International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; 9(8): 736-739
www.biochemjournal.com
Received: 07-05-2025
Accepted: 10-06-2025

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Response of humic acid and consortia on soil properties and yield parameters on brinjal (*Solanum melongena* L.)

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DOI: https://www.doi.org/10.33545/26174693.2025.v9.i8j.5303

Abstract
The present investigation was conducted to evaluate the effect of humic acid and microbial consortia on soil properties, growth, and yield parameters of brinjal (*Solanum melongena* L.) under varying levels of recommended dose of fertilizers (RDF). The field experiment was laid out in a Randomized Block Design (RBD) with 09 treatments and three replications during the 2024-25 at the section of Agricultural Chemistry and Soil Science, BTC College of Agriculture and Research Station, Bilaspur Chhattisgarh. Treatments included control, 100% RDF, and 75% RDF alone or in combination with humic acid and/or microbial consortia. The results revealed that the integrated application of 75% RDF + humic acid + microbial consortia (T_6) recorded the maximum number of branches per plant (5.04, 7.21, and 10.12 at 30, 60, and 90 DAT, respectively), highest fruit count (24.00), maximum fruit size (16.00 cm length and 4.45 cm diameter), and superior fruit yield (23.33 t ha^{-1}), representing a 20% increase over 100% RDF. The improved performance of T_6 was attributed to enhanced nutrient availability, root growth, hormonal stimulation, and increased microbial activity in the rhizosphere. Soil analysis indicated an improvement in organic carbon and available NPK under integrated treatments compared to control. The findings suggest that combining humic acid and microbial consortia with reduced chemical fertilizers can sustain high yields while improving soil health, offering a viable approach for sustainable brinjal production.

Keywords: Brinjal, humic acid, microbial consortia, soil properties, yield attributes, sustainable agriculture

1. Introduction

Brinjal (*Solanum melongena* L.), commonly known as eggplant or aubergine, is a vital vegetable crop cultivated globally for its nutritional value and economic significance. It is a rich source of dietary fiber, vitamins, and antioxidants, making it an essential component of sustainable agriculture and food security (Gürbüz *et al.* 2018) [4]. However, soil degradation, nutrient depletion, and environmental stresses pose significant challenges to optimizing brinjal yield and quality. To address these issues, the application of organic amendments like humic acid and microbial consortia has gained attention for their potential to enhance soil properties and improve crop performance.

Humic acid, a major component of humic substances derived from organic matter decomposition, is known for its role in improving soil structure, nutrient availability, and microbial activity (Canellas *et al.* 2015) [3]. It enhances soil fertility by increasing cation exchange capacity, water retention, and nutrient uptake, which are critical for crop growth in nutrient-poor soils (Nardi *et al.* 2021) [8]. Similarly, microbial consortia, comprising beneficial microorganisms such as nitrogen-fixing bacteria, phosphate-solubilizing bacteria, and plant growth-promoting rhizobacteria (PGPR), have shown promise in improving soil health and crop productivity. These consortia facilitate nutrient cycling, suppress soil-borne pathogens, and stimulate plant growth through the production of phytohormones and enzymes (Vessey, 2003; Bhattacharyya & Jha, 2012) [15, 1].

The combined application of humic acid and microbial consortia offers a synergistic approach to sustainable agriculture by enhancing soil physicochemical properties and biological activity.

Previous studies have demonstrated that such combinations can significantly improve soil organic carbon, microbial biomass, and nutrient availability, leading to enhanced crop yields (Puglisi *et al.* 2013; Schoebitz *et al.* 2016) [12, 14]. For instance, research on other crops like maize and wheat has shown that humic acid and microbial consortia improve root development and nutrient absorption, resulting in higher yields and better stress tolerance (Canellas *et al.* 2015; Nardi *et al.* 2021) [3, 8]. However, limited studies have explored the combined effects of these amendments on brinjal, particularly in terms of soil properties and yield parameters.

2. Materials and Methods

The field experiment was conducted during the 2024-25 at section of Agricultural Chemistry and Soil Science, BTC College of Agriculture and Research Station, Bilaspur Chhattisgarh, laid out in a Randomized Block Design (RBD) with 09 treatments and three replications. The treatments consisted of different combinations of recommended dose of fertilizers (RDF), humic acid, and microbial consortia, including 100% RDF, 75% RDF with humic acid, 75% RDF with microbial consortia, 75% RDF with both humic acid and microbial consortia, and control. The brinjal variety Pusa Kranti was transplanted and standard agronomic practices were followed uniformly for all plots.

Data on growth parameters (number of branches per plant at 30, 60, and 90 DAT), yield attributes (number of fruits per plant, fruit length, fruit diameter), and yield (t ha^{-1}) were recorded from five randomly selected plants in each plot. Statistical analysis was performed using analysis of variance (ANOVA) to determine the significance of treatment effects, and means were compared using the least significant difference (LSD) test at a 5% probability level.

3. Result and Discussion

3.1 Number of Branches per Plant

Data presented in Table 1 indicate that the number of branches per plant at 30, 60, and 90 days after transplanting (DAT) was significantly influenced by the application of humic acid and microbial consortia, either alone or in combination with RDF levels. At all stages of crop growth, the treatment T_6 (75% RDF + Humic Acid + Consortia) recorded the highest number of branches (5.04, 7.21, and 10.12 at 30, 60, and 90 DAT, respectively), which was significantly superior to all other treatments, including the 100% RDF (T_2). The lowest branch number was recorded in the control (T_1). The superior performance of T_6 can be attributed to the synergistic effect of humic acid and microbial consortia in enhancing nutrient availability, root growth, and hormonal stimulation. Humic acid has been reported to improve root architecture, promote cell division, and increase nutrient uptake through chelation and hormonal activity (Canellas & Olivares, 2014; Olaetxea *et al.* 2018) [14, 10]. Similarly, microbial consortia containing plant growth-promoting rhizobacteria (PGPR) can fix atmospheric nitrogen, solubilize phosphorus, and produce phytohormones such as indole acetic acid (IAA), which stimulate branching and canopy development (Vessey, 2003; Meena *et al.* 2020) [15, 7].

3.2 Number of Fruits per Plant

The data in Table 2 reveal that the number of fruits per plant ranged from 12.00 (T_1) to 24.00 (T_6). Once again, T_6 (75% RDF + Humic Acid + Consortia) produced the highest fruit count, which was significantly superior to all other treatments. This suggests that a balanced supply of nutrients through reduced RDF complemented by humic acid and beneficial microbes promoted not only vegetative growth but also a higher transition to reproductive stages. Humic substances may enhance enzymatic activities and stimulate flowering through improved carbohydrate metabolism, while PGPR increase flower retention and reduce fruit drop via phytohormonal modulation (Nardi *et al.* 2002; Sangeetha *et al.* 2006) [9, 13]. The combined effect likely ensured optimal nutrient partitioning towards fruit development.

3.3 Fruit Size Parameters

As shown in Table 2, fruit length and diameter were significantly improved under integrated application treatments. The maximum fruit length (16.00 cm) and diameter (4.45 cm) were recorded in T_6, followed by 100% RDF (14.80 cm and 3.32 cm, respectively). The improvement in fruit size under T_6 could be due to the better nutrient uptake, especially potassium and calcium, which are critical for cell expansion, fruit firmness, and shape development (Kundu *et al.* 2018) [6]. Humic acid's chelating property helps maintain these nutrients in plant-available form, while microbial consortia improve their bioavailability in the rhizosphere.

3.4 Fruit Yield

Fruit yield data (Table 2) show that the highest yield (23.33 t ha^{-1}) was obtained in T_6, which was significantly superior to all other treatments and showed a 20% increase over 100% RDF (T_2: 19.44 t ha^{-1}). The lowest yield was recorded in control (8.80 t ha^{-1}). The yield enhancement in T_6 can be explained by the cumulative effect of better branching (more photosynthetic area), higher fruit numbers, and improved fruit size, all contributing to higher total productivity. Several studies have reported that integrating humic acid with biofertilizers under reduced chemical fertilizer regimes sustains yields while improving soil fertility status (Paramasivan *et al.* 2015; Karthikeyan *et al.* 2019) [11, 5]. This synergistic approach ensures nutrient supply throughout the growth period, enhances soil microbial activity, and improves plant physiological efficiency, leading to sustainable yield gains.

Table 1: Effect of humic acid and consortia on number of branches $plant^{-1}$ of brinjal at 30, 60 and 90 DAT.

Treatment details		Number of branches $plant^{-1}$		
		30 DAT	**60 DAT**	**90 DAT**
T_1	Control	2.23	3.50	6.50
T_2	100% RDF	3.89	5.99	8.21
T_3	75% RDF	2.45	4.91	6.77
T_4	75% RDF+ H.A.	3.10	5.42	7.95
T_5	75% RDF + Consortia	3.00	5.39	7.02
T_6	75% RDF+ H.A. + Consortia	5.04	7.21	10.12
T_7	50% RDF+ H.A.	2.95	4.69	6.20
T_8	50% RDF+ Consortia	2.87	4.54	6.19
T_9	50% RDF+ H.A. + Consortia	3.30	5.48	7.72
	SEm (±)	0.34	0.41	0.56
	CD (5%)	0.69	1.12	1.58

Table 2: Effect of humic acid and consortia on yield attributes of brinjal.

Treatment details		Number of fruit plant^{-1}	Fruit length (cm)	Fruit diameter (cm)	fruit yield t ha^{-1}
T_1	Control	12.00	8.21	2.21	8.80
T_2	100% RDF	20.00	14.80	3.32	19.44
T_3	75% RDF	15.00	9.52	2.33	13.05
T_4	75% RDF+ H.A.	16.00	11.50	2.90	14.99
T_5	75% RDF + Consortia	15.83	11.07	2.87	14.72
T_6	75% RDF+ H.A. + Consortia	24.00	16.00	4.45	23.33
T_7	50% RDF+ H.A.	14.00	10.21	3.90	12.22
T_8	50% RDF+ Consortia	13.76	10.09	3.43	11.66
T_9	50% RDF+ H.A. + Consortia	18.00	13.10	3.12	16.11
	SEm (±)	1.21	1.66	2.11	1.45
	CD (5%)	3.44	4.32	6.23	3.89

4. Conclusion

The study demonstrated that the integrated application of humic acid and microbial consortia with a reduced chemical fertilizer dose significantly improved growth, yield, and soil properties in brinjal (*Solanum melongena* L.). Among the treatments, 75% RDF + humic acid + microbial consortia (T_6) consistently outperformed all others, producing the highest number of branches, maximum fruit count, superior fruit size, and the greatest yield (23.33 t ha^{-1}), surpassing the 100% RDF treatment by 20%. The synergistic action of humic acid, which enhances nutrient chelation, root architecture, and hormonal activity, along with microbial consortia that improve nutrient solubilization, nitrogen fixation, and phytohormone production, resulted in better nutrient uptake, improved photosynthetic efficiency, and enhanced reproductive success.

Furthermore, integrated treatments improved soil organic carbon and available NPK content, indicating their role in sustaining soil fertility. These findings confirm that the strategic combination of humic acid and beneficial microbial consortia can reduce dependency on chemical fertilizers without compromising yield, thereby promoting resource-efficient and environmentally sustainable brinjal production systems. Adoption of such integrated nutrient management practices is recommended for both yield enhancement and long-term soil health maintenance in vegetable cultivation.

5. Acknowledgment

The authors express their sincere gratitude to the section of Agricultural Chemistry and Soil Science, BTC College of Agriculture and Research Station, Bilaspur Chhattisgarh, for providing the necessary research facilities and technical support during the course of this study. Dr. Yushma Sao, also acknowledges the valuable guidance and constructive suggestions, which greatly contributed to the successful completion of the research work. Special thanks are extended to the laboratory and field staff for their assistance in data collection and analysis.

6. Future Scope

While the present study establishes the beneficial effects of integrating humic acid and microbial consortia with reduced RDF in brinjal, further research is needed to explore its long-term impact on soil microbial diversity and nutrient cycling under different agro-climatic zones. Multi-season and multi-location trials would help validate the consistency of these results. Additionally, exploring the economic feasibility and cost-benefit ratio for farmers at a larger scale can support widespread adoption. Studies on combining humic acid and consortia with other organic amendments, such as compost or vermicompost, may further enhance soil health and crop productivity. Incorporating precision farming tools to optimize the application rates could also improve resource efficiency and sustainability in vegetable production systems.

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