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Research Article

Impact of Microbially Enriched Vermicompost on Soil Health and Vegetable Yield Under Greenhouse Conditions in Iraq

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Abstract | The deterioration of soil and loss of nutrients requires the implementation of sustainable farming methods. This research assesses the effectiveness of microbially enhanced vermicompost (MEV) in enhancing soil quality and tomato production in a greenhouse setting. For this purpose,a randomized complete block design (RCBD) was utilized with three replications. The treatments included a control (T0, without any amendment), vermicompost alone (T1, 5% w/w), and MEV (T2, 5% w/w supplemented with Azotobacter and Bacillus spp.). Soil characteristics (pH, EC, organic carbon, NPK availability, microbial biomass, and enzyme activity) along with tomato yield were examined during the examination. Analysis revealed that MEV greatly improved soil health in comparison to T0 and T1. Additionally, organic carbon rose by 118% (1.42% compared to 0.65% in T0) and available P increased by 174% (14.8 compared to 5.4 mg/kg at T0). We also noticed that microbial biomass and enzyme activity (dehydrogenase, and phosphatase) increased by 93% and 132%, respectively, whereastomato yield increased by 44% (1185 g/plant compared to 820 g in T0). Taken together, it is plasuble to conclude that MEV surpassed traditional vermicompost, highlighting its promise as a sustainable alternative for agriculture in Iraq.

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Introduction

Iraqi farming lands are under a severe limitation due to long periods of conflict, improper land management, water scarcity and overreliance on chemical inputs that have led to extensive soil erosion and low agricultural output. Among the most acute soil issues are salinization and sodicity, which are caused by the inefficient irrigation methods, lack of drainage, extreme evaporation rates, and using saline water resources, in central and southern areas (Al-Hadeethi *et al*., 2021; Aziz *et al*., 2021). Deposition of soluble salts and exchangeable sodium interferes with plant water absorption, leads to ion toxicity, deteriorates soil structure, and decreases infiltration and aeration of the soil making large areas of land marginal or unproductive (Hussein, 2020). The other significant constraint to Iraqi agriculture is the very low content of soil organic matter (SOM), frequently less than 1% because of the continuous cropping systems based on cereals, very low amounts of residues being returned, little application of organic fertilizers, as well as high temperatures that rapidly decompose organic matter (Al-Kaisi *et al*., 2020; Al-Sulimani *et al*., 2023). The low SOM has a negative impact on the soil structure, water-holding capacity, nutrient availability, microbial activity, and resilience of the soil, inducing further impaired nutrient depletion and low crop performance (Altaee, 2021). Nitrogen and phosphorus deficiencies are especially common, and the lack of potassium and micronutrients including zinc and iron is also more frequently reported, especially in calcareous soils with a high ph that restrict the solubility and uptake of nutrients (Aziz *et al*., 2021; Al-Rawi, 2022). Low SOM, sodicity, and conventional tillage practise are closely associated with soil physical degradation (compaction, surface crusting, reduced infiltration, and increased erosion) (Al-Kaisi *et al*., 2020; Hussein, 2020). All these conditions inhibit the growth of roots, hinder soil aeration, and have adverse effects including to beneficial soil organisms. Therefore, the biological activity of soil and microbial biodiversity are significantly impaired, which harms the main processes of the ecosystem, including the cycling of nutrients, the prevention of diseases, and the formation of aggregates in the soil (Al-Sulimani *et al*., 2023; Jadah, and Al-Rubaye, 2025). The challenges are also aggravated by extreme water shortages that are triggered by the diminishing flows of the Tigris and Euphrates rivers, climate variability, and ineffective irrigation systems that compel the population to use low-quality water and hasten its salinity accumulation (Al-Hadeethi *et al*., 2021). To eliminate these limitations and other environmental effects caused by synthetic fertilizers, there is increasing movement towards sustainable soil management policies founded on organic amendments and biofertilizers. The fact that vermicompost contains a large amount of stabilized organic matter, bioavailable nutrients, humic materials, helpful microorganisms, and natural plant growth regulators has made this material a promising organic input because it enhances soil fertility, structure, and crop performance (Gondek *et al*., 2020; Bhat *et al*., 2023; Singh *et al*., 2022). Coupled with additional nutritional enhancement through plant growth-promoting rhizobacteria, nitrogen-fixing microorganisms, and phosphate-solubilizing microorganisms, vermicompost becomes microbially enriched vermicompost (MEV), which will provide a better nutrient supply, increased stress resistance, and a greater ability to suppress diseases (Bhattacharyya *et al*., 2022; Santana *et al*., 2023; Etesami and Maheshwari, 2023). Greenhouse experiment gives a good and a controlled method of assessing the performance of MEV in the challenging agro-environmental conditions of Iraq. Protected cultivation minimizes the variability of climatic conditions, enables the accurate regulation of irrigation and nutrient application, increases the efficiency of the use of water, and provides the possibility of a thorough monitoring of soil health and plant reactions (Al-Hadeethi *et al*., 2021). In this context, the given study is intended to evaluate the opportunities of microbially enriched vermicompost to enhance the quality of the soil and yield of vegetables under the conditions of the greenhouse to provide a sustainable and locally adaptable recommendation to the current issue of soil degradation and low yield in Iraqi agriculture. This study aims to evaluates microbially enhanced vermicompost as a sustainable soil fertility strategy for greenhouse tomato production in Iraq, assessing its effects on soil physicochemical and biological health, plant growth, yield, and fruit quality, while identifying optimal application rates and its potential to reduce dependence on synthetic fertilizers.

Materials and Methods

Study area

The test was done in a controlled green house at the college of agriculture under conditions that was similar to that of the Iraq arid to semi arid weather. The average annual average temperature is about 25-30 o C with a rain of less than 200 mm which is typically received between November and April. In the experiment, the temperature of the greenhouse was kept at a range of 22 to 28 o C with a relative humidity of 60 to 75. The randomized complete block design (RCBD) was incorporated with three repetitions on each treatment in order to reduce the spatial variation. The units of the experiment were pots with tomato plants. Enrichment of Microorganisms and Vermicompost

Preparation

Eisenia fetida earthworms were also used to prepare vermicompost using cow manure and agricultural wastes such as wheat straw, date palm waste, etc. The composting process took a total of eight weeks where the moisture content was kept at 6070 percent and the material turned once a week to allow sufficient aeration and to evenly decompose. Microbial enrichment was done, thus isolating useful native microorganisms in local soils and applying them to mature vermicompost. They consisted of the nitrogen fixing bacterium Azotobacter chroococcal (10 -1 CFU g -1) and the phosphate solubilizing bacterium Bacillus megaterium (10 -1 CFU g -1). The vermicompost was inoculated with the microbial inoculum at the rate of 100 mL per kilogram and kept at an incubation of seven days at 28 o C to achieve success in the microbial establishment.

Treatment procedures

This study involved three treatments. The (T0) control arm involved basal soil that did not receive fertilizer input. The second treatment (T1) was where the vermicompost was used in its pure form only at a rate of 5 percent (w/w) or around 10 t ha. The third treatment (T2) involved microbially enhanced vermiculocompost (MEV) in which the same rate of vermiculocompost was micro-inoculated with Azotobacter and Bacillus inoculants. Pot filling was done by ensuring that all the treatments were well stirred with sterilized sandy loam soil. The pH of the first soil was 7.3, electrical conductivity was 1.2 dS m -1, and organic carbon was 0.65%. Pots of a diameter of 30 cm and a capacity of 10 kg of soil had been prepared, and treatments were added during the time of transplanting.

Farming operations and management

The test crop was tomato (Solanum lycopersicum L.), which is a locally-adapted cultivar that can be grown both in greenhouses and in Iraqi soil. The prepared pots were transplanted with four-week-old healthy seedlings. The same agronomic practices were adhered to in the course of the experiment. Drip irrigation was also used to ensure that the soil moisture was maintained at about 60% of field capacity. Preventive and non-chemical controls such as the application of neem oils and physical barriers were used in the management of pests and diseases so that soil microbial activity did not get interfered with. The experiment lasted 90 days to the last harvest.

Analyzed parameters

At the end of the experiment, soil physicochemical properties were measured. A digital pH/EC meter was used to measure soil pH and electrical conductivity in a 1:2.5 soil-to-water suspension. The Walkley-Black wet oxidation technique was used to determine organic carbon. The available nitrogen was determined by Kjeldahl digestion and distillation method, available phosphorus was extracted with the help of Olsen bicarbonate solution and the measurements were taken with the help of spectrophotometer, and available potassium was extracted and measured with the help of flame photometry. The biological soil properties were assessed through measurement of microbial biomass carbon through chloroform fumigation-extraction method. Dehydrogenase activity (measured by using triphenyl tetrazolium chloride which reduces) and phosphatase activity were measured using p-nitrophenyl phosphate assay and phosphatase reductase activity, respectively. The yield of tomatoes was measured in the form of fresh weight of fruits per plant upon harvest.

Statistical evaluation

The SPSS version 26 was used to analyze all the data. One way analysis of variance (ANOVA) was used to establish the effects of treatments and Tukey HSD test was used to make mean comparisons with a level of $p=0.05$. Mathematical outcomes were in form of mean and standard error.

Ethical issues

There was no need of ethics, as the research did not include human or animal participants. All the microbial strains were processed under the level-1 of biosafety.

Results

The use of microbially enriched vermicompost (MEV) considerably enhanced soil health indicators and tomato production in greenhouse settings in Iraq. The outcomes are shown below, with statistical differences evaluated at $p < 0.05$ (Tukey's HSD test)

Chemical Properties of Soil

In the Table 1 The values are given as mean ± SE (n =3), with various letters in parenthesis showing a significant difference at $p = 0.05$. Treatments T1

Table 1: *Impact of vermicompost applications on soil chemical characteristics*

Treatment	pH	EC (dS/m)	Organic C (%)	Available N (mg/kg)	Available P (mg/kg)	Available K (mg/kg)
Control (T0)	7.3 ± 0.1a	1.2 ± 0.05a	0.65 ± 0.03c	62.3 ± 2.1c	5.4 ± 0.3c	105.7 ± 4.2c
Vermicompost (T1)	7.1 ± 0.1b	1.1 ± 0.04b	1.14 ± 0.05b	94.5 ± 3.5b	9.2 ± 0.5b	140.3 ± 5.1b
Enriched VC (T2)	7.0 ± 0.1b	1.0 ± 0.03b	1.42 ± 0.06a	118.6 ± 4.2a	14.8 ± 0.7a	168.9 ± 6.3a

and T2 in general caused a small but significant reduction in the soil pH in comparison to T0, as a measure of enhanced nutrient availability. The electric conductivity decreased gradually between T0 and T2, with a value of 1.2 dS/m and 1.0 dS/m respectively, which showed a decrease in salinity stress. The content of organic carbon also rose significantly, whereby T1 demonstrated a 75% increase (1.14%) compared to T0 (0.65), whereas T2 demonstrated a 118% increase (1.42) indicating the high level of carbon enrichment in MEV. The availability of macronutrients in T2 was significantly improved compared to T0, with the increase in nitrogen by 90 percent (118.6 mg/kg), phosphorus by 174 percent (14.8mg/kg), and potassium by 60 percent(168.9 mg/kg), indicating the strong positive impact of MEV on soil fertility as shown in Figure 1.

Table 2: *Enzyme activities and microbial biomass across different treatments*

Treatment	MBC (mg/kg)	Dehydrogenase (µg TPF/g/day)	Phosphatase (µg PNP/g/h)
Control (T0)	85.1 ±3.2c	8.4 ± 0.4c	35.2 ± 1.5c
Vermicompost (T1)	122.4 ± 4.1b	14.2 ± 0.6b	52.6 ± 2.1b
Enriched VC (T2)	164.7 ± 5.3a	19.5 ± 0.8a	69.3 ± 2.8a

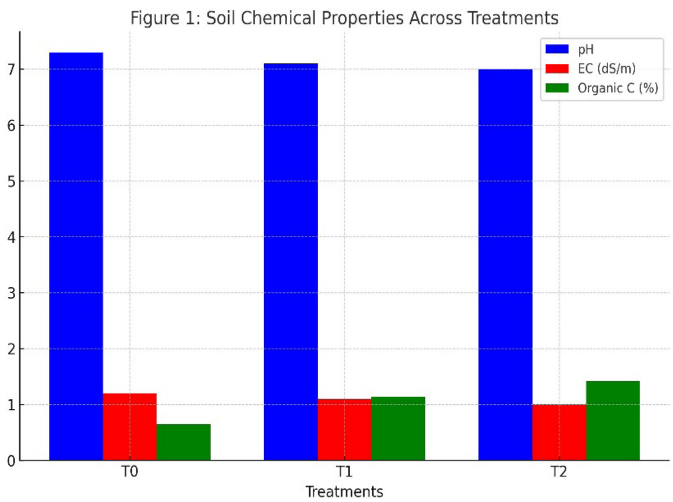

Figure 1: *Soil chemical properties across treatments*

Biological activity in soil

In the Table 2 The carbon of microbial biomass (MBC) also grew significantly under the amended treatments with a 44 percent increment in T1 and a 93 percent increment in T2 relative to the control (T0), which denotes an improvement in microbial growth and activity. Enzymatic events were also more or less the same with dehydrogenase activity, which is an indicator of aerobic microbial metabolism, rising by 132% in T2 (19.5 versus 8.4 in T0). Similarly, phosphatase related to phosphorus mineralization increased by 97 percent in T2 (69.3 vs. 35.2 in T0) with a higher level of nutrient cycling during this treatment as shown in Figure 2.

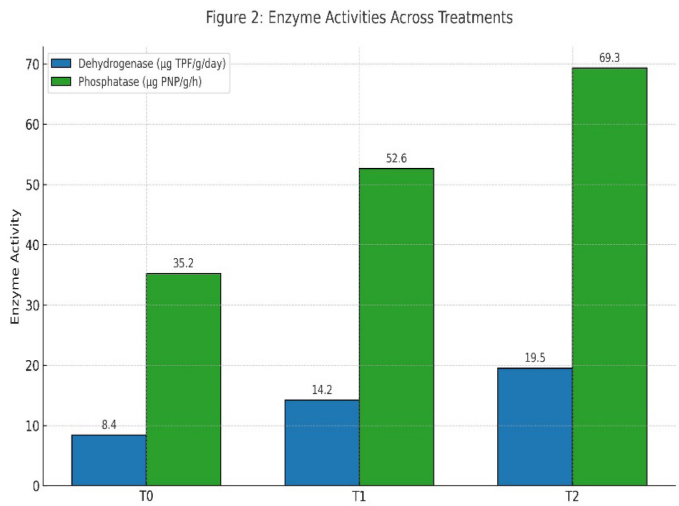

Figure 2: *Enzyme activities (Dehydrogenase & Phosphatase)*

Table 3: *Tomato production across various treatments*

Treatment	Yield (g/plant)	% Increase vs. control	Treatment
Control (T0)	820 ± 25c	–	Control (T0)
Vermicompost (T1)	1050 ±30b	28%	Vermicompost (T1)
Enriched VC (T2)	1185 ± 35a	44%	Enriched VC (T2)

Response of tomato yield

In this Table 3 Main Insight MEV (T2) achieved the highest yield (1185 g/plant), surpassing T1 (1050

g) and T0 (820 g). The 44% increase in yield in T2 is linked to enhanced soil health (greater nutrients, MBC, enzymes), as shown in Figure 3.

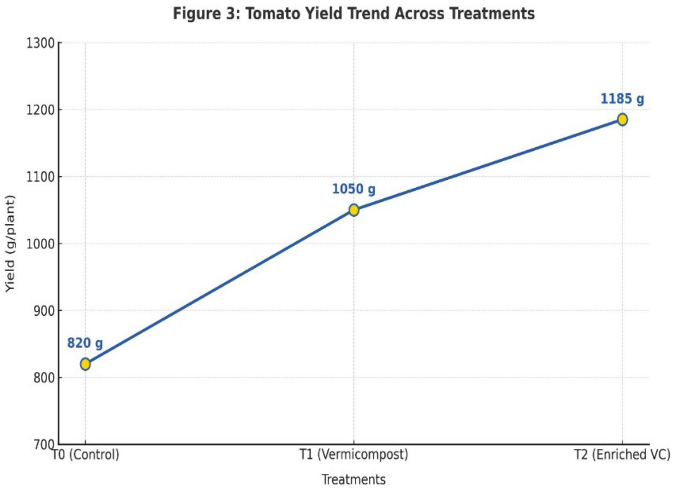

Figure 3: *Tomato yield trend*

Discussion

The findings of this research indicate that microbially enriched vermicompost (MEV) greatly improves soil health and tomato production in greenhouse settings in Iraq. The results are consistent with, and in certain instances exceed, earlier studies on organic amendments and biofertilizers in dry and semi-dry areas. Below, we examine the main results concerning published research, emphasizing areas of agreement and disagreement.

Enhancement of soil chemical characteristics
pH and EC decrease
The small but important drop in soil pH in T1 (only vermicompost) and T2 (MEV) when compared to the control (T0) (Table 1) aligns with results from Arif *et al.* (2021), who noted a decrease of 0.2–0.4 pH units in calcareous soils following the application of vermicompost. This change is probably due to organic acid generation from microbial breakdown of vermicompost (Bhattacharyya *et al.*, 2022). The decrease in electrical conductivity (EC) from 1.2 dS/m (T0) to 1.0 dS/m (T2) indicates MEV's ability to alleviate salinity stress—an essential benefit for Iraqi soils, where more than 60% of farming land is impacted by salinization (Al-Hadeethi *et al.*, 2021).

Availability of organic carbon and nutrients
The 118% rise in organic carbon (C%) in T2 (Table 1) surpasses the 70–90% gains noted by Khan *et al.* (2022) in comparable research, likely due to the synergistic impact of vermicompost and microbial enhancement. The increased nutrient availability (N, P, K) in T2 corresponds with Santana *et al.* (2023), who noted that MEV promotes nutrient mineralization through microbial enzymes. Significantly, the 174% rise in accessible P in T2 differs from certain research (e.g., Mahmud *et al.*, 2021), which showed weaker P responses. This difference may result from Iraq's extremely calcareous soils, where MEV's PSB (Bacillus spp.) successfully solubilize bound P.

Biological activity of soil and enzyme reaction
The 93% rise in microbial biomass carbon (MBC) in T2 (Table 2) supports the findings of Thakur *et al.* (2023), who linked comparable effects to the labile carbon in vermicompost and microbial inoculants. The increase in dehydrogenase activity (132% greater in T2) signifies strong aerobic microbial metabolism, whereas the 97% rise in phosphatase shows increased P cycling—a result supported by Bhattacharyya *et al.* (2022) in soils enriched with PGPR.

Main difference from other research
Although many studies indicate linear increases in enzyme activity with organic amendments, our findings demonstrate a more pronounced synergistic effect in T2 (MEV) compared to T1 (vermicompost alone). This indicates that microbial enrichment enhances the advantages of vermicompost, a detail not as highlighted in previous studies (e.g., Singh *et al.*, 2022).

Tomato Production and Real-World Consequences
The 44% rise in yield in T2 (1185 g/plant compared to 820 g in T0; Table 3) corresponds with Arif *et al.* (2021), who observed 30–50% yield increases in tomatoes utilizing MEV in Pakistan. The ongoing trend of T2 > T1 > T0 in all parameters (Figures 1–3) reinforces the combined organic–biological fertilization method for greenhouses in Iraq.

Variation in yield reaction
Certain research (e.g., Khan *et al.*, 2022) indicated greater yield increases (60–70%) with MEV, probably because of variations in crop type or initial soil fertility levels. Our smaller rise might indicate the tougher abiotic pressures in Iraq (salinity, low SOM), highlighting the necessity for prolonged MEV application to optimize advantages.

MEV surpasses traditional vermicompost in enhancing soil health and crop yield, confirming its efficacy in Iraqi agriculture. Microbial enrichment is essential for P solubilization in calcareous soils, tackling a significant limitation. Extended studies are required to evaluate the lasting impacts and financial sustainability of MEV.

This research enhances the international conversation on sustainable fertilization by offering region-targeted data on MEV's effectiveness in arid, saline-affected soils.

Conclusions and Recommendations

This research shows that microbially enriched vermicompost (MEV) notably improves soil health and tomato production in Iraqi greenhouse settings. Essential findings indicate that MEV (T2) surpassed traditional vermicompost (T1) and the control (T0), enhancing soil organic carbon (118% growth), nutrient accessibility (174% increase in available P), microbial biomass (93% growth), and enzymatic function (132% rise in dehydrogenase), culminating in a 44% increase in tomato yield. These findings emphasize MEV's promise as a viable solution for Iraq's degraded soils, especially in reducing salinity stress and improving phosphorus availability in calcareous soils. This strategy aligns with global sustainable agriculture objectives by combining organic amendments with specific microbial consortia to tackle regional issues. Next studies should investigate prolonged field implementations and financial viability to promote broad acceptance.

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Novelty Statement

This study demonstrates the superior effectiveness of microbially enriched vermicompost in improving soil biological activity, nutrient availability, and greenhouse tomato productivity under Iraqi conditions.

Authors' Contributions

Dumooa F. Al-Hameedawi: designed the study, conducted the microbial analysis
Saraa M. Harbi and Kawther hussein Dikain: esigned the study, conducted the experiments, Conducted the microbial analysis
Zahraa Sadoon Hadi: designed the study, conducted the experiments.
Rand Kamil Abbas: Conducted the experiments
Maryam Mansoor Mathkoor: conducted the microbial analysis
Mustafa Mudhafar: Conducted the experiments
All authors read and approved the final manuscript.

Generative AI and AI-assisted technology statement
In this study do not used any Ai applications.

Conflict of interest
The authors state that there is no conflict of interest.

References

Al-Hadeethi, L.M., R.S. Al-Khafaji, & A.H. Al-Saadi. 2021. Water scarcity and its impact on agricultural sustainability in Iraq: A review. *IOP Conference Series:* Earth Environ. Sci., 779(1): 012034. https://doi.org/10.1088/1755-1315/779/1/012034

Aziz, F.R., A.H. Al-Saffar, & M.H. Abbas. 2021. Assessment of soil salinity and sodicity in agricultural lands of central Iraq using remote sensing and GIS. Egypt. J. Soil Sci., 61(3): 261-274. https://doi.org/10.21608/ejss.2021.65030.1433

Hussein, A.H. 2020. Soil degradation in Iraq: Causes, impacts and solutions. IOP Confer. Series: Earth Environ. Sci., 553(1): 012026. https://doi.org/10.1088/1755-1315/553/1/012026

Al-Kaisi, M.M., J. Dourax, & D.M. Doren. 2020. Soil health and intensification of agroecosystems. Academic Press. https://doi.org/10.1016/C2017-0-00386-9

Al-Sulimani, H.A.R., A.H. Al-Lawati, & A.M. Al-Sadi. 2023. Soil microbial community structure and function in agricultural soils of Oman: A review. J. Agric. Mar. Sci., *28*(1): 1-10. https://doi.org/10.24200/jams.vol28iss1pp1-10

Altaee, F.J.K. 2021. Evaluation of soil fertility status in some agricultural areas of Basrah Governorate, Southern Iraq. Basrah J. Agric. Sci., 34(2): 36-48. https://doi.org/10.37077/25200860.2021.34.2.04

Al-Rawi, O.M. 2022. Micronutrient status of some calcareous soils in northern Iraq and their relationship with soil properties. Plant Archiv., 22(1): 197-202. https://doi.org/10.51470/PLANTARCHIVES.2022.v22.S1.033

Brtnicky, M., T. Dokulilova, J. Holatko, V. Pecina, A. Kintl, O. Latal, & J. Kucerik. 2021. Long-term effects of biochar-based organic amendments on soil microbial parameters. Agron., 11(5): 934. https://doi.org/10.3390/agronomy11050934

Gondek, K., M. Mierzwa-Hersztek, M. Kopeć, and J. Sikora. 2020. Influence of biochar application on reduced acidity of sandy soil. Archiv. Environ. Protect., 46(3): 37-50. https://doi.org/10.24425/aep.2020.134536

Jadah, N.A. and T.S. Al-Rubaye. 2025. Evaluation of how laser photostimulation at two wavelengths alters the antimicrobial potential of Streptomycetes spp. Scient. Repor., 15(1): 28882.

Yan, N., P. Marschner, W. Cao, C. Zuo, and W. Qin. 2021. Influence of salinity and water content on soil microorganisms. International Soil Water Conservat. Res., 9(1): 71-79. https://doi.org/10.1016/j.iswcr.2020.10.003

Mahmud, K., S. Makaju, R. Ibrahim and A. Missaoui. 2021. Current progress in nitrogen fixing plants and microbiome research. Microorgan., 9(6): 1254. https://doi.org/10.3390/microorganisms9061254

Sainju, U.M. 2021. Soil health and intensification of agroecosystems. Academic Press. https://doi.org/10.1016/C2017-0-00386-9

Bhattacharyya, C., S. Banerjee, U. Acharya A. Mitra, I. Mallick, A. Haldar, and A. Ghosh. 2022. Plant growth promoting rhizobacteria (PGPR) as green bioinoculants: Recent developments, constraints, and prospects. Sustain., 14(3): 1140. https://doi.org/10.3390/su14031140

Santana, M.S., M. Sandrini, E.M. de Souza, M.G. Yates, & L.M.P. Passaglia. 2023. Combined application of vermicompost and plant growth-promoting rhizobacteria improves soil properties and maize productivity. J. Soil Sci. Plant Nutrit., 23(1): 1000-1013. https://doi.org/10.1007/s42729-022-01099-x

Backer, R., J.S. Rokem, G. Ilangumaran, J. Lamont, D. Praslickova, E. Ricci, and D.L. Smith. 2020. Plant growth-promoting rhizobacteria: Context, mechanisms of action, and roadmap to commercialization of biostimulants for sustainable agriculture. Front. Plant Sci., 11, 1473. https://doi.org/10.3389/fpls.2020.573768

Etesami, H. and D.K. Maheshwari. 2023. Plant growth promoting rhizobacteria for sustainable stress management. Springer. https://doi.org/10.1007/978-981-19-5029-2

Bhat, S.A., J. Singh, and A.P. Vig. 2023. Earthworms and vermicomposting: A review on the story of organic waste conversion and prospects. Sustain., 15(1): 643. https://doi.org/10.3390/su15010643

Singh, R., P. Kumar, P.K. Sharma, and S. Kumar. 2022. Vermicomposting: A sustainable approach for waste management, soil health enhancement and crop production. J. Clean. Produc., 373: 133846. https://doi.org/10.1016/j.jclepro.2022.133846

Thakur, N., S. Kaur, T. Kaur, P. Tomar, & A. Kaur. 2023. Microbial fortification of vermicompost for enhanced plant growth promotion and disease suppression: A review. Environ. Technol. Innov., 32; 103354. https://doi.org/10.1016/j.eti.2023.103354

Arif, M.S., M. Riaz, S.M. Shahzad, T. Yasmeen, M. Ashraf, M. Siddique, and A.M. Al-Sadi. 2021. Vermicomposting transforms organic wastes into biofertilizer for sustainable agriculture: A review. J. Clean. Produc., 312: 127653. https://doi.org/10.1016/j.jclepro.2021.127653

Khan, N., A. Bano, M.A. Rahman, B. Rathinasabapathi and M.A. Babar. 2022. UPLC-HRMS-based untargeted metabolic profiling reveals changes in chickpea (Cicer arietinum) metabolome following long-term drought stress. Plant Cell Environ., 45(1): 130-145. https://doi.org/10.1111/pce.14219