Effect of Bio-inoculants and Organic Fertilization on the Macronutrient (N, P, K) Content of Eggplant (*Solanum melongena* L.) Leaves

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Abstract

The experiment was carried out during the growing season of 2024–2025 in a plastic greenhouse at Al-Musayyib District, Al-Mashrooa area of Babylon Governorate in a private agricultural field in Hilla city (32047'00"N, 44019'00"E). This was a three replication Randomized Complete Block Design (RCBD) experiment. In sandy loam soil, the Least Significant Difference (LSD) was used to compare the means for treatment at a 5% level of probability. The objective of the study was to study the effect of bacterial biofertilizers (*Azotobacter vinelandii* and *Bacillus subtilis*) as well as the four levels of application of compost organic manure (0, 1, 2, 3 tons per hectare) on the leaf nitrogen (N), phosphorus (P), and potassium (K) content. At the flowering stage, the results indicated that the treatment with the three –way interaction between the study factors in the proportion of 3 t ha^{-1} of *A. vinelandii, B. subtilis* or compost presented significant values for the contents of N, P and K, in mg per kg of dry matter: 7.8900, 0.6000 and 4.6100, respectively. The treatment with *A. vinelandii* was followed by the treatment with *A. vinelandii* + compost at 3 tons per hectare, which was the best in all traits except leaf P content, where the combined biofertilizer treatment (*A. vinelandii* + *B. subtilis*) recorded the value highest .

Keywords: Eggplant, biofertilizer, compost manure, N, P, K content.

Note: This research is extracted from the first author’s Ph.D. dissertation.

Introduction

Eggplant (*Solanum melongena* L) is an annual herb of the Solanaceae family and it is the fifth largest crop grown worldwide with an annual production of 56 million tons. It is rich in vitamins, minerals, fiber and phenolics (8). and is widely grown throughout the tropical and temperate regions.it is found that china is the largest producer (36.6 million tons) followed by India and Egypt (7) . Eggplant is an important economic crop in Iraq, and in 2023, 594.16 dunams of eggplant were cultivated, yielding 170.63 tons (6).

reported that biofertilizers consist of microorganisms living in the rhizosphere (0–30 mm around roots). According to (10) biofertilizers are living organisms which are introduced in soil or seeds to improve the nutrient level,is reflected in plant growth decrease mineral fertiliser and to provide good, environment-friendly food.

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In the case of eggplant, (14) evaluated four biofertilizers and reported that the Azotobacter plants contained more N,P,K in their leaves than the un-inoculated plants. In the same way, (3) reported that the *Azotobacter chroococcum* significantly increased N, P and K in tomata (*Solanum lycopersicum* L.) plants. Addition various organic manures also resulted in higher levels of N,P,K in tomato leaves (1) and eggplant leaves (13). Organic fertilizers such as poultry waste, vermicompost, dried blood and palm fronds were found to improve the concentration of NPK in (*Capsicum annuum* L.) leaf (3.40%, 0.42%, 4.11% respectively) by (4).

Materials and Methods

A field experiment was conducted to cultivate eggplant in one of the plastic greenhouses within a private agricultural field in Babylon Governorate, Al-Musayyib District, Al-Azawiya area, during the 2024–2025 season. The total area was 468 m² (52 m × 9 m) in sandy loam soil, to study the effect of bacterial biofertilizer and compost in the content of the major nutrients N.P.K eggplant. The soil was prepared by plowing twice perpendicularly. Random soil samples were taken from the plastic house at a depth of 0–30 cm to determine some physical, chemical, soil properties before starting the experiment.

Table (1): Some physical and chemical properties of the plastic house soil

Property	Value	Property Unit
Clay	110	g kg^{-1} soil
Silt	291	g kg^{-1} soil
Sand	599	g kg^{-1} soil
Texture	Sandy loam	—
Bulk density	1.37	g cm^{-3}
Electrical conductivity (EC)	2.16	dS m^{-1}
pH	7.4	—
Cation exchange capacity (CEC)	19.32	$cmol^{+}$ kg^{-1} soil
Organic matter (OM)	1.7	g kg^{-1} soil
Available N	26.4	mg kg^{-1} soil
Available P	7.3	mg kg^{-1} soil
Available K	158	mg kg^{-1} soil

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The soil was then leveled and well-tilled. It was divided into three ridges along the plastic house, with a 1 m isolation distance between each ridge. Each ridge was divided into 16 experimental units per sector. Drip irrigation networks were placed along each ridge. The experimental unit area was 5.8 m² (2.90 m × 2 m). The distance between experimental units within the same sector was 30 cm. The total number of experimental units was 48, arranged in a factorial experiment using a Randomized Complete Block Design (RCBD) with three replications. Treatment means were compared using the Least Significant Difference (LSD) at 5% probability.

The experimental units were randomly distributed by digging furrows on both sides of the ridge, adding compost table (2) at levels (0, 1, 2, 3 tons per hectare) to each furrow and mixing it with the soil. Seedlings were planted on February 12, 2025, after being inoculated with a liquid suspension of A. vinelandii and B. subtilis by dipping roots for 15 minutes with a concentration of 10^{-6} (16). The hybrid variety (Barcelona F1) was planted on both sides of the ridge, with 40 cm spacing between plants. After seedlings , thinning was performed ,after there were 2 plants leaving one plant per furrow. Chemical fertilizers were added according to the fertilizer recommendation for eggplant as reported by (11).

Soil particle size distribution was determined according to (5). Bulk density was measured as per (5) . Electrical conductivity was determined following (12) . pH and cation exchange capacity were measured according to (5). Organic matter was determined according to (5). Available nitrogen (Kjeldahl), available phosphorus (spectrophotometer), and available potassium (flame photometer) were determined following (5).

Table (2) shows the properties of the organic fertilizer used

Variety	From	To
Weight of a cubic meter wet (kg)	600	700
Weight of a cubic meter dry (kg)	450	550
Moisture content %	25	30
PH IN 1:10 extract	7.5	8.5
Conductivity (EC) IN 1ds\m^3 (10) extract	4.5	6.5
Water cross- sectional capacity%	200	300
Total N %	1.4	1.8
OM%	40	48
Organic carbon %	22.2	22.8
)C/N ratio(	1:15:4	1:16:6
Total p %	0.4	0.8
Total K%	0.8	1.8
Fe(ppm)	1500	2000
Mn(ppm)	100	150
Cu(ppm)	160	240
Zn (ppm)	40	80

Study Indicators

Leaf N, P, and K content of eggplant at flowering stage

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Samples were collected from the fourth leaf below the growing tip (physiologically active) from six randomly selected plants per experimental unit at the flowering stage. Leaves were washed with tap water, then distilled water, dried in an oven at 65°C for 48 hours until constant weight, and ground separately using an electric mill. The ground material was passed through a 0.5 mm sieve, mixed well, and 0.2 g from each sample was placed in a conical flask. Digestion was performed using a mixture of sulfuric and perchloric acids. After digestion, nitrogen was determined by distillation using a Kjeldahl apparatus, phosphorus was measured using a spectrophotometer, and potassium was determined using a flame photometer (2).

Results and Discussion

1. Effect of Bacterial Biofertilizer (*A. vinelandii* and *B. subtilis*) and Compost Levels on Leaf N Content (mg N per kg dry matter) at Flowering Stage

The averages of leaf nitrogen concentration as obtained by statistical analysis (Table 3) revealed that the bacterial biofertilizers and compost levels (either as single, dual or triple application) resulted significant increase in leaf nitrogen concentration as compared to the control treatment. In this case the three – way interaction between the study factors with mixed biofertilizer with compost at 3 ton ha^{-1} recorded a highest moral value compared to all the other treatments with an average of 7.8600 mg Nkg. It was followed by treatment with *A. vinelandii* and compost at 3 tons per hectare averaging 7.2300 mg N per kg when compared to the control.

The enhanced activity and abundance of soil microorganisms under composts may be explained by the fact that compost is an easily decomposed material that boosts soil microbial activity and abundance due to improved nutrient availability and microbial secretion, which boosts the activity of the root system, nutrient uptake, and hence nutrient concentrations in plant vegetative parts.

Moreover, the dual inoculation of *A. vinelandii* and *B. subtilis* with the highest compost dose could be attributed to better fertilizer use efficiency and nutrient supply capacity to the soil, which resulted in more uptake of nutrients (including nitrogen) by the eggplant roots and consequently higher plant concentration.

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Table (3) Effect of bacteril biofertilizer (*A. vinelandii and B. subtilis*) and compost levels on leaf nitrogen content (mg N per kg dry matter)

Mean		Compost levels (C) (tons per hectare)				Bacillus (BS)	Azotobacter AZ
AZ	AZ +BS	C3	C2	C1	C0		
4.9225	4.5725	4.8200	4.6800	4.5100	4.2800	BS0	AZ0
	5.2725	5.5800	5.3900	5.1800	4.9400	BS1	
6.6825	6.1775	6.6000	6.4400	5.8900	5.7800	BS0	AZ1
	7.1875	7.8600	7.1500	6.8800	6.8600	BS1	
0.01179	0.01668	0.03335					L.S.D
AZ*C							
L.S.D AZ*C =0.02358		5.2000	5.0350	4.8450	4.6100	AZ0	
		7.2300	6.7950	6.3850	6.3200	AZ1	
BS Mean		BS * C					
5.3750		5.7100	5.5600	5.2000	5.0300	BS0	
6.2300		6.7200	6.2700	6.0300	5.9000	BS1	
L.S.D BS =0.01179		L.S.D BS*C =0.02358					
L.S.D C =0.01668		6.2150	5.9150	5.6150	5.4650	Mean C	

AZ1 = Vaccination *A.vinelandii* **BS1= Vaccination *B.subtilis***

AZ+BS= Vaccination *A.vinelandii* + *B.subtilis*

AZ0 , BS0= Without vaccination **C= compost**

2. Effect of Bacterial Biofertilizer (*A. vinelandii* and *B. subtilis*) and Compost Levels on Leaf P Content (mg P per kg dry matter) at Flowering Stage

The result of statistical analysis gave Table (4) which revealed that the averages of the leaf phosphorus content applied with the bacterial biofertilizers and compost levels singly, dually and triply were significant increases compared with the control. The treatment triple interference and compost (3 Ton ha^{-1}) showed significantly higher than all other treatments with the average of 0.6000 mg P/kg. It was followed by the treatment with dual biofertilizer (*A. vinelandii* + *B.*

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subtilis) with an average of 0.5917 mg P per kg, compared to the control. This could be attributed to not only the nutrient content of the manure but also the contribution of compost to the substrates for soil microbial communities and to extending the activity of the added biofertilizer bacteria (particularly in the root-surface zone) that positively influence the availability and uptake of phosphorus.

Table (4): Effect of bacterial biofertilizer (*A. vinelandii* and *B. subtilis*) and compost levels on leaf phosphorus content (mg P per kg dry matter) at flowering stage

Mean		Compost levels (C) (tons per hectare)				Bacillus	Azotobacter
AZ	AZ +BS	C3	C2	C1	C0	BS	AZ
0.5113	0.4758	0.4933	0.4800	0.4700	0.4600	BS0	AZ0
	0.5467	0.5367	0.5600	0.5500	0.5400	BS1	
0.5533	0.5150	0.5300	0.5200	0.5100	0.5000	BS0	AZ1
	0.5917	0.6000	0.5900	0.5967	0.5800	BS1	
0.02061	0.02915	0.05830					L.S.D
AZ*C							
L.S.D AZ*C =0.04122		0.5150	0.5200	0.5100	0.5000	AZ0	
		0.5650	0.5550	0.5533	0.5400	AZ1	
Mean BS		BS * C					
0.4954		0.5117	0.5000	0.4900	0.4800	BS0	
0.5692		0.5683	0.5750	0.5733	0.5600	BS1	
L.S.D BS =0.02061		L.S.D BS*C =0.04122					
L.S.D C =0.02915		0.5400	0.5375	0.5317	0.5200	Mean C	

AZ1 = Vaccination *A.vinelandii* **BS1= Vaccination *B.subtilis***

AZ+BS= Vaccination *A.vinelandii* + *B.subtilis*

AZ0 , BS0= Without vaccination **C= compost**

3. Effect of Bacterial Biofertilizer (*A. vinelandii* and *B. subtilis*) and Compost Levels on Leaf K Content (mg K per kg dry matter) at Flowering Stage

Leaf potassium content averages significantly increased with increase in bacterial biofertilizers and compost levels when applied singly, dually or triply as revealed by the statistical analysis presented in Table (5). The treatment with triple interference biofertilizer and compost with 3 tons per ha rate showed significant improvement over all the treatments with average of 4.6100 mg K kg-1. This was followed by the treatment triple interference *A. vinelandii* and *B. subtilis* (without compost) which showed an average of 4.443 mg K per kg as compared to the control.

This increase in potassium content of leaves was probably due to the additional compost and to interaction with the study factors it plays an important role in plant physiological processes, which in turn leads to an increase in the ability of the plants to absorb the nutrients (including potassium) and an increase in their content in the vegetative organs.

Table (5): Effect of bacterial biofertilizer (*A. vinelandii* and *B. subtilis*) and compost levels on leaf potassium content (mg K per kg dry matter) at flowering stage

Mean		Compost levels (C) (tons per hectare)				Bacillus BS	Azotobacter AZ
AZ	AZ +BS	C3	C2	C1	C0		
3.167	2.306	2.420	2.693	2.220	1.890	BS0	AZ0
	3.088	4.220	4.180	3.930	3.780	BS1	
3.765	4.028	3.440	3.310	3.020	2.580	BS0	AZ1
	4.443	4.610	4.460	4.380	4.320	BS1	
0.1034	0.1463	0.2925					L.S.D
AZ*C							
L.S.D AZ*C =0.2069		3.320	3.437	3.075	2.835	AZ0	
		4.025	3.885	3.700	3.450	AZ1	
BS Mean		BS * C					
2.697		2.930	3.002	2.620	2.235	BS0	

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4.235	4.415	4.320	4.155	4.050	BS1
L.S.D BS =0.1034	L.S.D BS*C = 0.2069				
L.S.D C =0.1463	3.673	3.661	3.388	3.143	C Mean

AZ1 = Vaccination *A.vinelandii* **BS1= Vaccination *B.subtilis***

AZ+BS= Vaccination *A.vinelandii* + *B.subtilis*

AZ0 , BS0= Without vaccination **C= compost**

Conclusions

The dual bacterial biofertilizer (*Azotobacter vinelandii* and *Bacillus subtilis*) along compost at 3 ton per hectare significantly enhanced the level of nitrogen (N), phosphorus (P) and potassium (K) in leaf tissues of eggplant during flowering stage as compared to other treatments. The dual inoculation alone (no compost) also resulted in significant improvements, especially in phosphorus and potassium, suggesting that the bacteria themselves also are important in mobilizing nutrients. The higher compost rate (0 to 3 tons/ha) always increased the nutrient content of the leaves for most of the inoculation treatments. Based on this, the results suggest that use of biofertilizers in combination with organic manure are highly effective agronomic methods for enhancing mineral nutrition in eggplant in sandy loam soils. Moreover, dual biofertilizer application can achieve an acceptable uptake of P and K without any addition of compost. The findings emphasize the importance of using bacterial biofertilizers in addition to compost in agricultural extension programs for eggplant production in Iraq and further research in various soil types and different growth stages and in different climatic conditions to generalize these results and recommendations.

References

1. Al-Ameri, N. J. K., & Matloob, A. N. (2012). Effect of organic fertilizers on growth and production of tomato under heated plastic house conditions. *Al-Furat Journal of Agricultural Sciences*, 4(3), 21-38. (In Arabic)

2. Al-Sahhaf, F. H. (1989). *Applied Plant Nutrition*. Dar Al-Hikma Press, Ministry of Higher Education and Scientific Research, University of Baghdad. (In Arabic).

3. Al-Shibani, J. A. K. (2005). *Effect of chemical, organic and bio-fertilizers (fungal and bacterial) on growth and yield of tomato*. Ph.D. Dissertation, College of Agriculture, University of Baghdad. (In Arabic)

4. Al-Taee, S. H. M. (2022). *Study of the effect of sources and levels*

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of organic matter on phosphorus release and availability and their impact on growth and yield of sweet pepper in plastic houses. Master’s Thesis, Al-Musayyib Technical College, Al-Furat Al-Awsat Technical University. (In Arabic)

5. Black, C. A. (1965ab). *Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties*. American Society of Agronomy, Inc., Publisher, Madison, Wisconsin.

6. Central Statistical Organization of Iraq. (2023). *Vegetable production for the year 2023*. Ministry of Planning, Republic of Iraq. (In Arabic)

7. Chioti V., Zeliou , K., Bakogianni , A ., Papaioannou ,C., Biskinis ,A., Petropoulos ,C., Lamari , F.N.,& Papasotiropoulos , V. (2022) . Nutritional value of eggplant cultivars and association with sequence variation in genes coding for major phenolics. *Plants*, 11, 2267.

8. Ebrahimi, P., Nicoletto, C., Sambo, P., Tinello, F., Mihaylova, D., & Lante, A. (2023). Impact of agronomic treatments on the enzymatic browning of eggplants (*Solanum melongena* L.). *Antioxidants*.

9. El-Goud, A., & Amal, K. (2020). Efficiency response of vermicompost and vermitea levels on growth and yield of eggplant (*Solanum melongena* L.). *Alexandria Science Exchange Journal*, 41(January-March), 69-75.

10. Kumar, A., Prasad, S., & Singh, S. K. (2014). Screening of free living rhizobacteria associated with wheat rhizosphere for plant growth promoting traits. *African Journal of Agricultural Research*, 9(13), 1094-1100.

11. Matloob, A. N. A. (1989). *Vegetable Production*. Ministry of Higher Education and Scientific Research, University of Baghdad, College of Agriculture. (In Arabic)

12. Page, A. L., Miller, R. H.,&Keeney, D. R. (1982). *Methods of Soil Analysis. Part 2. Chemical and Biological Properties*. American Society of Agronomy, Inc., Publisher, Madison, Wisconsin.

13. Saloum, Y. F. (2012). *Effect of organic matter on growth, yield, fruit quality of eggplant and anthocyanin accumulation*. Master’s Thesis, Department of Horticulture and Landscape Engineering, College of Agriculture, University of Baghdad, Iraq. (In Arabic)

14. Seada, M. A., El-Sayed, M. N., Kassem, S., & Dabour, N. (2023). Impact of four biofertilizers on the abundance of insect pests of eggplant, *Solanum melongena* L. under soilless conditions: Evaluation of the net yield of fruits and nutrient contents of the plant. *Delta Journal of Science*, 46(3), 25-48.

15. Setiawati, M. R., Afrilandha, N., Hindersah, R., Suryatmana, P., Fitriatin, B. N., & Kamaluddin, N. N. (2023). The effect of beneficial microorganism as

biofertilizer application in hydroponic-grown tomato. *SAINS TANAH - Journal of Soil Science and Agroclimatology*, 20(1), 66–77.

16. Subba Rao, N. S. (1993). *Biofertilizers in Agriculture and Forestry*. Oxford and IBH Publishing Co., Pvt. Ltd., New Delhi, pp. 129-131.

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