



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(9): 588-592
Received: 21-06-2026
Accepted: 29-07-2026

Varsha TR
Department of Agronomy, College
of Agriculture, Keladi Shivappa
Nayaka University of Agricultural
and Horticultural Sciences,
Shivamogga, Karnataka, India

Veeranna HK
Department of Agronomy, College
of Agriculture, Keladi Shivappa
Nayaka University of Agricultural
and Horticultural Sciences,
Shivamogga, Karnataka, India

Girijesh GK
Department of Agronomy, College
of Agriculture, Keladi Shivappa
Nayaka University of Agricultural
and Horticultural Sciences,
Shivamogga, Karnataka, India

Nandish MS
Department of Microbiology,
College of Agriculture, Keladi
Shivappa Nayaka University of
Agricultural and Horticultural
Sciences, Shivamogga, Karnataka,
India

Anjali MC
Department of Soil Science, College
of Agriculture, Keladi Shivappa
Nayaka University of Agricultural
and Horticultural Sciences,
Shivamogga, Karnataka, India

Corresponding Author:

Varsha TR
Department of Agronomy, College
of Agriculture, Keladi Shivappa
Nayaka University of Agricultural
and Horticultural Sciences,
Shivamogga, Karnataka, India

Synergistic effect of Endophytic bacterial consortia and Humic acid on growth, root development, yield and economics of maize (*Zea mays* L.)

Varsha TR, Veeranna, HK, Girijesh GK, Nandish MS and Anjali MC

DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i9h.6570>

Abstract

A field experiment was conducted during *Kharif* 2025 at the Zonal Agricultural and Horticultural Research Station (ZAHRS), Navile, Shivamogga, Karnataka, India, to evaluate the effect of endophytic bacterial consortia (EBC) and humic acid, applied singly and in combination with graded levels of the recommended dose of fertilizer (RDF), on growth, root development, yield attributes and economics of maize hybrid P3304. The experiment was laid out in a Randomized Complete Block Design with twelve treatments, replicated thrice. Application of 100% RDF together with commercial humic acid and EBC recorded the highest plant height (226.77 cm), dry matter accumulation (295.24 g plant⁻¹), root dry weight (27.87 g plant⁻¹), grain yield (6947 kg ha⁻¹) and net returns (₹1,05,907 ha⁻¹) and was statistically on par with the corresponding areca-husk-based humic acid combination, 100% RDF + areca husk humic acid + EBC, almost at every stage and parameter. Both combined treatments significantly outperformed their respective sole-input counterparts (humic acid alone or EBC alone), confirming a synergistic rather than additive interaction between humic acid and EBC. Grain yield under application of 100% RDF together with commercial humic acid and EBC exceeded the lowest-yielding treatment, 75% RDF alone (5619 kg ha⁻¹), by close to 24 per cent and gave the highest absolute net returns while application of 100% RDF together with areca husk humic acid and EBC recorded the highest benefit-cost ratio (2.54), reflecting the lower input cost of the locally available areca husk compost-derived humic acid relative to the commercial formulation. These findings demonstrate that the combined application of humic acid and EBC with the full recommended fertilizer dose offers a biologically sound and economically viable strategy for enhancing maize productivity in nutrient-constrained sandy loam soils of the Southern Transition Zone of Karnataka.

Keywords: Maize, humic acid, endophytic bacterial consortia, root growth, synergism, economics

Introduction

Maize (*Zea mays* L.), a member of the family Poaceae, is the third most important cereal crop in the world after wheat and rice and serves diverse roles in human food, livestock feed and industrial use. In India, maize production during 2024-25 reached 43.41 million tonnes from 12.09 million hectares at a productivity of 3.59 t ha⁻¹, while Karnataka alone contributed 6.91 million tonnes from 1.91 million hectares at 3.23 t ha⁻¹ (Anon, 2025) [2]. As a C₄ plant with an exhaustive nutrient demand, maize is highly responsive to input management, yet continuous and intensive cropping under exploitative practices is progressively depleting the nutrient-supplying capacity and biological activity of Indian soils.

Humic substances, the principal component of soil organic matter, chelate plant nutrients such as phosphorus, iron and other micronutrients, improve cation exchange capacity, soil structure and water-holding capacity, and stimulate root growth through auxin-like activity (Nardi *et al.*, 2017; Shah *et al.*, 2018) [18, 21]. Endophytic bacteria, on the other hand, colonize internal plant tissues without causing apparent harm, enhance nutrient availability and uptake through biological nitrogen fixation and phytohormone production and confer tolerance to abiotic stress (Hallmann *et al.*, 2001; Strobel and Daisy, 2003) [13, 22]. While the individual benefits of humic acid and plant growth-promoting endophytes are well documented, their combined effect under graded fertilizer levels and specifically the relative performance of a locally derived areca husk compost humic acid against a commercial formulation, has received comparatively little attention in Indian maize

production systems. The present study area is a major arecanut (*Areca catechu* L.) production hub of Karnataka, where farmers routinely discard areca husk along roadsides owing to its slow natural decomposition. Recycling this agro-waste into humic acid offers a sustainable, low-cost nutrient-management option. Accordingly, a field experiment was undertaken with the objective of evaluating the growth, root, yield and economic response of maize to endophytic bacterial consortia and two sources of humic acid (areca husk compost-derived and commercial) applied in combination with 100 and 75 per cent of the recommended dose of fertilizer and of testing whether their combined application produces a synergistic advantage over either input applied alone.

Materials and Methods

The field experiment was conducted during *Kharif* 2025 at the Zonal Agricultural and Horticultural Research Station, Navile, Shivamogga (13°58'-14°1' N, 75°34'-75°42' E; altitude 615 m amsl), situated in the Southern Transition Zone (Zone VII) of Karnataka under Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences (KSNUAHS). The soil of the experimental site was sandy loam in texture (74.86% sand, 17.43% silt, 7.71% clay) of the *Alfisol* order, acidic in reaction (pH 5.9, 1:2.5), with low electrical conductivity (0.54 dS m⁻¹), low organic carbon (4.82 g kg⁻¹) and available nitrogen (233.20 kg ha⁻¹), high in available phosphorus (62.27 kg ha⁻¹) and medium in available potassium (210.71 kg ha⁻¹).

The experiment was laid out in a Randomized Complete Block Design (RCBD) with twelve treatments, replicated thrice, in a gross plot of 5.4 m × 3.6 m. The maize hybrid P3304 of 105-110 days duration, stay-green character was sown on 28 June 2025 at a spacing of 45 cm × 30 cm. The recommended dose of fertilizer (RDF) was 150:75:40 kg N:P₂O₅:K₂O ha⁻¹, applied through urea, di-ammonium phosphate and muriate of potash; the entire P₂O₅ and K₂O was applied basally, while N was applied in three equal splits at sowing, knee-height and tasseling. Humic acid (2.5 l ha⁻¹; 6 ml l⁻¹ of water) and the endophytic bacterial consortium (625 ml ha⁻¹; 6 ml l⁻¹ of water) were applied as soil drenches at 20 days after sowing (DAS).

The twelve treatment combinations are T₁ comprised 100% RDF, while T₂ received 75% RDF. T₃ consisted of 100% RDF + humic acid extracted from areca husk compost, and T₄ received 100% RDF + commercial humic acid. T₅ comprised 100% RDF + endophytic bacterial consortia (EBC), whereas T₆ received 100% RDF + humic acid extracted from areca husk compost + EBC. T₇ consisted of 100% RDF + commercial humic acid + EBC. Under the reduced fertilizer regime, T₈ comprised 75% RDF + humic acid extracted from areca husk compost, T₉ received 75% RDF + commercial humic acid, and T₁₀ consisted of 75% RDF + EBC. T₁₁ comprised 75% RDF + humic acid extracted from areca husk compost + EBC, while T₁₂ received 75% RDF + commercial humic acid + EBC.

Results and discussion

Growth parameters

Growth parameters viz., plant height, dry matter accumulation (DMA), leaf area index (LAI) were significantly differed among the treatments (Table 1). Plots applied with 100% RDF + commercial humic acid + EBC recorded the highest values throughout the crop growth period and remained statistically on par with 100% RDF + humic acid extracted from areca husk compost + EBC. These were followed by application of 75% RDF

combinations, whereas 75% RDF alone consistently recorded the lowest values.

At harvest, the highest plant height (226.77 cm) and dry matter accumulation (295.24 g plant⁻¹) were recorded under 100% RDF + commercial humic acid + EBC (T₇), compared to 166.77 cm and 198.61 g plant⁻¹, respectively, under 75% RDF (T₂). Thus, 75% RDF recorded a reduction of nearly 33 and 49 per cent in plant height and dry matter accumulation, respectively, compared with T₇. The higher growth under 100% RDF + commercial humic acid + EBC (T₇) and 100% RDF + humic acid extracted from areca husk compost + EBC (T₆) may be attributed to the complementary interaction between humic acid, inorganic fertilizers and the endophytic bacterial consortium. Humic substances improve nutrient availability through chelation, enhance cation exchange capacity and stimulate root development through auxin-like activity and activation of plasma membrane H⁺-ATPase, thereby promoting cell elongation and lateral root initiation (Nardi *et al.*, 2017) [18]. The endophytic bacterial consortium, in turn, may enhance plant growth through biological nitrogen fixation, production of phytohormones such as indole-3-acetic acid and cytokinins and solubilization of native and applied phosphorus and potassium (Strobel and Daisy, 2003) [22]. Similar synergistic effects of humic substances and plant growth-promoting bacteria on vegetative growth have been reported in maize by Conceicao *et al.* (2008) [7] and in sugarcane by De oliveira *et al.* (2018) [9]. The individual growth-promoting effects of humic acid have also been documented by Turan *et al.* (2011) [23] and Niaz *et al.* (2016) [19], while Egamberdiyeva (2007), Hameeda *et al.* (2008) and Mukherjee *et al.* (2021) [10, 14, 17] reported beneficial effects of bacterial inoculation on nutrient uptake and biomass production.

Leaf area index increased progressively with crop growth and attained their maximum values at 90 DAS, with 100% RDF + commercial humic acid + EBC (T₇) recording LAI of 3.59, before declining towards harvest (1.81). The subsequent reduction may be associated with progressive senescence of older and lower canopy leaves as the crop approached physiological maturity. The greater leaf area and LAI under with 100% RDF + commercial humic acid + EBC could have improved light interception and photosynthetic activity, thereby contributing to enhanced dry matter accumulation. The greater availability of nutrients under 100% RDF, together with the nutrient-mobilizing and growth-promoting effects of humic acid and EBC, would have favoured sustained leaf production and canopy development.

Interestingly, fertilizer level, i.e., 100 versus 75 per cent RDF, did not significantly influence the growth parameters when the endophytic bacterial consortium was included, suggesting that EBC partly compensated for the reduction in mineral fertilizer supply. This may be due to improved nutrient acquisition and utilization resulting from bacterial nitrogen fixation, nutrient solubilization and phytohormone production. Mukherjee *et al.* (2021) [17] reported substantial increases in plant biomass following microbial consortium inoculation, while the present findings further indicate the potential of EBC in maintaining crop growth even under reduced fertilizer application. Thus, the comparable performance of 100% RDF + humic acid extracted from areca husk compost + EBC and 100% RDF + commercial humic acid + EBC and of the respective 75% RDF combinations, demonstrates the potential of integrating humic acid and EBC for improving nutrient use efficiency without proportionately increasing fertilizer input.

Table 1: Plant height, dry matter accumulation and leaf area index of maize at 90 DAS and at harvest as influenced by endophytic bacterial consortia and humic acid

Treatment details		Plant height (cm)		Dry matter accumulation (g plant ⁻¹)		Leaf area index	
		90 DAS	At harvest	90 DAS	At harvest	90 DAS	At harvest
T ₁	100% RDF	182.11	183.97	162.44	228.29	2.86	1.04
T ₂	75% RDF	165.01	166.77	140.78	198.61	2.55	0.72
T ₃	100% RDF + Humic acid extracted from areca husk compost	187.81	189.67	178.25	248.78	3.04	1.23
T ₄	100% RDF + Commercial humic acid	190.81	192.87	186.44	260.59	3.12	1.31
T ₅	100% RDF + Endophytic bacterial consortia (EBC)	194.01	196.17	191.53	267.3	3.19	1.38
T ₆	100% RDF + Humic acid extracted from areca husk compost + EBC	213.01	215.27	205.35	288.55	3.49	1.7
T ₇	100% RDF + Commercial humic acid + EBC	224.41	226.77	210.13	295.24	3.59	1.81
T ₈	75% RDF + Humic acid extracted from areca husk compost	178.41	180.27	168.62	233.43	2.68	0.85
T ₉	75% RDF + Commercial humic acid	179.91	181.77	160.3	225.77	2.77	0.95
T ₁₀	75% RDF + EBC	185.51	187.37	175.85	245.52	2.95	1.13
T ₁₁	75% RDF + Humic acid extracted from areca husk compost + EBC	200.81	202.87	193.53	272.7	3.27	1.47
T ₁₂	75% RDF + Commercial humic acid + EBC	204.91	206.97	198.16	279.29	3.37	1.58
S.Em.(±)		10.87	12.22	7.04	10.22	0.20	0.10
C.D. @ 5%		31.89	35.85	20.64	29.99	0.57	0.29

Note: RDF: Recommended dose of fertilizer, 150:75:40 kg N:P₂O₅:K₂O ha⁻¹. Humic acid: 2.5 l ha⁻¹ (6 ml l⁻¹ water). EBC: Endophytic bacterial consortia, 625 ml ha⁻¹ (6 ml l⁻¹ water). Both applied as soil drenches at 20 DAS. DAS: Days after sowing

Root characteristics

Root length, root volume and root dry weight exhibited a similar trend to the shoot growth parameters. At harvest, 100% RDF + Commercial humic acid + EBC recorded the maximum root length (53.06 cm), root volume (54.76 cm³) and root dry weight (27.87 g plant⁻¹), whereas the corresponding values under 75% RDF were only 27.21 cm, 24.06 cm³ and 11.87 g plant⁻¹, respectively. Thus, the combined application of 100% RDF, commercial humic acid and EBC resulted in more than a two-fold increase in root biomass compared with 75% RDF alone.

The enhanced root development under 100% RDF + Commercial humic acid + EBC and 100% RDF + humic acid extracted from areca husk compost + EBC may be attributed to the combined influence of humic substances and beneficial endophytic bacteria on root initiation, elongation and nutrient acquisition. Humic acid can exert auxin-like effects and stimulate plasma membrane H⁺-ATPase activity, which facilitates proton extrusion, nutrient uptake and root cell elongation (Nardi *et al.*, 2017) [18]. Simultaneously, endophytic bacteria can produce phytohormones and improve nutrient availability through biological nitrogen

fixation and solubilization of phosphorus and potassium, thereby stimulating root proliferation and biomass accumulation. The greater root length and volume would have provided a larger soil exploration capacity and greater root-soil contact, facilitating improved water and nutrient acquisition and consequently supporting above-ground growth and dry matter production. The present findings are in agreement with Egamberdiyeva (2007) [10], who reported a 19 to 52 per cent increase in root dry weight following bacterial inoculation, and Kumar *et al.* (2024) [15], who observed an almost three-fold increase in root length under endophytic consortium application. Canellas *et al.* (2022) [6] also reported a marked synergistic enhancement of root biomass when humic substances were combined with microbial inoculants. The higher root growth observed under 100% RDF + Commercial humic acid + EBC and 100% RDF + humic acid extracted from areca husk compost + EBC in the present study therefore indicates a complementary interaction between adequate mineral nutrition, humic acid and endophytic bacterial consortium, which collectively promoted a more vigorous root system and improved overall crop growth.

Table 2: Root length, root volume and root dry weight of maize at harvest as influenced by endophytic bacterial consortia and humic acid

Treatment details		Root length (cm)	Root volume (cm ³)	Root dry weight (g plant ⁻¹)
T ₁	100% RDF	34.16	32.11	15.92
T ₂	75% RDF	27.21	24.06	11.87
T ₃	100% RDF + Humic acid extracted from areca husk compost	38.46	37.11	18.52
T ₄	100% RDF + Commercial humic acid	40.21	39.76	19.97
T ₅	100% RDF + Endophytic bacterial consortia (EBC)	42.76	42.46	21.62
T ₆	100% RDF + Humic acid extracted from areca husk compost + EBC	50.21	51.61	26.32
T ₇	100% RDF + Commercial humic acid + EBC	53.06	54.76	27.87
T ₈	75% RDF + Humic acid extracted from areca husk compost	30.06	27.21	13.62
T ₉	75% RDF + Commercial humic acid	32.31	29.36	14.47
T ₁₀	75% RDF + EBC	36.11	34.56	17.17
T ₁₁	75% RDF + Humic acid extracted from areca husk compost + EBC	45.31	45.71	23.17
T ₁₂	75% RDF + Commercial humic acid + EBC	47.76	48.36	24.62
S.Em.(±)		2.39	2.20	1.11
C.D. @ 5%		7.02	6.46	3.25

Note: RDF: Recommended dose of fertilizer, 150:75:40 kg N:P₂O₅:K₂O ha⁻¹. Humic acid: 2.5 l ha⁻¹ (6 ml l⁻¹ water). EBC: Endophytic bacterial consortia, 625 ml ha⁻¹ (6 ml l⁻¹ water). Both applied as soil drenches at 20 DAS

Grain yield and straw yield

The grain yield and straw yield were significantly influenced by the treatments (Table 3). Treatment supplied with 100% RDF + commercial humic acid + EBC (T₇) recorded the highest grain yield (6947 kg ha⁻¹) and straw yield (8797 kg ha⁻¹), which were on par with 100% RDF + Humic acid extracted from areca husk compost + EBC (T₆) (6825 and 8690 kg ha⁻¹). The lowest grain yield (5619 kg ha⁻¹) was recorded under 75% RDF (T₂). Treatment with 100% RDF + commercial humic acid + EBC recorded nearly 24 per cent higher grain yield over 75% RDF and 13 per cent over 100% RDF (T₁) alone.

The higher yield under 100% RDF + commercial humic acid + EBC (T₇) and 100% RDF + Humic acid extracted from areca husk compost + EBC (T₆) may be attributed to greater leaf area, longer leaf area duration, higher photosynthetic assimilation and better

root development, which enhanced nutrient and water uptake and translocation of assimilates to the developing cobs. The higher nutrient uptake under 100% RDF + commercial humic acid + EBC (T₇) further supports this response. The superiority of combined humic acid and EBC over their respective sole applications indicates a synergistic interaction, wherein humic acid improves nutrient availability and root activity, while EBC enhances nutrient acquisition through nitrogen fixation, phytohormone production and nutrient solubilization. Similar improvements in nutrient uptake and yield with combined humic acid and microbial inoculation were reported by Rajamani *et al.* (2021), Cozzolino *et al.* (2021) and Moturu *et al.* (2024). Baloach *et al.* (2014) and Canellas *et al.* (2013, 2015) [3, 4, 5, 8, 16, 20] also reported significant yield enhancement with combined humic substances and beneficial bacteria.

Table 3: Grain yield and straw yield of maize as influenced by endophytic bacterial consortia and humic acid

Treatment details		Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)
T ₁	100% RDF	6159	7959
T ₂	75% RDF	5619	7470
T ₃	100% RDF + Humic acid extracted from areca husk compost	6207	8012
T ₄	100% RDF + Commercial humic acid	6323	8122
T ₅	100% RDF + Endophytic bacterial consortia (EBC)	6440	8140
T ₆	100% RDF + Humic acid extracted from areca husk compost + EBC	6825	8690
T ₇	100% RDF + Commercial humic acid + EBC	6947	8797
T ₈	75% RDF + Humic acid extracted from areca husk compost	5761	7560
T ₉	75% RDF + Commercial humic acid	5885	7695
T ₁₀	75% RDF + EBC	6196	8016
T ₁₁	75% RDF + Humic acid extracted from areca husk compost + EBC	6555	8355
T ₁₂	75% RDF + Commercial humic acid + EBC	6684	8483
S.Em.(±)		164	203
C.D. @ 5%		483	595

Note: RDF: Recommended dose of fertilizer, 150:75:40 kg N:P₂O₅:K₂O ha⁻¹. Humic acid: 2.5 l ha⁻¹ (6 ml l⁻¹ water). EBC: Endophytic bacterial consortia, 625 ml ha⁻¹ (6 ml l⁻¹ water). Both applied as soil drenches at 20 DAS

Economics

Cost of cultivation varied with the input schedule, ranging from ₹63,982 ha⁻¹ under T₂ to ₹69,558 ha⁻¹ under T₇ and was not subjected to statistical analysis (Table 4). The highest gross returns (₹1,75,465 ha⁻¹) and net returns (₹1,05,907 ha⁻¹) were recorded under 100% RDF + commercial humic acid + EBC (T₇), which were statistically on par with 100% RDF + Humic acid extracted from areca husk compost + EBC (T₆) and 100% RDF + Endophytic bacterial consortia (T₅), while the lowest gross returns (₹1,42,267 ha⁻¹) and net returns (₹78,285 ha⁻¹) were recorded under 75% RDF (T₂). The highest B:C ratio was obtained under 100% RDF + Humic acid extracted from areca husk compost + EBC (2.54), which was on par with 100% RDF + Endophytic bacterial consortia (2.52) and 100% RDF + commercial humic acid + EBC (2.52).

The higher returns under combined humic acid and EBC treatments were mainly due to their greater yield and yield attributes resulting from improved nutrient availability, uptake and root development, as reported by Baloach *et al.* (2014), Gao *et al.* (2020) and Rajamani *et al.* (2021) [3, 11, 20]. Although 100% RDF + commercial humic acid + EBC recorded the highest absolute net return, 100% RDF + Humic acid extracted from areca husk compost + EBC achieved a marginally higher B:C ratio due to its lower cultivation cost, particularly the lower cost of areca husk-derived humic acid. Thus, 100% RDF + commercial humic acid + EBC was more advantageous for maximizing productivity and absolute returns, whereas 100% RDF + Humic acid extracted from areca husk compost + EBC provided better cost efficiency and offers an economically viable option for utilizing locally available areca husk agro-waste.

Table 4: Economics of maize cultivation as influenced by endophytic bacterial consortia and humic acid

Treatment details		Cost of cultivation (₹ ha ⁻¹)	Gross returns (₹ ha ⁻¹)	Net returns (₹ ha ⁻¹)	B:C
T ₁	100% RDF	66,214	1,55,714	89,500	2.35
T ₂	75% RDF	63,982	1,42,267	78,285	2.22
T ₃	100% RDF + Humic acid extracted from areca husk compost	67,714	1,56,914	89,200	2.32
T ₄	100% RDF + Commercial humic acid	69,352	1,59,799	90,447	2.3
T ₅	100% RDF + Endophytic bacterial consortia (EBC)	67,020	1,68,825	1,01,805	2.52
T ₆	100% RDF + Humic acid extracted from areca husk compost + EBC	67,920	1,72,417	1,04,497	2.54
T ₇	100% RDF + Commercial humic acid + EBC	69,558	1,75,465	1,05,907	2.52
T ₈	75% RDF + Humic acid extracted from areca husk compost	65,482	1,45,753	80,271	2.23
T ₉	75% RDF + Commercial humic acid	67,120	1,48,865	81,745	2.22
T ₁₀	75% RDF + EBC	64,788	1,56,664	91,876	2.42
T ₁₁	75% RDF + Humic acid extracted from areca husk compost + EBC	65,688	1,62,643	96,955	2.48
T ₁₂	75% RDF + Commercial humic acid + EBC	68,020	1,65,619	97,599	2.43
S.Em.(±)		-	6193	3592	-
C.D. @ 5%		-	18164	10536	-

Conclusion

The combined application of 100% RDF with commercial humic acid and endophytic bacterial consortia (T₇) recorded the highest growth, root, yield and nutrient uptake, and the highest absolute net returns among the twelve treatments evaluated, while the corresponding areca husk compost humic acid combination (T₆) was statistically on par with 100% RDF with commercial humic acid and endophytic bacterial consortia (T₇) for almost every parameter and gave the highest benefit-cost ratio. Both combined treatments significantly outperformed their respective sole-input counterparts, confirming a synergistic rather than additive interaction between humic acid and endophytic bacterial consortia. The locally available and lower-cost areca husk compost-derived humic acid, combined with EBC, therefore represents a practical and economically attractive alternative to commercial humic acid for enhancing maize productivity in nutrient-constrained sandy loam soils of the Southern Transition Zone of Karnataka, without any compromise on yield.

References

1. Akhtar N, Naveed M, Khalid M, Ahmad N, Rizwan M, Siddique S. Effect of bacterial consortia on growth and yield of maize grown in *Fusarium*-infested soil. *Soil and Environment*. 2018;37(1):35-44.
2. Anonymous. Agricultural Statistics at a Glance 2023. New Delhi: Department of Agriculture and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India; 2025.
3. Baloach N, Yousaf M, Akhter WP, Fahad S, Ullah B, Qadir G, Ahmed ZI. Integrated effect of phosphate solubilizing bacteria and humic acid on physio-morphic attributes of maize. *International Journal of Current Microbiology and Applied Sciences*. 2014;3(6):549-554.
4. Canellas LP, Balmori DM, Medici LO, Aguiar NO, Campostrini E, Rosa RCC, *et al*. A combination of humic substances and *Herbaspirillum seropedicae* inoculation enhances the growth of maize (*Zea mays* L.). *Plant and Soil*. 2013;366:119-132.
5. Canellas LP, da Silva SF, Olk DC, Olivares FL. Foliar application of plant growth-promoting bacteria and humic acid increase maize yields. *Journal of Food, Agriculture and Environment*. 2015;13(1):146-153.
6. Canellas LP, Canellas NO, da Silva RM, Spaccini R, Mota GP, Olivares FL. Biostimulants using humic substances and plant-growth-promoting bacteria: effects on cassava (*Manihot esculenta*) and okra (*Abelmoschus esculentus*) yield. *Agronomy*. 2022;13(1):80.
7. Conceicao PM, Vieira HD, Canellas LP, Marques Junior RB, Olivares FL. Corn seed coating with humic acids and endophytic diazotrophic bacteria. *Pesquisa Agropecuaria Brasileira*. 2008;43(4):545-548.
8. Cozzolino V, Monda H, Savy D, Meo VD, Vinci G, Smalla K. Cooperation among phosphate-solubilizing bacteria, humic acids and arbuscular mycorrhizal fungi induces soil microbiome shifts and enhances plant nutrient uptake. *Chemical and Biological Technologies in Agriculture*. 2021;8:31.
9. de Oliveira HP, de Melo RO, Baldotto MA, Andrade MA, Baldotto LEB. Performance of pre-sprouted sugarcane seedlings in response to the application of humic acid and plant growth-promoting bacteria. *Semina: Ciências Agrárias*. 2018;39(3):1365-1370.
10. Egamberdiyeva D. The effect of plant growth promoting bacteria on growth and nutrient uptake of maize in two different soils. *Applied Soil Ecology*. 2007;36(2-3):184-189.
11. Gao C, El-Sawah AM, Ali DFI, Alhaj Hamoud Y, Shaghaleh H, Sheteiwy MS. The integration of bio and organic fertilizers improve plant growth, grain yield, quality and metabolism of hybrid maize (*Zea mays* L.). *Agronomy*. 2020;10(3):319.
12. Gomez KA, Gomez AA. Statistical Procedures for Agricultural Research. 2nd ed. New York: John Wiley and Sons; 1984.
13. Hallmann J, Jeger MJ, Spence NJ. Plant interactions with endophytic bacteria. In: *Biotic Interactions in Plant-Pathogen Associations*. Wallingford, Oxon: CABI Publishing; 2001.
14. Hameeda B, Harini G, Rupela OP, Wani SP, Reddy G. Growth promotion of maize by phosphate-solubilizing bacteria isolated from composts and macrofauna. *Microbiological Research*. 2008;163(2):234-242.
15. Kumar P, Rathee J, Rani S, Suneja P. Formulation and effectivity of consortia of potential plant growth promoting endophytic bacteria from chickpea (*Cicer arietinum*). *Journal of Applied Biology and Biotechnology*. 2024;12(4):241-247.
16. Moturu US, Nunna T, Avula VG, Jagarlamudi VR, Gutha RR, Tamminana S. Impact of plant growth promoting endophytic bacterial consortia on biochemical parameters of maize under moisture stress conditions *in vitro*. *International Journal of Plant and Soil Science*. 2024;36(10):180-191.
17. Mukherjee A, Gaurav AK, Patel AK, Singh S, Chouhan GK, Lepcha A, *et al*. Unlocking the potential plant growth-promoting properties of chickpea (*Cicer arietinum* L.) seed endophytes bio-inoculants for improving soil health and crop production. *Land Degradation & Development*. 2021;32(15):4362-4374.
18. Nardi S, Ertani A, Francioso O. Soil-root cross-talking: the role of humic substances. *Journal of Plant Nutrition and Soil Science*. 2017;180:5-13.
19. Niaz A, Yaseen M, Shakar M, Sultana S, Ehsan M, Nazarat A. Maize production and nitrogen use efficiency in response to nitrogen application with and without humic acid. *Journal of Animal and Plant Sciences*. 2016;26(6):1641-1651.
20. Rajamani K, Reddy KI, Srinivas A. Influence of super absorbent polymer and humic acid on maize yield and nutrient uptake on rainfed alfisols. *International Journal of Environment and Climate Change*. 2021;11(12):97-106.
21. Shah ZH, Rehman HM, Akhtar T, Alsamadany H, Hamooh BT, Mujtaba T. Humic substances: determining potential molecular regulatory processes in plants. *Frontiers in Plant Science*. 2018;9:263.
22. Strobel GA, Daisy B. Bioprospecting for microbial endophytes and their natural products. *Microbiology and Molecular Biology Reviews*. 2003;67:491-502.
23. Turan MA, Asik BB, Katkat AV, Celik H. The effects of soil-applied humic substances to the dry weight and mineral nutrient uptake of maize plants under soil-salinity conditions. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*. 2011;39(1):171-177.