*FUDMA Journal of Sciences (FJS)*
*ISSN online: 2616-1370*
*ISSN print: 2645 - 2944*
*Vol. 10 No. 24, December, 2026, pp 265 – 270*
*DOI:* https://doi.org/10.33003/fjs-2026-1024-6389

# Production and Application of Formulated Organic Fertilizer on the Growth and Weed Colonization of (*Capsicum Chinense*)

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**Received:** 31 Oct. 2026
**Accepted:** 10 Nov. 2026
**Published:** 14 Nov. 2026

**ABSTRACT**
Poor soil fertility continues to hamper *Capsicum chinense* (*C. chinense*) growth and productivity. Organic fertilizer was produced using poultry waste, broiler starter feed, cocopeat, biochar and limestone. The influence of formulated organic fertilizer on germination index (GI), electrical conductivity (EC), radicle length, root elongation of seedlings and seedlings growth were evaluated. Best processing technology was investigated and the field trial of the fertilizer was conducted on *C. chinense*. Treatment coded 74%CP+11%PM+15%CL had highest impact on GI. All treatments showed promising pH for seed germination. Treatment 74%CP+11%PM+15%CL and 76%CP+9%PM+15%CL had highest number of leaves. Organic fertilizer produced via encapsulation technology supported more number of leaves, increased plant height, leaf area, stem girth and root elongation of seedlings. Application of different rate of Encapsulated Organic Fertilizer (EOF) significantly increased leaf area of *C. chinense* from week 1 after transplanting to week 6 after transplanting. Treatment with 120 kgN/ha gave highest leaf area than control (NPK). Highest plant height was recorded on 120 kgN/ha. Number of leaves of *C. chinense* significantly ($p<0.05$) increased on 120 kgN/ha. Highest wet weed weight (19.1 g) was recorded at week 6 on 40kgN/ha application rate while the least (4.1 g) was recorded on 120 kgN/ha. Similar trend was recorded for dry weed weight.

**Keywords:** Germination index, Encapsulation, Impregnation, Organic Fertilizer, Plant height

## INTRODUCTION

*Capsicum chinense* (*C. chinense*) is a globally cultivated vegetable prized for its nutritional value and culinary uses. Essential in salads and various dishes, *C. chinense* grow under diverse climatic conditions in many regions of the world. The fruits contain several vitamins including vitamin C, vitamin D and vitamin A. Carotenoids, minerals and bioactive compounds –capsaicinoids and phenolics are additional composition of pepper tissues and seeds that positioned it for extra nutritional and medicinal benefits often associated with elevated consumption of peppers (Adedayo et al., 2026). The inherent nutrients and compounds contribute to normalization cells physiological functions and antioxidant actions of *C. chinense*.

*C. chinense* grows best in warm, frost-free environments with adequate sunlight and fertile, well-drained soils rich in organic matter. A soil pH of approximately 6.0–6.5 is optimal, although a broader range may be tolerated. *C. chinense* is originally associated with the Amazon region of South America, however, it is now widely cultivated in tropical and subtropical areas, including the several African countries. Important types include habanero, chlli pepper, bell pepper and Scotch bonnet peppers (Barboza et al., 2022). Nigeria produces substantial quantities of peppers and there is still growing interest in cultivation of *C. chinense* due increasing population, industrialization and storage infrastructure improvements.

Cultivation of *C. chinense* is increasingly threatened by declining soil fertility which is a consequence of continuous cropping, poor land management and excessive reliance on conventional chemical fertilizers. The direct implication of the prevailing land use method is acceleration of soil degradation, nutrient imbalances and reduced biological activity ultimately compromising pepper yield and quality (Timilsina et al., 2025).

Soil health remained the foundation of sustainable agriculture in all regions of the world including agrarian desert lands. It encompasses not only the physical structure and chemical nutrient balance of the soil but also its biological integrity vis-à-vis microbial diversity and organic matter quality and content (Piccolo & Drosos, 2025; Xing et al., 2025).

Revitalizing degraded soils is therefore essential for increasing the productivity and sustainability of *C. chinense* farming. Innovative fertilization techniques such as the use of biological fertilizers, organic soil amendments, and controlled-release formulations are gaining attention for their ability to restore soil health while reducing the environmental footprint of agriculture (Mahanty *et al*., 2017).

The use of chemical fertilizers in boosting growth and development of *C. chinense* remained popular among small scale and large farm owners in many sub-saharan African countries where cultivation of *C. chinense* is predominant. Synthetic fertilizers are known to provide essential nutrients in amounts necessary for optimum performance. The nutrients are assimilated within days after application and have been used to provide the balanced nutrients needed for optimal *C. chinense* growth (Singh et al., 2017).

The use of organic fertilizers in farming practices is gaining widespread interest due to its potential benefits in improving soil health, boosting sustainable crop yields, and possibility of reducing weed proliferation (Frimpong et al., 2025; Bekchanova et al., 2024).

Weeds compete with *C. chinense* for essential resources like nutrients, water, and light, which negatively affects crop

growth. Organic fertilizers supplies essential nutrients for crop growth which translates into reduced space for weed emergence and growth. Additionally, when organic fertilizer is used as deep mulch or top dressing, the organic matter from the fertilizer could inhibit weed seed germination and decrease weed biomass. This way, organic fertilizer provides dual benefits of growth enhancement and weed suppression (Das et al., 2020).

Organic fertilizers that include plant and animal component supply important nutrients in their natural form, helping to improve soil structure, ventilation and growth of beneficial soil microorganisms (bacteria, fungi and actinomycetes) (Baidoo et al., 2016).

Organic fertilizers release nutrients more gradually compared to their inorganic counterparts, thereby aligning with the nutrient uptake of plants during active growth. Release of nutrients by organic fertilizers based on demand from crops offer reduction in leaching. In addition to promoting crop growth, organic fertilizers could play a pivotal role in weed management within *C. chinense* fields. Weeds compete with *C. chinense* for resources, space and light thus, adversely affecting crop yield and quality (Das et al., 2020). The improved soil structure and enhanced microbial activity from organic fertilizer use creates a competitive environment that limits weed emergence and growth. This integrated approach underscores the importance of organic fertilizers in fostering a resilient and productive agro-ecosystem, addressing both crop production and weed management challenges (Singh et al., 2020).

This holistic method not only stimulates the developmental progress of crops like *C. chinense* but offers an environmentally friendly option to inorganic fertilizers, which have been associated with negative environmental impacts such as soil deterioration and contamination of water bodies (Singh et al., 2024). There is need to develop organic fertilizers that could compete with inorganic fertilizers in terms of speed of release, maintenance of soil health and long-term output.

This study investigates the production of nutrient dense organic fertilizer using digested poultry manure and broiler starter using submerged state bioconversion, integration with biochar, cocopeat and limestone before encapsulation and impregnation. Product of the best technology is eventually tested on the field to measure efficacy on growth and development of *C. chinense*.

## MATERIALS AND METHODS

### Experimental Site and Land Preparation

Experiments were conducted between March and July, 2025 at the teaching and research farm of Faculty of Agriculture, Al-Hikmah University, Igbaja Campus (8.23°N, 4.88°E), Kwara State, Nigeria. The existing vegetation was cleared using cutlass and the average pH of the soil was 6.5. Zai pits measuring 25 cm x 20 cm and 50 cm apart was used for cultivation of *C. chinense*. Each plot was mulched with straw to 5 cm deep to retain moisture.

### Production of Biochar and Enriched Digested Poultry Manure (EDPM)

The biochar was produced using mixed tree branches trimmings gathered from Igbaja campus forest. The wastes were cut into approximately 46cm long using axe and cutlass. The size reduced forest waste was pyrolyzed at 450 – 550 ºC in an oxygen depleted pit kiln with dimension 55cm x 55cm x 110cm for 3h. The biochar was quenched with tap water and allowed to cool before removal from the pit kiln. The raw wet biochar was sun-dried, dried biochar was pulverized using mortar and pestle and stored in airtight container until further use (Baidoo et al., 2016). EDPM comprise potato tuber (10%), water soluble calcium (1%), industrial yeast (2%), probiotics (2%), ash extract (5%), poultry manure (30%) and rest was tap water. The potato was cooked to soft tissue, blend into a smooth paste and 1 g of yeast previously activated in 10 ml of water. All the ingredients were transferred into a large container and required water was added. The content was allowed to undergo fermentation at ambient temperature (25-28 ºC) for 2 weeks.

### Analytical Procedures

Germination index was performed by placing ten (10) viable tomato seeds in moisture equilibrated petri dish and kept in the dark for 5 days at 25 ℃. The number of germinated seed was recorded and converted to percentage. Electrical conductivity and pH were measured using required probes after extracting 5 g of sample with 50 ml of distilled water for 30 min via shaker. The plant height, stem girth, leaf number and leaf area of tomato seedling and *C. chinense* was measured weekly using a meter rule. Growth parameters were measured from the base to the tip of apical leaf. Stem girth was measured using Vernier calliper. The number of leaves was measured quantitatively by counting. The leaf area was measured using a non-destructive quantitative approach by measuring length and width and calculate the area using correction factor; all experiments were in triplicate (Rouphael *et al.*, 2010). The formular is as thus:

$$\text{Leaf area} = (\text{Leaf Length} \times \text{Leaf width}) \times \text{correction factor (0.7)}$$

### Organic Fertilizer Formulation, Impregnation and Encapsulation Process

The organic fertilizer was formulated using varied inclusion levels of cocopeat (70-78%) and poultry manure (7% - 15%) while biochar (6%) and limestone (9%) were constant. Formulated organic fertilizer was encapsulated by measuring BBOF and encapsulated using gelatine as binder. Encapsulated organic fertilizer was air dried at room temperature (25°C) and stored in a polythene bag. The impregnation process involved weighing all ingredients and mixing with EDPM without addition of binder and allowed to impregnate at ambient temperature.

### Fertilizer Application Method

The resulting organic fertilizer was applied directly to the plant root zone via soil injection method with the aid of fabricated fertilizer applicator which was inserted into the soil not less than 1.5 cm deep to avoid leaching.

### Statistical Analysis

Data collected was subjected to analysis of variance (ANOVA) using the SPSS. Significant difference at $p<0.05$ was determined and means were separated using Duncan Multiple Rate Test (DMRT). Field experiments were laid out using Completely Randomized Block Design (RCBD) with three replications.

## RESULTS AND DISCUSSION

### Influence of Formulated Organic Fertilizer on Seed Germination Index and Growth Parameters

The germination index (GI) and number of leaves produced by seedlings are critical parameters used to evaluate the potential of the growing medium in supporting plant life. Results of the GI showed that treatment coded 74%CP+11%PM+15%CL had highest impact on seed germination (Figure 1a); indicating low phytotoxicity and higher support for crop growth and development. Addition of

medium amount of poultry manure (PM) in commercial growing media has been reported as increased concentration triggers toxicity and reduced seed germination index (Kebede, 2023).

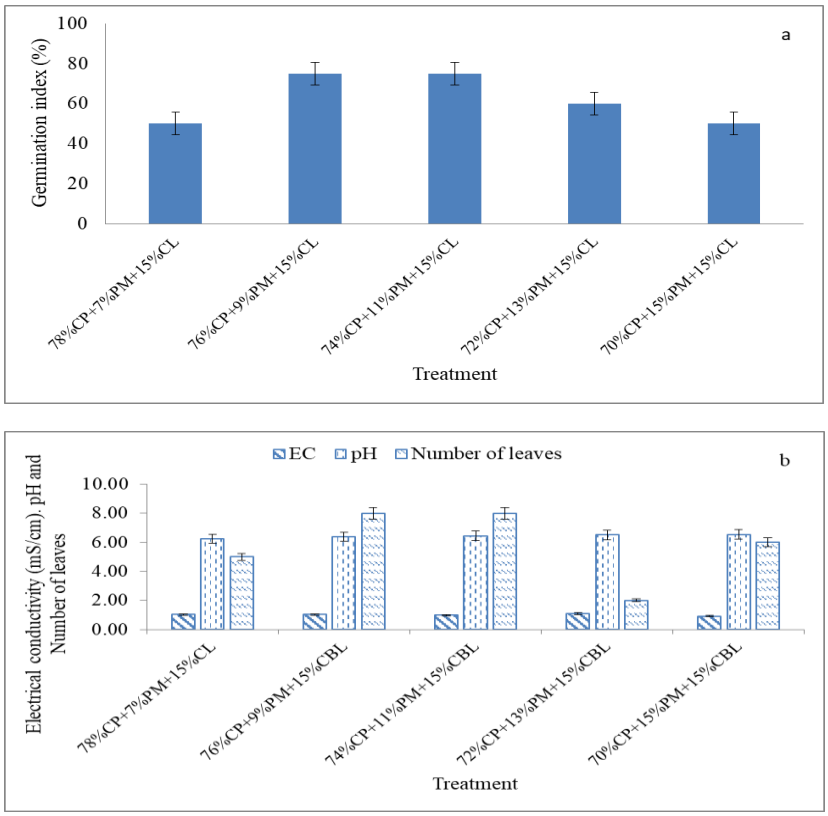



Figure 1: Effect of formulated media on (a) Seed germination (a) EC, pH and Number of leaves

The level of EC in all formulations falls within levels appropriate for seed germination and crop growth support. Observed pH level on all treatments showed slight variations though; they could all support seed germination. Treatment coded 74%CP+11%PM+15%CL and 76%CP+9%PM+15%CL had highest number of leaves (Figure 1b). This could be due to increased inclusion levels of poultry manure which might support foliage emergence and development. The ability of enriched organic media to maintain optimum pH, low EC and eventual support for foliage emergence have been reported and the results of present investigation are in tandem (Ayito et al., 2023).

**Influence of Processing Methods of the Formulated Organic Fertilizer on Seedlings Growth Characteristics**

The processing technique of the organic fertilizer influenced the performance on seedlings growth and development. Organic fertilizer produced via encapsulation technology supported more number of leaves, increased plant height, leaf area, stem girth and root elongation (Figure 2). The intense impact of encapsulated fertilizer could be attributed to increased nutritional support offered by the packed and condensed nutrients in the fertilizer matrix. Ability of the binder to support immediate nutrient release might be due to increased osmotic pressure between soil moisture and nutrients embedded in the encapsulated organic fertilizer (Barakat *et al.*, 2012).

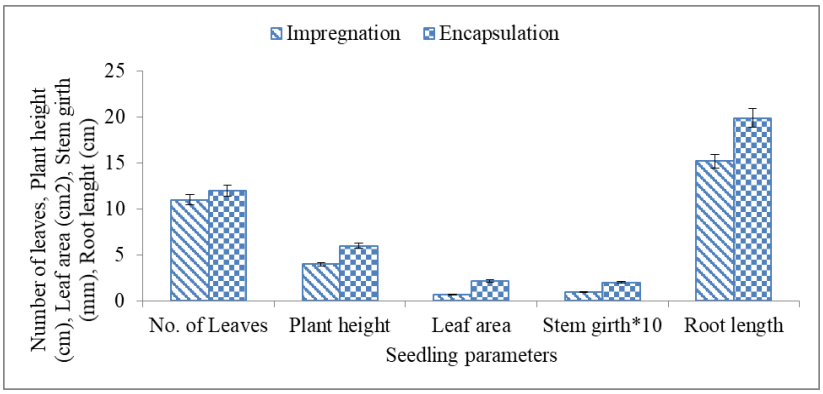



Figure 2: Effect of impregnation on processing biochar based organic fertilizer

**Effect Encapsulated Organic Fertilizer (EOF) on Leaf Area of *Capsicum Chinense***

Application of different amount of EOF significantly increased leaf area of *Capsicum chinense* (*C. chinense*) steadily from week 1 after transplanting to week 6 after transplanting in treatments and control (Table 1). Treatment with 120 kgN/ha gave highest leaf area compared to similar nitrogenous content in control (NPK). This outcome suggested steady release of nutrients by the EOF for promoting healthy growth and development of *C. chinense*. The ability of nutrient dense organic fertilizer to perform comparatively with synthetic fertilizer has been reported and this outcome aligns with such outcome (kumar et al. 2021).

**Table 1: Effect of EOF on Leaf Area of *C. Chinense***

| Treatment | Week 1($cm^2$) | Week 2($cm^2$) | Week 3($cm^2$) | Week 4($cm^2$) | Week 5($cm^2$) | Week 6($cm^2$) |
|---|---|---|---|---|---|---|
| 40 kgN/ha | $0.5^{a}$ | $1.6^{a}$ | $2.3^{a}$ | $3.6^{b}$ | $3.9^{ab}$ | $4.2^{a}$ |
| 60 kgN/ha | $1.3^{a}$ | $1.8^{a}$ | $2.3^{a}$ | $2.3^{a}$ | $3.3^{a}$ | $4.4^{b}$ |
| 80 kgN/ha | $1.4^{b}$ | $1.8^{a}$ | $2.3^{a}$ | $3.3^{b}$ | $3.5^{a}$ | $4.4^{b}$ |
| 100 kgN/ha | $4.1^{d}$ | $4.1^{c}$ | $4.5^{c}$ | $4.5^{c}$ | $4.5^{b}$ | $5.7^{c}$ |
| 120 kgN/ha | $2.8^{c}$ | $3.3^{b}$ | $3.4^{b}$ | $4.5^{c}$ | $5.2^{c}$ | $6.3^{d}$ |
| NPK 120 kgN/ha | $1.2^{a}$ | $3.2^{b}$ | $3.5^{b}$ | $4.7^{d}$ | $4.8^{b}$ | $5.2^{c}$ |
| Sig. | * | * | * | * | * | * |

*Values are significant at p<0.05

$^{a,b,c,d}$: different superscript denotes means are significantly different

**Response of Plant Height of *Capsicum Chinense* to EOF**

Plant height of *C. chinense* significantly ($p$<0.05) responded to increased application rate of EOF. Highest outcome was recorded on 120 kgN/ha which was slightly higher than same application rate of control (Table 2). The *C. chinense* responded faster to NPK application compared to the organic fertilizer and could be attributed to readily availability of dissolved NPK constituent. The organic fertilizer however outpaced in NPK in steady supply nutrients. The time effect of NPK and organic fertilizers in relation to plant height influence has been reported (Olatunji et al., 2021; Barakat *et al.*, 2012). However, this work showed that with encapsulation of organic fertilizer, the speed of release could improve in comparison to NPK.

**Table 2: Effect of EOF on Plant Height of *C. Chinense***

| Treatment | Week 1(cm) | Week 2(cm) | Week 3(cm) | Week 4(cm) | Week 5(cm) | Week 6(cm) |
|---|---|---|---|---|---|---|
| 40 kgN/ha | $4.0^{a}$ | $5.5^{a}$ | $5.9^{a}$ | $7.8^{a}$ | $7.8^{a}$ | $9.3^{b}$ |
| 60 kgN/ha | $5.0^{a}$ | $5.4^{a}$ | $7.5^{c}$ | $7.5^{a}$ | $8.0^{b}$ | $8.5^{a}$ |
| 80 kgN/ha | $6.0^{c}$ | $7.0^{c}$ | $7.2^{c}$ | $7.6^{a}$ | $7.6^{a}$ | $9.3^{b}$ |
| 100 kgN/ha | $6.0^{c}$ | $6.6^{b}$ | $6.8^{b}$ | $7.6^{a}$ | $7.6^{a}$ | $10.3^{c}$ |
| 120 kgN/ha | $7.5^{d}$ | $7.9^{c}$ | $8.5^{c}$ | $9.4^{b}$ | $10.6^{c}$ | $11.9^{d}$ |
| NPK 120 kgN/ha | $5.5^{b}$ | $6.5^{b}$ | $10.0^{d}$ | $10.2^{c}$ | $10.4^{c}$ | $10.5^{c}$ |
| Sig. | * | * | * | * | * | * |

*Values are significant at p<0.05

$^{a,b,c,d}$: different superscript denotes means are significantly different

**Influence EOF on Number of Leaves of *C. Chinense***

Number of leaves of *C. chinense* significantly ($p$<0.05) responded to increased application rate of EOF. Highest outcome was recorded on 120 kgN/ha which was higher than same application rate under NPK (Table 3). The crop responded quicker to NPK application compared to the organic fertilizer however EOF showed consistent foliage increase. Supply of nutrients by NPK could be fast due to high propensity of immediate release of nutrients composition (Sarma et al., 2017). There have been reports of ability of organic fertilizers to trigger sustained plant growth as suggested by current outcome (Adebayo et al., 2021; Schrader et al., 2021).

**Table 3: Effect of EOF on Number of Leaves of *C. Chinense***

| Treatment | Week 1 | Week 2 | Week 3 | Week 4 | Week 5 | Week 6 |
|---|---|---|---|---|---|---|
| 40 kgN/ha | $9.5^{c}$ | $11.0^{b}$ | $13.0^{c}$ | $13.0^{bc}$ | $15.0^{c}$ | $18.0^{bc}$ |
| 60 kgN/ha | $9.5^{c}$ | $11.0^{b}$ | $11.0^{b}$ | $11.5^{a}$ | $13.0^{a}$ | $14.0^{a}$ |
| 80 kgN/ha | $9.0^{b}$ | $11.0^{b}$ | $11.0^{b}$ | $12.5^{b}$ | $13.5^{b}$ | $15.5^{a}$ |
| 100 kgN/ha | $8.0^{a}$ | $8.5^{a}$ | $10.0^{a}$ | $12.0^{b}$ | $13.0^{a}$ | $16.0^{b}$ |
| 120 kgN/ha | $9.0^{b}$ | $11.0^{b}$ | $11.0^{b}$ | $14.0^{c}$ | $17.5^{d}$ | $24.5^{d}$ |
| NPK 120 kgN/ha | $9.0^{b}$ | $12.0^{c}$ | $13.0^{c}$ | $15.0^{d}$ | $17.0^{d}$ | $21.0^{c}$ |
| Sig. | * | * | * | * | * | * |

*Values are significant at p<0.05

$^{a,b,c,d}$: different superscript denotes means are significantly different

**Effect of EOF Application on Weed Density on *C. Chinense***

In this study, weeds began to emerge at 8 days after transplanting *C. chinense*, and the wet and dry weight was monitored. The results revealed significant ($p$<0.05) increase in wet weed weight across all treatments with highest wet weed weight (19.1 g) recorded at week 6 on 40kgN/ha application rate while the least (4.1 g) was recorded on 120 kgN/ha (Table 4). Similar trend was recorded for dry weed weight. The increased weed colonization could be due to low

growth in observed treatment while low weed weight in treatment 120 kgN/ha could be attributed to increased plant canopy that might prevent weed emergence. This finding is consistent with previous works where use of organic amendments such as poultry manure triggered increased growth that prevent weed infestation (Kumar et al 2021).

**Table 4: Fresh Weed Weight during the Whole Growing Period**

| Treatment | Week 2 | | Week 4 | | Week 6 | |
|---|---|---|---|---|---|---|
| | Wet weight(g) | Dry weight(g) | Wet weight(g) | Dry weight(g) | Wet weight(g) | Dry weight(g) |
| 40 kgN/ha | $4.3^{c}$ | $1.2^{b}$ | $10.2^{c}$ | $4.6^{c}$ | $19.1^{d}$ | $5.0^{c}$ |
| 60 kgN/ha | $3.8^{b}$ | $1.3^{c}$ | $8.1^{b}$ | $2.5^{b}$ | $10.2^{c}$ | $6.7^{d}$ |
| 80 kgN/ha | $5.7^{d}$ | $1.2^{b}$ | $11.5^{d}$ | 6.3 | $11.5^{cd}$ | $7.3^{e}$ |
| 100 kgN/ha | $4.4^{c}$ | $1.1^{b}$ | $9.2^{bc}$ | $1.5^{a}$ | $8.6^{b}$ | $3.3^{b}$ |
| 120 kgN/ha | $1.3^{a}$ | $0.2^{a}$ | $2.2^{a}$ | $1.2^{a}$ | $4.1^{a}$ | $1.3^{a}$ |
| NPK 120kgN/ha | $3.0^{b}$ | $0.9^{ab}$ | $7.0^{b}$ | $3.0^{b}$ | $10.0^{c}$ | $4.0^{c}$ |
| Sig. | * | * | * | * | * | * |

*Values are significant at $p<0.05$

$^{a,b,c,d,e}$: different superscript denotes means are significantly different

**Conclusion**

Formulated organic fertilizer containing medium amount of cocopeat and digested poultry manure supported profound seed germination, electrical conductivity and number of leaves. Encapsulation technology supported more number of leaves, increased plant height, leaf area, stem girth and root elongation of seedlings. EOF with 120 kgN/ha gave highest leaf area, plant height and number of leaves of *C. chinense*. Increased EOF application led to reduced weed weight. Farmers especially smallholders are encouraged to switch to nutrient dense organic fertilizers with increased awareness and training to educate farmers on the optimal application rates, types of organic fertilizers and practices for their use. Further microbial and soil analysis should be conducted to identify and characterize the classes of beneficial bacteria present in organic fertilizers.

**REFERENCES**

Adebayo, A. G., Olatunji, O. M., & Adewale, B. D. (2021). Growth and yield response of pepper (Capsicum spp.) to organic fertilizer application in southwestern Nigeria. Journal of Organic Agriculture and Environment, 9(1), 45–52.

Aliyu, M., Abdulmalik, Z., Bako, Z. M., Jega, R. M., & Kareem, W. (2024). Organic fertilizer production using banana peel, eggshells, and yeast: Effects on Amaranthus growth. FUDMA Journal of Sciences, 8(6), 562 – 567

Das, T. K., Ghosh, P. K., & Rana, K. S. (2020). Weed management in vegetable crops. Indian Journal of Agronomy, 65(3), 345–354.

Kumar, V ., Yadav, S., & Sharma, R. (2021). Biological weed management: Concepts and prospects. Agronomy International, 3(1), 22–34.

Olatunji, O. M., Adebayo, A. G., & Oladipo, O. T. (2021). Growth response of *Capsicum chinense* to different organic fertilizer treatments. African Journal of Plant Science, 15(3), 73–79.

Singh, G., Mahajan, G ., & Gill, G. (2017). Chemical weed management strategies in horticultural crops. Weed Science Journal, 55(2), 205–212.

Singh, R., Yadav, P., & Kumar, V . (2020). Effect of organic liquid fertilizers on growth and yield of chili (*Capsicum annuum*). Internati onal Journal of Current Microbiology and Applied Sciences, 9(5), 2370–2377.

Rouphael, Y., Cardarelli, M., Colla, G., & Rea, E. (2010). Yield, water relations and water use efficiency of grafted mini-watermelon plants under deficit irrigation. HortScience, 45(5), 730–736.

Barakat M.R., Yehia, T.A. & Sayed, B.M. (2012). Response of Newhall Naval Orange to bio-organic Fertilization under Newly Reclaimed Area Conditions I: Vegetative Growth and Nutritional Status. Journal of Horticultural Science of Ornamental Plants. 4(1), 18–25.

Adedayo, R. A., Akanbi, W. B. & Fawole, T. O. (2026). Comparative nutritional, bioactive, and mineral profiling of ten Capsicum cultivars grown in Southwestern Nigeria. Journal of Renewable Agricultural Technology Research, 13(1).

Barboza, G. E., Carrizo García, C., de Bem Bianchetti, L., Romero, M. V. & Scaldaferro, M. (2022). Monograph of wild and cultivated chili peppers (*Capsicum L., Solanaceae*). PhytoKeys, 200, 1–423.

Timilsina, R. R. R., Khosla, S. K., Rahut, D. B., Jena, P. R. & Sonobe, T. (2025). A comprehensive review of the soil health status for enhancing agricultural sustainability. Frontiers in Environmental Science, 13.

Piccolo, A. & Drosos, M. (2025). The essential role of humified organic matter in preserving soil health. Chemical and Biological Technologies in Agriculture, 12, 21.

Xing, Y., Xie, Y. & Wang, X. (2025). Enhancing soil health through balanced fertilization: A pathway to sustainable agriculture and food security. Frontiers in Microbiology, 16, 1536524.

Mahanty, T., Bhattacharjee, S., Goswami, M., Bhattacharyya, P., Das, B., Ghosh, A. & Tribedi, P. (2017). Biofertilizers: A potential approach for sustainable agriculture development. Environmental Science and Pollution Research, 24(4), 3315–3335.

Kebede, T., Berhe, D. T. & Zergaw, Y. (2023). Effects of biochar and compost application on soil properties and on the growth and yield of hot pepper (*Capsicum annuum L.*). Applied and Environmental Soil Science, 2023, 8546135.

Ayito, E. O., John, K., Iren, O. B., John, N. M., Mngadi, S., Heung, B. & Moodley, R. (2023). Synergistic effects of biochar and poultry manure on soil and cucumber (*Cucumis*

*sativus*) performance: A case study from the southeastern Nigeria. Soil Science Annual, 74(4), 183903.

Sarma, B., Borkotoki, B., Narzari, R., Kataki, R. & Gogoi, N. (2017). Organic amendments: effect on carbon mineralization and crop productivity in acidic soil. Journal of Cleaner Production, 152, 157–166.

Schrader, J., Shi, P., Royer, D. L., Peppe, D. J., Gallagher, R. V., Li, Y., Wang, R. & Wright, I. J. (2021). Leaf size estimation based on leaf length, width and shape. Annals of Botany, 128(4), 395–406.

Baidoo, I., Sarpong, D. B., & Bolwig, S. (2016). Biochar amended soils and crop productivity: A critical and meta-analysis of literature. International Journal of Development and Sustainability, Vol. 5, No. 9, pp. 414–432. https://isdsnet.com/ijds-v5n9-1.pdf

Frimpong, K. A., Owusu, S., Darko, R. O., Hanyabui, E., Abbey, A. N. A., & Tetteh, D. A. (2025). Effect of biochar application rates on soil properties and growth of *Amaranthus caudatus*. Discover Agriculture, 3(1), 21.

Bekchanova, M., Campion, L., Bruns, S., Kuppens, T., Lehmann, J., Jozefczak, M., & Malina, R. (2024). Biochar improves the nutrient cycle in sandy-textured soils and increases crop yield: A systematic review. Environmental Evidence, 13(1). 3.

Singh, S., Devi, N. B., Divya, D., Kumar, A., Singh, S., Singh, G., Nath, A., & Kumar, A. (2024). Soil fertility management: Role of organic amendments and bio-fertilizers: A review. International Journal of Research in Agronomy, 7(12), 766–772.

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