK_{100}). However, it was comparable with split application of 100% RDK with KSB (RDK_{50+50}+KSB) (2.7) and 75% RDK+KSB (RDK_{75}+KSB) (2.5). Further reduction of RDK irrespective of KSB treatment was uneconomical. Lowest B:C ratio (2.3) was recorded with 0% RDK and 50% RDK with KSB (Table 5). Cost incurred by the addition of KSB through seed treatment and soil drenching was more than that of increment in gross returns owing to KSB application which resulted in numerically higher B:C ratio with RDK_{50+50}; however, it was equivalent with RDK_{75}+KSB. Similarly, numerically highest economic efficiency was recorded with RDK_{50+50} (1117 ₹ ha^{-1} day^{-1}) and it was comparable with all 100% RDK±KSB and RDK_{75}+KSB (Table 5). Biswas et al. (2023), and Majumdar et al. (2012) had also inferred that in order to get high monetary returns from maize, application of K-fertilizer was indispensable.

3.5. Correlation study

The correlation matrix illustrated the interrelationship among nutrient content, growth parameters, and yield of sweet corn. Kernel and stover nutrient contents (N and K) exhibited significant positive associations with leaf area and dry matter accumulation recorded at different growth stages (Figure 2). Leaf area measured 60 and 90 DAS showed strong correlations (p≤0.001) with dry matter accumulation at corresponding stages, highlighting the pivotal role of photosynthetic surface expansion in supporting biomass production. Dry matter accumulation at 60, and 90 DAS was positively and significantly correlated (p≤0.001) with both green cob yield and stover yield, confirming that progressive biomass accumulation serves as a critical determinant of final productivity. Similarly, nutrient concentrations in kernels and stover displayed positive correlations with green cob yield and stover yield, indicating that efficient uptake and partitioning of nitrogen, and potassium were essential for sweet corn yield (Figure 2). Overall, the analysis suggested that nutrient assimilation and retention in both kernels and stover, coupled with sustained leaf area development and dry matter accumulation across growth stages, were integrally linked to yield performance in sweet corn. These findings underscored the importance of integrated K-nutrient management in optimizing both cob and stover productivity and quality. Synergistic interaction between K and N nutrition and potential of KSB in improving plant performance was also reported by Li et al. (2023) and Tian et al. (2024), respectively.

4. CONCLUSION

For improving sweet corn performance, recommended K dose was imperative, in K-rich sandy loam soil, while dual-mode KSB application augmented the growth, yield, and quality. Higher cob and stover yields were recorded with all 100% RDK and 75% RDK+KSB. Improvement was also reflected in TSS, N, K, and crude protein content. Micronutrient content remained unaffected, whereas P content increased with KSB application. Thus, substitution of 25% RDK with KSB produced comparable quality yield, and economic returns.

5. ACKNOWLEDGEMENT

Authors are thankful to PJTAU, Hyderabad for rendering necessary funds and laboratory facilities for conducting this innovative experiment. The senior author would like to acknowledge the Indian Council of Agricultural Research, New Delhi, for granting fellowship to the first author.

6. REFERENCES

Amanullah, Iqbal, A., Irfanullah, Hidayat, Z., 2016. Potassium management for improving growth and grain yield of maize (*Zea mays* L.) under moisture stress condition. Scientific Reports 6(1), 34627. DOI: https://doi.org/10.1038/srep34627.

Anees, M.A., Ali, A., Shakoor, U., Ahmed, F., Hasnain, Z., Hussain, A., 2016. Foliar applied potassium and zinc enhance growth and yield performance of maize under rainfed conditions. International Journal of Agriculture and Biology 18(5), 1025–1032. DOI: http://dx.doi.org/10.17957/IJAB/15.0204.

Anonymous, 2024. Economic survey 2023–24. Government of India, New Delhi. Available from: https://www.indiabudget.gov.in/budget2024-25/economicsurvey/doc/echapter.pdf. Accessed on: 20-02-2026.

Anonymous, 2022. Vegetables 2021 summary. United States Department of Agriculture. Available from: https://esmis.nal.usda.gov/sites/default/release-files/02870v86p/zs25zc490/9593vz15q/vegean22.pdf. Accessed on: 20-02-2026.

Barman, A., Pooniya, V., Zhiipao, R.R., Biswakarma, N., Kumar, D., 2025. Pre- and post-anthesis dry matter and nutrient accumulation, partitioning, remobilization and crop productivity of maize under long-term integrated crop management practices. European Journal of Agronomy 164, 127527. DOI: https://doi.org/10.1016/j.eja.2025.127527.

Bhargavi, B., Behera, U.K., Rana, K.S., Singh, R., 2019. Productivity, resource-use efficiency and profitability of high-value crops embedded diversified cropping systems. Indian Journal of Agricultural Sciences 89(5), 821‒827. DOI: http://dx.doi.org/10.56093/ijas.v89i5.89664.

Biswas, S., Saha, A., Debnath, S., 2023. Effect of potassium level on growth, yield, nutrient uptake and economics of hybrid maize. Environment and Ecology 41(3D), 2155‒2159. DOI: https://doi.org/10.60151/envec/PVAS3711.

Cao, W., Sun, H., Shao, C., Wang, Y., Zhu, J., Long, H., 2025. Progress in the study of plant nitrogen and potassium nutrition and their interaction mechanisms. Horticulturae 11(8), 930. DOI: https://doi.org/10.3390/horticulturae11080930.

Chen, J., Guo, Z., Chen, H., Yang, X., Geng, J., 2021. Effects of different potassium fertilizer types and dosages on cotton yield, soil available potassium and leaf photosynthesis. Archives of Agronomy and Soil Science 67(2), 275‒287. DOI: http://dx.doi.org/10.1080/03650340.2020.1723005.

Cui, J., Tcherkez, G., 2021. Potassium dependency of enzymes in plant primary metabolism. Plant Physiology and Biochemistry 166, 522‒530. DOI: https://doi.org/10.1016/j.plaphy.2021.06.017.

Etesami, H., Emami, S., Alikhani, H.A., 2017. Potassium solubilizing bacteria (KSB): mechanisms, promotion of plant growth and future prospects: a review. Journal of Soil Science and Plant Nutrition 17, 897‒911. DOI: http://dx.doi.org/10.4067/S0718-95162017000400005.

Fadhil, H.M., El-Hamdani, H.I.H., Noor, F.M.A., Suad, S.S., Mohammed, O.M., 2025. Effect of potassium fertilizer and planting dates on the growth and production of maize (*Zea mays* L.). Plant Science Today 13(1). Available from: https://horizonepublishing.com/journals/index.php/PST/article/view/9827.

Gnanasundari, R., Sellamuthu, K.M., Malathi, P., 2019. Effect of potassium on growth, yield and NPK uptake of hybrid maize in black calcareous soil. Madras Agricultural Journal 106, 32‒37. DOI: https://doi.org/10.29321/MAJ.2019.000218.

Hu, W., Zhao, W., Yang, J., Oosterhuis, D.M., Loka, D.A., Zhou, Z., 2016. Relationship between potassium fertilization and nitrogen metabolism in the leaf subtending the cotton boll during development. Plant Physiology and Biochemistry 101, 113‒123. DOI: https://doi.org/10.1016/j.plaphy.2016.01.019.

Hwalla, N., El Labban, S., Bahn, R.A., 2016. Nutrition security is an integral component of food security. Frontiers in Life Science 9(3), 167‒172. DOI: https://doi.org/10.1080/21553769.2016.1209133.

Jackson, M.L., 1973. Soil chemical analysis. Prentice Hall of India Pvt. Ltd., New Delhi, 106‒203. Available from: https://archive.org/details/soilchemicalanal030843mbp/page/n13/mode/2up.

Kabir, S.H., Das, A.K., Rahman, M.S., Singh, S.K., Morshed, M., Marma, A.S.H., 2019. Effect of genotype on proximate composition and biological yield of maize (*Zea mays* L.). Archives of Agriculture and Environmental Science 4(2), 185‒189. DOI: https://doi.org/10.26832/24566632.2019.040209.

Kinge, S.S., Bhagat, S.B., Bodake, P.S., Chavan, V.G., Salvi, V.G., Kunkerkar, R.L., 2024. Influence of tillage, nutrient management and growth regulator on quality of sweet corn. Plant Archives 24(2), 1625‒1630. DOI: https://doi.org/10.51470/plantarchives.2024.v24.no.2.230.

Kumar, A., Rabha, J., Tayung, K., 2024. Plant growth promotion activities of *Bacillus* spp. isolated from Jakrem hot water spring of Meghalaya, North East India. Journal of Experimental Biology and Agricultural Sciences 12, 335‒353. DOI: http://dx.doi.org/10.18006/2024.12(3).335.353.

Kundu, S., Pooniya, V., Kasbe, S.S., Likhitha, A., Saikia, N., Barman, A., 2025. Biofortification and its impact on human health. Chronicle of Bioresource Management 9(1), 031‒037. Available from: https://ojs.pphouse.org/index.php/CBM/article/view/6053/3165.

Lavanya, N., Laxminarayana, P., Devi, K.B., Jayasree, G., 2024. Impact of drip irrigation and tailored fertigation levels at various stages of crop growth on yield and nutrient uptake of high-density sweet corn (*Zea mays* var. *saccharata* Sturt). Journal of Applied and Natural Science 16(4). DOI: https://doi.org/10.31018/jans.v16i4.5921.

Li, J., Zhou, Y., Gu, H., Lu, Z., Cong, R., Li, X., Ren, T., Lu, J., 2023. Synergistic effect of nitrogen and potassium on seed yield and nitrogen use efficiency in winter oilseed rape (*Brassica napus* L.). European Journal of Agronomy 148, 126875. DOI: https://doi.org/10.1016/j.eja.2023.126875.

Majumdar, K., Kumar, A., Shahi, V., Satyanarayana, T., Jat, M.L., Kumar, D., 2012. Economics of potassium fertiliser application in rice, wheat and maize grown in the Indo-gangetic plains. Indian Journal of Fertilisers 8(5), 44‒53. Available from: https://www.cabidigitallibrary.org/doi/full/10.5555/20123180547.

Maurya, B.R., Meena, V.S., Meena, O.P., 2014. Influence of inceptisol and alfisol potassium solubilizing bacteria isolates on release of K from waste mica. Vegetos 27(1), 181‒187. DOI: http://dx.doi.org/10.5958/j.2229-4473.27.1.028.

Mohamed, A.A., Allam, M., Radicetti, E., Mancinelli, R., Bakheit, B.R., 2025. Enhancing hybrid maize performance and yield through potassium sulfate fertilization: a field-based assessment. Nitrogen 6(4), 104. DOI: https://doi.org/10.3390/nitrogen6040104.

Okumura, R.S., de Cinque Mariano, D., Franco, A.A.N., Zaccheo, P.V.C., Zorzenoni, T.O., 2013. Sweet corn: genetic aspects, agronomic and nutritional traits. Applied Research and Agrotechnology 6(1), 105–114. DOI: http://dx.doi.org/10.5935/PAeT.V6.N1.13. https://scholar.google.com/citations?view_op=view_citation&hl=pt-BR&user=Z1fnbm0AAAAJ&citation_for_view=Z1fnbm0AAAAJ:UeHWp8X0CEIC.

Olaniyan, F.T., Alori, E.T., Adekiya, A.O., Ayorinde, B.B., Daramola, F.Y., Osemwegie, O.O., Babalola, O.O., 2022. Soil microbial potassium solubilizers in potassium availability and dynamics. Annals of Microbiology 72(1), 45. DOI: https://doi.org/10.1186/s13213-022-01701-8.

Olsen, S.R., Cole, C.V., Watanabe, F.S., Dean, L.A., 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circular No. 939, United States Department of Agriculture. Available from: https://www.scirp.org/reference/referencespapers?referenceid=1117235.

Piper, C.S., 1966. Soil and plant analysis. International Science Publication, New York. Available from: https://www.scirp.org/reference/referencespapers?referenceid=2430186.

Rawal, N., Vista, S.P., Khadka, D., Paneru, P., 2024. Grain yield, nitrogen accumulation and its use efficiency of maize (*Zea mays* L.) as influenced by varying nitrogen rates. International Journal of Agronomy 2024(1), 4104123. DOI: https://doi.org/10.1155/2024/4104123.

Reddy, K.B., Reddy, M.M., Padmaja, B., Srijaya, T., Yakadri, M., 2023. Residual effect of shredded cotton (*Gossypium* species) stalks and fertility levels on productivity, quality parameters and economics of sweet corn (*Zea mays*). Indian Journal of Agronomy 67(4), 450–453. DOI: https://doi.org/10.59797/ija.v67i4.154.

Revilla, P., Anibas, C.M., Tracy, W.F., 2021. Sweet corn research around the world 2015–2020. Agronomy 11(3), 534. DOI: https://doi.org/10.3390/agronomy11030534.

Ruanjaichon, V., Khammona, K., Thunnom, B., Suriharn, K., Kerdsri, C., Aesomnuk, W., 2021. Identification of gene associated with sweetness in corn (*Zea mays* L.) using GWAS and SNP marker development. Plants 10(6), 1239. DOI: https://doi.org/10.3390/plants10061239.

Sattar, A., Naveed, M., Ali, M., Zahir, Z.A., Nadeem, S.M., Yaseen, M., Meena, V.S., Farooq, M., Singh, R., Rahman, M., Meena, H.N., 2019. Perspectives of potassium solubilizing microbes in sustainable food production system: A review. Applied Soil Ecology 133, 146–159. DOI: https://doi.org/10.1016/j.apsoil.2018.09.012.

Senila, M., 2024. Recent advances in determination of major and trace elements in plants using ICP-OES. Molecules 29(13), 3169. DOI: https://doi.org/10.3390/molecules29133169.

Subbiah, B.V., Asija, G.L., 1956. A rapid procedure for estimation of available nitrogen in soils. Current Science 25, 259–260. Available from: http://scirp.org/reference/ReferencesPapers?ReferenceID=2138694.

Tian, S., Xu, Y., Zhong, Y., Qiao, Y., Wang, D., Wu, L., Yang, X., 2024. Exploring the organic acid secretion pathway and potassium solubilization ability of *Pantoea vagans* for enhanced rice growth. Plants 13(14), 1945. DOI: https://doi.org/10.3390/plants13141945.

Walkley, A., Black, I.A., 1934. Estimation of soil organic carbon by chromic acid titration method. Soil Science 37(1), 29–38. Available from: https://www.scirp.org/reference/referencespapers?referenceid=2496917.

Wang, J., Lu, Y., Zhang, X., Hu, W., Lin, L., Deng, Q., 2024. Effects of potassium-containing fertilizers on sugar and organic acid metabolism in grape fruits. International Journal of Molecular Sciences 25(5), 2828. DOI: https://doi.org/10.3390/ijms25052828.

Wang, Y., Yin, X., Wang, X., Ali, M.F., Lin, X., Gu, S., 2025. Split potassium application delays senescence and increases grain yield in winter wheat grown on sandy and silt loam soils. Frontiers in Plant Science 16, 1599296. DOI: https://doi.org/10.3389/fpls.2025.1599296.