ISSN 2518–2021 (Print) 2415–4474 (Electronic)

Fundamental and Applied Agriculture

Journal home page: https://www.f2ffoundation.org/faa/index.php/home

Vol. 11 (1), pp. 53 – 59: 2026, doi: https://doi.org/10.5455/faa.326899

Plant Protection | ORIGINAL ARTICLE

Optimizing Cucumber Growth and Yield with Organic Amendments: Impact of Compost, Vermicompost, and Vermiwash on Plant Performance and Nutrient Enrichment

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ARTICLE INFO

Article history
Received: 15 Oct 2025
Accepted: 10 Dec 2025
Published online: 31 Mar 2026

Keywords
Cucumber, Organic fertilizers, Sustainable agriculture, Vegetable, Eco-friendly strategy

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ABSTRACT

Frequent use synthetic chemical fertilizers in vegetable crop production provide short term yield gain but leads to long-term soil degradation and environmental problems. Therefore, it is crucial to adopt cost-effective and eco-friendly strategies for sustainable vegetable crop production. The aim of the study was to evaluate the effects of organic fertilizers (compost, vermicompost and vermiwash) for improving sustainable cucumber (*Cucumis sativus* L.) production. In this study, we found compost, vermicompost, and vermiwash application had differential effects on leaf number, fruit length, accumulation of nitrogen (N), calcium (Ca), and potassium (K), improving plant biomass and total cucumber yield. Compost increased leaf number per plant, followed by vermicompost. Application of vermicompost 4 showed the highest cucumber size (18.41 ± 0.63 cm). Vermicompost2 showed the highest level of nitrogen (2.82 ± 0.05%) accumulation in cucumber. Among the three organic fertilizers, the vermicompost amendment showed better performance for improving total plant biomass and cucumber yield, produced vermicompost application could be a better option for improving cucumber yield. These findings together suggest that the cost-effective and eco-friendly organic amendment-based strategy would be effective to horticulturists and farmers for sustainable cucumber and other horticultural plant production.

1. Introduction

Vegetable crops contribute significantly to human nutrition and global food security. Until now, Vegetable production relies heavily on synthetic chemical fertilizers worldwide. The uncontrolled useof nitrogen (N), phosphorus (P) and potassium (K) based synthetic fertilizers provides short-term yield gains but it imposes long term ecological impacts. The excessive use of chemical fertilizers is neither cost-effective nor environmentally friendly. Moreover, long-term use of chemical fertilizers degrades soil organic matter (SOM), disrupts microbial community structure (MCS), increases soil acidity (decline soil pH), increase leaching of nitrates and phosphates into groundwater and surface water bodies, their by leading to eutrophication, loss of soil aquatic biodiversity and induce health risks for human (Savci., 2012 and Zhang et al., 2015). Recently, several studies have indicated that intensive chemical fertilization is responsible for around 10-12% of agricultural gas emissions globally through releasing nitrous oxide (N2O), leading to climate change impacts on total system of agricultural crop production (Mahmud et al., 2025) . Moreover, uncontrolled use of several pesticides and fertilizer salts accumulate in vegetable tissues, which directly poses health risks to consumers by the direct toxic exposures (Mahmud et al., 2025 b). In this overall scenario, it is crucial to introduce cost-effective and eco-friendly strategies for vegetable production as a sustainable alternative to chemical fertilization.

Among the cost-effective and eco-friendly sustainable alternatives for plant production. (Ahmed et al., 2025, Haque et al., 2025, and Yatoo et al., 2020), organic amendments specifically compost, vermicompost and vermiwash have gained popularity due to substantial scientific and agronomic benefits. Compost substantially improves soil structure, water retention and cation exchange capacity (CEC) while providing a slow-release reservoir of macro- and micronutrients. Vermicompost, a

Cite This Article
Ahmed MA, Rasheed SMS. 2026. Optimizing Cucumber Growth and Yield with Organic Amendments: Impact of Compost, Vermicompost, and Vermiwash on Plant Performance and Nutrient Enrichment. *Fundamental and Applied Agriculture*, 11(1): 53–59. https://doi.org/10.5455/faa.326899

product of enzymatic and microbial transformation of organic residues by earthworms including Eisenia fertida and Lumbricus rubellus. Vermicompost beats compost in terms of nutrient bioavailability, richness of growth promoting microorganisms, content of humic acids (Nath et al., 2022).

Vermicompost enhances several soil enzymes (urease, phosphatase, dehydrogenase) activity, subsequently stimulate beneficial rhizospheric microbes that suppress soil borne pathogens (Arancon et al., 2021). Vermiwash, a collection of liquid totals during vermicompost processing. Vermiwash acts as biostimulant containing plant bioavailable nutrients, several plant hormones (cytokinin, auxin and gibberellins), and bioactive compounds promote root development, stomatal regulation and biosynthesis of photosynthetic pigments (Yadav et al., 2023).

In spite of of benefits of organic amendments individual, research gaps remain regarding combined application and the dose-response dynamics among three types of organic fertilizers include compost, vermicompost and vermiwash in vegetable production. Most previous studies have been conducted on amendment in isolation or applied for examining single level on plants, However, it has been omitted or largely unknown the synergistic or antagonistic interactions among the organic fertilizer levels (Kumar et al., 2014). It has not been adequately addressed on how organic amendments modulate nutritional accumulation in vegetable plants, which is crucial for understanding organic amendment based nutritional improvement in horticultural plants (FAO, 2023). Therefore, it is imperative to address these study gaps for recommending organic farming as a sustainable alternative to chemical pesticides as well as to align it with sustainable development goals (SDG2: Zero Hunger; SDG12) (Lazcano and Dominguez, 2021).

Cucumber (*Cucumis sativa* L) is one of the widely cultivated vegetables globally, ranked as 4th in vegetable production after tomato, onion, and cabbage. The cucumber fruits contain high vitamin C, dietary fiber, also cucurbitacin bioactive compound having with anti-inflammatory and antioxidant properties, providing important component of human nutritional benefits (Mukherjee et al., 2022). Cucumber is highly sensitive to soil nutrient availability. plant growth, fruits setting and yield are highly dependable to proper soil nutrient managements. Therefore, introducing ideal soil nutrient management, cost-effective and eco-friendly strategies are crucial for sustainable cucumber production and global food security.

In this current study, we designed the study plans relevant to single organic fertilizer and different dose effects on plant morphological growth, total biomass, nutrient accumulation in fruits, yield per plant and final yields of cucumber. We found the these traits are influenced differently in response to soil amendments (compost, vermicompost and vermiwash), which substantially improved our understanding, and these combined findings provide new insights of research on organic farming of cucumbers and other vegetable crops.

2. Materials and Methods

2.1. Designing of experimental material and area The Cucumber (*Cucumis sativus* L.) seedlings were grown in a poly shed greenhouse in the Zakho district, Duhok governorate, Iraq during the 2025 season. In this study, the effects of compost, vermicompost, and vermiwash were investigated for several agricultural parameters of cucumber. The experiments were designed as Randomized Complete Block Design (RCBD) with three replicates. The plastic shed greenhouse was prepared clearing old crop residues, plowing, and leveling the soil thoroughly. Soil samples were taken at a depth of 0-30 cm before planting to examine the physical and chemical characteristics of the soil.

2.2. Soil physio-chemical analysis

The soil properties and soil physicochemical analyses were performed precisely (Table 1).

Table 1. Type of experimental soils and different elemental concentrations

Soil type	Unit	Amount
Sand	%	9.2
Silt	%	51.1
Clay	%	39.7
Parameter	Unit	Present in clay loam soil
Total – N	Mg kg $^{-1}$	1.040
Available phosphorus	Mg kg^{-1}	0.214
Available potassium	Mg kg^{-1}	37.440
Organic matter	(%)	0.68
pH	1:1	7.14
Ec conductivity	(ds.m-1)	1.117

2.3.Plant cultivation and application of soil amendment

Cucumber seeds of the variety SAYFF were planted on February 15 inside the plastic house, with one seed per pot. The seedlings were transplanted to the permanent planting site on March 20, 2025, with a spacing of 30 cm between plants, 50 cm between varieties, and 75 cm between rows. All other agricultural practices were uniformly applied across all experimental units, following typical local farmer practices. Three primary soil treatments were used: In first amendment (FA), animal manure and grass derived compost fertilizer with three treatments (control, 2, and 4 kg unit $^{-1}$) was applied, where second amendment (SA) was considered the vegetable leaves based vermicompost fertilizer at three levels (control, 2, and 4 kg unit $^{-1}$), and in third amendment (TA) liquid residue based vermiwash at three levels (0, 6, and 12 L unit $^{-1}$). Finally, it has been subjected total 27 (3 × 3 × 3=27) combinations, each replicated three times for a total of 81 experimental units.

2.4. Data collection and analysis

At the end of the experiment, the following parameters were recorded: plant length, fruit length, number of leaves per plant (leaf plant $^{-1}$), plant yield (kg plant $^{-1}$), nitrogen content in fruits (%) according to (Horneck and Miller, 1998), calcium content in fruits (%), and potassium content in fruits (%) according to (Richards., 1954), as well as total yield (t 500 m^{-2}). Following experiment all data were analyzed systematically. The data of first amendment (FA), second amendment (SA) and third amendment (TA) were analyzed, their group means, standard deviation (SD) and standard error (SE) were analyzed. Different organic fertilizer and their differential dose effects were presented group mean with standard errors. The significant variations among the treatments or dose, and the comparison of increase (%) or decrease (%) values were presented in tables. At least three independent biological replications were conducted for determining organic fertilizer or dose effect for a particular trait of cucumber.

3. Results

3.1. Compost and vermicompost enhanced cucumber leaf growth

The effect of FA of com2 enhanced best leaf development 47.13 ± 1.44 (Leaf plant $^{-1}$) that was 5.36% and 7.92% higher compared to same dose of vermicom and vermiwash (Table 2). In supplementation of SA their is no substantial difference among the treatment groups (Table 2). In supplementation of TA, the vermicom6 exhibited the produced the highest leaf number (46.20 ± 0.35 Leaf plant $^{-1}$) development that was 2.66% higher than control, and 4.05% and 4.35% compared to compost and vermicompost (Table2).

Table 2. Effect of compost, vermicompost and vermiwash on leaf development of cucumber

FA (kg unit^{-1})	FA Leaf plant $^{-1}$	SA (kg unit^{-1})	SA Leaf plant $^{-1}$	TA (kg unit^{-1})	TA Leaf plant $^{-1}$
Com control	42.53 ± 0.37	*Com control*	43.07 ± 1.27	*Com control*	42.20 ± 1.22
Com2	47.13 ± 1.44	*Com4*	43.87 ± 0.47	*Com6*	44.40 ± 1.36
Com4	44.73 ± 2.95	*Com8*	42.80± 1.06	*Com12*	45.13 ± 0.68
Vermicom control	42.67 ± 0.87	*Vermicom control*	43.13 ± 0.37	*Vermicom control*	45.00 ± 0.50
Vermicom2	44.73 ± 0.47	*Vermicom4*	45.67 ± 0.98	*Vermicom6*	46.20 ± 0.35
Vermicom4	44.47 ± 1.35	*Vermicom8*	45.80 ± 0.23	*Vermicom12*	42.53 ± 1.07
Vemiwash control	44.40 ± 1.33	*Vemiwash control*	44.00 ± 1.70	*Vemiwash control*	44.40 ± 1.72
Vermiwash2	43.67 ± 0.90	*Vermiwash4*	43.53 ± 1.71	*Vermiwash6*	44.27 ± 0.93
Vermiwash4	45.67 ± 1.03	*Vermiwash8*	45.00 ± 1.00	*Vermiwash12*	45.67 ± 1.60

Abbreviation: Com, Compost; Vermicom, vermicompost; FA, First Amendment; SA, Second Amendment; TA, Third Amendment, Com2, compost 2 kg unit^{-1}.

3.2. Compost and vermiwash increased fruit length of cucumber

FA Vermiwash4 produced the greatest fruit length 18.41 ± 0.63 (cm) that was 6.1% higher compared to vemiwash control. The highest fruit length was 6.92% higher than the same dose of vermicompost (Table 3). The TA vemiwash showed the similar results 18.30 ± 1.02 cm in fruit length that was 6.27% higher compared to vermiwash control (Table 3). However, in case of SA organic fertilizer treatment, No significant differences were observed among the treatments. among the treatment doses of compost, vermicompost and vermiwash (Table 3).

Table 3. Impact of compost, vermicompost and vermiwash on fruit length (cm) growth of cucumber

FA (kg unit^{-1})	FA Fruit length (cm)	SA (kg unit^{-1})	SA Fruit length (cm)	TA (kg unit^{-1})	TA Fruit length (cm)
Com control	17.10 ± 0.43	*Com control*	17.23 ± 0.25	*Com control*	17.80 ± 0.14
Com2	17.68 ± 0.45	*Com4*	17.09 ± 0.45	*Com6*	17.73 ± 0.27
Com4	17.94 ± 0.77	*Com8*	17.36 ± 0.73	*Com12*	17.69 ± 0.34
Vermicom control	17.16 ± 1.12	*Vermicom control*	17.41 ± 0.09	*Vermicom control*	18.13 ± 0.33
Vermicom2	16.88 ± 0.39	*Vermicom4*	18.15 ± 1.36	*Vermicom6*	17.51 ± 0.56
Vermicom4	17.38 ± 0.73	*Vermicom8*	17.97 ± 0.77	*Vermicom12*	16.81 ± 0.77
Vemiwash control	17.35 ± 0.58	*Vemiwash control*	18.97 ± 0.47	*Vemiwash control*	17.42 ± 0.40
Vermiwash2	18.33 ± 0.33	*Vermiwash4*	18.43 ± 0.32	*Vermiwash6*	18.21 ± 0.50
Vermiwash4	**18.41 ± 0.63**	*Vermiwash8*	18.01 ± 0.90	*Vermiwash12*	**18.30 ± 1.02**

Abbreviation: Com, Compost; Vermicom, vermicompost; FA, First Amendment; SA, Second Amendment; TA, Third Amendment, Com2, compost 2 kg unit^{-1}.

3.3. Vermicompost enhanced N accumulation in cucumber

FA vermicom2 showed the best N accumulation 2.82 ± 0.05 (%) in cucumber fruits that is 9.3% higher compared to vermicom control (Table 4). The FA vermicom2 involving N accumulation is 11.02% higher compared to vermiwash, and 4.44% higher compared to com2 (Table 4). In SA, vermicom8 showed the significantly increased for N content 2.52 ± 0.09 (%) in cucumber fruits that was 0.8 % higher than vermicompost control (Table4). In TA, vermiwash control. In TA, their is not considerable variation observed among the treatment groups. However, the overall N accumulation in cucumber fruits was higher compared to SA compost supplementation. (Table 4).

Table 4. Role of compost, vermicompost and vermiwash on N (%) content in cucumber fruit

FA (kg unit^{-1})	FA Fruit N (%)	SA (kg unit^{-1})	SA Fruit N (%)	TA (kg unit^{-1})	TA Fruit N (%)
Com control	2.26 ± 0.02	*Com control*	2.33 ± 0.11	*Com control*	2.28 ± 0.05
Com2	2.70 ± 0.13	*Com4*	2.48 ± 0.11	*Com6*	2.41 ± 0.03
Com4	2.37 ± 0.12	*Com8*	2.33 ± 0.09	*Com12*	2.43 ± 0.02
Vermicom control	2.58 ± 0.25	*Vermicom control*	2.50 ± 0.14	*Vermicom control*	2.48 ± 0.08
Vermicom2	2.82 ± 0.05	*Vermicom4*	2.32 ± 0.18	*Vermicom6*	2.61 ± 0.13
Vermicom4	2.65 ± 0.07	*Vermicom8*	2.52 ± 0.09	*Vermicom12*	2.56 ± 0.12
Vemiwash control	2.54 ± 0.08	*Vemiwash control*	2.20 ± 0.18	*Vemiwash control*	2.65 ± 0.08
Vermiwash2	2.56 ± 0.16	*Vermiwash4*	2.41 ± 0.06	*Vermiwash6*	2.48 ± 0.05
Vermiwash4	2.37 ± 0.08	*Vermiwash8*	2.41 ± 0.12	*Vermiwash12*	2.48 ± 0.02

Abbreviation: Com, Compost; Vermicom, vermicompost; FA, First Amendment; SA, Second Amendment; TA, Third Amendment, N, nitrogen, Com2, compost 2 kg unit^{-1}

3.4. Vermicompost and vermiwash improved Ca accumulation in cucumber

FA vermicom2 enhanced the best accumulation of Ca in cucumber fruits. The highest Ca accumulation was obtained 0.32±0.04 (%) in vermicompost2 followed by vermiwash2 (Table 5). The maximum Ca accumulation 0.32±0.04 (%) that was 6.66% higher compared to vermicom control. In case of SA and TA, No significant differences were observed among the treatments among or between the group treatments of the organic fertilizers compost, vermicompost and vermiwash (Table 5).

Table 5. Effect of compost, vermicompost and vermiwash on Ca (%) content in cucumber fruit

FA (kg unit^{-1})	FA Fruit Ca (%)	SA (kg unit^{-1})	SA Fruit Ca (%)	TA (kg unit^{-1})	TA Fruit Ca (%)
Com control	0.27±0.01	*Com control*	0.31±0.04	*Com control*	0.27±0.02
Com2	0.27±0.02	*Com4*	0.29±0.03	*Com6*	0.27±0.02
Com4	0.31±0.02	*Com8*	0.28±0.28	*Com12*	0.28±0.03
Vermicom control	0.30±0.04	*Vermicom control*	0.30±0.05	*Vermicom control*	0.28±0.02
Vermicom2	0.32±0.04	*Vermicom4*	0.28±0.03	*Vermicom6*	0.29±0.03
Vermicom4	0.28±0.01	*Vermicom8*	0.30±0.03	*Vermicom12*	0.29±0.04
Vemiwash control	0.27±0.01	*Vemiwash control*	0.29±0.02	*Vemiwash control*	0.28±0.03
Vermiwash2	0.32±0.04	*Vermiwash4*	0.27±0.02	*Vermiwash6*	0.29±0.01
Vermiwash4	0.27±0.01	*Vermiwash8*	0.29±0.01	*Vermiwash12*	0.25±0.01

Abbreviation: Com, Compost; Vermicom, vermicompost; FA, First Amendment; SA, Second Amendment; TA, Third Amendment, Ca, calcium, Com2, compost 2 kg unit^{-1}.

3.5. Vermiwash enhanced K content in cucumber

TA vermiwas6 enhanced the highest level of K content in cucumber fruits (Table 6). The highest K content was

2.42±0.10 (%) that was 6.14% higher compared to vermiwash control, and 15.23% and 5.67% higher competed to same dose of compost and vermicompost, respectively (Table 6). However, their is no considerable difference was observed in FA and SA group treatments of three fertilizers.

Table 6. Role of compost, vermicompost and vermiwash on K(%) content in cucumber fruit

FA (kg unit^{-1})	FA Fruit K (%)	SA (kg unit^{-1})	SA Fruit K (%)	TA (kg unit^{-1})	TA Fruit K (%)
Com control	1.96±0.13	*Com control*	2.30±0.10	*Com control*	2.12±0.07
Com2	2.06±0.12	*Com4*	2.31±0.18	*Com6*	2.10±0.11
Com4	2.32±0.08	*Com8*	2.41±0.22	*Com12*	2.09±0.13
Vermicom control	2.40±0.13	*Vermicom control*	2.31±0.16	*Vermicom control*	2.07±0.08
Vermicom2	2.41±0.15	*Vermicom4*	2.41±0.23	*Vermicom6*	2.29±0.14
Vermicom4	2.31±0.17	*Vermicom8*	2.43±0.16	*Vermicom12*	2.15±0.14
Vemiwash control	2.16±0.9	*Vemiwash control*	2.34±0.18	*Vemiwash control*	2.28±0.04
Vermiwash2	2.28±0.01	*Vermiwash4*	2.32±0.26	*Vermiwash6*	**2.42±0.10**
Vermiwash4	2.31±0.10	*Vermiwash8*	2.44±0.27	*Vermiwash12*	3.29±0.22

Abbreviation: Com, Compost; Vermicom, vermicompost; FA, First Amendment; SA, Second Amendment; TA, Third Amendment, K, potassium, Com2, compost 2 kg unit^{-1}.

3.6. Total plant biomass yield increased in response to vermicompost and vermiwash

The TA vermicom12 and vermiwash8 improved the total cucumber plant biomass (Table 7). The highest plant biomass 4.81±0.66 (kg plant^{-1}) observed in response to compost and vermicompost respectively (Table 7). The second highest total plant biomass 4.58±0.70 (kg plant^{-1}) vermicom12 that was 15.90% higher than vermicom control plant, and 16.46% higher than both same dose of was observed in response to SA vermiwash8 that was 15.0% higher than vermiwash control, and 35.90% and 13.08% compared to same dose of compost and vermicom, respectively (Table 7).

Table 7. Effect of compost, vermicompost and vermiwash on cucumber total plant biomass (kg plant^{-1}) yield

FA (kg unit^{-1})	FA Plant biomass (kg plant$^{-1)}$	SA (kg unit^{-1})	SA Plant biomass (kg plant$^{-1)}$	TA (kg unit^{-1})	TA Plant biomass (kg plant^{-1})
Com control	2.90±0.49	*Com control*	3.77±0.69	*Com control*	4.16±0.71
Com2	3.82±0.29	*Com4*	3.53±0.87	*Com6*	3.78±0.65
Com4	3.55±0.42	*Com8*	3.37±0.67	*Com12*	4.13±0.70
Vermicom control	4.04±0.70	*Vermicom control*	3.70±0.85	*Vermicom control*	4.15±o.65
Vermicom2	3.86±0.74	*Vermicom4*	3.20±0.50	*Vermicom6*	4.15±0.55
Vermicom4	3.78±0.48	*Vermicom8*	4.05±0.83	*Vermicom12*	**4.81±0.66**
Vemiwash control	3.71±0.77	*Vemiwash control*	3.98±0.74	*Vemiwash control*	4.25±0.47
Vermiwash2	3.69±0.59	*Vermiwash4*	3.74±0.79	*Vermiwash6*	4.00±0.55
Vermiwash4	3.65±0.66	*Vermiwash8*	**4.58±0.70**	*Vermiwash12*	4.13±0.90

Abbreviation: Com, Compost; Vermicom, vermicompost; FA, First Amendment; SA, Second Amendment; TA, Third Amendment, Com2, compost 2 kg unit^{-1}.

3.7. Cucumber yield trait improved by vermicompost

TA vermicom12 significantly increased the yield (ton/500 sm2) (Table 8). The highest level of yield was observed 10.67±1.46 (t 500 m^{-2}) that was 15.72% higher than control, and 16.23% and 16.35% higher compared to the same dose of compost and vermiwash, respectively (Table8). In SA vermiwash8 showed the second highest level of total yield that was 10.16±1.56 (t 500 m^{-2}). This yield result was 15.06% higher compared to control, and 36.01% and 12.88% higher than the same dose of compost and vermicom (Table 8). However, No significant differences were observed among the treatments. in FA of three compost groups (Table 8).

Table 8. Impact of compost, vermicompost and vermiwash on cucumber yield (t 500 m^{-2})

FA (kg unit⁻¹)	FA Yield (t 500 m⁻²)	SA (kg unit⁻¹)	FA Yield (t 500 m⁻²)	TA (kg unit⁻¹)	FA Yield t 500 m⁻²
Com control	6.44±1.08	*Com control*	8.37±1.52	*Com control*	9.23±1.58
Com2	8.48±0.64	*Com4*	7.83±1.93	*Com6*	8.39±1.44
Com4	7.88±0.95	*Com8*	7.47±1.49	*Com12*	9.18±1.56
Vermicom control	9.00±1.56	*Vermicom control*	8.21±1.88	*Vermicom control*	9.22±1.45
Vermicom2	8.58±1.64	*Vermicom4*	7.09±1.12	*Vermicom6*	9.20±1.24
Vermicom4	8.39±1.05	*Vermicom8*	9.00±1.84	*Vermicom12*	**10.67±1.46**
Vemiwash control	8.24±1.72	*Vemiwash control*	8.83±1.63	*Vemiwash control*	9.42±1.04
Vermiwash2	8.20±1.30	*Vermiwash4*	8.30±1.76	*Vermiwash6*	8.89±1.21
Vermiwash4	8.10±1.44	*Vermiwash8*	**10.16±1.56**	*Vermiwash12*	9.17±2.01

Abbreviation: Com, Compost; Vermicom, vermicompost; FA, First Amendment; SA, Second Amendment; TA, Third Amendment, Com2, compost 2 kg unit⁻¹.

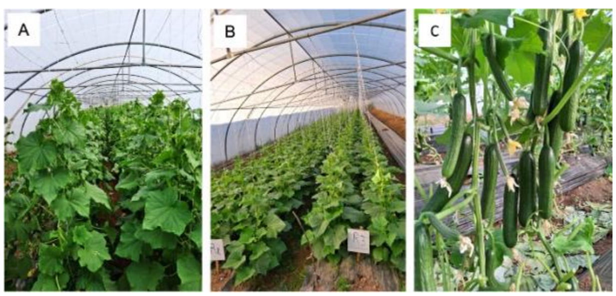

Figure 1. Different views of cucumber (*Cucumis sativus* L.) production in poly shed greenhouse condition. A) close view of cucumber plants under shed greenhouse condition. B) different respirations of growing cucumber under compost, vermicompost and vermiwash organic fertilizer. C) final yield production of cucumber fruits poly shed greenhouse condition.

4. Discussion

Organic fertilizer-based crop improvement represents a sustainable approach to horticultural production for horticultural plant production. In this study compost, vermicompost and vermiwash amendment differentially improve cucumber traits. In this following section, we have addressed the findings obtained in cucumber, revealed the mechanistic insights, and explained those relations with previous findings.

In this current study, induction of leaf number in response to compost and vermicompost suggest that traditional compost improve soil quality, while vermicompost consistently produced higher leaf numbers (Table 2), faster biomass accumulation (Table 7), indicating superior vegetative performance. These results are consistent with previous findings (Al-Tawarah et al., 2024). Moreover, the vermicompost showed the better performance compared to compost. The fundamental differences depend on how these organic fertilizers are processed. The compost relies solely on thermophilic (high heat) microbial decomposition, whereas vermicompost utilizes a non-thermophilic, symbiotic digestive processes between earthworms (e.g., Eisenia fetida) and microorganism (Elissen et al., 2023).

Previous studies have confirmed that diluted vermiwash supplementation (10-20% in range) significantly improved plant height, leaf number and cucumber fruit yield compared to control plants (Gudeta et al., 2021 and Al-Maamori., 2024). In this current study, we found that vermiwash enhanced cucumber fruit length that is consistent with the study. Vermicompost improved N and Ca accumulation in cucumber fruits (Table 4-5). In organic waste, N is bound in complex protein and structural proteins. As earthworms ingest these materials, their grinding gizzard and digestive enzymes breakdown this structure. Interestingly, the specialized gut microbiome significantly mineralizes this organic N into ammonium (NH4+) and produced nitrate, the preferred, highly mobile form of N for plant development Al-Maamori., 2024). Thus, high N accumulation may be attributed to enhanced nitrogen mineralization and nitrification response to vermicompost in cucumber.

Earthworms possess special calciferous glands along with esophagus. The glands excrete CaCO3 into digestive tract to neutralize organic acids during digestion (Al-Maamori., 2024). This process transforms insoluble, bound Ca from the waste into highly amorphous soluble form within the finished worm casts and drastically increasing exchangeable Ca in the soil solution. So, This may be explained by calcium solubilization through the activity of earthworm calciferous glands is the cause of high Ca in cucumber. In addition, the increase K level in cucumber fruits due to liquid extraction process concentrate high K in plant (Naiak et al., 2024).

The vermicompost enhances total plant biomass and cucumber yield. Possibly, the vermicompost delivers a steady influx of bioavailable nutrients (N, P, K) to the rhizosphere. The root-zone optimization is driven by humic substance that activate root plasmamembrane H+-ATPase, enhanced plant total biomass yield and fruits yield in vegetable crops (Yatoo et al., 2020). In this current study, vermicompost performance in plant biomass yield and total cucumber yield are consistent and supported by the recent study (Rehman et al., 2023).

5. Conclusion

This study demonstrated improvements in cucumber growth and fruit production using eco-friendly and cost-effective organic amendment. Compost, vermicompost, and vermiwash amendments showed differential responses for improving leaf number, fruit length, accumulating N, Ca, K content, plant biomass and total cucumber yield. This current study suggests that among the three organic fertilizers, vermicompost showed better performance for developing total plant biomass and cucumber yield, was associated with vermicompost could be the best option for improving cucumber yield. The overall findings suggest that the cost-effective and eco-friendly organic amendment-based strategy would be effective to horticulturists and farmers for sustainable cucumber and other horticultural plant production.

Funding: This research was funded by the Dept of Horticulture, College of Agricultural Engineering Sciences, University of Duhok, Iraq.

Author contributions: The experimental work, data collection and analysis were done by Mohamed A. Ahmed. The research was conducted under the supervision of Dr. Sanaa M.S. Rasheed who also gave advice on the design of the experiment and helped in the interpretation of the findings. The writing and revision of the manuscript was done by both authors.

Conflict of interests: The authors declare that their is no conflict of interests regarding the publication of this paper.

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